# ORGANIZATION STRUCTURES

## THEORY AND DESIGN, ANALYSIS AND PRESCRIPTION

*By*

Helmy H. Baligh

Springer

# ORGANIZATION STRUCTURES: THEORY AND DESIGN, ANALYSIS AND PRESCRIPTION

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HELMY H. BALIGH
*Duke University, Fuqua School of Business*

Springer

Helmy H. Baligh
Duke University, NC, USA

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# Dedication

*Sara, my wife, and our*
*daughters Aziza, Magda and*
*Laila and our grandchildren*
*Aziza's daughters, Kenzi and*
*Nazli, and Laila's son Talib and*
*daughter Adaira*

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# Preface

Helping those who would design organizations that do things the designers want done and to do so efficiently and well is what this book is about. Using the design rules that are the its conclusions would give the designer a description of an organization structure that is effective or efficient in a given set of circumstances, and for a given desired outcome. But useful rules must meet certain conditions, of which the first is that they be stated in terms of the decisions and actions that turn a description of an organization structure into a real one. Also if a designer is to use a set of design rules and be confident in their implied or explicit promises, and also be capable of modifying them for his requirements, then he or she would need to know where the rules come from. The designer needs to understand the relations between the structure and what it does, between what it does and the outcome which he wants to have, and between the structure and the costs of its operation and maintenance. The theory in this book from which its design rules are drawn makes these rules meet these conditions. It is a theory that is rigorous, fairly close to being comprehensive, and is in operational terms.

Morphology is the discipline where the structures of living things are related to their performances, and these are connected to their ability to survive and reproduce in environments of various kinds. Engineering also has theories that relate structure to performance in various environments for machines, and there are the theories that do analogous things for organizations. All three kinds of theories deal with the same subject matter of structure, performance, environment, transformations and outcomes, and the theory in this book is one such theory that is about the relations between organization structures and their performances.

The theory in this book deals with the relation of structure and environment to performance, with the relation of structure and environment to cost, and with the relation of performance and environment to outcomes. These partial theories are put together to make one theory that is stated in terms of operational definitions of structure, performance, environment, and outcomes. From this theory are derived design rules that may be used in the process of designing real organization structures, because the rules are stated in terms of variables that are operational. The analytic propositions and the rules of design are in terms of real world easily identifiable variables the values of which the designer can actually discover, or actually make into fact. If the rules of design are to be useful, then they must not only be operational, they must be well founded in theory, they must form the elements of an efficient process of design, and they must produce designs of structures that are efficient structures. Every effort is made to make the analysis systematic and rigorous so that the connections between the theory and the design rules are correct and clear. The derivation of design rules is a complicated process because each design rule is derived from a combination of theoretical statements of fact, but is itself a statement that is a conditional imperative. All derivations, complicated or not, are fully explained and the legitimacy of all design rules is shown.

In short, from the conclusions of the theories, the book derives design rules that may be used to create designs which identify what the components of a structure ought to be. These are, as they should be, the very same operational components used to define the structure we theorized about.

Borge Obel and Richard M. Burton and I have spent a good amount of time together studying, analyzing and discussing this subject of organization structures and their designing. I thank both of them deeply for the knowledge I gained from this collaboration. I am also very grateful for the reasoned advice, relevant suggestions and constructive criticism I received from Richard M. Burton whenever he read the book manuscript which he was generously willing to do whenever asked. My deep thanks to Pamela Wilson, Program Coordinator, and Nancy Gump, Administrative Specialist, for transforming the manuscript into one that met all the conditions for publication. My deep thanks also to Sara Baligh, my wife, for her immense help in the final proofreading of the manuscript.

*Helmy H. Baligh*
Professor Emeritus of Business Administration
The Fuqua School of Business
Duke University
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# CHAPTER 1

# STRUCTURE, PERFORMANCE, COST, AND OUTCOME

## 1. Structure and Performance

Organizations differ one from another in all sorts of ways, and there is very little that one can say or do about how well they work or how to design them unless they all have something in common. Each is a set of people who are put into some order on the basis of a specific logical relation that exists between one person and at least one other in the set. The set and the logical order create a 'pattern' of the people in the set, something that we may call a structure. When the logical relation we use is that of genetic parentage, then the set of people becomes ordered, and a pattern or structure becomes evident. Called a family this structure is often described on paper as a family tree. Like families, organizations are also structures, but ones defined on a logical relation that is not that of parentage, but on the basis of the connection between people that comes into being when decisions made by one person are based on the use of a rule created in part or whole by another person. The ordered set of people here is an organization that is often described as a hierarchical chart where the up and down location of people connected by a line represents the relation of logical dependence of the decisions of these people. All organizations share this basic feature and are thus legitimate subjects of generalizations. It is possible for people to learn things from what they did when they were in an organization producing and selling cars which they can apply to determine what they ought to do when they join another organization that is brewing and selling beers. It is this concept of the organization structure that makes it meaningful to talk of experienced managers, without any reference to what the organization to which they belong does. Meanwhile researchers and academics use this basic concept of an organization structure to create generalizations that may be used to replace the learning from experience or at least make it richer and faster. It is this fundamental concept that makes the traditional organization chart of boxes connected by lines have the same meaning whether it is called the government of the United States, or a beer making firm, or a university, or a household.

At its very simplest, an organization structure would have a set of two people (or one person at two different points in time), and one or two decisions to be made. A simple structure might be created when a person who bought a house decided that the large rock that was in the front yard was to be moved to the back yard. Though the rock sat on top of the ground, it was too heavy for the owner to move by himself, and so he asked his neighbor to help. The neighbor agreed to help, and when the two went over to where the rock was, the owner showed his neighbor where to stand, the direction in which to push the rock, and how hard he was to push. He also told him to start pushing when he heard the owner say 'now', and to stop pushing when he heard the owner say 'that's it'. The owner then stood next to the neighbor, sent him the message by saying 'now', and started to push as did the neighbor. Pushing together in the same direction, they began to move the rock to the required spot. When the owner decided that the rock was where it should be, he sent the second message by saying 'that's it', and both stopped pushing. For his effort the neighbor was offered a beer, which he accepted, and the two sat down and got acquainted. While they were in the process of moving the rock the man and his neighbor were an organization, people who are connected by decision rules that they make for one another to use to determine what they are to decide or do. In this case the rules were made by the owner and were the rule which told the neighbor where to stand, the one which told him the direction in which to push, the one which told him how hard to push, the one which told him when to start pushing, and the one which told him when to stop pushing. Together, the people and the rules that connected their decisions were an organization structure, which determined what was to get done, the performance, and did it. The effort expended and the time it took to get the desired outcome tell us something about the efficiency of this structure compared to other structures which may have been used to get the same outcome. What is important is that this two person organization structure is logically identical to one that describes the organization that is General Electric, or the Catholic Church, or Duke University, or the household of Jill and Jack.

That organization structures have identical logical structures does not mean that they do not differ one from the other. The house owner has a large variety of structures from which to choose, many of which could perform the task of moving the rock, and many that could not. What is the process by which the owner is to identify the organization that would perform in the manner that would move the rock to the right place and do so efficiently? What are the things which the owner has to decide on in order to identify the structure he is to create? The things the owner has to do are to specify the logical relations between what his neighbor is to do, and what he is to do. He has to become an organizer, and choose specific connections between the two of them. Each set of connections creates its own unique pattern or structure, and what each of these does depends on what the structure is. Where exactly the rock ends up and the time and effort it takes to get there depends on the structure chosen. Meanwhile the cost of the structure, costs of sending messages etc, are affected by the nature of the structure. The efficiency by which the rock is moved depends on the structure chosen to move it. Effort expended by one or both pushers, the time used up in the pushing, the damage to the yard, all depend on the structure. If the owner were interested in efficiency, he should be interested in the structure, that is, the specific connections, he chooses and in the process he should use to identify the choice. Since the choice of a structure involves the creation of connections, the owner would want to know what would happen if he were to choose this or that set of connections. He should be interested to know what would happen if some or all of the rules on the direction on which to push and those on when to push, which he and his neighbor followed, were made not by him alone but by both him and his neighbor. What would happen if instead of having the owner send the signal of when to stop, he and his neighbor were to stop when each one of them saw that the rock had arrived at some marked spot? How good the owner is at choosing a structure depends on what he understands about the relations between the structure and what it does, between what it does and the outcome which he wants to have, and between the structure and the costs of its operation and maintenance. How good he is at making the choice also depends on the process by which he uses that knowledge in making the choice.

Creating connections is the same thing as designing a structure, and the manner of creating these connections is the process of designing. Structure design and the process of designing are the subjects of what follows in this work. More specifically, what interests us is the problem of designing structures that are efficient or good or best in a given set of circumstances, and for a given desired outcome. To begin with, a theory is developed, one that shows the relation of structure to performance, and the relation of performance and the world in which the structure exists to outcome. This theory is built up by creating smaller theories, each of which deals with only a few of the relations, which are then combined and fitted together to make a coherent whole. We are also interested in the efficiency of the process of using this theory and its parts to design structures in real world settings. To this end, design rules are derived from the theory, and the rules are such that they are operational which means that they are in terms of elements of the structure within the power of the designer to make them what they are to be. To get these rules, we need the theory to be in terms that are clear and unambiguous. This work begins with the creation of detailed and unambiguous definitions of what an organization structure is, and the definition of what it does, that is, its performance. Also developed are the definitions of the environment in which the structure exists and performs, and of the transformations that describe how aspects of the world are transformed by this performance.

At the heart of the theory is the set of relations between the nature of a structure and its performance. The identification and analysis of relations analogous to these are to be found in many disciplines. Morphology is the discipline where the structures of living things are related to their performances, and these are connected to their ability to survive and reproduce in environments of various kinds. Engineering also has theories that relate structure to performance in various environments for machines, and there are the theories that do analogous things for organizations. All three kinds of theories deal with the same subject matter of structure, performance, environment, transformations and outcomes. Because organizations are human constructs, the theory on the relation of structure to performance should be usable in designing organization structures, similar to the manner in which engineering theories are used to design machines. The history of theories on the subject of the relation between the organization structure and its performance is long and honorable (Child, 1972), (Duncan, 1979), (Schoonhoven, 1981), (Miller, 1991, 1992) (Volberda, 1996), (Burton and Obel, 1998), (McKendrick and Carroll, 2001), (Birkinshaw, Nobel, and Ridderstrale, 2002) and many others. The theories are all about the structure of the organization and its performance, and about how the environment and the performance determine outcome. Since structure affects performance, and the environment affects the outcome of the performance, it is logical and useful to study the issue of the fit or match between structure and environment and many theories are stated in such terms. But the theories differ in very many ways, even at the most basic levels of their concepts of what a structure is, what a performance is, and what the components of each are. The sets of variables in which the theories are stated differ from one another, and variables with the same name are often defined differently. Relations between parts of structure and parts of performance also differ from one theory to the next, as do variables that are the subjects of their design rules and the manner of their derivation. In this and the following chapters we offer one more theory of the connections between the structure of an organization and what it does. A set of design rules are then derived from this theory for use in designing real structures that are efficient.

Because the theory is intended to be the basis for the derivation of design rules that may be used in the process of designing real organization structures, it is developed in terms of variables that are operational. The analytic propositions and the rules of design are in terms of real world easily identifiable variables the values of which the designer can actually discover, or actually make into fact. If the rules of design are to be useful, then they must not only be operational, they must be well founded in theory, they must form the elements of an efficient process of design, and they must produce designs of structures that are efficient structures. Every effort is made to make the analysis systematic and rigorous so that the connections between the theory and the design rules are correct and clear. The derivation of design rules is a complicated process because each design rule is derived from a combination of theoretical statements, and because the rules are conditional imperatives while the theoretical statements are categorical. Design rule derivations are clearly made in terms that are explicit, so that their theoretic foundations and the logic in which they are combined are easy to accept or to refute. Explicit derivations also make it easy to establish whether the use of these rules produces designs of structures that are efficient or not. Finally, useful design rules should be such that they may used in a process that is itself efficient, and therefore much attention is paid to this issue in what follows. The design rules we hope to derive in this work are those which can be used in an efficient way to produce designs of efficient organization structures which can be used to create real structures.

## 2. An Overview

To design an organization that will do what one wants it to do, one needs theories on the relation of organization structure and environment to performance, on the relation of structure and environment to cost, and on the relation of performance and environment to outcomes. To be useful, these theories need to be stated in terms of operational definitions of structure, performance, environment, and outcomes, and this often means that appropriate properties have to be defined for structure, for performance and so on. Also, useful theories should help us develop an understanding of the relations of structure properties to performance properties in the context of the transformations and technologies that are within the control of the structure. Relations of performance properties and environment properties to outcomes need to be uncovered. Finally the manner in which these relations are to be used to produce those that are their inverses need to be developed. Knowing how to get from structure to outcomes in two sets of relations must be translated into knowing how to get from outcomes to structures in the two inverse sets of relations. Analysis must be turned into design. The rest of this work supplies some of these needs of the designer of organizations structures.

Our object then is to develop a theory that incorporates three sets of relations: those between organization structures and their performances, those between combinations of structure performances and environments on the one hand and the outcomes that result on the other, and those between organization structures and the costs of creating and maintaining them. The theory is an analytic one that deals with causal relations. From these we obtain a set of relations that specify what is to be done if such and such an outcome is desired, and such and such are the conditions of the world. These are prescriptive relations that are steps to be taken in the process of designing a structure. They are created from various combinations of the analytic ones. They are not merely inverses of the analytic ones, but are the results of the recognition of the existence of complementary and substitutable analytic relations, and of interactions of different kinds between the effects of one set of variables on those of another. From these complex analytic relations, design rules are inferred and their use ordered and sequenced to form the steps of an efficient process of designing efficient organization structures. The process of design is for those who want to organize people to do things that attain some goal. What people want may be profit, or electoral votes, or destruction of armies, or curing ill, or whatever the reason for creating an organization might be. All these and most others goals are obtained at some cost, including the cost of designing the structure and the cost of the operation and maintenance of the structure organization. What is needed is a process of design that is an efficient one and that produces efficient designs.

Designs of structures are useful to the extent that they are stated in terms that refer directly to real world components of the structures which they describe. Designs and the theories from which they are derived must therefore be operational, which means that these theories must be in terms of variables are identifiable in the real world, and are either ones that are to be given values directly or are there with values that are observable. In general, a theory is operational if it can be used to direct behavior. The theory we want is that which directs the design of organization structures. To be operational the theory's mappings must have domains and ranges that are sets of variables with direct real world references. All mappings should be orderly, which means that the elements in them must be such as to allow one to put them into a logical order. It is this order that will permit us to develop a systematic search procedure which identifies a non-random, guided path from one element to the next or to a better one. The search is then an efficient one.

Suppose we had a theory on the sale of cars based on the property of their likeability. The more likable a car, the more we sell. In designing the car we would want to make it likable. But how do we do that? There is nothing in a real world car which we can control that carries the label likeability level. How do we translate likeability into a variable the value of which we can control? If we could turn likeability into color we would turn the non-operational variable of likeability into the operational one of color. We can pick the color and make the car actually that color. But if we had six thousand colors and six thousand levels of likeability, the mapping from this latter to the former would have that many elements. How do we find the element that shows the pair (likeability level, color) where the likeability level is highest, or the one that meets some minimum level we require, and so on? Without an order on this set of pairs, the mapping, we might have to start randomly then move to another pair randomly, and so on. There is no basis for identifying a route through the set. But if the set were ordered, say, on the basis of the wave length of the color, then we could proceed systematically from any starting point and move to another close to it in terms of wave length, and so on. Order on the sets that are connected by the theory is critical to the identification of an efficient process of searching the set of designs for that which meets various quality levels.

## 3. Practical Needs of the Analysis

Throughout this work the terms thing, structure, variable, decision variable, parameter, connection, etc., will occur over and over. They are the words used to refer to the essence of the subject of the analysis and theory that are developed. We accept these terms as referring to naive concepts, ones to be defined but not argued or analyzed. It is thus well worth our while to define each as clearly as possible, and to discuss these definitions so that the meanings are as clear as we can get them. Once all this is done in one place here early in the work it can then be used without further explanations in the analysis without interrupting it. Some definitions of basic concepts follow.

**Thing:** This term is used to refer to an object which is to be taken as a whole without parts for purposes of the analysis. The important point here is that whenever the term is used, it is intended that the makeup of the thing is not part of the analysis, but the unit as a whole is. For example, a person be may the thing we refer to, and that means that whatever goes into making a person is of no relevance to the analysis. Only the thing, person as a whole, concerns us. Anything in the world is then either a person or not, and we can tell which it is. A thing does not have to be physical, but must be conceptually identifiable. Color as an abstract concept is a thing, independently of its physical manifestation. The same is true of number, or word, or idea.

**Set:** This term refers to any collection of things. If the set is one of things that are in some way distinguishable one from another, but are all similar in the fundamental identity that they have as things, then the set is no longer an arbitrary collection, and is useful if we have a rule that determines what is in it and what is not. A person is a thing, and so the concept of a set of things, each of which is a person, exists. Each person is logically identified and distinguishable as such, and the rule defining the set may be age of the person, or level of education, or anything that applies to what we defined as a person.

**Property:** This says something about a thing. A thing may be distinguished by various characteristics which are ascribable to it. A non-arbitrary set may be one of persons where each is defined on some given basis. The persons in this set may have characteristics other than those needed to put them into this set but which make each different from others in the set. These things are said to be properties of this thing or others in the same set. A set is itself a thing, and the number of elements in it is a characteristic it has. The set of persons is defined on the basis of some set of criteria. If height is not one of these, then one may use it to distinguish between the persons that are in the set, and one may be said to be tall, the other very tall and so on. The person as a thing has a property of tallness, something that may be applied to any person.

**Variable:** This is a thing which may be given any one of a number of identities. Thus a wall is a thing, the color of this wall is a property of it, and white, black, red, etc. are things which the color of this wall may logically be. A set is a thing and the number of elements in it is a property of that set. Six is a thing or number which this property may be. A variable may take any one of a number of values. This is not to be confused with numbers. The values a color may take may be specified as red, or green, or blue. The values that health may take may be identified as high and low. Values that variables may take are part of the theory development, and some may be useful, others not.

We can summarize by saying that thing is a person, it has a property of tallness, and sixteen is the specific tallness of that person. Another property of the person is the person's hair color, which takes the value black in this case. Finally, the value a variable may take has what we call dimensions. One may choose to define size of an individual so that each value this variable may take is made up of an ordered pair, for example value of distance around the chest and distance around the biceps. What this variable may be is strength, which in this case is a two dimensional variable.

**Connection:** This says something about a logical order into which one puts pairs of elements in the set. The order imposed is a connection between the two elements and this logical order may be defined in any terms we choose, including totally arbitrary ones. The interesting orders, however, are those that come from something about each of the elements of the set. One basis for ordering the elements of the set is a property that its elements have. We may order the elements of this set on the basis of the value of one property that each has. This means we have to order the set of values first. Thus at the basic level, all orders are arbitrary, but from there they may not be so. A connection exists between two elements of a set whenever it is meaningful to say some specific thing about the pair of elements as a pair. If we say that Walking Bird is the father of Sleeping Deer, then we say some specific thing about two people, and the statement is meaningless unless it is about two things. There is no meaning to the statement "A is the father of". The connection here is that one person is the father of another person, or that one is the daughter of the other. The truth of the statement does not in any way affect the logic of the concept of connection. Any set may be ordered and produce a set of pairs, each of which identifies two elements in the original set that are ordered, that is, that are connected in a specific way we define. The set of pairs so created is known as a relation based on the original set.

**Structure:** This refers to a set of things and a relation on that set. The set and the set of pairs that are connected in a predefined manner, together define a structure. One aspect of the structure then is the set of all elements in the original set that appear in at least one pair of the pairs that make up the relation obtained from a connection which we predefined. The other aspect of the structure is the set of pairs itself. We have people A, B, C, and D. The relation we define is that of motherhood. We assert that A is the mother of B, and A is the mother of D, but no other person in the set is the mother of any other in the set. Only two connections of motherhood exist in the original set. We have now identified a structure based on the relation of motherhood. This structure is made up of the things A, B, and D, and the pairs (A, B) and (A, D). If A were not the mother of D, but B is the mother of D, then our structure would have the same three elements A, B, D, and the pairs would be different, that is, (A, B) and (B, D). The same three people are there, but there is a different structure. If we had used the connection of parenthood, then we would include in the relation all pairs connected by fatherhood as well as motherhood. The result would be a definition of a genetic family, a set of people each of whom is related to at least one other according to the definition of the connection of one being a parent of another.

To define a structure one starts with a set of things. These are defined and remain as such in all discussions of this structure. Next one defines a connection, a logical relation that is meaningful in terms of the things defined first. When the connection is established between various pairs of things, the result is a set of pairs, each of which is there by virtue of the existence of the connection between the two units of the pair. The structure is the set of things and pairs, a set of things ordered by a specific connection. If we use more than one connection, then a structure is the set of pairs that results from using each connection. It is the set that is the union of the sets of ordered pairs that arise from the application of each connection. If a structure is a connected set of things, can it be a thing also? The answer is yes. What is a structure in one level of analysis may be considered a thing in another level. Just as a molecule is a structure made up of connected things each of which is an atom, the atom is itself a structure made up of things, a nucleus, electrons etc. It is the analysis which determines whether the structure is to be viewed as such, or whether internal makeup is relevant to the analysis.

**Performance:** This is what a thing does. There is being and there is doing. Things perform when they take actions at which point it is meaningful to make them the subject of verbs. A person is a thing, and that person sends a message to another. The first person is then said to have performed something and what he did was to send the message. This person's performance is defined by this act. Each performance may involve more than one act and may be described by a number of statements. These we term the components of the performance.

Structures also do things, and therefore have performances. Performance is action, and it may have properties as we have defined this concept. A person performs when that person runs, or opens a business, or sells a product at price of 3 Euros. This running may be assigned an adjective such as fast, and the pricing an adjective, such as competitive. Fast is the specific value taken by the property of speed which running has, and competitive is a high level of the property of dependence of the performance on the behavior of others. We have performances for things and for structures, and we have properties of things and of performances.

The concept of a variable may be refined to allow us to distinguish between two different kinds of variables. A variable is termed a decision variable for thing X if and only if the value taken by the variable is determined by the direct action of X. We say that X sets the value of the variable, and that makes the variable a decision variable of X. If There are some specific values of the variable which

X may set, and some which it may not , or can not, then we say the variable is a decision variable for X for the first set of specific values. It is a decision variable for some proper subset of the values it may take. If this set of values is empty, it means that X has no way of giving the variable any of the values it may take. The value it takes is thus not for X to determine. This variable is then termed a parameter for X. The person X may be allowed to find out what the value is, but he cannot set that value. Decision variables for X are those the values of which are made real by the choice and action of X, the values are set by X. A parameter is a variable the values of which X cannot set. Person X may however may be said to read, and so know the values of the parameter.

For a person in a car, the depth to which the brake pedal may be pushed is a decision variable, but the location of stop signs is not, at least legally that is. The driver may set the level of the former, thereby perhaps affecting the car's movement, but he may only read the second. Is the car's movement a decision variable for this driver? The answer depends on the connection between the brake pedal position and the wheels of the car. This may be a decision variable or not. If it is, then movement may be viewed as an indirect decision variable, otherwise it is a parameter. Metaphorically speaking, decision variables are knobs which one turns, and parameters are dials which one reads. Finally there are variables which we might term the goal variables of X. These are variables which may be decision variables, or they may be variables the values of which are determined by the values of decision variables of X and the values of some set of parameter variables. Goal variables are those variables the values of which are identified by X as being important to her well being and are causally related to the values X gives her decision variables and to the values of variables that are parameters.

**Transformation:** Any mapping that assigns a value to a variable as a consequence of the values taken by some other variables is a transformation. If this set includes both decision variables for X and parameters, then this transformation is a critical element in the decision problem for X because it describes the causal connection between the values given the decision variables, and the values which the parameter variables happen to be to the values of variables which matter to the decision maker. Transformations describe ways in which the world changes, and those that contain variables that we can control are ones that matter here.

The set of parameters is made up of variables that are components of a decision problem the values of which are facts, and therefore given, for the problem at hand. This makes up what we call the environment of some organization or part of one. The environment is thus described by the specific values taken by these parameters. The problem relevant environment includes the value of only the parameters the values of which along with those of decision variables determine the values taken by goal variables. A transformation relating the value of the goal variable of the car's movement to the value of the decision variable of the distance to which the brake pedal is depressed, and to the value of the parameter of the road's wetness is a transformation. The goal variable is to stop before reaching the observed parameter value of the stop sign location. The pedal distance to the floor is determined by the driver, the wetness of the road is not. The problem is to depress the pedal so that the car will stop, given its speed and the time of pushing the pedal, as close as possible to the stop sign location, under the wetness condition of the road. The problem is in operational form because humans control foot movement, and the facts needed to make a good decision, distance to sign, and wetness of road, can be estimated by the driver.

## 4. Basic Analysis

The analysis of organization structure is in terms of sets and mappings which connect these sets in different logical ways. There are the following components of our analysis.

a) A set of organization structures the elements of which are structures, each defined in terms of components such as a set of people, a set of decision rules, etc.
b) A set of properties of structures defined in terms of the components of a structure, and a set of values which each property may take.
c) A set of technologies where each element is defined as a connected set of transformations. Each of these describes a process by which some segment of the universe is changed from one state to another.
d) A set of properties of technologies defined in terms of the components of a technology, and a set of values which each property may take.
e) A set of performances where each element is defined in terms of a vector of values given to decision variables. A performance describes what the organization structure decides to do or does.
f) A set of properties of performances defined in terms of the components of a performance, and a set of values which each property may take.

g) A set of environments where each element is defined in terms of a vector of values taken by variables which make up a segment of the universe. This segment is made up of the variables which are embedded in the technologies and take values which are beyond the structure power to set. These variables are parameters and the values they take describe the state of the relevant environment of a structure.

h) A set of properties of environments defined in terms of the components of an environment, and a set of values which each property may take. For each property, we specify the mapping or process by which the value taken by the property is determined for a given environment.

i) A set of goal outcomes where each element is defined in terms of a vector of values taken by variables which are identified as those that are goal variables.

The set of mappings are:

a) For each defined property of structure, we specify the mapping or process by which the value taken by this property is determined for a given structure.

b) For each defined property of technology, we specify the mapping or process by which the value taken by this property is determined for a given technology.

c) For each defined property of performance, we specify the mapping or process by which the value taken by this property is determined for a given performance.

d) For each defined property of environment, we specify the mapping or process by which the value taken by this property is determined for a given environment.

e) A set of analytic mappings or functions each of which is derived from theoretic arguments, and each of which asserts a causal relationship between values taken by a property of the structure and the values taken by a property of the performance of that structure. The mapping may be subject to given property values of the technology.

f) A set of analytic mappings or functions each of which is derived from theoretic arguments, and each of which asserts a causal relation between pairs of values, the first of a performance property, and the second of an environment property, and the values taken by a single goal variable. The mapping may be subject to given property values of the technology.

To use these analytic mappings to design a structure, we start with the last analytic mapping of this list. We first identify what our goal variables are, and what values we should like them to have. Then given our environment, we identify the performance properties needed. Next we identify the structure properties needed to get these performances. Then we identify costs of the structures which have these properties, and finally we choose the structure which gives the best (or good etc.) value to the difference between the value of its outcomes and that of its costs. We now have designed the structure that is most efficient, or highly efficient, or good enough, and so on. We have not however paid any attention to the process of searching through the inverses of our mappings, the backtracking, to determine what our search process should be. If the sets and the mappings are well ordered we use the order to determine an efficient search process. This is why our sets and mappings will be carefully defined to have as much order as we can get without distorting any real connections.

## 5. Examples from The Literature

Examples from the well known existing literature would help connect past work on the analysis and design of organization structures to what we have developed above and to what we do below here. The problem is that there are no good examples from that literature, not ones that pay strict attention to the clarity of definitions, the operationality of the sets, the correctness and order of the mappings etc. Nonetheless we can find examples that would give us coarse analogues to what we do below based on the above logical scheme. No example may do things in the order or terminology we used above, but all can be recast in that mold. There are similarities between the work of the following chapters and that in the literature, but there are also differences. Volberda's (1996) discussion of the performance property of flexibility is based on a definition of it that includes both the variety of what the organization can do and the speed with which it can do it. He distinguishes between four types of flexibility but not between flexibility and speed. We consider variety and speed to be two different properties, one relating to variety of activities, flexibility, and another relating to the time it takes to do it, responsiveness. In our theory we distinguish between the property of flexibility, which is similar to having a variety of behaviors in inventory, and responsiveness which is related to the speed with which the new circumstances become known and the speed with which appropriate behavior is retrieved from the ones in inventory. There is a link between the two properties but we do not consider them to be the same as does Volberda (1996). This allows us to make responsiveness dependent on the speed with which the organization discovers that circumstances have changed and on choice and implementation of the new behavior appropriate to the new conditions. To be flexible it is not enough to be able to do very many things, but to be able to do very many things and to be able choose from them the one that meets a certain level of quality for the circumstances which have come into existence. As for the four types of flexibility Volberda defines, we recognize only two, performance and structural, and because the second is meaningful only when the properties of performance have been considered, we discuss it after we have dealt with them. The concept of flexibility of this work does not refer to only the number of different things that the organization can do, but those that are good and recognized to be so in the context of an identified set of circumstances. This requires that the inventory be not one of behaviors, but of pairs of (circumstances, behavior) , where the behavior can be implemented within a preset period of the recognition of the existence of the circumstances, and do so at a preset quality level for the circumstance.

There is also some similarity between what is done in our theory and the work of Galbraith (1973). He defines structure in terms of programs that "specify the necessary behaviors in advance of their execution", "and in terms of a 'hierarchy of authority and reward powers'". The first quote refers to what we would call the flexibility of the performance of the structure. The second quote refers the components of the structure that relate to hierarchy and their properties, and one such property of structures is that which refers to the number of programs, another to the nature of the hierarchy. These are vague concepts but they obviously relate to our concepts of decision rules and their properties. Our theory has concepts that are rather similar but more clearly defined. Gailbraith's (1973) theory deals with technology which is defined in terms of the tasks to be performed and the relations between them. One property that is important to this theory is that of task interdependence. The definition of performance is that it is the actual behavior or tasks performed and some of its properties are its coordination and its variety. Situations faced by the structure in the real world describe its environment, and one of its properties is the proportion of new, previously unmet situations, to old ones. The outcome which interests him is profit. Relations from structure to outcome are given as follows. The higher the task interdependence and the higher the reliance on programs, the less variety of coordinated performances which the structure has. The higher the newness of the environment and the lower the variety of performance, the lower the returns. The design conclusion is that which states that if the environment has a high level of newness, then performance variety should be high. In the context of a high interdependence between tasks, this high level of performance variety calls for a structure with a low proportion of rules or programs to hierarchical relations of authority. In short, if the environment has many situations you have not seen, and if the technology is interdependent, then you need to have many performances that the structure may be asked to give. The structure that does this is one that has a high proportion of hierarchical relations to programs. Of course all this is useful only if we can determine how much newness an environment has, decide or determine the interdependence level of the technology, determine when a performance is coordinated or not, and determine exactly what hierarchical relations are and how we can make them exist. Our theory does that because it also deals with hierarchy and so on, but does so in terms of operational concepts like decision rules, and their properties of comprehensiveness and so on. Our theory does much of what his theory does, and it does so with concepts that are in terms of real structure design decisions.

Duncan (1979) has concepts and mappings that are similar to ours, but differ in important ways. To him a structure is a pattern of interactions, and one property is the extent of its decentralization, or the proportion of decisions made at lower levels relative to those made at higher levels. But it is not clear what it is that makes one level higher that another, or what a higher level of hierarchy means and how it can be measured. In our theory the same issues are discussed in terms of the properties of the decision rules which may be used to restate Duncan's theory. But when that is done, there appear to be many different degrees of 'higher', and many different levels of making a decision. The generalizations based on yes-no views of these two variables of structure, are of very little real use in design, and our conclusions cannot be translated into his. The same problem exists with the comparison of the concepts of environment and technology he uses and the ones we use. He defines the latter in terms of the functional units of the organization, their nature etc., and properties of a technology are pooled interdependence etc. Again performance is defined in terms of the decisions made, actions taken, and performance properties are coordination, and response time (the quickness with which performances are chosen when conditions change). The same is true in our theory, and our concept of the environment is not very different from the environment Duncan (1979) defines in terms of components, of which there are competitors, suppliers, etc. The properties of this environment relate to its simplicity and its dynamism. Outcome of relevance is profit. The relations from structure to performance state that with high technology interdependence, decentralized structures will produce performances that are low in coordination but high in response, that is, high in quickness. When the environment has a high level of dynamism, then a high level of quickness produces high outcome levels. But if the environment is simple, then coordination increases produce small outcome increases. In conclusion, if the environment is simple and dynamic, then quickness of decisions or actions, i.e. a quick performance is required for high output while a coordinated performances is not. The structure we should design if the technology is not highly interdependent is a decentralized one. This means that in the structure decisions are made at lower levels. These conclusions are the in the same logic as those of our theory, but they are not in the same terms nor are they the same in what they mean. But some correspondence can be found. There are properties of decisions rules that we define that may be used to identify decentralized structures and there are properties of the environment that may be combined to translate into the property of dynamism.

Though the work of Mintzberg (1980) is in terms of what he calls "the five classes of organizations" (there are no other "pure classes" in the scheme), the work can be recast in terms of properties, etc. Classes of structures are defined in terms of structure properties, such as ones that describe the nature of the jobs, the task assignments to people, and the nature of the rules. Other properties of the structure are defined in terms of whether it is bureaucratic or not, and by its formalization. The structure's performance is the work that is done, and properties of performance are in terms of its coordination, and quickness of response. The world around the organization is its environment and this can be hostile or not, simple or not, and dynamic or not. The technology is not given much attention, but is defined in terms of the tasks and the relations between them, and has properties such as sophistication. The theory is developed using these properties, and one argument developed defines a simple structure as one that has very few rules. If the structure has one person who makes all the decisions, then it is defined as having the property of being bureaucratic. Such a structure it is argued has a performance which is quick and coordinated if the technology is not well defined and is not complex. In an environment that is hostile and dynamic, quick response and coordination have high levels of returns to the organization. So it is that the simple and bureaucratic structure is related to output. The prescription for the structure we should have backtracks over these connections and tells us that if the environment is such and such, then such and such performance properties are best and therefore this or that type of structure should be chosen from the five types described. How one's choices are restricted to five types, and what classification scheme produces this number of classes is not explained.

More recently Baligh, Burton, and Obel (1990,1990a, 1992, 1994, 1996) have worked with both the set of traditional properties of the literature and with some newer ones that are used in the theory developed in the coming chapters. The work of these authors starts with the definition of structure in terms of components (Baligh and Damon 1980), of which one is a set of allocations of decision variables to people, another is a set of decision rules, another is a set decision variables, and so on. Structure properties are defined in terms of these components, and one such property is that of rule comprehensiveness which refers to the extensiveness of the circumstances covered by the rules. Technology is defined in terms of sets of transformation mappings and the connections between their domains and ranges. Properties of technologies are defined in terms of mappings and connections , and are randomness, etc. The performance of a structure is defined in terms of the actual values given the decision variables, the work done, and its properties take such names as coordinatedness, responsiveness, etc. The theory mappings are of the form: if the technology is complex and the structure has a high degree of rule comprehensiveness, then coordinatedness of the performance is high. When the transformations are highly connected, then coordinatedness produces high levels of outcomes. On this basis the authors develop design rules that tell one what to design when the environment is such and such etc, and these rules are put into a computer expert system which designs the appropriate structure given the facts.

## 6. Restating the Theory

The general mappings we talked about earlier may be restated in terms of our defined terms. One mapping connects a set of decision variable values for structure Y, and a set of parameter values, to a set of goal values for Y. Another mapping might connect the values of a performance property of a structure, and those of the properties of the environment, a set of parameter values, to goal variable values. We might argue, for example, that in an environment that changes often, the structure with a performance that can change over a wide range will have better profits than a structure with only one performance that never changes. The statement relates the values of the properties of the performance's changeability, and the values of the environment's changeability to the profits of the structure the performance which is of interest. If we have another mapping that relates the values of the structure's property of centralization to the value of the change in quality of its performance, then one would have related the former by way of the latter to the values of the goal variable of profits. There is now the theory that helps one to choose the structure property value one needs to have in order to achieve the profits one wants.

In the development of the theory, in either of its positive or prescriptive form, we will be refining and identifying specific variables, performances properties etc. Many issues such as the usefulness to theory or to practice of the set of values which we allow a variable to take have to be addressed. Which properties we define, how we define them, and the nature of the values that may be assigned are subjects to be discussed in the development of the theory. What we have done so far is define the general meanings of the terms which are the contents of these theories. For a number of reasons, the theories will be developed in pieces which are then put together to create the theories that represent more accurately real organizations. The order in which the pieces of the theory are developed is now discussed.

## 7. Analysis and Design

Patterns of connections between people in a given set describe the structure of the organization to which these people belong. If we change the people between whom a connection exists, we change the structure. The same is true if we change the kinds of connections that exist between people, or if we change the set of people who are connected by any of the relevant connections. Each structure is then connected to a set of performances, the things it can do. Some part of the real world contains variables that describe the segment that is relevant to some set of people, and the values these variables take are the objects of the actions or performance of the organization structure the people create. They want to find out how to create that structure which performs in a manner that changes the state of this segment of the world in the desired manner. How a structure performs, or what the people in it do depends on the pattern of relations these people have with one another. The people and these connections with others are the components of the structure of the organization. If someone describes what he is doing to another, then this person may do something she would not have done had she not been given that information. The information passed from one to another is a connection of one kind among many that describe a structure. What both people do will produce certain changes in the part of the world that describes their goals. These changes will depend on other happenings, besides what these people do, in the world. It is clear that routes from structure to performance to outcome exist, and it is not any structure that will perform in a manner that produces the best outcomes, or the better ones, or desirable one, or whatever. The theory developed in this work identifies the routes from structure to performance to outcome and does so in terms that makes them useful when we want to create a real structure.

We are interested in getting those outcomes we consider to be the right ones. From the identified and wished for outcomes we backtrack over our routes all the way to specific components of an organization structure. Backtracking over the routes means that we go from the outcomes to the performances that produce them and from these to the structures that give these performances. The result is a structure or set of structures which we can create to give us the outcomes we want. But the work is not finished, because a structure has costs as well as outcomes. The structure designer now has an economic problem. The outcomes produced by a structure through its effect on performance must be combined with the structure cost to give the net value of that structure. That structure with the highest such value is the one we would want to design. This process of choice gives us the design of the efficient structure.

The process of design, including both the backtracking from the outcome to a set of eligible designs of structures and the evaluation of their costs, is itself costly. So we would be better off if the process we use were an efficient one. We should be looking for an efficient process of design which produces efficient structures that give the performances that help us attain a set of goals. The theory developed should be a general one that applies in many if not all cases and circumstances.

## 8. Multiple Routes and Backtracking

The routes from structure to performance to outcome are many. There are routes leading to many outcomes from every structure, and there are many structures from which there is a route that leads to some given performance. Analogous statements may be made about the routes from performance to outcome. Furthermore, the connections on which the routes are based are themselves sometimes connected to variables in the theory. Technology determines along with structure whether there is to be a route from a structure to a performance, and if there is a route, what its nature is. The environment determines along with performance whether there is a route from a performance to an outcome, and if so, its character. Identifying the routes in our theory requires that we work with technology and with environment as well as with structure and performance.

The complexity of the task of defining the routes and the process of efficient backtracking is exacerbated by the untidiness of our set of structures, performances, outcomes, environments, and technologies. Each of these sets is hard to order in a logical and simple way. There is no way that we can order any one of them as we do numbers or even as we do vectors of numbers. Nonetheless without order on these sets we cannot talk of efficient processes of design, or of a workable theory of structure to outcome through performance given environment and technology. We will need to create substitute sets to work on, sets that are well ordered, and clearly connected to the original sets. They are sets of measures on the properties of the structures, performances, technologies, and environments, the original sets. The properties are chosen to be those that are relevant and take values or measures that are reasonably well ordered. Besides being ordered, properties are of little use unless they are defined operationally. Each must be so defined that a measure or value which it takes can be directly related to a specific subset of elements in the original set.

What follows in this work is the development of a set of theoretical relations, causal ones. It starts with defining the sets that are the things between which theoretical connections are shown to exist. Organization structures are defined in terms of their components. Properties are defined for the components of structure, and the nature of the values they may take is analyzed. Every property of a structure is thus a property of one of its components. Properties of performances are analogously defined and analyzed. Environment, technology, and outcome are similarly treated. Theoretical mappings are identified and their natures analyzed.

The causal connections are called mappings. Each is a relation of a special kind, one that might state that: the returns to increases in the measure of responsive of a performance increase with the increases in the measures of the raggedness of the environment. Responsiveness is a property of the set of performances of a structure. Raggedness is a property of the environment. The statement is a mapping from the set of measures of a property of performance and the set of measures of a property of the environment to the set of measures of a property of the returns or outcomes. Together, the first two sets of measures form the domain of the mapping, and the last forms the range of the mapping. The statement describes the nature of the mapping, and the theory must now show this to be true. If our properties are defined properly, we should be able to tell what the measure of the raggedness is, and to specify what a desirable measure of responsiveness should be. If this property is defined properly, then we should be able to work from this measure to a set of performances that have this measure for this property. Our analytic mappings would then be used to work back from this required value to this property to the values of appropriate structure properties and then from these to specific structures.

## 9. Efficient Structures: Organizations and Others

Whoever heard of a bicycle with square wheels? Why would one design such a machine, which, incidentally, may no longer be correctly termed a bicycle since its wheels are not round? In fact, the shape of the wheel and the changes in the level of the surface, its smoothness etc., on which it is ridden determine the smoothness of the ride one gets. Imagine a surface that is in the form of corrugated iron sheeting where the cross section of each of the parallel ridges was in the shape of half a circle that had a two foot circumference. The bicycle that gives the smoothest ride when ridden over this surface is one with square wheels. This is what some mathematicians have shown to be the case as Kim (2001) reports. In this case the wheels would have sides of one foot each, and the bicycle would be ridden across the ridges and could make turns as long as they were not sharp. Kim (2001) draws several surfaces with different configurations and wheels of different shapes, and asks the reader to match each surface with the wheel shape that gives the smoothest ride. The correct matches show that each wheel shape, so very unlike the circle shape, gives the smoothest ride for only one surface shape.

It all starts with the concepts of structure and performance and the relations between the two. There are some examples from moths, horses and yachts that may be used show the essence of this problem of the relations between structure, performance etc, and an excellent place to start is the research done on Scandinavian moths by Rydell and Lancaster (2000). Their study uncovered some interesting connections between the structure of the moth, what it is, the performance of the moth, what it does, and the outcome, its chance of staying alive. They found the moths to be of two kinds, each with its own structure and performance. The environment of the moths contains bats which feed on these moths and prevent their survival. A moth which can perform in a way that allows it to avoid being captured by the bats will be more likely to survive than is a moth that does not perform in a manner that avoids capture. Bats find the moth's location by the use of sonar, by emitting sound waves and interpreting their echoes. The moth feeds in shrubbery or bushes, and needs to fly from one bush to another to find food. It is when the moth is in the open, that is, when it is flying and not in a bush, that the sonar can locate it, and thus when its chances of being located and captured by the bat are good. The first species detected the sound emitted by bats and when it heard it, it responded by flying into places, bushes, where the bat sonar sounds did not penetrate, where the bats did not detect moths and where they did not go. Detecting the sounds made by the bat was possible because the moth had ears and a brain and the two made it fly to specific places when the sounds were heard. These places were those where the moth was surrounded by plant parts which interfered with the echoes of the bat's sound emissions and so made its moth detection device ineffective. Unable to locate with precision where the moth was, the bat could not find it and so could not eat it. The second species of moth could fly very fast, much faster than the first one, and could make large and sudden changes in its direction of flight. The second species could not detect the sound of the bat's sonar because it had no ears, but it did have big wings which it used to fly in this seemingly erratic manner at all times. The bats could locate and find this moth, but they found it very difficult to predict its path and to catch and eat it. The behavior of the moths of the first species, the one with ears made it more difficult for the bats to find them, the behavior of the second, the one with big wings made it more difficult for the bats to catch them.

The structural differences between the two species of moth determined what each could do. What they could and did do along with the facts on bats, their sonar, the presence of bushes that defined their world, and so on, had an effect on the chances that they would be eaten by bats. Rydell and Lancaster (2000) found that the structure with ears species could hear the sonar and fly tolerably well to get out of the open spaces and so make it harder for the bats to find it. The structure without ears could not hear the sonar, but flew so well that it was never in a unchanging and smooth flight path long enough for the bat to catch it easily. The two species performed in different but effective ways in the same environment. The structure of the moth determines what its performance can be. The hearing species, the one alert to the presence of bats had ears, which are structure parts made up of specialized cells arranged in a manner that allowed the moth to detect the presence of and changes in sound waves. In this structure a segment of its cells were allocated the special task of sensing sound, and the cells were arranged in a way to give it substructures we call ears, that could detect sound. Its structure had two such ears and they were ears placed on either side of its head, so its structure had some redundancy in it, which increased the space from which it could hear, and made it alert to changes in sound that originated from many more points in space than if it had only one ear, or two that were placed close together. The moth also had cell segments capable of interpreting the sensation picked up by each ear and sent to its brain by yet another set of transmission cells. The brain had built in decision rules that directed behavior, and told the brain that when it got the message that the sound was there, it was to activate and direct the flying parts of the structure. Flying was to be at high speed, away from the source of the sound, and towards a bush, where the moth was to enter among the foliage, where flying was to stop, and where it was to stay for a while. The moth was alert and used this alertness to do things that made it harder for the bats to find it, and so the outcome is that moth has a better survival rate than it would have had with out the ears.

In the other species the structure of the moth did not have the substructures with the specialized cells that made up ears which could detect sound waves. However, the structure of the moth gave it wings that were much larger and thinner than those of the other species. These relatively large thin wings had a higher ratio of area to weight, a structure property known as wing loading. It is these wings, ones with the structure property of high wing loading, that allow the moth to change its flight path from one direction to very many other directions, and to do so quickly without reducing speed or control. Its brain has built in decision rules that tell it that under all conditions it is to change its direction of flight very often, and that the changes are to be made quickly, and be without any fixed order. What the moth is determines what it does, and this moth has wings that allow it to fly at high speed with rapid direction changes. It also has the brain which tells it to fly in this manner all the time. Bats can track the flight of this moth with their sonar, but they have a difficult time predicting its flight path and making the rapid changes in direction needed to catch it. One moth is built in a way that lets it act in a manner that makes it hard for bats to find it, while the other is built in a way that makes it hard for bats to catch it. The environment, the bats, what they eat, how they catch it etc., are some of the elements that make up the environment of these moth.

Structure determines performance and performance together with the environment determine outcome. But structure also has costs and the efficiency issue becomes relevant. In this case, given the equal effectiveness of the two performances, one should be interested in which performance costs less to get than the other, and so we come to the issue of the cost of maintaining and operating the two moth structures. Rydell and Lancaster (2000) conclude that the structure with ears costs less in energy to maintain and operate than the does the one with big light wings. The specialization of cells to sense and others to interpret sounds could be done with cells that require a certain amount of energy to maintain and carry around in flight. Greater speed and fancy rapid direction change flying require cells that cost more energy than the hearing ones. Greater speed and maneuverability, greater flexibility of performance, need a structure with more cells and higher body temperatures which means the structure needs more energy for its maintenance than that needed for the hearing cells. In turn, this means that the fancy flying species of moth needs more food than does the first, which means it has to visit more shrubs in a day in order to find food to give it this energy, which means that it is has to be in flight for longer periods of time during that day, which means it has to expose itself to bats for longer parts of that day, which means that it is more likely to be caught and eaten. The environmentally knowledgeable or alert but dull flying species is more efficient than the non alert but spectacular flying one. Though it does not necessarily follow that the more efficient species would have the larger population, in this study of moths it did. The authors of this study, Rydell and Lancaster (2000), found that the more efficient moth made up 95% of the population and the inefficient one made up the remaining 5%. There is of course the possibility that a performance that is less alert than the one and less flexible than the other might be more efficient than both. This study does not address this question of the general relations between the structure of a moth and its performance. It does not need to do so, because even if the question is of some academic interest its answer is not of much use. Because it is not interested in this question, the study makes no use of general concepts of structure or performance properties. We introduced terms like redundance and alertness when we described this study of moths, because we are interested in knowing how structure performance changes when changes are made in the structure. Because there are cases where humans use a structure and have some measure of control over it, such knowledge can be very useful. Rydell and Lancaster (2000) show us in clear terms what it is to connect structure to performance. In the next example, there is the same analytic treatment of structure and performance, but with a structure that that is to be used and over which there is some measure of control.

A structure that is more useful to humans than the moth is the horse, and the connection of its performance to its structure is interesting and useful, and one in which the structure and its performance are closely related. This performance gives it an outcome of successful survival in the wild or in return for useful service to humans (Hildebrand, 1987). Starting with behavior, and concentrating on what interests humans most, movement, one may describe many different things about the way a horse moves. Important characteristics of the things a horse can do are: a horse can run faster than most mammals; it can run at that speed for relatively long periods; it can change direction, rate of movement, and location in three space quickly and easily; it can do all this while carrying a normal sized adult; it can pull heavy loads. Its movement performance has the properties of speed, endurance, maneuverability and strength. We are talking about what a horse is capable of doing because it is what it is, and about the usefulness of what it does to us. We mentioned speed, etc, because we have concluded that these are some of the properties of what it can do that determine the outcome we get from using the horse. But why is it that a horse can perform in this manner given its weight, but other animals cannot? The answers lie in the nature of the structure of the horse, the way it is put together, and in particular in the structure of its legs. If we know the details of these answers, and if we have any measure of control over the structure of the animal we actually use, then we can begin to discuss issues of the efficiencies of structures, and make decisions on what structures we should look for to buy or breed.

Speed, etc are performance properties, not actual components of the performance. There is nothing called speed that the horse actually does. What the horse does is move its legs, and properties of this movement may be connected to speed. The distance a horse moves its legs is one property, and the time it takes it to move one leg after another is also a property. The further the horse moves it legs and the rate at which it moves them determine speed as Hildebrand (1987) tells us. He develops and explains arguments that relate various components of the structure and their properties to the properties of its performance. First there must be the concept of structure, which in this analysis is seen as muscles, bones, etc. and the relations between them. For example, one thing that affects the rate of leg movement or stride is the location of the set of points where muscles are attached to leg bones. It is the distance from these points to the joints between the leg bones that are turned by the muscles that is the property of structure that is relevant here. He tells us that higher rates are obtained by "..shifting the insertions of leg muscles closer to the joints turned." One structure property is connected causally to one performance property, according to general principles of Mechanics that apply just as well to doors and the locations of the handles that are used to open and close them. The length of the stride is determined by the length and weight of the legs. Longer, lighter legs mean more length of stride. But it is not just the length that is the relevant property, but rather the length relative to the body size, defined in terms of such properties as length of body, etc. But, after some point, greater leg length relative to body length causes the legs to strike one another, and that reduces speed. The relation of structure property to performance property is not monotonic.

Hildebrand (1987) goes on to discuss leg weight, the rotation of joints in three space, and so on. When he is done he has explained the measures of the running performance of a horse in terms of measures of properties of its structure, and has made it clear how these last measures are obtained from pieces of the structure itself, and of the relation of these to one another. If we could design a horse, or if not, then breed it, to have what we wanted we could use this analysis to get more speed or more endurance. Endurance depends on the amount of energy recovery which is determined by the four suspensory ligaments in each leg and their relations to the bones to which they are attached. Identifying these relations is not possible without a clear understanding of what a structure is. We must know the pieces that make up the structure and the relations they have to one another. In this case the pieces are bones of certain shapes and muscles of certain compositions, and the relations of the physical connections between all of them.

What is not discussed by Hildebrand (1987) is why the horse needs to run fast, for long distances etc. This is not Morphology, but economics broadly conceived. The answers come from consideration of the horse's environment and the performance that would allow it to survive and reproduce in the environment. This analysis involves explaining that speed is necessary for survival because the horse lives on flat open land where its food is, and is prey to other animals who can run medium fast for very long distances, such as the wolf. Speed and endurance help the horse get away from its enemies, and the sooner it starts running the better off it is. It starts running when it senses the presence of its enemies in its environment, so the sooner it senses such a change the better off it is. What it needs are components that make it sense such changes as soon as they occur, components that make it alert. It has them in its ears and its eyes. Its ears can be moved over almost 360 degrees and that allows it to hear sounds from all parts of its environment. Because its ears can be moved separately it can cover, at the same time, more than one direction from which sounds of danger may exist. Meanwhile its eyes are set wide apart which allows it to focus very well on distant objects and to see, albeit not very clearly, nearly anywhere in its environment by merely moving its eyes. The components are comprehensive in their scopes, and there are four of them. This redundancy in the structure allows it to cover a lot of the environment more often than if it had just one component, and this more frequent sweep enhance its alertness by increasing the probability that it detects any sign of danger within some time from its happening. The fact that the horse structure includes components that sense different aspects of its environment makes it more flexible. Two kinds of sensing components, each sensing a different aspect of its environment gives it the flexibility to detect two different, and often independent, aspects of its environment and enhances it alertness. If there is no sound it might well catch sight of the danger and conversely. The horse's structure determines its performance. High levels of alertness and flexibility are properties of the horse's performance that serve it well. Components of its structure are such that the structure has high levels of the properties of comprehensiveness and redundancy, which give its performance the two desirable properties. With this kind of knowledge, one has a basis for breeding horses that survive in the wild, or ones that can do what we want them to do, be maneuverable for Polo, or have great endurance at relatively low speed for the 100 mile races. Though we cannot design horse structures, we know enough about genetics to breed them to have the desired structures, or to buy them when they do.

The same logical problem is faced by the designers of the 12 meter yachts that race for America's Cup (Nova, 1988). Again the property of speed of movement concerns the decision makers. This property of performance is however determined in this case not by length of stride, but by the measures of the properties of lift, drag, flow, and so on. Meanwhile all the performance properties are defined in terms of structure properties that include the shape of the hull, the weight and shape of the keel and so on. Designing a boat that is fast in many different environments of sea and wind, and at the same time, stable and strong is no easy problem (Nova, 1988). It requires an understanding of the relation of structure to performance, and the knowledge of how different performance properties and their values affect the boat's ability to win the races. Horse or boat, the problem is of one logical form. The names of the variables differ from one problem to the next, and the branches of knowledge needed also differ. But in both cases the analysis must uncover how the measures of performance properties are related to the measures of structure properties.

We should like to do something like this for organization structures and the environments in which they exist. Because our structures and environments are not simple as those of the bicycle and surface, our arguments will not be straightforward pairings. Nonetheless, the main purpose of this work is to find the organization structure that is efficient given the nature of its environment and the chosen technology. In more general terms, we hope to develop a theory which identifies the relations from structure components, environment components, and technology components to whatever outcome we might want. We want this theory to be in a form that allows us to accomplish our second goal, which is to design the structure, that is, to identify the real components of the structure that is best or highly efficient given the environment and the technology. Finally we want the process of designing efficient structures to be efficient and operational, which means that it is to be a systematic process made up of well identified steps that are described in terms of what the designer actually does. To achieve these goals, we need to do a large number of things, from defining terms to developing the arguments that produce the theory mappings and the backtracking rules. The blocks we identified earlier, structure, performance, properties of each, environment, technology and performances of both must be defined in detail. The concepts of a mapping and of rules of movement of the design process must also be defined. All sets of definitions require that we start with the most basic of concepts and define and discuss them once all together.

# CHAPTER 2

# ORGANIZATION STRUCTURES

## 1. Components of Organization Structures

Two people are connected by a decision rule if one of them specifies in some measure what the other is to do. It is this connection which makes an organization of those so connected, just as the connection of parenthood makes a family. The decision rule connection is necessary to the definition of an organization structure, but it is not sufficient. There are other connections that may be used to define an organization structure, but a structure is an organization only if there are the decision rule connections between people. The components of an organization structure are given in Baligh and Damon (1980) as:

1. A set of people
2. A set of operating decision variables
3. A set of parameter variables
4. A set of things that are used as rewards
5. A set of assignments each of which pairs a decision variable from the set of component 2 with a subset of people in the set of component 1
6. A set of assignments each of which pairs a parameter variable from the set of component 3 with a subset of people in the set of component 1
7. A set of assignments each of which pairs a reward variable from component described in component 4 with a subset of people of component 1
8. A set of decision rules each of which involves one decision variable from the set of component 2
9. A set of decision rules each of which involves one parameter variable from the set of component 3
10. A set of decision rules each of which involves one reward variable from the set of component 4

## 2. People in the Structure

This first component may be a set of people with identities in real life, such as Amina, John, Liu, Obafemi, or it may be a set of any 4 persons such as (person 1, person 2, etc.). These are people who belong to the organization, are members of its people component. By the basic definition of an organization, they are the people who are connected by decision rules to one another, or are expected to be so connected. In any given case, one might put into the set the people who are actually connected by decision rules. This would be a description of some real structure. One could list the people who are alleged to be members of an organization by virtue of other criteria. In this case the set defines people who must be connected by decision rules if they are to be eligible by our criterion for membership. By our definition, a person cannot be in this set unless he or she is connected to another by a decision rule.

## 3. Variables of the Structure

A number of the components of a structure are made up of the variables embedded in the transformations that the organization uses to attain whatever changes it aims to make in order to fulfill some goal it has. The goal may be profit, and the transformations are those that produce and sell spoons. The goal may be to prevent the control of Kuwait oil wells by Iraq, which requires the destruction of Iraqi armies which involves the use of destructive technologies of war. In all transformations there are variables involved each of which represents some aspect of the world. To an organization, the variables that matter are those which are the aspects of that segment of the universe in which its goals and its capacities are defined. Goals relate to the aspects that the organization wants to become the facts, and capacities relate to what it can make into facts, and the two are connected in ways described by what we term the transformations. Some of these are known to the organization, and it is capable of using them to make that segment of the world that is relevant to it to become what it wants it to be or something close to it. These are the organization's transformations, and the variables they contain are the elements which make up components of its structure. Like all variables, these take on different identities or values. The color of eyes is a variable and the color of this pair of eyes takes the identity we call brown, and that pair the identity we call blue, and so on. Identities are generally referred to as values, and variables are said to take on specific values in the real world when they take on an identity. Transformations connect the values of variables to one another. A simple market transformation connects the value of the variable of price to the value of the variable of the units sold. Each organization has a set of variables that come from its transformations, and each variable takes on one of a given set of values. It is important to distinguish clearly between a variable and its value. The variable is an aspect of the world, such as price, and for this variable there is one or more sets of values it may take. One set is relevant in any given case, and for the variable price it is the set of all numbers greater than zero, and the number is of US dollars.

Variables in the organization's transformations which take on values that are given them directly by the organization are termed decision variables, and they are the elements of a set that is a component of this organization. Decision variables take on values which the organization gives them, and they are variables that are in the transformations the organization uses and the values of which are made facts by people in the organization. The number of units of some part moved from inventory in the warehouse to the shop floor is one such variable, as is the message sent in advertising the product. We distinguish between decision variables that involve operations, those that involve rewards, and those that involve information. The first refers to what the structure does in terms of its activities that directly impact the outside world and bring about an outcome which the structure is created to obtain. The second are those restricted to the actions that are directed to people in the organization and specifically those acts which reward these people. The third refer to things done with information, and are described after we define the set of parameters. The distinctions are made for reasons that become clear when we discuss the efficiency of the process of designing structures.

Parameter variables are the variables in transformations which cannot be given values by the organization. These variables take on values which are totally beyond the capacity of the organization to affect. All aspects of the weather are such variables, and it is these variables that are the elements of a component of the organization's structure. The set of decision variables that have already been given values may be considered to be parameters as long as the values they have been given are to remain facts. Finally there is a set of variables that may be created from various combinations of the decision and parameter variables. The set of variable parameters that makes up the component of the organization is the union of these three subsets.

A decision variable is given values by the organization and it is what the organization decides it is to be. Parameter variables cannot be set by the organization, but may become known to an individual. The process of acquiring this knowledge by an individual involves a class of decision variables which are information related, and included in the definition of the set of decision variables. Though the organization cannot set the value of a parameter it can read it, record it, store it, or send it from one person to another. Reading a value may involve many decision variables, but for our purposes it involves only the decision to find out what that value is. Information is what these variables deal with, and later we will make them the set of decision variables for what we term the information substructure.

## 4. Assignments of the Structure

The next group of components of the structure are made up of sets of assignments. A pair of the form (set of people, set of variables), means that this set of variables are given to this set of people for action. The people in the first component set of the pair are to do something with the variables in the second component set, for example, give them values or read their values. In each pair the set of variables is made up of operating decision variables only, of reward decision variables only, or of parameters only. Three types of variables are used to define three substructures, each with its components of people, variables, assignments and decision rules. We call these an operating substructure, a reward substructure, and an information substructure. In short they are the O, R, and I substructures.

## 5. Decision Rules

Decision rules are the necessary connections for defining an organization structure. As a starting point, we view a decision rule as made up of a set of people who make the rule, a set of people who use the rule, a set of actions or things involved in using the rule, and a mapping. This mapping is a list made up of two columns side by side. An entry in the first column represents a circumstance, a description of part of the real world, a set of facts. The entry in the second column represents what is either to be made into facts, or what is to made into known facts. Pairing the entries, by putting them on the same line means that an action is to be taken when the entry in the first column is a fact, and the action is to make the entry in the second column into a fact. The action involved in a rule is associated with the subject of the rule. For operating rules the actions are to choose, or to choose and set, values of decision variables. For reward variables the actions are the same as for operating rules, and for information rules the actions are various logical combinations of read, send , receive, record and store.

## 6. Substructures

In the definitions of the components there are the basics for recognizing three substructures of an organization structure. Each would be defined in terms of the components of the original structure that refer to only one of the following: operating variables, reward variables, or information variables. The people component of each substructure would be a subset of the people component of the original structure. The operating or O-substructure would be defined as having the components:

a) A set of people (subset of components of original),
b) A set of operating variables (same component as in the original)
c) A set of assignments of operating variables (same component...)
d) A set of decision rules on operating variables (same component... ).

The components of the other two substructures are defined analogously.

Strictly speaking, our substructures as defined are segments of the whole. Calling them substructures is not, however, a serious logical error, since the definitions may be slightly altered to make them real substructures. But whatever the term we use, the organization structure is made up of these three substructures and is created to achieve some ends. These ends must be translated into things that the structure does. The connection from action to goal is described by the transformations in the real world that may be made and which the people in the structure know. The set of decision variables which forms one component of a structure comes from these transformations.

## 7. Source of Examples

Master Brewer Corporation is a firm that is used in this book to illustrate concepts and connections of the analysis, properties used in the analysis, and the design rules derived from this analysis. The theory, or analysis, is about the efficiency of different structures under different sets of circumstances, and the process is about creating structures that are efficient. If we were to fix the structure of this firm, MBC, then we could not use it to supply a variety of illustrations needed. We therefore allow MBC to be whatever is needed to give the appropriate illustration. But because we need it to be also a good source for comparative illustrations, we have to keep some basic things fixed. In general therefore we describe MBC as being engaged in using a number of transformations to brew beers that have different characteristics. The firm also uses a number of transformations to sell the beers it brews. The details of the transformations differ from time to time, and the outcome in which the firm is interested depends on the details of the transformations and the way the firm uses them, that is the decisions made. These decisions are the result of the organization structure of MBC, which is a set of elements of each of the components of the structure as defined above.

What MBC is will change as the things we need to illustrate differ. It is defined as brewing many different brews in many different breweries. It sells these beers in many different markets that differ from one another in many ways: geography, culture, competitor behavior, government regulation and so on. These different competing breweries and markets change over time in a number of different ways. Some change often a little each time, others change rarely but change a great deal when they do, and still others change in the manner of one or the other of the two remaining ways. But to start, we will describe a very simple MBC, and design a structure for it that is efficient in terms of the output the structure gives and the cost of its design and operations. In designing the structure for MBC, it matters not that the output is beer rather than knives, or that the input is hops rather than steel, and so the terms we use are the general ones: output amount instead of gallons of beer, price per units of effort instead of dollars per half page advertisement. The structure designed is thereby clearly applicable to MBC and to many other firms.

## 8. Designing the Organization Structure For a Simple MBC

Our example of direct design of an organization structure is for a simple, very young MBC. The firm has seven members to whom we refer as the Super Seven (Baligh, 1978) of MBC, and it is the structure of which the set made up of them is a component that is to be created. The set of people we call the Super Seven is the first component of the vector that describes this structure, and now we need the elements of the component that is the set of decision variables, the one that is the set of set of parameter variables, the one that is the set of decision rules for each of the seven people to use, and so on. When the structure is complete, then the Seven will have been organized. To concentrate on the structure issues we will leave out details of the business of MBC that are not relevant to the problem of structure design.

Purposeful design of an organization structure starts with the transformations that the structure is to operate. These are made up of decision variables to which the structure gives values, and parameter variables the values of which the structure can only discover. The design problem involves choosing the structure which operates with these variables. The design we want is one that makes the decisions that get the Super Seven of MBC to its goals. To describe the fundamental nature of this problem of design we start with an example of the direct design, with direct moves from transformations to environment components, and from these to structure components (Baligh, 1978). For the example, MBC is of a firm engaged in the production and marketing of only one kind of beer. It wants an organization structure that makes decisions that maximize its profits. First there are the revenues and costs of the actual operations, and the difference between the first and the second is termed operating profits. The ultimate goal is to maximize the difference between the outcome of the structure's decisions, which are in this case operating profits, and the cost of operating and maintaining the organization structure that makes the decisions on operating variables, parameters etc. Once we design a structure with the seven people which maximizes these net profits, we investigate variations in the number of people and the rest of the structure to see whether the changes save more in cost of the structure than they lose in operating profits from the decisions they make.

A set of transformations is defined, and it represents the ways by which the set of people of MBC can change the state of the world. There are transformations that describe how some things are turned into other things, and how money is turned into things, and conversely. In other words, there are some production functions, and some market response functions. These are what the Super Seven, the set of seven decision makers, have to live with. From these transformations we can identify the parts of the world that are beyond the seven to influence, and the parts the nature of which they determine. The former are the parameter variables in the transformations, and the latter are the decision variables. Each variable in the transformations takes on any one value from a set of these at any given instant in time. This value is defined in terms that describe one element or component of the world. For example, price takes on a value in dollar amounts, while consumer attitude takes on a value described as friendly or hostile. Variables that are parameters take on values that the seven persons of the structure have no power to affect. All they can do is to find out what these values are. We call this "reading" the parameter value. Decision variables are ones that are given values by one or more people in the organization. We call this "setting" the variable value.

The business is in an environment that goes from one state to the next every so often, with prices and technology changing. We want our organization to make decisions that maximize profits each period and to reach those decisions as soon as possible after the time of the change in the states of the environment and technologies. Profits in a period depend on the decisions the seven people make and on the particular environment of their business in that period. There are seven people in this organization, and we need to organize them, or design a structure that has as a component this set of people. Creating this design is an exercise that should make the concept of an organization structure very clear. The exercise gives one an experience of how one is to deal with the important issues of the detail with which one specifies a structure, of the clarity of the statement of the connections, of the problems of fitting pieces of the structure together, and the problem of relating structure costs to the structure components. The exercise has all the elements of the structure of an organization in it, along with examples of two major concepts described earlier, namely, a technology and an environment. The design of an organization structure for this operation is to be complete with all its components fully specified. The whole problem is formulated with assumptions about transformations (technologies), environment, and goals that makes it easy to expose the essentials of what a design of a structure is. The object is not to show what a realistic structure looks like, nor is it to describe an efficient process of design. Rather the object is to show what a complete, fully detailed, and operational design is, and how the design determines the decisions made and the effects of these on the outcome.

Even though the world of the Super Seven changes from time to time the length of this period is not allowed to change. We assume that these periods are of some fixed length and that our Seven, the firm, start operations in any period after all decisions are made (every decision variable in every transformation is given a specific value). The profits made in any period depend on the decisions made, on the time operations actually start, which is when all the decisions are made, and on the values of the parameters that describe the environment of the firm. For every set of decisions made, operating profits fall rapidly with the time it takes to make these decisions. Once the decisions are made, the seven spend their time making sure that the decisions are implemented. The object is to design a structure that makes decisions that maximizes the profits made from the operations each period. Once this is done, the cost of the structure is to be considered so that the highest net profits, operating profits minus structure costs are obtained. What is needed now is to organize these seven people, that is, to design the organization that has this set as its first component, and gives the set of decision variables the values that maximize operating profits in each period.

One may take on the identity of one of the seven people in MBC and with it the task of organizing seven people (six others and oneself), in such a way that the decisions made in any period are optimal (maximize operating profits), and are obtained in the shortest possible time. Later we will alter the design to get the one that maximizes operating profits minus the cost of the structure. In any design we choose, each decision is made by one or more of the seven, and each person making a decision (seeking the optimal values for a variable) goes through a process of solving a problem. All the facts about the environment (parameter values) can be obtained at the beginning of an operating period. When the decisions are made, the firm spends money to buy inputs, and at the end of the period, the firm sells its outputs and gets its revenues. We assume that the time it takes any group of people to solve a problem (give values to decision variables) increases rapidly with the number of decisions to be made. A problem with four decision variables to be given optimal values takes a lot more than twice the time it takes the same group to solve a problem with two decision variables. Also, it is assumed that the time it takes to solve any decision problem falls very little as the number of people working on the solution increases, and that the time it takes to send messages from one of the seven decision makers to another takes almost no time compared to the time it takes to solve decision problems, even those with only one decision variable.

MBC produces only one kind of beer, and the and details of the transformations that describe its brewing operations are given below. It produces amounts of this product in one or both of two factories or breweries. In each factory the production process uses up amounts of four different inputs to produce some amount of the product (output). The exact relations between the amounts of the inputs used and the amount of output that results change from period to period. The total amount produced in both factories in any period can be sold only in that same period. There are two markets in which the business may sell its products. The total amount sold in both markets in any period cannot exceed the total amount produced in both factories in that period, but the amount sold in either market may be in any combination of amounts from the two factories. The amount it may sell in each market is determined by the price it charges in that market and by the amounts of two demand generating activities (marketing inputs) it undertakes.

At the beginning of a period the business starts out with money. It uses some of that money to buy amounts of its production inputs, whatever is needed to make the beer it makes in each of its two factories, or breweries. Some of the money is used to obtain the things needed, marketing inputs, to sell the beer each of the two markets. The business then transforms its production inputs into amounts of output in the two factories, and uses its marketing inputs to help generate sales in the two markets. At the end of a period amounts of the outputs are sold and money is received. All the facts describing the relevant circumstances of the period can be found out in very little time at the beginning of each period. The circumstances and the decisions determine the profits made in the period. One may assume that all seven people are reasonably competent at solving problems and making decisions that get them whatever is required. One may also assume that they are all honest, trustworthy, and willing to do their parts in helping this business maximize its profits. When the work of collecting facts, of sending and receiving messages, and of solving the decision problems is finished, the people work diligently at making what is actually done match what ought to be done.

The operations that fully describe this business are known by the people in the organization. Every transformation, whether it is one showing amounts of things turned into amounts of other things or amounts of things turned into money, is described by an equation. Some transformations are production functions, some are market response functions, some are cost functions, some are revenue functions, and some are definition functions. Our first transformation describes the operations of the first brewery and is of the form:

$$q = f(w, x, y, z, a, b, c, d)$$

Here, q is the output amount of beer brewed in this factory, and each of w, x, y, and z is an amount of an input used in the production processes. Each of the terms a, b, c, and d refers to a number that connects some input amount to the output amount. All eight terms are variables, where the term 'w' may be the number of units of labor used, a number the organization is allowed to choose. The term 'a' may be a number that represents the labor skill level and so affects the way in which labor units may be turned into output units. This number is not like the number 'x' since it cannot be chosen by any one in the organization. It may, however, be found out by the organization. In this transformation terms, w, x, y, and z are numbers that are chosen and set by someone in the organization. They are values taken by variables we call W, X, Y,.., and they are real values which are for the organization to determine. Hence the variables are termed decision variables and the choice of each value 'w', etc. is made and made a reality by someone in the organization. Each variable represents an aspect or component of the real world that takes one value from a set of these. The value it takes, or the state in which it is at any time, is determined or set by one of the seven. For our purposes all these variables are given values that are positive numbers. In some transformations the specific choice of the number may be constrained but there are always multiple choices left.

The output obtained when the decision variables are given number values by the decisions of the seven people also depends on the variables values represented by the letters 'a', 'b', 'c', and 'd', in the transformations. These letters stand for things about the circumstances of the brewery and the inputs used. They are values of components of the environment, where 'd' takes a value that is the average daytime temperature which affects the speeds at which the machines may be run and so affects the output obtained from them. The number this term takes at any time is beyond the organization to affect, let alone set, and it changes from time to time. At some time this variable may take on a value we call 70 degrees Celsius, or one we term warm, or whatever. The variable is called a parameter, and it is a component of the part of the real world that is embedded in the transformation of this factory. Its value cannot be set, but it can be found out. We term finding the value of such a variable reading it, and we term the variable a parameter. This variable of the transformation is one component of the real world, and it is relevant to this organization because it is embedded in its transformation. This aspect, or dimension of the real world which we may call variable A, takes on a value which we represent by the letter 'a' in the transformation, and it could be one of many in some set of values. Whatever it is, this value is beyond the organization to affect, and so the variable is termed a parameter. A parameter is a variable in the transformation the value of which cannot be affected by the organization, though it may be found out. In our simple example all parameters take on values that are real numbers. These numbers represent such things as the age of the brewery, the weather, the quality or purity of raw material, the skill of the workers, and so on. These numbers differ from one period to another, and all numbers are positive and between zero and one. All may be found out at the beginning of the period. A list with values of decision variables and parameters in one column and value of output in a second column describes this transformation and is interpreted as stating that the numbers in the first column give the number in the second. Lists of this kind that meet certain conditions are known a functions, and we assume this transformation is such a function. When these are well behaved, they may be represented by equations. For this version of MBC, all the transformations are described by functions in equation forms which are known in full by the people in the organization.

Other transformations are needed to complete the set that involves this unit of operation of the organization. These are the transformations that describe how the chosen values for the decision variables are made real, that is, set and made facts so that they may be used in the production process described by the transformation. In our example, the organization must buy the chosen amounts of the decision variables. So that when it chooses the value of x it must buy that amount, and this involves transforming an amount of money the organization has into the amount x it wants. We assume that the transformation of buying for all four decision variables is linear. The price paid per unit bought is the same regardless of the amount bought, When it is time to buy, the organization may read this price before it makes its choice of the amount to buy.

The transformations that describe the operations of the second brewery are analogous to those defined above. In this case there is the production transformation

$$q^* = f^*(w^*,x^*,y^*,z^*,a^*,b^*,c^*,d^*)$$

There are also the transformations that describe the markets where the input amounts w* etc. are bought. As before, the first four terms are amounts of things we call decision variables, amounts of things used to produce output. This transformation has an output that is identical in nature to the output of the first factory. The amount produced is however, whatever it is, and q and q* are any two numbers. The same is true for all the terms w and w* all the way to d and d*. Furthermore, f is not the same mapping as f*, one transformation being more modern than the other. This production process also involves the transformations of amounts of money into amounts of decision variables in markets that are analogous to the first case but are not necessarily the same markets. There are four prices, one for each decision variable.

When the our firm produces some amounts q and q* which total Q units of beer, they sell this total in two markets. Each of these involves transforming units of outputs into money, and they do so according to some specific transformations. Each market is described by its own transformation, and though both are analogous to one another, they are not the same. For the first market we have the transformation

$$s = g(u, v, p, k, l, m, n)$$

Here s is the amount of the products sold, u and v are the amounts of different efforts made to sell the product, advertising and personal selling, and p is the priced charged. The parameters in this transformation are represented by k, l, m and n, where one represents the season of the year, another the successes of the local sports teams, and so on. The decision variable amounts chosen by the organization, the number of advertisements put out, and the number of salesman hour expended, are acquired in markets in return for money. The rate of exchange in each market is constant, which means that each is a price that is fixed, a parameter. The price that holds for each period may be read by people in the organization at the beginning of the period and may be any number of units of some kind of money.

The transformations that describe the marketing of the product in the second market are analogous to those for the first market. There is the transformation for the amount sold

$$s^* = g^*(u^*,v^*,p^*,k^*,l^*,m^*,n^*)$$

There are also market transformations which describe the way in which the prices charged, and the marketing inputs used in the marketing effort are transformed into sales. These inputs, advertising and personal selling, are bought at various prices that are fixed for the period but change from one period to the next. There are two more transformations needed to complete the starting set which are described by the equations which state that the total amount of output produced in any period is $Q = q + q^*$, and the total amount sold in any period is $S = s + s^*$. The amount Q produced in a period may only be sold in that period. The amount S sold in any period cannot be larger than the amount produced in that period.

## 9. The First Structure Design

We can now proceed to design an organization structure, that is organize the seven people named **A, B, C, D, E, F, G** who are to make the decisions with the first stage objective of maximizing the difference between the revenues the firm receives from selling an amount in each period and the costs it incurs in producing and marketing that amount. Decision variables and parameters are identified by the functions that describe the transformations, and organizing the Seven now turns to the determination of the assignment of the former to those who are to give them values, and the latter to those who are to find out their values.

The state of the environment is defined by the number values taken by the parameter variables. Someone in the organization reads the numbers and then inserts them into the transformations that hold for the period in which the decisions are to be made. All the transformations allow many choices to be made in the manner in which a given amount of the product is to be produced and marketed. In a factory, a given amount of output may be produced in any given period by many different combinations of input amounts, and the set of these combinations will differ from period to period because it is determined by the specific parameter values that hold for the period. The design of the organization structure for this case is described by a vector of ten components, a version of the general vector defined in the first part of this chapter. When the components of this vector are fully described, they will be the blueprint or design of the organization structure that is to do all that which is needed to operate the transformations to some end. The first structure we want to design is the one that maximizes operating profits, which are defined as: net total revenues in markets 1 and 2 minus total cost in factories 1 and 2. Because the time it takes to get these decisions determines when they can be implemented, and because the longer this takes the less return they have, we want a structure that gets these decisions in the shortest time possible.

Our first design will be created without any consideration of the costs of the structure. Costs of the rewards to the decision makers, costs of finding out parameter values, the costs of deriving parameter variables, the costs of sending, receiving, and storing information and many others will not be considered in getting the first design. When this first design is obtained, we will be making changes in its components and then seeing what effects on revenues, cost, etc. we get. There may well be changes in any one of the components of the structure we design that will improve the net profits. We may change our decision to keep and use the services of all seven decision makers and keep only six, which means we have to decide which of the seven to cut, and then rework the rest of the design and replace the decisions each makes and the decision rules they make and use, and so on. These changes will save reward costs and maybe some information costs, but they may well reduce operating profits. The new structure, which will reduce operating profits and reduce structure costs, may or may not give higher net profits than did the old one. Whatever the case, these changes require that we have something to change, and we have to start somewhere. We choose to start by ignoring the costs of the structure we design and go for the one that includes all seven people, maximizes operating profits by making the best decisions, and does so in the fastest time possible. When we have this design completed, we may decide to make changes in it and evaluate the results, and estimate their effects on operating profits and on costs of the structure. If the effects on net profits are positive, then we make the changes and then repeat the process. If the effects are negative, we try another set of changes. We stop making changes and implement the design at the stage where the facts we learn from the changes we have made are such as to lead us to believe that further changes would produce effects that are too small to justify the effort of making and evaluating them. There is no general stopping point defined in terms of structure features that can be identified for all cases of design.

Given the set of transformations that the structure is to operate or use, we now design a structure. This will be a design in terms of the components of structure. The process will work from the transformations, the variables within them and the relations between them to the structure components, ones that are operational since they represent directly real things that can be done. The first component of structure as we defined it earlier is the set of people in it. Every person in is set connected by a decision rule to at least one other person within it, and this rule involves a decision variable within one of the given transformations. We specify components of the structure design by starting with the choice of this set and then following it with the specification of the second component in the list that defines a structure.

The design of the structure, that is, the blueprint for the structure, is given next using the variable definitions given earlier, among which are q and q* as the outputs of factory 1 and 2 respectively, s and s* the sales in markets 1 and 2 respectively, Q the total output of both factories and S the total sales in both markets.

**Component 1.** The set of people that are to make decisions in this structure is the set of seven people, {**A, B, C, D, E, F, G**}

**Component 2.** The set of decision variables that are to be given values by people in the structure is the set of all decision variables each of which appears in one or more of the given transformations. This is the set of variable represented by s, x, y , z, x*, w, w*, etc in the given transformations.

**Component 3.** The set of parameter variables the values of which are to be read by people in the structure is the set of all parameter variables, each of which appears in one or more of the given transformations. This is the set of variables represented by a, b, c, d, a*, d*, k, k*, l, l*, etc in the given transformations.

**Component 4.** The set of variables to be used as rewards in this structure is the set with only one element, money. Decision makers will receive only money for being in the structure. This component is a set, {money}.

The next component is a set of pairs identifying the assignment of subsets of decision variables to people in the organization structure. Each element is of the form of a pair (specific person, { x, y., ....}). For example, it may pair **A** with the variables of the transformation that describes factory 1. Every such pair is an assignment of decision variables to a person and means one of two things. The first is that the value for any variable in the set assigned is to be chosen and set by this person. The second is that this person will choose values for the variable and give decision rules to another who will use them to choose its value and to set it, or will choose values for it and give decision rules to another, who will use the rules to repeat this procedure, and so on, till the last person chooses a value and sets it. The sequence may contain any number of steps. It should be noted that to choose a value for a variable and to set the value of the variable mean different things. To set the value of a variable means to give it one specific explicitly stated value, whereas to choose a value for a variable does not necessarily entail the identification of a specific value, but may well be a choice of value which is not specified as such, but in terms of its properties or the outcomes it brings about. Also, setting a value implies making the value a fact, while choosing a value implies only its identification in some form.

**Component 5.** The set defined as: {(**C,** the set of all decision variables of transformations defined for factory 1 ), (**G**, the set of all decision variables........for factory 2), (**F**, the set of all decision variables.............for market 1), (**E**, the set of all decision variables.......for market 2), (**B**, the set of all decision variables........for factory 1 and for factory 2, the total produced), (**D**, the set of all decision.................for market 1 and for market 2, the total sold), (**A**, the set of decision variables for the whole firm : total produced and the total sold, the total produced and sold)}.

To assign a parameter variable to a person is to state that this person will do one of the following things with it: read (find out) its value, receive its value from another in the structure, send its value to such a person, or store its value. The set that defines this component is analogous to the previous one. It is a set of pairs, each of which has a component that is a person, and one that is a set of parameters.

However, there is nothing in this set that is analogous to the distinction between choosing and setting a value. We could alter the definition of this component to make the elements in it triples instead of pairs. In each triple there is the same pair of person and set of parameters, and a third which would be any subset of the action to be taken. This set would contain any logical combination of the acts read, receive, etc. and would mean that the assignment was to do any or all of those things.

**Component 6.** The set defined as:{ (**C**, the set of all parameters of transformation for factory 1, prices of all inputs (decision variables) of this transformation, a list showing lowest total cost (optimum) input amounts for each level of output of factory 1, and a list, called C(q), showing the total cost of the optimum input amounts (minimum total cost) for each level of output of factory 1), (**G**, same as previous but for factory 2, with all references made to factory 2 in place of factory 1, and a list C*(q*) replacing C(q)), (**F**, the set of all parameters of transformation for market 1, prices of all inputs, a list showing highest revenue minus marketing cost (optimum) inputs and selling price for each amount sold in market 1, and a list, called R(s), showing revenue minus marketing cost amount (maximum revenue net of marketing cost) of the optimum input amounts and price for each amount sold in market 1), (**E**, same as previous but for market 2, with all references made to market 2 in place of market 1, and a list R*(s*) replacing R(s)), (**B**, the lists C(q) and C*(q*), a list showing the lowest total cost (optimum) output amounts of factory 1 and of factory 2 for every amount of total output, and the list, called C(S), showing the lowest cost amount for every total output amount), (**D**, the lists R(s) and R*(s*), a list showing the highest total revenue net of market input cost (optimum) amounts sold in market 1 and in market 2 for every total amount sold, and the list, called R(S), showing the highest revenue net of marketing cost amount for every total amount sold), (**A**, the lists C(Q) and R(S) and the two amounts Q and S that maximize operating profits) }.

Because everybody is rewarded with only money the next component is very brief and is:

**Component 7.** The set {({**A, B, C, D, E, F, G** }, m)}.

The next three components are those which describe the rules that govern the decisions made on operating variables, on parameter variables and on reward variables. A rule is defined above simply as (m, u, f) where m is the set that determines f, u is the set that uses f to make decisions, and f is a mapping which associates with each of a number of real circumstances (sets of facts) a set of values that of which one is to be chosen for a decision variable, or to be chosen for and actually given to the variable. The next component is a set of the decision rules on operating variables for our organization of the seven people. We start with the component that is set of decision rules on operating variables. These rules are set on the basis of goals, which we assume to be profits for this organization. The largest amount of profit is the goal, and this means that optimal decisions must be made on how much to produce and sell, where to produce it, where to sell it, how to produce it, and finally how to sell it and how to produce it. For this organization, we assume that the total amount sold is equal to the sum of the amounts sold in markets 1 and 2, that the total amount produced is equal to the sum of the amounts produced in factories 1 and 2, and that the total amount sold equals the total amount produced. We will use the term circumstances to indicate the values of all the relevant parameters. Component 8 of the design gives the set operating of decision rules that produce maximum profits in any period.

**Component 8.** The set defined as: {(**A** makes a rule for **A** which states that at the start of every period **A** is to set, for the existing circumstances of the period for both factories and both markets, the total amount which is produced and sold and gives the maximum of operating profits that the organization could possibly make.) (**A** makes a rule that holds for all periods for **B** which states that at the start of every period **B** is to set, for the existing circumstances of the period for the two factories and for each amount of the total output that might be set, the amount to be produced in factory 1 and the amount to be produced in factory 2 which entail the lowest cost of getting the relevant total amount produced.) (**A** makes a rule every period for **B** which states that whatever the circumstances for this period are, set the number of the total units produced at Q” (a specific number).) (**B** makes a rule that holds for all periods for **D** which states that at the start of every period **D** is to set, for the existing circumstances of the period and for each amount of the total sales that might be set, the amount to be sold in market 1 and the amount to be sold in market 2 which entail the highest revenue net of marketing costs of getting the relevant total amount sold. (**A** makes a rule every period for **D** which states that whatever the circumstances for this period may be, set the total number of units sold at S”(a specific number).) (**B** makes a rule that holds for all periods for **E** which states that at the start of every period **E** is to set, for the existing circumstances of the period for factory 1 and for each amount of the output of factory 1 that might be set, the amount of input 1, the amount of input 2, etc., which form the combination that costs the least amount of money of getting the relevant amount produced.) (B makes a rule every period for **E** which states that whatever the circumstances for this period may be, set the number of units produced in factory 1 at q" (a specific number).) (**B** makes a rule that holds for all periods for **F** analogous to that for **E** and relating to factory 2.) (**B** makes a rule every period for **F,** analogous to that for **E,** on output q*".) (**D** makes a rule that holds for all periods for **G** which states that at the start of every period **G** is to set, for the existing circumstances of the period for and for each amount of units in market 1 that might be sold, the amount of input 1, the amount of input 2, etc., and the price charged, which forms the combination that generates the most amount of revenue net of the input costs from selling the relevant amount.) (**D** makes a rule every period for **G** which states that whatever the circumstances for this period may be, set the amount sold in market 1 at s"(a specific number.) (**D** makes a rule that holds for all periods for **C** analogous to that for **G** and relating to market 2.) (**D** makes a rule every period for **C,** analogous to that for **G,** on sales s*).}

People in the organization need the facts that are in the domains of the decision rules, before they can use these rules. Many of these facts are themselves generated by people using rules, and needed by others who need them to use their rules. Information, or facts needed for decision making, to be collected, generated, stored and transmitted if the rules which produce the profits sought are to be used to get it. The component of design that is now created is the set of decision rules on the facts that are to be read, stored transmitted, etc. Every element of this set is related to one or more rules in the previous component. It is understood that all rules on information collection, transmission etc., are to be used in the most rapid manner.

**Component 9.** The set defined as follows: {(**A** makes a rule that holds for all periods for **B** which states that **B** is to: a)collect and store from the use of his operating decision rules in this period the list which pairs every total output amount produced with the amounts from factories 1 and 2 which give that output at the least cost, b) collect and send to **A** the list that pairs every total output amount produced with least amount of cost needed to get that amount, that is , the list C(Q) ), (**A** makes a rule that holds for all periods for **D** which states that **D** is to: a) collect and store from the use of his operating decision rules in this period the list which pairs every total amount sold with the amounts sold in market 1 and market 2 which generate the largest amount of revenue net of market costs from selling that amount, b) collect and send to WA the list that pairs every total amount sold with the largest amount of money obtained from selling that amount that is the set R(S)), (**B** makes a rule that holds for all periods for **E** which states that **E** is to: a) collect and store the values of all the parameters that are in any of the transformations of factory 1, b) collect and store from the use of his operating decision rules in this period the list which pairs every output amount from factory 1 with the amounts of input 1, input 2 etc., which in combination give that output at the least cost, c) collect and send to **B** this list, we call C(q) ), (**B** makes a rule that holds for all periods for **F** which states that **F** is to: do the same things as rules to **E** but applying to factory 2), (**D** makes rule that holds for all periods for **G** which states that **G** is to: a) collect and store the values of rules all the parameters that are in any of the transformations of market 1, b) collect and store from the use of his operating decision rules in this period the list which pairs every amount sold in market 1 with the price charged, the amount of input 1, the amount of input 2, etc., which in combination get from that amount the most revenue net of the costs of the inputs, c) collect and send to **D** the list R(s*), (**D** makes rule that holds for all periods for F which states that **F** is to : do the same as rule to **G** but applying to market 2.).}

For simplicity we assume that all decision makers will use the operating and information rules correctly and do so in the shortest possible time. The reward rules specify a fixed salary amount for each decision makers.

**Component 10.** The set defined as follows: { (**A**, $m), (**B**, $n),… .} The term $k is an amount, largest for **A,** next largest for **B** and **D,** and smallest for **C, E, F, G.**

Putting the design of this simple organization structure into words makes it seem a lot more complicated than it is. If put in mathematical terms the design would be much easier to describe but the description would still be complicated. In either case this structure maximizes the operating profits by choosing values of the variables that do just that. It also chooses these values in the shortest possible time, given we make a few realistic assumptions which we identify below. Just as it takes a whole set of blueprints to describe the design for a house, so it takes a lot of symbols to describe the components of the design for an organization structure. For the design to become a reality, then all people in the organization must follow all the decision rules and everyone does exactly what the rule tells her or him to do. The real outcome of the decisions made is the highest level of operational profits, the outcome which guided this first stage design. The problem formulated for the organization stated that the sooner the decisions were made, the better the results. The design we have is one that makes decisions much faster than many others. Our structure has four people working simultaneously investigating different parts of the problem and identifying important elements of the final decisions. This is clearly faster than if these investigations were done by one person sequentially, but it is also more costly to hire the three people. Is it worth hiring them? The answer depends on what the speed produces in profits and on what the people have to be paid.

## 10. Structure Costs

People in organization structures make decisions which they derive through a problem solving process. Costs incurred in this process include among others the rewards given people to solve problems, the costs of buying and operating tools used to work through the process of making decisions, the money spent on collecting information, storing it, sending it, and so on. Designing the structure or parts of it costs money. The structure we designed was intended to maximize operating profits, and these did not include any of the structure costs of rewards, and so on. To design the structure that maximizes profits from the operations of producing, buying and selling is not enough. It gives us a good starting point of designing the next structure which is one that maximizes the difference between these operating profits and the costs incurred in operating the structure that performs in the manner that gets these returns. It may be interesting to note that this first phase structure was not in fact created without any consideration of the costs of operating. Why, for example, is **E** told to send **B** the list C(q), the minimum cost function, but not the lists from which **B** gets this function? **B** is told to collect the list of input prices, and to generate and store the list that shows for every output amount, the input amounts that give that output amount at the least cost. The function C(q) is derived from these two. But the structure design specifies that the cost function be sent rather than these two functions because it is assumed that it is less costly to derive from them the cost function and then send it than it is to send both and then derive the cost function. Sending the two instead of the one would cost more. Furthermore, **B** needs the cost function to use his decision rules on where to produce any given output, but does not need the other information, hence he is sent the distilled form rather than the crude form which he will need to distil. The designed structure has considered a number of cost issues but by no means all of them. There are very many changes that could be made in the design, changes that might affect both outcome and costs. To improve on our design and to do so efficiently, we propose that we use a sequential process of design.

The proposed sequential process of design, which should be as efficient as we can make it, involves making small design changes, and calculating their effects on structure outcomes and costs. If the new structure is better than the old one, then we have a new starting point. If it is not, then we return to the first starting point. In either case, the small change made and its effects on outcome and costs should be analyzed and used to determine what the next small change should be. This marginal process of design when applied to our structure may well start with a downsizing change. **A** is the present maker of the basic rules, and the one who makes the final decision. **A** also costs a lot of money, and it is decided that he is to be fired. If this is the only change we make, we lose all the profits we might have made and save this person's salary. This is not what we want, and we need to have the design and decisions that had been made by the person eliminated made by somebody. One way to get the same output is to replace every entry that said **A** in our original design by one that said (**B, D**). All the decision rules by the one fired, all the decision made by him, and all the information collected etc. is now done by this pair of people. If we assume that these two can operate as well as did the one fired, and work as fast, then the decisions of the new structure will be identical to the ones in the old. If the increase in salary these two have to receive for doing more work is less than what the fired one would have received, then the change looks good. But time is important, and the effects on the speed of decision making needs to be considered.

In the old structure there was a sequence wherein a set of rules were used by four of the people to generate information, which was then sent to two others who used decision rules to generate information, which was sent on to one person, the one to be fired. He in turn used decision rules to derive two more rules which he sent to the two who had sent him the information. Each of these two then used decision rules to derive two rules which were then sent to the two who had sent him the original information. In the new structure the person no longer exists, and is replaced by two who send the same messages and rules as before, except that they now send both to the other person in the pair. There is no differences between the number of messages and rules sent in each structure, nor in the sequences in which they are sent. Since the two structures can make the same set of decisions, the only differences between them are the time it takes the two people of the one structure to derive the rules that the one did alone, and in the amounts of money given to the two for the added work they now do and that received by the one a fired. We would need to evaluate any potential problems of having the two cooperate, how much more money they need to be paid for the extra work they now do, and for the cooperation they will need before we decide whether it pays to fire the one person or not.

Whatever the decision, the process we have just been through may give us some information on what the next change investigated might be. Suppose we found out that the change made did produce an increase in the time it took to make the decisions. Two people working on the problem took longer that one person for whatever reason. This increase in time was not great, but its effects on the operational profits was relatively large; a small increase in time made a large difference in profits. It now appears that a structure that takes less time should be designed and tested. In both the structures designed so far the process of making all the decisions involved the following: a) four people read parameters, b) same four people then use decision rules to derive lists, c) same four send lists to two others, d) these two then use decision rules to top derive lists, e) these two then send these lists to another, f) this one uses decision rules to derive decision rule, i) then this one sends one rule to each of the two, j) each of these two uses a rule to derive two rules, k) each of the two now sends his two rules to two of the four each of whom gets one rule, l) each uses this rule to make a rule. At this point all decisions are made.

Each of these twelve steps takes time but they give decisions that maximize operating profits. The design of the structure has many activities done at the same time by having different people do parts of the decisions simultaneously. If one person was all we had in the structure, he would have to do the work done by the four in the first step in four steps one after the other. Step one now becomes four steps. To reduce time we have to reduce the number of steps from the current twelve. But we know that the twelve steps are necessary if the structure is to make the decisions that maximize profits. To reduce the time we have to reduce the structure by removing decision rules, messages etc. The new structure will have fewer elements in its components than the old. All the elements of the old have to be there if the structure is to make the decisions that maximize operating profits. The change made will give us a structure that cannot make the decisions that maximize operating profits. But it will be designed to reduce the time the structure takes to make decisions, and this counters some if not all of the negative effects on operating profits. By having fewer elements in its components, this structure is simpler than the previous one, and will cost less to operate. Whether the change is made or not cannot be answered until we know the magnitudes of these opposing effects.

In the interest of brevity, only the outline of the changes made will be given, and they start with the removal of **A** from the structure, along with all the rules he made and used, the information he received, etc. Along with this change we will change the rules that **B** and **D** make and use, and we start with the change in the assignments components. We assign **B** all the decision variables and all the parameters of transformations of factory 1 and market 1, and assign **D** those for factory 2 and market 2. We leave all the assignments of the remaining four unchanged. The rule that **B** makes first is one for all time for himself, and that is that he choose the amount produced in factory 1 and sold in market 1 so as to maximize the difference between revenue net of marketing costs and the cost of producing this amount in factory 1. Another rule he makes is the one he makes every period on the amount produced in factory one and the rule on the amount sold in market 1. The rules **B** gives to **E** are identical to those that he gave in the old structure. The rules he gives **G**, for market 1, are identical to those that **D** had given in the old structure except that the list generated by **G** now goes to **B**, not **D**. Analogous changes are made for **D**, for **F** and for **C**. The time it takes for all decision to be made each period is now the time needed go through only the time it takes to go through 5 steps instead of the 12 needed before the change. But the cheaper to run and takes less time structure does not allow any sales from factory 1 in market 2 or sales from factory 2 in market 1. This cannot improve profits, and is very likely to reduce them. The structure we choose is the better of the two when both changes in costs and in revenues are considered. Following that choice, we go on to the next change if we detect something from the results of this change.

## 11. More on The Master Brewing Co. Example

The economic operation for which an organization structure is designed above is one good source of examples for the theory and design of organization structures that are developed in the rest of this work. In its simple form, MBC served as an excellent example that showed the essential elements of structures and their design. This is only one form of the many we will give MBC. The details of this operation and its structure are left unspecified so that we might be free to make them good illustrations of those aspects of the theory or design we want to illustrate. In all its forms, the Master Brewing Corporation is a firm that is involved in the brewing and selling of beer, and its features will become those that make it a good illustration of whatever theoretical or design issue we a want to relate to real world conditions. All the forms we will use will involve transformations in which variables such as malt, hops, etc. combine to produce amounts of beers which are described by variables such as color, taste, etc. The production transformations describe how beer color is determined, how beer taste is affected by containers in which it is fermented, how to get it to be Ale, Lager, etc. The manner in which one can get this or that aspect of the beer to be the one desired, and the stages in the process of production at which liquids of different characteristics may be combined to get such levels are also described in the transformations. The market transformations describe how amounts of beer of various kinds, packaged in various ways, advertised in this or that medium, and priced at this or that level, sold under this or that set of conditions, at this or that place, during this or that season, are turned by the market place into cash received at this or that time, given what other brewers are doing about these aspects of their beers. All these transformations contain all the decision variables and all the parameters of the operation of this firm which brews beer of different levels of alcohol, of different tastes, colors, aerations, and so on. It puts them in different kinds of containers, and sells them to people or organizations that buy them for consumption, for resale in many different settings such as stores or bars, in privately owned stores or only in government owned ones.

Others decisions the firm makes include those on the kinds of beers it makes and sells, on the brand names it gives them, on the colors and shapes of the containers and so on. It decides on the geographic markets where it sells, the age of the buyers to whom it wants to sell, and on the many dimensions of the transactions it makes. These may include the location where control of the product is transferred, time of the transfer, etc. All these decision variables on the selling side are matched by decisions variables on the buying side, whether it is the price at which an ingredient is bought or the form of the ingredient bought. Then there are all the decisions the operation needs to make on the financing of its operations, decisions on form, sources, terms, etc. Finally there are the decisions to be made on the rewards the members of the organization are to get, such as, money, stock options, recognition, time off with pay, and so on. There are the decisions on whether to reward this and that person on the basis of the decisions he makes, on the extent to which he uses the decision rules he is given, on some outcome of the decisions made, or on a combination of these, or anything else.

There are also facts which the firm collects, and these include the value of any parameter embedded in the transformations. They may include competitor prices, the manner in which the competitor connects his prices to ours, or the myriads of laws that regulate the age of those to whom beer is sold, or the manner in which it is advertised. Tastes, fashion, the entry and exit of beer makers, brewing methods, transportation methods, motivations of consumers, market idiosyncrasies, all may be relevant, and therefore facts that are to found out, sent to various people in the organization, and so on. The operation may also decide that it needs to know various facts about the many circumstances of its relation with its customers and their customers, and facts about the competitors' relation with theirs customers and suppliers. There are also facts about the ingredients it buys, and the funds it borrows.

Rather than describe a whole new set of circumstances for each example and design the structure for them, we will concentrate on describing parts, or changes in parts, of these circumstances that illustrate specific elements of the theory such as the definition of a property, the contents of a proposition, the change in design that make a structure more efficient in the changed circumstances, and so on. The firm MCB is whatever we want it to be.

## 12. Loss of Innocence and Gain of Generality

As the world gets more complex, the difficulty of designing in the direct manner of our example becomes more and more difficult in an exponential manner. We need a process that tells us something about where to get our first design, how to choose the small changes that are to be made and how to measure their effects, and also how to derive the clues to the next set of small changes that are to be made. This is the traditional process of using properties of the units of the analysis and design. In designing the simple structure no use was made of the standard concepts of organization theory. Not once were any of the standard terms, of specialization, centralization, reports to, functional, divisional, etc, used. It is obvious that the first structure designed was a functional and centralized one, while the second was a divisional and decentralized one. These properties are relevant only if they can to be used to derive some generalization from the structure designed or from general theorizing. What is needed are properties that can be used to create categorical generalizations that are reversible into prescriptive ones. If we have these generalizations, then we may learn from our experience of designing structures, and from the experience of others. The result is the development of general theories which will allow knowledge to be disseminated efficiently, and efficient processes of design to be created. Most important of all is that the theorizing produce rules that are good and useful in the complex real world.

In complex situations, descriptive terms or properties of the structure are needed to guide us to the design, rather than describe what we designed. But not every set of terms is as equally useful as another. The old standard concepts will need to be changed, and new ones created, ones that are useful in the process of design. The new concepts must be operational, which means that they are defined in terms of design decision variables, or design parameter variables. In turn this implies that each concept must be defined in a manner that allows the designer to specify a set of values which it may take. Finally, to be useful, these values must be real, so that they may be distinguished one from the other by the designer, and so may be realistically made into facts by the designer.

Generalizations are at the heart of the creation of knowledge. They allow one to learn from one's experience and that of others. Generalizations are the essential elements of efficient decision making. They are the bases for efficient everyday decisions such as ones made at breakfast time. One decides to fill a bowl with pieces of dry stuff of a certain shape from a box which is in one's pantry and has the word cereal on it. One then pours over the stuff in the bowl the white liquid from the bottle in the ice box. One then sits down and puts a spoonful of the mixture into one's mouth. What did one not do in making all these decisions? One did not taste a tiny piece of every bit of the dry stuff to make sure it was the same as what tasted the last time. One did not test the white liquid to make sure it was milk. One did not test every drop of milk to be sure it was not sour. One avoided all these costly processes and made decisions on the basis of generalizations. There is the generalization that the stuff of this shape in a box of this labeling contains edible tasty food which one likes, the one about white liquid being milk, and about the sourness of the milk not being possible for one drop from the bottle but not for the next drop, and so on. All these are generalizations that make decision making efficient if not necessarily foolproof. There is no logical difference between the decision process on breakfast and that by the physician working on generalizations from observed symptoms to decisions on medical processes, and the boat designer working from generalizations on water behavior, drag, etc. to the shape of the boat. All the generalizations are useful if they reflect reality well; if they are in terms that allow one to relate them directly to the facts of the world one is in; if they are in terms that translate their form from the categorical conditional, if X is true then Y is true, to the prescriptive conditional, if you want Y to be true, then make X true. We start with the subjects of the categorical and prescriptive generalizations that are to be the elements of our efficient and intelligible process of designing organization structures.

## 13. The Pieces of Analysis

The three major components of the analysis and design of organizations are the structure of the organization, the world of which it is a part, and the transformations that it has and by which in brings about changes in the world. Purposive organizations, our interest in this work, are created by humans with the purpose of changing the state of some part of the world. The ways that changes may be made are described in mappings that we call transformation. These tell one what happens to a small part of the world when the organization does something to some other small part of the world. These transformation may be perfect pairings or not, may be complete or not, and may be certain or not. They tell us that when we do something to one part of the world something will happen in another part. They also tell us that this causal relation is affected by what a third part of the world is like. The transformation is made up of sets of things: things the organization can do; things that happen as a result of what the organization does; and things in the world that specify the details of what happens. The first set we call decision variables, and they are those changeable parts of the world which the organization can make be what it wants. The second set we call outcome variables, and they are those changeable parts of the world which the organization would like to be something but it can only make them so indirectly through the first part. The third we call parameter variables, and they are those parts of the world which are what they are, regardless of what the organization wants them to be. What they are determines what happens to the outcome part when the decision part is made to be this or that. This third part is what we call the environment of the organization. The structure is to determine what the decision variables are to be in order to make the outcome variables what the structure wants them to given what the parameters are.

A transformation states that sales for a firm depend on where it locates, on the price it charges, on the density of population in the area of six miles radius, and on the temperature of the atmosphere outdoors in the area. The decision variables are location and price, and what they are to be, that is by the values they are given. The variables are identified in terms of an address and an amount of dollars. The parameters are identified in terms the density of population in an area six mile radius from location, and the temperature of the atmosphere in the open in that area. The transformation says that you get so many units sold when you locate at this spot, charge so much, the density is so much, and the temperature is so much. The transformation is a list of pairs, the first the four values of decision variables and parameters, and the second the sales figure. The environment is the term we use for the two parameters, and the state of this environment at any point in time is a pair of values of what the density and the temperature are. The identity of the environment is determined by the nature of the parameters. The state of the environment is determined by what the values of the parameters are. We define and discuss environments some more below after we discuss structure and transformations

## 14. The Thing and Its Properties

The properties of something must be defined in terms of the components that define the thing. If the thing is an environment, then its properties must be defined in terms of the components that define the environment. The property may be in terms of the components directly or in terms of vectors of values of these components. The environment is defined by a vector, in which each component is a set of elements, that is, a subset of some predefined set of things. This might be all persons alive today, and the component in a specific case might be a set of just two of these people. For each component of the vector there is a such basic set vector, and each specific vector has a component made up of a set of elements that belong to the basic set. If the component of the environment is a price charged by competitor X, then the basic set is the set of all real numbers of dollars that he may charge. At any given moment in a specific environment this component is a specific number of dollars. This component describes the actual price charged, and is one dimension of the environment that we consider to be relevant to an organization. The organization may have any kind of relevant environment, and this might include many more components, and besides competitor X price there might be competitor Y price, aspects of the weather, government regulation, etc. Each may take on a value such as dollar amount, temperature average for the day, number of regulations, and so on. In each case the important thing is to match the definition of components and value set to the analysis and to choose both in a way that fits one's capacity to observe the values taken by the components of the environment.

In defining and analyzing properties we must adhere to the requirements that we set earlier. In summary, these involve a clear definition made in terms of the components of the thing to which the property applies; the identification of the exact manner in which the property may be measured; the uni-dimensionality of the measure of the property, or if that is not the case, then a clear understanding of its multidimensionality; the use of a measure that is reasonably well ordered and observable or actually possible to set; and the defining of properties that are relevant, that is, can be shown to be generally related to the outcome of the performance or to the structure (Baligh, Burton, and Obel, 1990). For every property we create and use in our analysis of structures and in creating designs of these we will give the following:

a) a definition in terms of the components of a thing to which the property attaches;
b) a set of values the property may take, the explanation of the order we can impose on this set, and the observability of the elements of the set;
c) a function that maps values of the components into values of a property;
d) reasons why the property is a relevant one;
e) the specific application of all the above to our special case.

When this is done for all the properties, we discuss the relations between the values of environment and performance properties and the value of outcome. The structure of MBC will be used to illustrate some relations.

# CHAPTER 3

# PROPERTIES OF THE ORGANIZATION STRUCTURE

## 1. Properties of Organization Substructures: The Operating Substructure

An organization structure may be required to give performances that have the properties of being highly coordinated, or flexible and so on. What is now needed is to define those properties of the structure which we expect are those that determine the properties of its performance, and then show the nature of these analytic relations. Each property of the structure of the organization may be usefully defined in terms of only one substructure at a time. This will allow us to analyze and design each of the operating, information and reward substructures separately before putting of them all together. Properties of the operating substructure are to be defined in terms of one or more of the components of this substructure of the organization. The vector that describes this substructure has as its components a set of people, a set of decision variables, a set of assignments of variables to people, and a set of decision rules.

## 2. Logical Operations on Components

The efficiency of the design process is going to depend on the definitions of the properties of the components of the vectors which describe organizations structures, and the nature of the logical operations we define for these vectors. Before we get to the former, we will define a logical operation that we will need in order to define a process of design that creates structures one step at time. This is the operation of adding one structure to another (Baligh 1990). When one structure is added to a second one, each component of the vector describing the first structure is added to its analogue describing the second. When the component is the set of people, the set of decision variables, the set of parameters, or the set of reward variables, then the addition of the two components is the union of the two sets. The set of people of one structure is added to that of another to get a third set of people which is defined as the union of the two sets that are added. This algebraic operation is needed if we are to be able to work on designing parts of structures which are then put together, or added, to become a structure of the parts added. As defined, this algebraic operation of adding structures, is such that it always produces a structure, gives the same result when we add set A to set B as it does when we add set B to set A, and has the identity element of the empty structure which when added to any other structure gives this structure as a result.

An assignment is defined as a pair of the form (an identified person, a set of decision variables). Two sets of assignments may be added to one another in the following way: for every element in the first set, there is either an element in the second set which has the same first component or not. If there is one element with person X in the first set, then there is either one in the second with person X or not. If there is one, then we add the two assignments that have this one person as the first component. The result is an assignment with that same person X as the first component, and a second component made up of the union of the two sets of variables, that is, the second components of the original assignments being added. For example, if we have (X, V) as an assignment in a structure and (X, W) as one in the other the structure, then the addition of the two structure involves adding the two assignments. In this case the sum is (X, U) where U is the union of sets V and W. If there is no assignment in the second set that has X as a component, then the pair describing the assignment in the first structure goes into the set that is the result of the addition. If the second set has an assignment that has X as a component, and there is no assignment in the first set with this component, then the assignment of the second structure becomes an element of the set in the addition. Again, this algebraic operation has the same three properties as the previous one; the addition of two assignment always gives an assignment, the order of addition is irrelevant, and adding the identity element to any other element gives this other.

Adding the assignment components of the reward substructures follows the same rule as does the addition of the parameter assignment component of the information substructure. All but one component addition is now defined. The one remaining is the decision rule component, and the addition of two of these to get a third decision rule is defined below, after we look more closely at the nature of these rules. Also, the ways in which these algebraic operations may be used to create relatively more efficient processes of design are discussed when we finish with efficient designs and take up efficient ways of making them.

## 3. People and Variables

The people who are in the organization are those included in the set that is the first component of the vector that describes this organization's structure. How does one identify the elements of this set? Is the set one that identifies specific people or one that tells only what properties its elements must have? Specifying this component of the structure, or any of its substructures, is necessary if a structure is to be completely described or defined. However that may be, we do not discuss in any depth this design problem in this work. It is too vast a topic, making up a large discipline known as "Organization Behavior". In this body of work, the behavior of people in organizations is analyzed, and that involves the study of the relations between the decision on the elements of the set of people and those of the other components, such as, decision rules. For our purposes, the design of this component is left to be determined after the other structure components are designed. When this is done, the designs are put together in a manner that produces a self-consistent whole with all the components adjusted one to the other. The kinds of people one puts into the set depends on the kinds of decision rules they have to make and use and so on. However these rules must depend on the availability and costs of people who are needed to fit in with these rules. The process of design we recommend is a sequential one. First a set of people is assumed to be whatever set best fits whatever the other structure components we decide on in our design. Next, the costs and availability of the set that emerges as that needed by our design are determined. Next the remaining components are modified to get a better combination with a set that they require. A series of such steps should produce better total designs up to some point. At each stage of the process, the availability and cost of the matching people set are balanced against the efficiencies and costs of the remaining components. In this process one may use such properties of the people set as that of educational level, or age, or diversity, or cultural identity, etc. It should be obvious, for example, that a global organization would be interested in this last property to a much greater degree than a non- global one.

## 4. The Set of Assignments and Its Properties

**People Inclusiveness:** This property is defined in terms of the set of people that is a component of the substructure and the set of people also assigned operating decision variables. The first set is that of those who are considered to be part of the operating organization, and will in fact be involved in making decisions. The second set is obtained from the variable assignment component of the structure in which the elements pair decision variables with people, and a pairing means that the variables are assigned to the people who are to set their values. The second set is identified from the elements of the set of assignments of the substructure. All the people who appear in these pairings of the assignment component make up the second set of the definition of this property of people inclusiveness. The measure of this property is the ratio of the number of people in the second set to that in the first. A measure of one means that every person who is part of the organization is recognized as such and given an assignment that involves him or her in the making of decisions. If the number is less than one, it means that someone in considered to be in the organization, but is not part of those who are transformations organized and given something specific to do.

**Variable Inclusiveness:** This property is defined in an analogous manner to the previous property. The issue is one of identifying whether all the decision variables that appear are connected to someone who is to be involved in giving them a value. Here also the measure is the ratio of the number of the set of those variables that appear in the pairings of the assignments to the number in the set that is the decision variable component of the definition of the structure. If this number is less than one, then there are variables that are not assigned to anyone, and we have the situation that Mackenzie (1986) calls the case of virtual power, where there are elements of the set that makes up the decision variable component of the definition of the structure that are not are assigned and that triggers power plays to fill them.

**Commonality:** This property is defined in terms of the subset that is the second component of an assignment. The larger the intersection of the two subsets from two assignments, the higher the commonality measure for them. We could measure the commonality between any two assignments by the ratio of the number of elements in the intersection to the number in the union. For the whole structure the measure would be the average for the ratios found for all pairs of assignments. Two things will be shown by the measure on this property. The measure shows the inverse of the extent of job separation. It and the decision rules together will show such things as the levels of hierarchy, the separation of jobs, and the degree of decentralization. All these terms are defined in their traditional sense as in Robbins (1990).

**Orderliness:** This property is defined in terms of the similarity of the elements that make up the assignment subsets. The number and identity of the properties that the elements share among themselves is the basis for defining and measuring similarity. The basis for similarity may be the transformations, the identity of the variable, or whatever is used to sort the variables, if there is a sort. The assignment subset may be restricted to elements related by a specific number of transformations, or to a specific identity or class, etc. The result is that we may have orderly subsets where all elements come from the same transformation, or complete disorder where there is no sorting of the variables prior to their collection into assignments. This last is the random assignment. This property then is measured by the average number of classes it takes to include all the variables in each subset. The smaller this number, the higher the orderliness. There may be in some cases a possibility of identifying the basic classes for each assignment and for the whole set of them. We might get jobs that are distinguished from one another by transformations, in which case we would call the structure a functional one, meaning that they are all from specific production transformations, or marketing ones, etc.

Operating structure properties are defined if we expect them to be relevant to the analysis and design of structures, and they are relevant only if they affect its performance properties. Though the best justification of the choice of the properties is their relevance, this will not become apparent till we use the defined properties in the analysis. Some argument other than this relevance is needed to justify the choices of properties that are defined, and there are such arguments to support the properties we define for all substructures. The choice of the property of commonality may be used to illustrate these arguments. Along with the decision rules, commonality measures how many people are assigned the same decision variable, and hence the extent to which the value given this variable is shared by people in the organization. Issues of rewards now crop up since the values given the variable may be expected to have some relation to the rewards given to the people who set it at this value. Commonality allows one to get some measure of responsibility, a concept long connected to rewards and extensively used in the analysis of organizations. Also, the property of inclusiveness of both kinds defined earlier is strongly related to the presence of possibilities for creating "virtual positions" (Mackenzie 1986), and hence to the extent to which there will exist power struggles in the structure. Such struggles in turn affect the level of the coordination of the structure's performance. People inclusiveness suggests that it would be useful to know what might be the effects of not assigning a person in the organization anything to do. If the person does nothing, then it is best that he be removed from the structure. If the person does things, they may be contrary to what we would have chosen for this person to do had he been assigned them. Inclusiveness is a structure property that is defined because it is connected to the performance property of controlledness of the structure.

## 5. The Set of Decision Rules

The decision rule component is the dominant one in defining what the organization structure, and also its three substructures of operating, reward, and information substructures, really are. We have very many properties to define here, and we will start with the redefinition of a decision rule. Throughout this discussion the term decision rule will be used to mean a decision rule of any one of three kinds, i.e., a rule which is an element of the rule component of the operating, information, or reward substructure.

The decision rule connections of an organization structure are important determinants of its performance, and the subject of a large volume of literature. A simple concept of decision rules is embedded in generalizations found in many works including those of Fayol (1916), Weber (1974), Barnard (1938), Simon (1976), Hage (1965), Baligh and Richartz (1967), Pugh et. al.,(1968), Mintzberg (1980), Ouchi (1980), Daft (1992), Robbins (1990), Volberda(1996), Burton and Obel (1998), Harris and Raviv (2002) and very many others, including one from as long ago as the fourteenth century, Ibn Khaldun (c. 1396). The concepts of formalization, centralization, authority, policy, standard operating procedures, bureaucracy, adhocracy, organic structures, mechanistic structures, matrix structures, chain of command, delegation, and management by objectives are in fact about decision rules. The concept of a decision rule is, however, rarely explicitly recognized as central to these concepts, and is rarely well defined or analyzed in detail. The works of Marschak and Radner (1972) and of Baligh and Damon (1980), contain explicit uses of decision rules. The concept is defined, its logical properties explored, and its use in the analysis of organization performance is explained in Baligh (1990). We will be using this concept later.

Generalizations about poorly defined and badly understood concepts such as organic structures, etc., can be made to mean many different things, and the arguments in their support can be correct or incorrect depending on what meaning we give the generalizations. We cannot test these one against another or combine them to get new ones because we don't know how they map one onto another. To do better we need to make an investment in the definition and analysis of the concept of the decision rule, and to define them in terms of simple, clear, and well understood components. This will make it easier to analyze logical relations between rules, and to describe and investigate some algebraic operations on these rules. It is these algebraic rules that will be used to create efficient processes of designing structures. Components of rules and their structures are also used as a basis for the definition of operational properties of rules. Without such operationality, it is not possible to establish clear logical relations between these properties of the rule component of the structure and properties of the performance of this structure. Unless these performance properties are measurable, the analytic relations between structure and performance properties cannot be transformed into usable design rules. Performance properties have been defined to meet the relevance and measurability conditions, and we now define decision rules to meet the relevance and operationality conditions. The analytic propositions on structure and performance developed below will be in terms of these definitions as will the arguments given in their support. These propositions will be in terms that are not much like those commonly used in the literature, and our analysis and design will also be mostly in terms which are not those commonly found in the literature. For a number of reasons we will not be using terms like functional, divisional, complexity, centralization, formalization, diversity, delegation of authority, which are to be found in the literature. Because those who use these terms do not define them clearly, there is no understanding of the concepts that underlie the terms. But the main reason that we do not use these terms is that they do not refer to real world things that one can do. If one should conclude that centralization should be at a high level, what exactly does one do to get that? Does one work with only the number of people making decision, and if so, does making a decision mean doing something or just making a choice? The questions about the meaning of this term go on and on. To avoid this problem of meaning and realism, and to meet our requirement that the analysis produce recommendations in terms of what one actually does when one creates an organization structure, we work with new concepts and terms. The basic concept of an organization structure is the decision rule (Baligh and Damon, 1980) (Baligh, 1990), and it is where we start.

We define decision rules for the operating decision variables in a more detailed form as follows:

r = (m,u,f), a decision rule;

f = {(p,v),....}, a mapping, s.t., v = f(p);

P = a vector of values of parameter variables;

V = a set of prescriptively allowed values of a decision variable, one of which is to be made into a fact ;

m = a set of people that specifies, creates, etc., the mapping f ;

u = a set of people that uses the rule r by giving a value to the decision variable according to f, or creates a new rule r* by specifying a mapping f* that is logically consistent (defined later) with f;

P = {p,....}, the domain of f;

P' = m(r), the minimal potential domain of the mapping f of the rule r, i.e., the set of all vectors from which P is drawn;

g = h(r), the set of goals to be attained by the decisions made according to the rule r.

The mapping f is the heart of the rule r. It is created by the set of rule makers m, for the set u of rule users. A decision rule mapping is always a set of “if-then” statements. In this special mapping, the first component of every pair in the set is a vector of "values" already taken by variables, i.e. , facts, and the second component is a set of values one of which is to be given to a variable, i.e., something to be made a fact. The intent of the rule is to specify behavior, to identify what is to become a fact; it is a set of conditional imperatives. For every element (p,v) in a mapping the component values of p are things that are, and may be found out, read, estimated, guessed, etc. Values in the set v are things one of which is to be made into fact.

This definition captures real world decision rules quite well. Rules are words, symbols, and signs made by one or more people who intend that the words be used by some set of people as a guide to its behavior. Very simply, the statement, "if the competition price is 50 or below, charge a price of either 30 or 34", is a single element rule mapping. It has one element in the domain, and one in its range, which element is itself a set of two elements. The mapping is made by some set m and is directed at some other set u of people who are to actually set the price. The minimal potential domain P* of the rule has 2 elements in it, competition price 50 or below, and above 50. Only one of these is included in the mapping. Real rules are more complex than this since they are often mappings that have a "then" segment that is made up of many elements connected by "and" or by "or". It can be shown that such complex real rules may be described by different sets of the rules as we've defined them. The rule we define is a unit rule which can be collected with others to represent complex ones. A complex rule which states "if a, then do either b, or c, but not both" may be represented by 2 rule mappings each of which has two elements and meets our definition: {(p,v), (p',v')} i.e. {(if p, do v), (if p', do v')}

a) {((a,b),(not c)),((a, not b),(c))}
b) {(a,c),(not b)),((a, not c),(b))}

Real rules also involve probabilities, and our definition can be easily amended to capture this probability in both the "if" and the "then" segments. It is easy to capture the uncertain fact and the weak imperative by making any single value, e.g., p into (value, probability), e.g., (p, probability). Another aspect of real rules which we could easily include in our definition involves the time when the facts of the domain are relevant. This is the element which specifies whether the rule is to be used once, when that is, or over all time, or anything else.

Any decision rule r, be it one on an operating, reward, or information variable, may be expressed in a number of ways or forms. The sets m and u may be explicitly given in list form, or implicitly given as elements that have some stated property. The mapping f may be given in extensive form, i.e., a set in which every element, a pair, is listed. It may explicitly state the name of the variables, or these may be made implicitly and be understood in the context, or from the mapping itself. All values of domain or range may not be stated explicitly, but may be given in terms of some other variable. Thus, a component of an element in the range may be "set price to maximize profits", and a value in a domain may not be given as "competitor price is 50 or below", but in terms such as "competitor price that hurts us." Finally the range of a mapping may or may not mention explicitly the goal variables, the values of which the decision variable values are intended to affect. In the statement "set price at 30 or 34", no goal variable is mentioned. In the statement "set price to maximize profits", the goal is explicitly mentioned. All this discussion of adding structures is useful only if we follow a sequential process of design and we want the process to be logical and efficient. Such a process is defined and discussed later.

Decision rules in all three substructures contain the set of elements described for the operating substructure. Those on parameter variables have a component that identifies what is to be done, be it read, send, store, etc. Reward decision rules contain an element that is a set of people. These are the people to whom the reward variables that are the subjects of the rule apply. Neither of these variations affects any of the analysis on operating variable decision rules that follows.

## 6. Rule Consistency and Rule Addition

Most organizations build their decision rules by a sequential process, such as that in which the maker of a rule derives its mapping from the mapping of another rule of which he is the user. The specific nature of the process of derivation determines how a rule is transformed and how the end rule conforms to the initial and intermediate rules. Conformity, or logical consistency, of rules is clearly important in all cases where rule making follows some hierarchical process. A second process is that in which a rule is built up by the addition to and removal of elements from its mapping. This process may be used to take advantage of experience, or be an intentionally systematic way of structure design (Baligh and Damon, 1980). The specific nature of the process of adding and subtracting will determine the resulting rule, and hence the decisions that actually emerge from its use. Rule addition and logical consistency are important issues in the analysis and design of organizations, and are the concepts that underlie conclusions that have been made in the literature about such things as unity of command, delegation of authority, legitimacy of decisions, freedom of choice, and line of command. All these conclusions are intended to provide appropriate levels of logical consistency and clarity of rules, of freedom of decisions for rule users, and so on. If rule creation is sequential and hierarchical, then logical consistency is what determines whether the choices made by using rules could be different from the choices that might have been made by using rules from which the first rules are obtained. Concepts of hierarchy and line of command are useful in analysis only if the nature of what they really mean for someone to be above another in the hierarchy is clear. Rule consistency describes one aspect of this relation.

Logical consistency between two rules may be defined in terms of the choices that could be made when one rule is used as compared to those that could be made when another rule is used. Rule r is logically consistent with rule r* if and only if any of the choices made when rule r is used could have been made if rule r* had been used. In formal terms, the concept of logical consistency between rules and the algebraic operation of rule addition is defined for any two rules r = (m, u, f) and another, r* = (m*, u*, f*) when both rules belong to a set of rules all of which are about the same decision variable and have mappings with the same potential domain. Rule consistency is defined in terms of the rule mappings only, and rule r is said to be consistent with rule r* if and only if:

a) The domain of f is a subset of the domain of f*, and
b) For any f(p) defined, then f*(p) is a subset of f(p).

When f = f*, then both conditions are met, and r is consistent with r*. It is also true in this case that r* is consistent with r. If , on the other hand, f and f* are not equal and r is consistent with r*, then it follows that r* is not consistent with r. If decision rule r is consistent with decision r* then we know that the user of rule r can not make a decision he would not make if he were to use rule r*. Using rule r would never produce a decision that would violate the rule r*. In an organization the user of one rule does one of two things: he uses it to give the decision variable a value, or else, he uses that rule as the basis for another rule which he makes for someone else to use to set a value for the variable or to derive another rule, and so on. Rule consistency is the relation that will tell us if the rules made in such a sequence would or would not produce decisions made if only the first rule in the sequence were used. Consistency is logically attainable, and for any rule r* and its mapping f* there is always a rule r with a mapping f that is consistent with it.

What this means is that decision rules may be made sequentially to reach some desired final rule, which may well be a more efficient process than getting this rule directly. Further it is not logically necessary that the rules in the sequence be made by the same person to get consistency. The same consistent sequence of decision rules may be obtained with different rule makers for rules in the sequence, provided that the users of a rule in the sequence are the makers of the next rule in it. The structure we designed for our simple example was one which had sequences of rules that were logically consistent and could have been made by the top man or by a sequence of different sets of people. The work on the delegation of authority, and on decentralization (Mintzberg, 1980), (T. Marschak, 1972), (Baligh, Burton and Obel 1990), (Huber et.al., 1990) (Burton and Obel, 1998), (Jones, 2001) is all about who makes decisions. Comparing the costs or speed of decision making of decentralized structures with those of centralized ones may be done correctly only if the decentralized structure has rules that are consistent. Without consistency there is no way to be certain that the decentralized structure can arrive at the same set of final decision rules and the same decisions as the centralized one. None of these works recognizes the consistency requirement explicitly, but some define the decentralized ones in their analysis in a manner that implies that their rules are consistent with and their decision the same as those of the centralized one. The works that use linear decomposition to define decentralization and to produce its final decisions (T.Marschak, 1972), (Burton and Obel, 1984), show that the solution to the decomposed problem is the same as that of the integrated one. Logical consistency of the decision rules is built into the decomposition process. Consistency by itself is an important concept in structure analysis and design, and its importance and usefulness increase when it is combined with the definition of the process of rule addition.

Rule addition is defined as a logical operation written as r + r* = r** (Baligh, 1990), where r = (m, u, f), r* = (m*, u*, f*), and their addition is defined as r** = (m**, u**, f**) where m** is the union of m and m*, u** is the union of u and u*, and f** is the set of elements each of which is one of the following:

a) the union of f(p) and f*(p), if both exist, that is are defined in f and f* respectively;
b) f(p) alone if f*(p) is not defined;
c) f*(p) alone if f(p) is not defined.

This binary operation can be shown to be closed, commutative, associative, and to have at least one identity element, the rule (0,0,0). We can sometimes subtract one rule from another, though not always because element r has no inverse. The sum of two rules is not consistent with either of those added except when these two are equal to one another. Any mapping f with a potential domain a set of vectors of n dimensions may be transformed into a logically equivalent mapping f* with a potential domain of a set of vectors of the original n dimension plus k more. This mapping f* is a redundant form of f. If we cannot add two rules because the potential domains of their mappings have different dimensions, we can create two rules with redundant mappings that have potential domains with the same set of dimensions, and then add these rules.

The addition of a rule to an existing set without attention to what is in the set leaves it up to the users to add together any combination of the rules and possibly get rules that are not necessarily consistent with some old rules or the new one. The adding operation is equivalent to using either one of two rules at will. When the user seeks legitimacy for his actions, such a situation is very useful. Thus, the Israeli Military in the West Bank and Gaza follows a rule that is the result of adding Turkish rules, British Mandate rules, Jordanian rules, and Israeli rules. In any given situation it chooses which rule to follow. This gives it a legitimate source for many more actions than it could get from only its own rules which can be kept free of internationally unpopular elements. Children do the same thing by asking permission from both parents separately, and people in a matrix organization may be tempted to behave the same way.

A second operation on two rules r and r* may be defined in cases where the composition of the two mappings f and f* is defined. This rule composition is such that the result is a rule r** where m** is the union of m and m*, u** is the union of u and u*, and f** is the mapping that results from the composition of f and f*. This is a way by which two rules may be written as one. It is equivalent to using first one rule, then another based on the facts that emerge from the use of the first rule. Both this and the previous operation are useful in analysis. Rule composition is at the heart of the distinction made between rules and procedures by Weber (1947), Hage (1965), and Mintzberg (1980). Procedures are clearly sequences of rules, and in fact, are of the form of the composition of the rule functions.

## 7. Decision Rule Properties: Makers, Users, and Goals

In this section we define properties of rules in terms of the set of rule makers m, the set of rule users u, and the goal set h(r). Properties are the bases of classification schemes where the classes serve as subjects of generalizations. Unless the properties used to create the scheme are explicitly and systematically applied, the resulting set of classes is often incomplete. The three classes of Ibn Khaldun (1396) and Ouchi (1980) which are the hierarchy (bureaucracy) , the tribe (clan) , and the market (market) are an example of creation of classes without systematic use of properties. Baligh and Burton (1981), identify a set of structure properties which produce these three classes and the missing fourth, the one that must have a logical existence, given the bases used to define the other three. When the basic properties are clear, the missing fourth class appears. The properties used implicitly by the creators of the three classes, are shown to be properties of the set of decision rule makers and that of users and on the identity of the set whose goals are used to create the mappings of the rules. Whether one chooses to define classes and then generalizes about them, or define properties and then generalizes about these, the explicit definition of properties in operational terms makes the work of analysis and design easier, and its conclusions firmer and clearer. To this end, we begin by defining some decision rule properties in terms of their makers and users.

**Enfranchisement:** This property is defined in terms of the extent to which people in the organization participate in making the decision rules (no taxation without representation). It is measured on the basis of the number of people in the set of the makers of a rule and the number in the set of people in the organization. For every rule there is a measure of the ratio of the first to the second. The average of the ratios for all rules in the structure may be used as a measure of the level of its property of enfranchisement. In some cases one may want to make the measure the weighted average for all rules. Weights may be based on the importance of the rules, or on the place that a rule has in the sequence of rules each of which, except the first, is derived from and consistent with the previous one. This sequence of rules is discussed in more detail below.

**Independence:** This property is defined in terms of the freedom that users have in making the rules. The more influence users have in specifying the rule mapping, the more independence they have. This property is measured on the basis of the ratio of the number of users of the rule, who are also makers of the rule, to the number of the makers of a rule. If the ratio is zero, then no user is also a maker. If the ratio is one, then every user is also a maker. If the ratio is between zero and one, then there is at least one maker who is not a user, or at least one user who is not maker. For a structure, the measure may be the average for all its rules or the average obtained after is each rule is weighted by its place in a sequence of consistent rules. If only the users of a rule are its makers, then the independence of its user set is at its highest.

These two properties are not the same even if they are somewhat related to one another. Whereas enfranchisement is about the participation of all the people in the organization, makers and users in rule making, user independence is about the absence of non users from the set of the makers of the rule, or the presence of rule users in the set of rule makers. Independence is a property that tells us how much freedom the person who uses a decision rule has. It is a property about the absence of non-rule users from the set of rule makers, and the presence of rule users in the set of rule makers. The latter is about the participation of people in the organization in the making of rules they use, and the former is about excluding non-users of a rule from being among its makers. The use of this one ratio to measure independence means that it will not tell us whether the restriction of independence results from excluding users from the set of makers or the presence of non users in the set of makers. Nonetheless, the measure tells us that if one were to have maximum enfranchisement, then one must have a low level of freedom, and the lowness will depend on the number of people making all the rules. On the other hand, one can design a structure that has extremely low levels of both properties. It is also true that there are other ways to change the level of user independence without removing others than the user from being makers. By changing the rule mapping one can change the independence level of all makers, and of the user among them. Also, by changing the place, within the sequence of consistent rules, of the rule in which the user is the maker, the independence level of the user may be changed. The properties of the rules that allow this to happen are discussed below.

Participation as defined by Vroom and Yetton (1973) is a concept to which both our properties are related, though neither of them is identical to it. The concepts of centralization as found in Robbins (1987), Hage (1965), T. Marschak (1972), Huber et. al.(1990) and others are also related, but not identical, to our properties. Neither participation nor centralization is the same as either enfranchisement or independence because each of the first pair is defined in terms of combinations of the second pair. An excellent illustration of the properties of enfranchisement and freedom is the structure of the political organization that is the government of the United States of America. The organization has a high level of enfranchisement, even if it is representative rather than direct. It is also a structure that gives individuals a high level of independence in some aspects of their lives. It is a democracy that allows most people to be in on the making of rules, either directly or through representation. However, for some rules, it excludes all but the user from making the rule. The Bill of Rights, amending the original Constitution of the government of the U.S.A., identifies the set of rules that are to be made only by their users. Such are the rules governing speech, religion, etc., rules which the government may not make.

The mapping of any decision rule is created to attain some set of goals. These may be the goals of some set of people which may be in the organization or outside it. Goals could be those of the makers of the rule, or they could be those of the users or the goals of a set that is neither the maker or the user set. The goals are not explicitly identified in the definition of a rule we use, but they can be derived from the rule mapping or identified by questioning the rule makers. We define h(r) as the set of goals which the mapping f of rule r is created to achieve. The goals may be made of any combination of those of the rule makers, those of the rule users, or those of some group outside the organization.

**Maker Orientation:** This property is defined in terms of the extent to which the goals in the set h(r) are those of the makers of the rule. It may be measured by some function of the proportion of all the goals that underlie the rule mapping that are goals of the makers of the rule. For a set of rules, the measure may be obtained as some function, the average say, of the individual measures.

**User(non maker) Orientation:** This property is intended to give us some description of the extent to which the goal set h(r) is that of people who are users and are not also makers. The more goals in the set that are user goals, the more user oriented the rule. Both this property and the one before involve the intent, i.e., the goal to be served by the mapping f. In the case where there are no rule users in the set of rule makers, and all the intended goals are those of makers, then the rule is high in maker orientation and low in user orientation. The larger the number of elements of intersection of the set m and the set u, the closer to one another will be the measures on these properties be.

**Rule Openness:** This property is defined in terms of the proportion of all the goals that underlie a rule that are goals of people who do not belong the union of the set m and the set u. It may be measured in the same manner as the two previous properties. Charitable organizations tend to have rules that are high in the measure of openness as do organizations in the Soviet Union where the rules tend to serve the goals of the Communist party, rather than the organization itself. Many organizations use goals for their accounting rules that are set by a national group of accountants, and use the safety goals of work rules set by government agencies. The distinctive characteristic of Mintzberg's (1980), professional bureaucracy may not be that its members are professionals, but that it uses the goals of outsiders such the AMA or the ABA.

## 8. Decision Rule Properties: Mappings

A distinction is made between making choices and making decisions (Baligh 1990). Making a choice is defined as specifying a set of values, one of which is to be given to a decision variable. Making a decision is defined as choosing a value and actually giving it to the decision variable. It is a choice made into a fact. The decision rule is the operating mechanism which allows one person's choice to become another's decision, thereby bringing order to the actions of a set of people (Baligh, 1990). Later we show how the properties of the mapping of a decision rule affect the actual decisions of people using it, i.e., the performance of a structure. The whole issue collapses into the freedom of decision of the users, and encompasses both concepts of formalization and centralization of Hage (1965), Robbins (1990), and many others. Whatever measures we define for the properties, they must allow one to choose and set their values.

**Comprehensiveness:** This property is defined in terms of the circumstances for which the rule explicitly assigns a set of values for the decision variable. The measure of comprehensiveness of a rule (of its mapping f) is defined in terms of the number of elements in the domain of the rule relative to the number of elements in the smallest domain which could be logically derived from the non-redundant form of the actual domain of the rule. Suppose there is rule with an actual domain that contains as an element a vector with one component that reads "summer", and does not contain any vector that has any other value for this component. The term "summer" is a value taken by the parameter variable called season and the actual domain is redundant if the only value that a season may take is this one value. The inclusion of the parameter variable season is useful and not redundant only if it could possibly take at least one value other than summer. For the inclusion of the value of summer to be useful, there must be at least the value of "not summer". The actual domain that includes the value summer but excludes the value not summer is logically incomplete. Comprehensiveness is the property that refers to the extent to which a domain is logically complete, and it may be measured by the ratio of the number of elements in the domain to the number that is in its non-redundant logically complete form. The measure for a set of rules is some function of the average. There may however be times when we need something more that just logical completeness as the standard. One could argue that if the parameter variable of season takes on the value "summer", then it means that it could take one of three other values. The basis for the argument is not logic alone, but logic and language usage. To escape from the strict logical completeness standard, we might define the property of common sense comprehensiveness which would substitute some determined common sense basis to create the complete domain. In both these definitions the complete domain has the same set of parameter variables for its dimensions as does the actual domain. It may be useful at times to allow the complete domain to have for its dimensions any set of parameter variables one chooses. Absolute comprehensiveness may be a good term to use to refer to this third form of the property. All three forms are measured in logically equivalent ways. But whereas the first two measures for a particular rule may be changed only by changing the number of elements in the set defined by a given set of dimensions, the third may be changed both in this way, and by changing the set of dimensions. We can increase the measure of first two properties of a rule by increasing the number of elements in it without changing its dimensions. In the third definition we may change the dimensions. The more the circumstances for which the rule identifies some prescriptively allowable decision variable values, the more comprehensive the rule.

**Fineness:** This is a property defined in terms of the range of the mapping of a rule. The range of a rule mapping is a set in which each element is itself a set of values, one of which is to be given a decision variable. The rule mapping pairs each of these sets with at least one element in the domain. Every such pair states that when the circumstances are described by the vector that is the first part of the pair, then the decision variable is to be given any value from those that make up the set that is the second part of the pair. The fineness of a rule deals with the number of elements in these sets, and is a property that relates to the degree of guidance the rule gives its user. The property may be measured by the inverse of the average number of elements to be found in each set. If a rule has 8 elements in the set that it pairs with an element in its domain, then the fineness of this pair of the rule mapping is 1/8. The fineness measure for a the whole rule is the average of this measures for all its pairs, and for the structure it is the average of the measure for all rules in the structure. The highest level of fineness for any rule is one, which is the case when every element in its range is a set that has only one member, the smallest number that it could have. Other concepts of averages may, of course, be substituted for this one, e.g., that obtained by weighting each set by the probability of occurrence of circumstance described by the vector with which the set is paired. It is clear that all concepts of bureaucracies really refer to organization structures with decision rules that are very comprehensive and very fine. This is true of Weber (1947), and almost everyone else. These two properties and others are used to describe structures in a manner that is much more operational than concepts such as of formalization and centralization which are then dispensed with.

**Lumpiness:** This property is defined in terms of similarities in the elements of the range assigned different elements in the domain. The more nearly similar the subsets of decision variable values assigned to the different elements of the domain of the mapping of a rule, the more lumpy the rule. Each element in the range of the rule mapping f is a set. If we take any two of these sets, then we could count the number of elements in their intersection. The ratio of this number relative to the number of elements in the union of these two sets may be obtained. If the intersection has no elements, then the measure is zero. If the number in the intersection is the number in the union, then this measure is one. This measure is obtained for every pair in the range of the rule, and the average of all these is the measure of the lumpiness of this rule. For the operating structure, the measure of its property of lumpiness is the average of the measures for all its rules. The measure tells us something about the differences between the values which the rules specify are to be given to the decision variables in the different circumstances.

**Domain Resolution:** This property is defined in terms of the sharpness with which we distinguish between the elements in the domain. It is somewhat like the property of the sharpness of the image in a photo or on a TV screen. The larger the number of elements a component in the vector of the domain of a rule may be given, the more resolution there is in the rule. Each dimension, or parameter variable, of the domain P of a rule mapping is allowed a set from which its value is specified. The set may be the elements that are multiples of ten , or the set of real numbers. The more elements there are in the set, the closer to the real value will be the value given it for the mapping. Domain resolution may be measured in terms of the number of elements in the set of allowed , or in terms of the ratio of this number to the largest number that could logically be used. The measure for a rule would be the average of the measures of all its dimensions, and the measure for a set of rules would be the average of the measures for the set.

**Range Resolution:** This property is analogous to the previous one. Here the property involves the set of values from which a value for the one decision variable may be drawn. The more elements there are in this set, the higher the range resolution of the rule. If money is the variable, giving it value in cents means greater resolution than giving it value in dollars.

**Domain Explicitness:** This property is defined in terms of the manner in which one states the values of the components of the domain The set of values that a component of the domain may take is made up of elements that may be stated in terms of different levels of explicitness based on the amount of inference that is needed to get from what is stated as the value to what the value is in fact. If the component of the domain is the price that a specific competitor charges, then its value in fact is some number of dollars, such as $7 or $7.38. In a rule, the values taken by this component of the domain of the mapping may be, a price that has strong down effects on our market share, and a price that does not have such strong effects. In any rule, the value may be given as a number or as a number that is to be derived from effects it has on some thing. The rule user can use the rule only if he makes the inference to the real fact of the price from the relation it has to the market share. He may even have to find the relation of competitor price to our market share himself. For any dimension of a rule, the complexity and length of this inference making process may be used as a basis for measuring the level of this property of explicitness. The level of rule explicitness of a rule is then the average measure of the values for all its elements. For a structure, the measure is the average of the averages of the measures of all its rules.

**Range Explicitness:** This property is defined analogously to the previous one. Its measure for an element of the range, (which is itself a set), is given by the ratio of the number of its elements explicitly stated, e.g. set price at 63, to the number of elements not explicitly stated, e.g., set price to hurt competitor X. For the range of a rule, the measure is the average for its elements, and for a structure, the measure is an average of its rules.

**Connectedness (domain-domain):** This property is defined in terms of the dimensions and vectors that define the domains of two rules. A precise definition is given later.

**Connectedness (range-domain):** This property is defined in terms of the dimensions and vectors that define the range of rule and the domain of another. A precise definition is given below.

**Durability:** This property is defined in terms of the length of time the decision rule is to be considered valid.

This last property requires that we include time in the definition of a decision rule, This is easily done by pairing variable values and time measures. A time measure would refer to the time for which the value of the variable paired with it would hold. It is the time the value of a parameter is a fact, or the value a decision variable is to be made a fact. Now the domain of the rule may specified for one period, and another domain for another. Time may also apply to the range of a rule, and be used to specify that the variable is to be given some value now, or for all time (The Ten Commandments), or anything in between. Basically this property is based on the life of the rule or the number of times a rule is to be used. After that number there is another rule that is given the user, or else there is no rule and she makes her own. A high level of durability is what we may find in long established structures, the machine bureaucracy (Mintzberg 1980). Low durability is what we might find in a new structure, one in which the correct decisions for all circumstances and time have not yet been discovered, the simple structure of Mintzberg (1980). The real difference between the two kinds of rules has nothing to do with either age or the decisions called for by the rule. In one case the rule is there for the user to use until it is replaced by a new rule, and in the other case the rule has to be sent to the user each time the decision is to be made. Both rules may specify the same decisions, but they do so in different ways and at different costs. By stressing the ages of the organization in which the two kinds of rules are to be found, we confuse the issue, since it is not age we are talking about but rule durability, that is, how long the rule is intended to hold, not how long it has held. This property is not really useful to finding solutions of the problem of designing structures. It does not relate directly to performance unless rule expiration is considered to mean permanent rule absence. This property is defined in terms of the number of different basic units that make up the organization structure or substructure. It is measured by the sum of the numbers of elements in the sets that make up the components of the structure or substructure. It may be simply defined and take on the value which is the sum of the numbers of people, variables parameters, assignments, and so on, or it may be split into special kinds of sizes. This would give us the people size, the problem size, etc. with values taken being the numbers of the elements in the relevant components of the structure.

## 9. Properties of Information Substructures

The value of information is in its use (J. Marshak and Radner, 1972), and the decision rules of the operating substructure determine the facts, or information, which the organization needs and the uses to which these facts are to be put. Facts are supplied by the information substructure which should be designed to supply the information the operating substructure needs to make the decisions for the organization. Because the work of collecting, transforming, sending, and storing information is costly, the two substructure should be designed to fit one another and be efficient. Fit and efficiency requirements along with the knowledge that the two substructures are logically similar may be used to determine the properties of the information substructure which we expect to be useful in the analysis, and hence should be defined. First there are the properties of the operating substructure which are defined in terms of components of the operating substructure that have analogues in the information substructure. For example, the comprehensiveness of the rules on information reading, sending, storing, deriving, and receiving is a relevant property. It refers to the conditions under which information is say, to be sent to someone, and ranges from always send, to send if only one circumstance exists, to never send. Clearly this property is related to how well the information substructure serves the operating one and to the costs of having the former. Properties of this kind need to be renamed and redefined for the information substructure, if only to make their use in the processes of analysis and design easier. These and other useful properties of the information substructure are defined next.

**People Inclusiveness**: This property is defined in terms of the set of people that is a component of the information substructure and the set of people who are also assigned parameters. The first set is that of those who are considered to be part of the organization, and will in fact be involved in collecting, transforming, etc., information. The second set is obtained from the variable assignment component of the substructure in which the elements pair parameters with people and where a pairing means that the parameters variables are assigned to the people who are to read, send, etc., their values. The second set is identified from the elements of the set of assignments of the substructure. All the people who appear in these pairings of the assignment component make up the second set of the definition of this property of people inclusiveness. The measure of this property is the ratio of the number of people in the second set to that in the first. A measure of one means that every person who is part of the substructure is recognized as such and given an assignment that involves him or her in the making of decisions. If the number is less than one, it means that someone in considered to be in the organization, but is not part of those who are organized and given something specific to do.

**Parameter inclusiveness:** This property is defined in an analogous manner to the previous property. The issue is one of identifying whether all the parameters that appear in all the transformations are defined in terms of these, and are elements of the set that makes up the parameter component of the definition of the substructure, or are assigned to someone who is to be involved in reading their values, etc. Here also, the measure is the ratio of the number of those parameters that appear in the pairings of the assignments to the number in the set that is the parameter component of the definition of the structure. If this number is less than one, then there are parameters that are not assigned to anyone in the substructure. The assignment of a parameter to a person means that this person is to do at least one of the following with this parameter: read its value; send this value to this or that person; receive a value sent to him by someone; store the value. From any assignment set one can derive the set of all parameter variables each of which appears at least once in a pair. We now count the number of parameter variables in this set that are also in the set of parameter variables defined earlier. We also count the number of elements in this latter set. The ratio of the former to the latter is a measure of the property of inclusiveness. When the number is one, then every parameter in the component set is assigned to at least one person; otherwise there are some that are not.

We assume that if a person reads the value of a parameter variable, sends it to someone, receives it from someone, records it, or stores it, then this person knows the value of this parameter variable. If the person does none of these things, then he does not know this value. This measure tells us something about the proportion of the number of parameter variables in the component set, the values of which are known to at least one person in the set of people that is a component of the structure vector. Knowledge is a "yes-no" condition here, but later we will allow it to take on more values.

**Diffusion:** This property is defined in terms of the same two sets we used to define inclusiveness. Here we are interested in the extent to which the values of the recognized parameter variables are known to the people in the organization. In the set of assignments the elements are pairs of the form of a parameter and a person. The pair specifies that the person is to read, send, receive, or store the value of the parameter. For each person there is a number of parameters with which he is paired. Regardless of whether the pair refers to reading the value of the parameter or to sending, receiving, or storing it, the pair implies that this person is assigned the duty of knowing the value of this parameter. There is for each person a number of parameters with which he is paired, and for the person there is the ratio of this number to the total number of parameters that are elements of the set that is the parameter component of the vector that describes the structure. When the ratios of all the people in the set that is the people component of the vector that describes this structure are averaged, we get the measure of the structure's property of parameter diffusion. This property tells us something about the extent to which people in the organization know of what there is to know about its world and what it is doing.

**Redundance:** This property is defined in terms of the number of people who are assigned to read the values of each parameter. It is derived from the read assignments and measured in terms of the intersection set of all assignment sets and the set of all parameters. First the number of times each parameter is found in all the assignment sets is identified, and an average is calculated. Then the ratio of this number to the total number of assignments is a measure of this property.

**Repetitiveness:** This property is defined in terms of the number of times parameter values are read in a period of specified length, or the time elapsed between the readings. The logic of the measurement is the same in both cases. It is measured in terms of the domains of the decision rules on reading parameters. If time or its analogue is a dimension defining the domain of a rule, then the time elapsed between readings to be taken of the parameters' values can be ascertained and an average obtained. The measure of this property for the information, or I, substructure is the average for these averages.

**Rule fineness:** This property is defined in terms of the range of the read decision rules of the substructure. It is derived from the number of values in the elements of the ranges of the rules. For read parameters each rule identifies the circumstances when the value of the parameter is to be read, and the range identifies for each circumstance a set of values allowed for the reading, one of which is the real one. The larger the spread of the allowable readings the lower the fineness for this rule. This property is the same as the one we called fineness in decision variable rules. It is measured in the manner that this latter property is measured, but its meaning is different. In the case of decision variables the issue is related to the number of values that may be given, that is, made real for the variable. In the parameter case it is the number of values that may be accepted as the real ones for the parameter.

Many of the properties of the operating substructure components apply to the set of components of the information substructure. They need minor changes when they are used to refer to reading parameter values etc., rather than setting variable values. The same is true for the components of the reward substructure with appropriate changes that may be needed.

## 10. Properties of the Reward Substructure

Just as some properties of the operating substructure were relevant to the information substructure, so there are some that are relevant to the reward substructure. The properties defined for the rules of the operating substructure apply to the rules in the reward substructure. Because these latter rules are person specific, some definitions may need to be reinterpreted, and some may be of little use, and some may be missing. It should be noted that reward rules as defined earlier are person specific as well as being decision variable specific, like operating rules. The specification of the rules of the reward substructure is of great interest to unions, and here is where they are likely to seek to come into the process of designing the structure. The definitions of some properties that are important to the reward substructure start with the one that tells us who makes the rules.

**Ownership:** This property is defined in terms of the participation of the set of people to whom the reward rule applies in the making of that rule. Reward rules have the set of makers, the set of user, and the set we might term receivers. This is the set of people whose rewards are determined by this rule, and the size of the intersection of this set with the set of rule makers relative to the size of the union of these two sets is the basis for determining the measure of this property. In a sense, the extent to which the reward receiver affects what she receives as reward is a good measure of the extent she may consider herself be an owner of part of the operation and act accordingly.

**Involvement:** This property is defined in terms of the intersection of the reward receiver set in the rule and the set of rule users. The measure of this property is defined in terms of the size of the intersection of the two sets relative to the size of their union set. Do the receivers of the reward read or participate in the reading of the values of the variables that define the domain of the mapping of the rule? Do they participate in making the mapping into facts? In short, this property has to do with the actual use of a reward rule, and the extent to which the users are involved in the process. It is probably best if we allowed the participation to be by representatives of the receiver who are chosen by the receiver. The measure of this property is analogous to the previous one, with the exception that we allow receivers to choose representatives to replace them in the relevant set.

**Consistency of Mapping :** This property is defined in part on the basis of the similarity between the domains of rules for persons who receive the rewards and belong to specified subsets. Once a subset of people is determined, then the consistency of the domains of the reward rules for people in this set may be determined. A subset could be defined on the basis, for example, of the similarity in the assignments in the operation substructure. Once we establish this subset, then this property is measured in a number of steps. First, For every pair of people in the subset we calculate the ratio of the number of elements in the intersection of the domain of the rules for the two relative to the total number of elements in the union of these two rule domains. The average of all the ratios, one for every pair that can be defined from the subset, gives a measure of this property for this one subset. When such a measure is made for all subsets, then the average of the ratios for all the subsets in the substructure is the measure of its property of domain consistency. The property is also defined in part by the similarities of the mappings of rules for persons who receive the rewards and belong to specified subsets. The similarity is based on the similarity of the domains of the two rules, of the ranges of the two rules and with the list that maps elements in the domains into elements in the range. Two variables are similar if they differ in only one dimension, which is that involving the identity of the receiver. Two domains are similar to the extent that they have similar variables defining them. The people in the specified set and to whom this property is applied is determined by the similarity of the work they do. The involvement of the receivers of the reward rules in determining this set is essential if this property is to have meaning. The measure is determined by the intersections of the variables of the domains, the ranges and the elements of the mapping lists.

**Outcome Based:** This property is defined in terms of the components of the domains of the rules. It may be measured by the average number of the dimensions of the domain that are variables that define the outcome of the person's decisions. There is then an average for all persons in each given subset we define, and an average for all these.

**Decision Based:** This property is defined in terms of the components of the domains of the rules. It may be measured by the average of the dimensions of the domain that are variables that define the person's decision. The variables that define the outcome are replaced here by the decision variables given values by the person.

**Receiver Orientation:** This property is defined in terms of the goals used as the bases of the reward decision rule and as the bases for determining the dimensions of the range of the rule. A reward rule that is receiver oriented has a range to its mapping that has dimensions that are in the receiver's goals. The mapping is receiver oriented when the elements of the range it specifies derive from the goals of the receiver. This requires an understanding of what it is that the receiver values and then making it part of the reward.

## 11. Theorems on Relations Between Decision Rules

There are some things we could do with the algebraic relations defined earlier that would help us in designing an organization structure. We show later that a sequential process of design can be very efficient, and one step in the process is to add rules to existing ones and so on. But if we are to add rules, and we are interested in some properties of the structure we are creating, then we need to know if the addition maintains properties or not. If we add rules in a sequential design process, or if we allow users to add rules from the same source or different sources, then is the resulting rule consistent with either, both, or neither of the added rules? Is it more or less comprehensive, more or less fine than either? The answers are important, and some theorems could tell us what happens as we add rules in a systematic and sequential process of design.

Baligh (1990) has shown that all the following theorems are true:

Theorem 1: For $r + r^* = r^{**}$ , then $r^{**}$ is no less comprehensive than either r or $r^*$;

Theorem 2: For $r + r^* = r^{**}$, then $r^{**}$ is no less fine than either r or $r^*$;

Theorem 3: If r is consistent with $r^*$, then $r^*$ is at most as comprehensive as r and at least as fine;

> Theorem 4: For r + r* = r**, then r** is consistent with r if and only if r is consistent with r*. The same is true when we transpose r and r* in this theorem.

Addition of two rules produces a rule that is equally or more comprehensive than either, and equally or less fine than either, exactly the opposite of what is needed for logical consistency. Allowing rule addition in organizations could produce rules that counter the intent of the makers of each of the rules that are added together. If fineness, comprehensiveness and consistency are important issues, then these theorems tell us what happens or might happen to them if we allow a rule user to get rules from two sources (no unity of command), or what happens if a sequential process of rule building is followed. The theorems tell us when we do and when we do not have to check every single case to see what is happening to the values of properties we want our structure to have whenever we add a structure to it or subtract one from it. The effect of this on the efficiency of the process of design is enormous, as we will show later.

## 12. Structure Properties of MBC

All the properties defined may be used to design or describe a structure for the Master Brewing Corporation. If, for the first example of structure, we choose the one designed in the last chapter, then we can apply the definitions of the decision rule properties of comprehensiveness and fineness to any rule in it. There is the rule which tells one person to choose the values for the input amounts which produce any level of output and to do so for every such level. How comprehensive is it? It is as comprehensive as it can get because it wants the decisions on the inputs, the decision variables, for any level of output. If the rule is stated to be applicable to every period, then it is applicable to all values of the parameter variables and is fully comprehensive in these dimensions of its domains. It is also very fine because it specifies that for every level of output and every value of each parameter value, the decisions should be the ones that minimize costs, and there are only a few sets that do that. The rule is also very low in explicitness, because no mention is made of the actual values to be given the decision variables. These values are specified in terms of the effects they have, not on what they are. The rule which says to the same person to produce a single specified output amount at the lowest cost is fully comprehensive, fine, and explicit. The rule applies regardless of circumstances, it identifies one and only one amount, and it is fully explicit. Other properties defined earlier also apply to this simple structure. The logic of the assignment of variables to people is that of the free standing transformations, which are the two production functions, etc. The set of variables that make up the transformation that describes the production of beer in one of the factories are assigned to a specific person who is given the appropriate decision rules to go with it. One could identify the set of people whose goals are the ones that underlie these rules. Since the rules are based on the goal of maximum profit, they are those goals that belong to those who share that profit. The reward system we choose for this structure should be one that is consistent with the manner in which these profits are distributed to the seven people. Consistency is discussed in the next chapter.

If we think of a more realistic situation for MBC, we might allow it to produce a number of different beers in a number of breweries and sell the outputs in a number of different markets. The beers are produced in a number of different places, each of which can be used to produce only a subset of the beers. The markets in which the beers are sold also differ one from the other in the expectations that resellers of the beers have for delivery time, amounts bought, payment schedules, and so on. Consumers in the different markets also differ one from the other in their preferences for types and colors of beer, and in the reasons why they drink beer, and why the specific one they do drink. The decision rule part of the design is quite complicated. What rules should there be relating to visits made by sales people to reseller? There will be decision rules on the order in which they should they be visited, rules on how much time is to be spent with each, on the speed of delivery offered, on the prices offered, and the prices quoted, and so on. A rule may state that resellers with sales over K dollars a month are to be visited M times a week, those with sales less than K but more than K* are to be visited less than M but more than M*. If the rule is created in discussion with the person who is to use it, then there is some level of enfranchisement. The more of the set of all positive numbers that are included in all the sets of sale ranges, the more comprehensive is the rule. The bigger the differences in the units in which K, K* etc are stated K* and K** etc., the lower the domain resolution of the rule. The larger range between M and M* etc., the lower the fineness of the rule, and the more the ranges M to M*, M* to M** overlap, the more lumpy is the rule. All structure properties may be used to describe any structure.

# CHAPTER 4

# STRUCTURES: CONNECTIONS, CONSISTENCY AND COSTS

## 1. Levels of Decision Rule Connections

Organizations are connected sets of people, and among the many connections of organizations the defining one is the decision rule (Baligh, 1990). The specific decision rules of an organization affect its performance as we show later. It is reasonable to conclude that the relations between the decision rules of an organization also affect its performance. Decision rules may also be connected to the transformations which describe the ways by which the organization brings about changes in some part of the state of the world. When these transformations are connected together they describe the technology of the organization. When decision rules and transformations are connected in various combinations, the result may be called a decision process. Such a process is made up of parts of the structure of the organization, connected decision rules, parts of its technology, connected transformations, and the connections between the elements of the two parts. The organization's decision processes affect the performance of the organization. Performance, in turn, affects the attainment of goals the organization has.

Every property that involves decision rules is defined in terms of only one rule, and by extension defined for the set of rules that is the third component of the operating structure. Other properties may be defined in terms of pairs of rules, specifically in terms of the connections between two rules. Recall that a decision rule r is defined as (m, u, f), where m is a set of rule makers, u a set of rule users, and f a mapping which assigns a subset of the set of values which a given operating decision variable is logically allowed to take to a circumstance or state of part of the world. A circumstance can be thought of as a vector of some finite dimension. Decision rules are connected by way of their makers, users, and by the domains and ranges of their rule mappings. Transformations are mappings that describe changes in a part of the world which the organization structure can bring about. When connected together through overlapping domains and ranges, these transformation mappings may also have intersecting domains or ranges and thus be connected. The structure, the technology, and the connection between them describe a decision process.

It is useful to relate the organization structure parts of decision processes to organization performance. Also of value to the analysis which we do below is the clear definition of what a decision process is. We need to indicate what the relation between a decision process and performance might be like. In what follows immediately we define decision rules, transformations, connections between decision rules, connections between transformations, and connections between rules and transformations. Though the first of these has just been done, we redo it in a manner that suits better the purposes of showing how rules are connected one to another. The definition will be slightly different in form, but logically identical to the earlier one. Next, a number of relations between any two decision rules are defined, all of which are in terms of logical connections between pairs of components, one from each of the two rules.

## 2. The Decision Rule and the Transformation

For each given organization we need to define two basic sets. The first is a basic set of people which contains all the decision makers of that organization. The second is a basic set of variables which contains all the variables the values of which are of concern to the organization. Every element in the first set has a unique identity and name, as does every element in the second set. In this set some elements are pure parameters, variables the values of which can not be set by the whole set of people or by any proper subset of it. These variables take values which are determined by forces or people outside the organization. Other elements in this set are decision variables, that is, variables the values of which may be set by the whole set of people or by any proper subset of it. Any decision variable may be treated as a parameter by any proper subset of the basic set of people.

A decision rule is defined by three components. The first is a set of people, the ones who make the rule, i.e., specify the third component of the rule. The second is also a set of people, the ones who are to use the rule, i.e., use the third component to give a value to a decision variable or to make another rule. Both the set of rule makers and the set of rule users are subsets of the basic set of people. The third component of the rule is a mapping which associates values to be given to one decision variable with each of a number of circumstances. Every rule mapping relates to only one decision variable which is an element of our basic set of variables. Each circumstance is described by a vector of values taken by a subset of our basic set of variables. An element of the mapping of a rule is a pair (circumstances, set of values). The second component of every element in that mapping identifies a set of values, one of which is to be given to a decision variable. Every second component of the pair has values that may be given to the same variable. This variable is called the subject of the rule. The first component of an element of the mapping refers to a vector of values each of which is the value taken by a variable in our basic set. The mapping is an imperative which specifies the values from which one is to be made into a fact, when a circumstance is a fact. The rule users are to use it to make a fact or new rule, while the rule makers specify the imperative the users use.

The first component of every element in a rule mapping refers to a vector of values of the same subset of the basic set of variables. This vector describes a circumstance. Each circumstance in a rule describes a state of the same part of the world. Each circumstance is a set of statements of fact, one for each of the same subset of our basic set of variables. Every element of the mapping is an “if-then” statement. It associates a set of facts about any number of things, the “if” part, with a set of possible facts about only one thing, the “then” part. One and only one of these permissible facts is to be made into an actual fact. An example of an element might be, "if the competitor's price goes down and our production capacity is between ten and twenty percent idle, then lower our price by five to ten percent." A second element in this rule might refer to a number of changes, only one of which is to be made in our price when the competitor drops his price, and our production capacity is less than ten percent idle. The rule mapping may have any number of elements from 1 to infinity.

The technology part of a decision process is described by transformations and the connections between them. A transformation is logically identical to the mapping of a decision rule with one exception. Instead of saying if a do b, the mapping says if a then c. The transformation is a mapping that is a conditional categorical statement, whereas the rule is a conditional imperative statement. The difference is in the meaning of the mapping, not in the logical structure of the mapping. Everything stated above about this logical structure of the decision rule mapping applies to that of the transformation mapping. This, in fact, is in essence a production function in the traditional sense. It describes changes in a part of the universe. The mapping describes a set of moves, one for each of a set of states, and each is a move from one state to another. Insofar as these changes are understood or designed by, and their occurrence predicted or controlled by, decision makers in the organization, these changes are transformation that are part of the technology of the organization. They are the production processes that describe how the organization changes part of the universe around it to its advantage, or takes advantage of changes it predicts are coming. Transformations and the connections between them describe the technology segment of a decision process.

All rule connections need to be defined in terms of only two rules. Strings of connections can be built up from such overlapping connected pairs. So if rule r is connected to rule r*, and rule r* is connected in the same way to rule r**, then we have a string of connections. The first connection we define and relate to structure performance is that between the makers of two rules: rule r with subject variable v, and rule r* with subject variable v*. If the maker of r, the set m, and the maker of r*, the set m*, contain some elements in common, then the two rules are maker-maker connected. If the structure we design has two rules dealing with the same variable, and the rules are not connected in this manner, then they may contradict one another. A maker-maker connection is important. In the case where the two rules are on two different decision variables, then under some conditions this connection may be useful in getting some level of coordination between the two rule mappings. Yet another connection between rules is that in which the makers of rule r* are among the users of r. This user-maker connection is one where the users of r contain members of the set of makers of rule r*. The makers of a rule delegate, in effect, the responsibility for making rules about how a decision variable is to be given values to another set of people. If it is important that the rule r* be consistent with the rule r, then such consistency may be obtained by making the group that makes the rule r* have members that are also members of the users of the rule r. This would give some people the knowledge needed to get this consistency and make it available to others who make rule r*.

Decision rules may also be connected by way of their mappings. Mappings may be connected if their domains are connected or if their ranges are connected. A rule mapping assigns a set of values of one variable to each of a number of vectors of values of a fixed group of variables. This domain of the mapping is inside a Cartesian space. Each dimension of the space is made up of a set of values of one of the variables in the basic set we defined earlier. In an example, one such set might be two values that might be taken by a specific competitor's price: the present price of fifty, and a price lower than fifty. The only other dimension of this rule may be a set of values of the variable of the excess capacity of our plant. Let the two values for this variable be ten percent or more, and under ten percent. The elements in this domain of a rule might be: (50, > 10%) and (<50, <10%). This rule specifies what is to be done when only two parameter variables take on one of only two values each. This rule's domain is characterized by these two things: a set of variables, and a collection of nonempty sets, one for each of these variables, and with each such set made up of the values that are mentioned in the domain for its variable. The range of a rule has two characteristics. The first is its subject variable which in our example we might make the decision variable of our price. The second characteristic is described by the decision variable values allowed anywhere in the elements of the range. This is the set of all values of this variable that appear as members of any element of the range. In our example, we may specify that our price be 50 or 51 in one case and 50 or 49 in the other. This rule, the first, may have any one of the following connections with another rule; the second: domain-domain connection or range-domain connection (range precedes domain in the order).

The domain-domain connection exists if the second rule has any of the following:

a) the competitor's price as a dimension, and an element in the domain with this component being either 50 or less than 50, 50 being the number of parameters that are common or shared.
b) the production capacity as a dimension and an element in the domain with this component being either 10% or less than 10%, 10% being the number of values of the shared parameters that are common. As we increase either of these two measures, we increase the measure of the connection between the two rules. As for the range-domain connection, the first rule and the second rule have this connection if the second rule has the following:

c) our price as a dimension of its domain, and an element in its domain with this component being one of the values 49, 50, or 51. As we increase the number of values that occur in the range of the first rule that also occur in the domain of the second rule, we in increase the measure of this connection. This measure and the previous one of domain-domain connection may be used to define a rule connection property for the set of rules that make up the decision rule component of the organization structure.

**Connectedness:** This property is defined in terms of domain-domain connections or range-domain connections. It is measured on the bases of the measures defined above for the case of domain-domain and the case of range-domain connections. The first measure is obtained for every pair of rules and an average for all pairs is obtained. The same is done for the second, and the average of these two averages may be used to measure the extent of the connectedness of the rules in the component of the structure. It is also possible that we may find it useful to distinguish between domain-domain and range-domain connectedness, and to measure each by the appropriate average.

Decision rules are at the heart of the definition of organization structures found in the literature from the early days to the present. They can be found is such works as Burton and Obel (1998), Jones (2001), and Harris and Raviv (2002). Such near universal use is to be expected, given that the organization chart describes the fundamental relation that defines an organization, the decision rule connection, and does so in a clear and concise fashion. Terms used with these charts are inherently ones about decision rules. Up and down relations between the rectangles that represent people describe the makers and users of rules, and the uses of lines between the rectangles that stand for people describe the actual rule connections. Adding terms about the subject of the work of a rectangle identifies the decision variables that are the subjects of the rules used by the rectangle and received from a rectangle that is higher. The annotated chart can then be used to give clear and efficient descriptions or illustrations of different structure forms, and thus form a basis for classifying them and using the differences to explain something about them such as what they can do or whatever. But the discussion of the issue of rule addition, rule consistencies, and the identification of a large number of bases for distinguishing between rules and between their properties makes it very clear that the traditional chart is of little use.

## 3. Decision Processes

Simply defined, rules, transformations, and connections between combinations of these two give us the tools by which we can define decision processes in organizations. These definitions would be in terms of specific organization structure design variables and technology variables. In designing an organization one builds up its defining decision process from simple pieces. These may be parts of a structure, parts of a technology, or some combination. The designer works with rules and transformations, and connections between one rule and another, between one transformation and another, and between one rule and one transformation. Again decision processes are created from building blocks, and changes in them may be made in small marginal steps. One should find it easier and more efficient to design decision processes if these were defined in terms of much simpler concepts. Mackenzie's (1991) concept of a process is both similar to ours, and put in terms of its own building blocks very clearly. Other works are not so clear, and therefore end up in confusion. Perhaps the best way to show this is to use an example of the three technologies of Thompson (1967). First we define them in our terms, see whether we can enrich the variety of technologies we can represent, and finally show how we can systematically design a technology in an orderly manner. In the process we show that Thompson's concept of a technology incorporates elements of the organization's operating structure, and is in fact a decision process. The structure and the technology are lumped together into what he calls a technology. Thompson's technologies are decision processes made up of connected rule mappings, and connected transformations. The difference between rule mappings and physical transformation mappings is that the former connect facts to what is to be done to make facts, and the latter connect facts to facts. The latter describe transformations that exist in the world, that is, the way the world changes. These are the "technology" pieces. The former prescribe the changes that are to be made by a person in the world, given a state of that world. These are the operating structure pieces. Together they may be used to describe the organization, but they are not the same thing. The prescriptions of the operating structures need to be realistic if they are to be useful, and that means they must conform to real world transformations, including the users' capacities to be part of such transformations. The long linked technology of Thompson

(1967) may be described in our terms by a set of mappings, (transformations and rules), in which the range of one is connected to the domain of the next, and its range is connected to another domain and so on. This does not restrict the definition to the case where the domain of one mapping is restricted to be only the range of the preceding one. Further, our definition need not be time sequenced, and our connections may well be logical only, and in reverse order of occurrence in time. The intensive technology of Thompson (1967) is one in which the mappings, rules, or transformations, are connected reflexively. The range of one is the domain of the other, and the range of the other is the domain of the first. That is precisely what we have in simultaneity or, in recursiveness, which is logical simultaneity once removed. It is also possible to view this class of technology in slightly different terms, which Thompson calls intensive technology. Here the technology may be described by mappings that have domains that are made up of the unions of the ranges of other mappings. Such is the case where there are many resources and people acting on them, with the result being dependent on all these. By this redefinition we see that the class is really two classes, with two dimensions, and is perhaps better seen as four classes. Again the "technology" is really part technology and part organization operating structure, i.e., the processes of making decisions and creating facts.

Finally, Thompson's (1967) mediating technology may be described by two mappings with connected ranges, but disconnected domains. In the limit of this case we have the transaction in which a variable takes a value determined by two people, with each choosing a value based on a domain not connected to the other. It also requires that the values chosen by the two people be equal for them to become real. The term “pooled interdependence” means that nothing happens until there is agreement by two people. That is a condition that is quite common, one that involves what Baligh (1986a) refers to as a shared variable, a necessary component of exchange and transaction. It is not necessary for there to be a mediator to get agreement on value, and there are interesting strategic considerations to what the people in such a situation might do to get an agreed value as close to the one they wanted if the variable had not been a shared one. Agreement may be reached by various combinations of strategies (Baligh, 1986a). Whether the technology pooling connection can be resolved in a similar manner without mediators is an interesting problem, but its solution will not make Thompson's (1967) three classes homogeneous, or exclusive, or exhaustive Real decision processes may be of any of these classes, or of any combinations of all of them, as is apparent in the chart used to describe a process (Thompson, 1967) which belongs to all three classes. In drawing this process, one can proceed one connection at a time. Given the set of transformation mappings allowed by the real world, one may choose transformations, rules, and connections between them. These decision processes may be built up in a manner that is efficient. The object is to create efficient decision techniques, or ones that produce the appropriate performances. Organizations are just such combinations of processes made up of connected sets of transformation mappings and rule mappings, of technology and structure. The design of structure must surely take into consideration transformations, (technology), and the choice of these must consider structure. In the previous chapter we discussed the nature of transformations and their being the origins of the decision variable component of structure. The question of structure design may be viewed as one in which a given set of technologies is chosen, and a structure designed. Another set of technologies close to the first is chosen and a structure designed for it. The two pairs are then compared, and the better pair chosen. Another set of technologies is then chosen, and the process repeated, until no further worthwhile improvements are expected.

## 4. Theory and Design

It is our goal to develop an understanding of the relations between the nature of an organization structure and the things it can do. This is a process of theorizing which produces categorical statements that explain facts about structures and what they do. The theory and its conclusions may be used to supply imperative statements that may be used to design efficient structures. Conditional imperative statements, i.e., design rules, tell us how and what structures to create in order to get the performances that are needed to get whatever outcomes we desire. But organization structures are complex things, and the processes of theorizing and design rule derivation are difficult ones. However, both may be made somewhat easier if we first segment the structure into parts that are disconnected one from the other, theorize and derive design rules, and so on, for each part separately. When that process is over we can work on modifying the theories and design rules to get ones that are to be used for the whole structure made up of the segments and the previously ignored connections between them. We work on three segments which are referred to as substructures and are the operating substructure, the information substructure, and the reward substructure.

The concept of consistency is defined and used in the discussion of structure design by many, among whom are T. Marschak(1972), J. Marschak(1959), J. Marshak and Radner(1972), MacCrimmon (1974), Miller (1991,1992), Baligh, Burton and Obel(1994,1996), Burton and Obel(1998), and others. Consistency may not be the term used in all these works, but they all refer to such and such structures doing well in such and such environments, of combinations of pieces of structures that result in better performances and so on. All use terms such as fit and misfit, or the match between structure and environment, between structure parts or elements, or whatever. They are all talking about the same thing. It is clear that they consider the concept to be valuable and useful in the analysis and design of organization structures. We also define and use the concept of substructure consistency to help in the process of sequential design of the three substructures. There is internal consistency which deals with the relations between components of a substructure and its performance. Substructure analysis produces conclusions of the form that state that this or that pair of components always produce a more efficient substructure than this or that pair. These may be used to derive criteria for defining logical and economic compatibility, fit, or consistency of components. Consistency between structures is the concept used to design substructures that are compatible, fit one another, or are compatible with one another when they are put together to get a whole structure. Criteria derived from the analysis of structure consistency are used to derive design rules for designing whole structures that have substructures that are logically and economically compatible or consistent (Burton and Obel, 2004). They are also used in the derivation of the design rules for each substructure. The criteria for external consistency are combined with those of internal consistency in the derivation of the design rules for each substructure. The rules that result from this combining of criteria are ones that produce substructures that are more nearly alike those which would have emerged if the whole structure had been designed directly.

In the process of design there are two steps. First, three substructures, each of which is internally consistent, are designed separately from one another. Next, a whole structure is designed by changing these substructures to get three that are efficient as a whole and consistent with one another. In fact, they cannot be efficient if they are not consistent, but the reverse is not necessarily true. By starting with ones that are more nearly alike those we want in our whole design, this step is shortened, and so made more easy. Consistency issues are not left to the second step of the design process, but are considered in the first as well.

But all this stuff about efficiency and consistency is relevant only if we want structures that do things, and only if structures have costs that differ with the details of the substructures. If we want to design efficient structures, then we must theorize about what the structures do and what they require of our resources. Structures are obtained at some cost. There are costs which are incurred in the processes of designing, maintaining, and running the structure. The relations of structure performances to outcomes is one issue; the relations of structure to cost is another. A number of theories are developed. There is the theory on the performance and the returns and costs of this performance, and there is the theory on what structures can give this performance and the costs of these structures. There are four distinct sets of mappings in the theory from which rules for designing efficient structures are derived. The first set of mappings is that from performance to returns. The second is from performance to costs. These are combined into one which is that from performance to returns net of operating costs, what we term outcome. The third mapping is from structures to performance, and the fourth is that from structures to the costs of these structures. These two sets may be logically analyzed and combined into one which identifies for each performance the lowest cost at which it may be obtained. The design rules derived from these sets of mappings are those that identify the structures that give the greatest difference between the outcomes that their performances generate less the costs of designing and running them. The first set of theoretic mappings we derive are the easiest one, those that relate structures to the costs of designing, operating, and maintaining them. But first, the concept of structure or substructure consistency needs to be fully defined, because consistency is itself a determinant of these costs.

## 5. Meaning of Consistency

An organization structure may be described as the combination of three parts: the operating, the information, and the reward substructure. The distinction is made on the basis of the nature of the variables that are dealt with by the substructure. The information substructure deals with the parameter variables of the total structure. It reads them, sends values of them, etc. The reward substructure deals with the decision variables that specify the rewards people in the organization get. The operating substructure deals with all the decision variables, i.e., those that have to be given values by the structure, except those that assign rewards to the people in it. For these three substructures there are two kinds of consistency. There is internal consistency which refers to relations between the components of the substructure itself. There is also the concept of the fit between structures which is based on external consistency, or the relation of the components of one substructure to components of another. Both concepts are used to bring the separate analytic theories together to obtain a theory of the whole. Because many relations are developed in terms of single components of a substructure, the interconnections between that component and others are ignored. Substructures are also analyzed as units. That ignores the relations between components of one and those of another. Consistency analysis is what we use to include into the theorizing the connections between components that are ignored in the first level of theory development. The concept is one of logic and economics and is similar to what Burton and Obel (2004) refer to as the fit or misfit that exists between elements of a structure.

## 6. Consistency Within a Substructure

Internal consistency of a substructure is defined in terms of logical relations needed to make a substructure efficient. It may be determined on the basis of economic considerations or some other logic derived from the reasoning that produced the peculiar definitions of our substructures. An organization structure is defined as a set of people connected by decision rules, and the definition is easily specialized for the substructures. But if this is so, then why not define the operating substructure, for example, as a set of decision rules only? These contain in their definition sets of users and makers, and for any set of rules there is a set of people made up of the unions of all these rule sets that describes those in the substructure. We could also derive everything in the assignment set from these rules by collecting all the people and variables in the rules. In fact the definition of a substructure in terms of four sets, people, variables, assignments of variables to people, and rules, is three times redundant. The concept of the consistency of the components of a substructure, the set of people, the set of variables, the set of assignments, and the set of rules is what we use to get the pieces put together. Thus one may argue that a substructure is internally consistent if all people have been assigned some variables, and that they are either makers or users of rules involving these variables, even if some of these are equivalent to the no guide rule which says nothing about what is to be done to the variable. To be consistent is to make sure that no rule is made by people who are not in the set we have in the organization. If the description or design is consistent in all pairs of sets identified, then it is at least complete even if it is incorrect as description or inefficient as design. There is good reason why this is there, and it is this that it allows us to develop the theory in pieces, studying one or two variables at a time. But this partial theory of necessity ignores some connections between components which are then incorporated into the theory by the use of the concept of consistency.

Suppose we had a definition of a substructure in which Harry Itoma was in the set of people, but not to be found in any of the maker or user sets of the decision rules that are in the set that is a component of the vector that defines the structure. This is one situation we would call an inconsistency in the description or design. Does it mean that Itoma is, not or should not be, in the organization? Does it mean that he is in, but that the decision rules in which he is a maker or a user did not exist, or have been missed in making the description or design? Does it mean that he is in, but his rules had been of such a nature as to be the equivalent of null rules, and if so, is it not safer to include the null rules so that we could tell they were null rather than that they were ignored? All these questions are easily handled and all uncertainties of this form are removed by the redundancy and the consistency checks we can run on our design of a substructure. And so we go back again to consistency.

## 7. Consistency Between Substructures

Because we theorize about each substructure separately, we ignore many connections between them, and so these partial theories are altered and integrated into a theory of the whole by the use of the concept of consistency or fit, as Burton and Obel (2004) call it. The conclusions of the partial theories are tested and modified to make a theory that is applicable to all of them. Consistency is the test applied, and one substructure is said to be consistent with another if a number of conditions derived from logic and economics are met. Suppose that person P in the operating substructure is given a decision rule that has a mapping with the set of values of parameter y as one of the dimensions of its domain. To use the rule, this person must know the value taken by this parameter. The information substructure may or may not have decision rules that specify who is to read this value and to whom it is to be sent. If there is no rule in this substructure that specifies either of these for this parameter y, then there is nothing in the information substructure that gets the value of y to P. Logic suggests that if P does not know this value of y, she then cannot use the decision rule given to her by the operating substructure. Very simply, it is not logical to have someone base a decision on a specific fact and not to have her find out the fact or arrange for someone to give it to her. This is thus a case of an inconsistency in the logic of an actual or a designed structure. The person who finds herself in this situation cannot use the decision rule since no one gives her the parameter value nor the rule to find it out for herself. She then does not use the rule, or reads the value herself. In both cases what she does is to change one or the other of the designed structures to get what would be a logically consistent pair. There are many other bases which produce substructures that are logically inconsistent with one another.

Economics becomes the issue when the reverse situation occurs. A rule on the reading of a parameter's value is in the information substructure, but there is no rule in the operation or reward structure that has this parameter's set of values as a dimension of its domain. Facts are found out, but no one uses them. Whatever the cost of getting the fact, it must be positive or zero. It is uneconomical to incur any positive cost, and there is an economic inconsistency between the rules in the information substructure and those in the operation substructure and the reward ones. We should not collect information no one uses to make decisions. We should not send anyone information not intended for use in the making of decisions. We should not aim for levels of accuracy in the values of a variable sent or read unless they would lead to changes in the decisions made. The rules in the information substructure should be required to get only that level of accuracy that is reflected in the rules of the operating or reward substructures. The reflection occurs only when the decisions change when the level of accuracy changes. If the rule says do x when the sun shines and y when it does not, then this rule has no place in its domain for values involving the brightness of the sun. The user need only be sent a message about whether the sun is shining or not, and not about the brightness of the shine. Further, the rule used by the sender should be such that it tells him to send a message only when the state of the sun goes from shining to not shining, or the other way. This is so regardless of how often the rule tells the message sender and parameter reader to read its value.

The rules in the reward substructure must be designed to get the rules in the operating and information substructures to be used. The reason rewards are given to people in the organization is to get them to do whatever it is that serves the organization's goals. There is a distinction between what we call rewards and what it is that the person gets from being in the organization. A reward is what one person receives for doing something. To the person in the organization, what is done is governed by decision rules. What the person gets of value from doing what the rule says determines whether the person will use that rule or some other. If the use of the rule which the person is given to use brings appropriate returns, then it will be used. If one person makes a rule for another, then this other will use it if it brings the correct results for him. Rewards are things of value to a person which he gets from the organization as determined by its the reward substructure's decision rules which are designed to produce the decisions that are to emerge from the use of the decision rules in the other two substructures. Rewards are there only to get people in the organization to use the rules they are assigned by the operating and information substructures, and therefore must be so given as to make the person use the rules that it is intended that she use. Rules governing rewards must be based on the decision rules in the other two structures because the realization of what is in these rules depends on what is put into the rules of the reward substructure.

It is in the domain of a reward decision rule mapping that the connection to the operational decision rule is made. From the latter we have the set of rule makers and the element of the user's participation. From its mapping we have the details of the dimensions of its domain and the elements of its range. An operating substructure rule might indicate that the user is the sole maker. What the reward rule must now do is to get the user/maker to devise the rule that produces the decision the person giving the reward wants the operation rule maker to make. Since the reward giver does not participate in making this rule, the only basis for rewarding the operation rule maker is the outcome of the rule's use. Any other basis for reward, such as the decisions made, would involve the use of the operating decision rule that the person who gives the reward would have made, and so be incompatible with allowing the user to be the sole maker of his operating rule.

At the other extreme, there is the operating rule in which the user set does not contain anyone from the maker set. If this rule also has high levels of comprehensiveness and fineness, then none of its users has anything to do with the rule mapping; that is, with the decision making specified by the rule, and all that is for the user to do is to use the rule or not. Since the rule was devised as it is, the reason must be precisely to exclude the user from the creation of the rule which leaves him with any discretion in the making of the rule, or even in its use. To get this person to use this rule, we must reward him for his use of the rule. We compare his decision in each real case with what the rule would indicate the decision should have been. The closer the two are to one another, the higher the reward. Whatever the outcome of the use result of the rule might be, it is the outcome of the decision specified by the rule. Since the user has no say in the latter, then he cannot be causally connected to the outcome when he uses the rule. The rule user can be expected to do whatever he considers to be the causal connection between what he does and what he gets. If the reward is based on the correct rule, he will seek to do that. If it is based on outcome of decisions, then the user may or may not use the rule. The reward substructure that is consistent with an operating one that has such a rule would be one in which the decision rule on the reward for the user of the operating rule have as its domain the measure of the extent to which the rule is followed. There should be nothing in this domain involving the outcome of the use of the rule.

There is much more to be said about the consistency of the information and reward substructures with the operating substructure. Once we show what the properties of the operating substructure must be like, given the outcomes it seeks and the environment in which it operates, we will need to identify the properties of the other two substructures that fit, i.e., those that make them consistent with the operating substructure. The concept of consistency will be used to guide the derivation of the properties of the information and reward substructures that are needed to make them fit the properties of the operating one. Because the costs of maintaining, running, and designing a substructure vary with the properties it has, both the consistency of the substructures and their costs are used to determine what properties the substructures which we design will have.

It is clear that substructure consistency is not an all or none process. It is logical for one to make statements that include such terms as "more consistent", meaning that more elements are consistent in one pair of substructures than in another. There is a logical concept of the level of consistency, and we will make an important assumption about it when we discuss the mappings from substructure performance properties to outcomes. If we design each substructure separately, because designing all three as one is a very complex and inefficient process, it does not mean that what we want is a set of three substructures, each a good one for its part of the structure, but all three bad for the whole of the structure. The designs made separately for the parts need to fit together and to make a good design for the whole, and so we include the requirements of this fit in evaluating the substructure designs. Only then can we claim that the sequential process of piece by piece design is more efficient than that of simultaneous design of all parts of the whole.

The partial designs we create must therefore meet certain consistency conditions which are explicitly stated in terms that are fully operational. There are two kinds of consistencies which are defined above. When we derive theoretical conclusions about the nature of analytic relations between performance properties of the operating substructure and outcome, we assume that the level of consistency within each substructure and the levels of consistency between all three substructures are as high as is needed to make the proposition true. In the process of design, questions of consistency are addressed every time some design decision is made on the level of a substructure property. The effects of the rule on the comprehensiveness property of the operating substructure on the property of coordinatedness of the performance cannot be asserted unless the information needed to use the rule is available. This is the case where consistency between substructures exists.

Internal consistency must also exist if the propositions and prescriptions are to be meaningful. Because the properties are defined in terms of all the elements of a component of a substructure, there is not a one to one mapping from a level of the property and a specific set that defines the component. A given component has only one level of a property, but many different components have the same level. The assumption on consistency means that any proposition made about a the level of a property is made with the understanding that the component to which this level applies is that which meets the requirements of internal consistency. Both the analytic propositions and the prescriptive ones are made with assumptions that internal and external consistency is maintained. This requires that design rules stated in terms of property levels be complemented by the rules that produce this consistency.

## 8. Design Costs of the Operating Substructure

There are three kinds of costs associated with each of the three substructures. The first is the cost of designing and redesigning the substructure and fitting it with the other two. This is called the design cost. The second is the cost of maintaining the structure, that is, of keeping the actual structure the same as that of the design. Control over the structure itself is the object of maintenance, which has a cost. Last, there are the costs of running the substructure, and these are the ones which are incurred in the process of getting real results from the substructures, i.e., of using the rules in them. These are the costs of the people in it, of the tools such as computers, telephones, all the costs of buildings, heat, light, etc., and whatever it takes to make the people use the rules in the substructure and make decisions.

Designing any one of the three substructures entails the work that produces the elements of the sets that are the components of the substructure. Variables must be identified, people specified, allocations of the first to the second worked out, and rules specified. If this substructure is to be fitted to the other two, all these decisions have to be made for all three, where the design of one takes into account that of the other two, and the same for these other two.

Difficult and hard is the work of the designer who seeks an efficient structure. Work on the design of the operating substructure starts with identifying what needs to be done. What are the decision variables that are to be given values, and then made into facts? This is not an easy problem, since its solution depends on the designers' knowledge of the transformations in the technologies to be used. This is tantamount to knowing the basics of the operations, such as the making of shoes and their distribution and sale. Clearly one designer might not be able to get all this knowledge, and many people will be needed to design an organization. Even then, complete knowledge may be too much to ask for, and the design variables given values will be a proper subset of the complete set. An incomplete design is the result, and this gives rise to situations where virtual positions (Mackenzie 1991) become possible. In any case, identifying the decision variables of the operating substructure may be quite difficult and costly. Meanwhile, maintaining the substructure involves supervision and feedback information which are yet other sources of costs. The designer of substructures needs information on the relations between the properties of these and their costs. We supply this need by stating and proving propositions on the relations between the properties of the operating, information and reward substructures, and the costs of designing, maintaining and operating them.

Proposition: The larger the size of the operating substructure, the higher the costs of its design. Size is determined by the numbers of elements in each of the sets that make up the components of the vector which describes the structure. More people, more variables, more assignments, more rules, all mean more size.

Argument: For any two designs with the same level of completeness, the larger will cost more to design simply because there are more elements to be chosen or specified. There are also more rules to be worked up, more people for whom more reward rules are to be specified, all of which makes for more work and more costs. More components and elements in a structure also mean more costs off maintaining and running the structure.

Proposition: The higher the level of internal consistency of a substructure, the higher the substructure design costs.

Argument: Recall that internal consistency means such things as having every variable assigned to an individual have a decision rule specified. The rule would say something to the individual about the value to be given to the variable assigned to her. Greater consistency thus means more elements to be specified as part of the design, and that means more cost. A similar argument may be made for maintenance and running costs.

Proposition: The higher the level of people inclusiveness, the higher the substructure design costs.

Argument: The reasoning here is directly related to numbers, but the costs involved are likely to be quite low in most cases.

Proposition: The higher the level of variable inclusiveness, the higher the substructure design costs.

Argument: The argument is analogous to the one above, except that costs here may be quite large. The issue here is more than counting people. To identify the variables, the nature of the decision problem must be understood. This is not always easy, and the number of problems that may be involved could be large. Costs of identifying decision variables and parameter variables may well be relatively large and worthy of attention.

Proposition: The higher the level of commonality of the assignment component of the substructure, the higher its design costs. This assumes that the commonality is not just determined randomly, but that it is there for some reason such as the coordination between the decisions it brings about.

Argument: Higher levels of commonality are obtained by increasing the intersection of the two sets of variables assigned to any two people respectively. This means more variables are assigned to at least one person. In turn this means a higher cost of design as shown in an earlier proposition. It is reasonable to expect that meeting the conditions of internal consistency would increase the costs of structure design because it gives the designer more things to worry about.

Proposition: The higher the level of orderliness, the higher the costs of designing the substructure.

Argument: Orderliness involves the creation of bases for identifying similarities between decision variables. This requires the understanding of the decision problems and the connections that exist between different decision variables, as well as the effects these connections have on outcomes. The more the orderliness, the more such relations must be considered, uncovered, etc., and this means more design work and higher design costs.

Proposition: The higher the level of rule enfranchisement of the substructure, i.e., the more that people in the organization participate in making rules, the higher will be the costs of substructure design.

Argument: It is more difficult to have two people agree on the rule content than to have only one agree with himself. As the number of the rule makers increases, this agreement gets more difficult to get, and the costs of making rules increase.

Proposition: The higher the level of rule user independence, the lower the costs of the

substructure design.

Argument: For the structure as a whole, higher levels of this property mean fewer people are makers of any given rule. There are fewer people who have to agree on the rule mapping, and the making of the rule can be expected to cost less.

Proposition: The higher the level of user (non-maker) goal orientation, the higher the costs of the design of the substructure.

Argument: We assume that makers of a rule will use their goals when they make a rule. They may or they may not use the goals of those who are not also among its makers. If the makers of the rules want to use the goals of these non-maker users, they must first get to know and understand these goals. The makers of the rules have to learn and understand the goals of these users. This takes time and effort, and makes costs of rule creation more costly.

Proposition: The higher the level of rule openness, the higher the cost of designing the decision rules of the substructure.

Argument: The argument is analogous to the previous one, because the goals of outsiders are likely to be as costly to discover as those of users. It follows from the definitions that the effects of the level of maker orientation on design rule costs are the opposites of those of the last two propositions.

Proposition: The higher the level of rule comprehensiveness, the higher the costs of designing the substructure.

Argument: Increasing the level of comprehensiveness results in an increase in the number of elements in the domain of the rule. This larger domain requires solutions to be found for the added element, and perhaps more complexity in the problem for which the designer must have solutions. Both the increase in the number of elements in the rule mapping and the greater complexity of the problem require more design time and effort, and both of these increase costs.

Proposition: The higher the level of the domain resolution of the rule, the higher the design costs of the substructure.

Argument: Resolution level increases mean finer distinctions between values of one or more parameters. To maintain the same level of optimality in the decisions along with this increase in domain explicitness requires that the distinctions between decision variable values increase. This means higher costs of solving the problems, making the rules, of using the rules, and so on.

Proposition: The higher the level of the range resolution of the rule, the higher the design costs of the substructure.

Argument: The argument is analogous to the previous one.

Proposition: The higher the level of rule fineness, the higher the costs of designing the substructure.

Argument: The range of an operating decision rule is a set of sets each of which has as elements values which may be given to a specific decision variable. Each of these sets will be termed an assigned set. Rules are finer when their assigned sets have fewer elements. The fewer elements, the fewer the acceptable number of values to be given the variable. To get a smaller set is more work than to get a larger one. The definition of this property implies that the sets are made smaller not by arbitrary removal of decisions, but by the elimination of less acceptable ones. To determine what these are takes work, and that costs money. The finer the decision rules in the substructure, the higher cost of its design.

Proposition: The higher the level of rule lumpiness, the lower the cost of substructure design.

Argument: The more lumpy the rules, the less the differences between the decisions that are acceptable for different circumstances. To reduce lumpiness one must consider the possibility that what might be an acceptable variable value for one circumstance is not acceptable for another. To reduce lumpiness is to expend more effort to reduce the number of choices of what to do in the different circumstances. To get less lumpiness, choices are to be removed from the sets that make up the elements of the range of the rules. These should be the inferior ones. Finding these requires more analysis of more complex problems, and this is costly.

Proposition: The higher the level of range explicitness, the higher the costs of designing the substructure.

Argument: The more explicit the range of the rule, the closer to the actual value of a variable is an element of an assigned set. The difference may be, for example, between an explicit value of 50, and the more implicit, or less explicit, value that might be defined as "that which maximizes revenues". An even less explicit definition might say "that which maximizes sales revenues but does not bring about heavy competitor response". The making of the rule takes less and less effort as its mapping loses range explicitness.

Proposition: The higher the level of domain explicitness, the higher the costs of designing the substructure.

Argument: The argument is analogous to the previous one.

Proposition: The higher the level of rule durability, the higher costs of designing the substructure.

Argument: The longer the rule is to be used, the lower the expectation that it will need changing within some specified period of time. Such confidence comes with knowledge, and knowledge comes at a cost. However such expectations do not always accompany durability, and so the relation to cost is not true for all cases.

Proposition: The higher the level of rule connectedness (domain-domain or range-domain), the higher the costs of designing the substructure.

Argument: Higher levels of connectedness imply that decision problems are formulated in a manner that recognizes the logical connections between them. The higher this level of problem integration that exists, the more difficult it is to solve the problem. Good solutions to such problems are usually ones with much interdependence between decision variable values. The design that incorporates these interdependencies will do so by having rules that have a high level of connectedness. The time, effort, and intellectual capacity which are invested in the process of designing a structure increase as the level of rule connectedness in the structure increases. If higher levels of rule connectedness in a design of a structure are justified, then there are two conclusions one may draw. First, one may conclude that the decision problems that the structure is to solve are highly integrated and complex. Second, one may conclude that the structure that is to make these decisions is itself complex and connected. As the levels of both problem complexity and rule connected increase, then time, effort and intellectual capital invested in the design increase, and that means higher design costs.

## 9. Maintenance Costs of Operating Substructure

Having designed the structure, the next thing to do is create a real structure that matches that of the design. Even when that is done, there is the task of keeping the real structure matching the design. In the case of the house structure, there is a need for the designer to make sure that the builder builds a house that is the one in the design. The same applies to an organization structure. Unlike a house, an organization structure may be changed at any time by anyone of the people who are in it. It is as if the house had some component set that moved doors or windows or walls at any time. Making the real operating substructure be and remain what the design says it is to be is a continuing process. Some of the activities that are required to maintain the real structure and make and keep it the same as the designed include those of finding out and describing the real structure, comparing this description to the design, noting the differences between the two, and then doing whatever is needed to change the real, and remove these differences. Maintaining a structure is a task that may require a structure of its own in order to perform. A meta-structure may be designed to do whatever it takes to keep the operating substructure what the blueprints say it should be. It is a little like the police organization that works on crimes of people, and the internal affairs part of this police organization that works on the crimes of police in their capacity as police. This difficult issue of meta-structure comes up also in the design of structures. We may need such meta-structures to produce designs, and the cost of design is connected to this meta-structure, which is related to the process of design. The same is true of maintaining the substructure as we have defined it here. Costs of maintaining an operating substructure change with the structure to be maintained, i.e., with the designed structure to which the real structure is made to conform. Unless such an end is to be sought, there is no point to making a design in the first place.

Two kinds of maintenance costs may be identified. The first kind results from the things that have to be done to get a match. These are the costs of finding out what the real structure is, determining what mismatches between it and the designed structure there are, and making the changes. The second set of costs involve the rewards to the people who are in the meta-structure that is doing the matching. The first kind of maintenance costs increase with the number of elements in each component of the designed structure. These are variables, people, assignments, and decision rules. It must be that way, since larger numbers mean more things that have to be matched, and that means more things that have to be monitored and adjusted. The maintenance meta-structure has more things to do in structures that have large components (more elements) than in those with less, and that means the costs of maintenance rise with these numbers. An increase in the number of variables, for example, increases the number of assignments and rules, which in turn increases design costs even more. But these increases in assignments of variables also make the design more costly to maintain. Small changes in the basic nature of a structure may need to be accompanied by many other changes to maintain the consistency of the structure. What looks like a small change may become much bigger and so have a large cost.

Propositions about structure properties and maintenance costs will often be similar to those on design costs. Costs of maintaining a substructure get bigger as the numbers of dimensions and the number of elements in the domains of decision rule get bigger. Again, the matching activity needed for rules is greater, the larger the dimensions and elements in the domains of these rules. There are more things to match. Also, designed rules with ranges that have as elements sets with smaller numbers require more work by the meta-structure which is making the actual rules match them. If the designed rule specifies many values for the variable in a given circumstance, then getting one of these numbers to be matched in the real is a lot easier than if the rule had specified only a few numbers. The more this is true for more circumstances, or larger domains, the bigger the cost differences for this matching. Analogous arguments can be made that would produce supported propositions for maintenance costs on the one hand, and structure internal consistency, comprehensiveness, range resolution, etc., on the other. For some properties though, the relation of maintenance costs to property level is the inverse of that for design costs. All propositions made so far on the design cost apply to the maintenance and the running of the structure, with some exceptions. Among these exceptions are those which are replaced by ones specifically referring to these two kinds of cost. First we state the propositions that involve the maintenance cost.

Proposition: The higher the level of rule enfranchisement, the lower the costs of maintaining the substructure.

Argument: More participation by the people of the structure in the making of rules increases the likelihood that they agree with the contents of the rules. This means that they are more likely to use them. Maintenance costs are incurred to assure such use, and are therefore lower when users are more likely to use these rules.

Proposition: The higher the level of user independence, the lower the costs of maintaining the substructure.

Argument: The fewer the non-users involved in making the rules, the more likely will the users, who are among the makers of these rules, use them. It is, after all, only they who made he rule and one may expect them to use them without the reward incentives that make up maintenance costs of the rules.

Proposition: The higher the level of user (non-maker) goal orientation relative to the level of goal maker orientation, the lower the costs of maintaining the substructure.

Argument: As the level of user orientation gets higher, more emphasis is put on the rule users goals when the rule is created. This means the rule is more likely to be accepted by the users, and more likely to be used. The previous argument can now be used to show that this user behavior means lower maintenance costs.

## 10. Costs of Running the Operating Substructure

The actual substructure has people in it who are doing things. They are making rules and giving decision variables real values. One of the costs of doing these things is the cost of the people, i.e., the rewards they are given. The details in the design of the reward substructure will determine these costs. We can, however, say something about the reward costs before we design the reward substructure. If we assume that this designed reward substructure is made to fit the operating one, then we can make a number of general statements about these costs of running the actual structure that matches to a large degree the designed one.

Propositions made about the costs of designing operating substructures are a good place to start the discussion of the costs of running them. In most cases the propositions are similar, though sometimes the arguments will vary somewhat. More important is the fact that the cost relation for running a substructure will be the inverse of that for designing it.

Proposition: The more people in the structure, the higher the costs of running the substructure.

Argument: Reward costs can be expected to increase with the number of people in the designed operating substructure. Downsizing is an easy way to lower substructure running costs.

Proposition: The higher the level of rule comprehensiveness, the lower the costs of running the substructure.

Argument: This is the inverse of that proposition for designing costs. Costs of running the structure, involving rewards given people etc., can be expected to increase as the skill and capacities for decision making of the individual increase. Decision making capacities and skills needed by people in the substructure vary with the kinds of rules these people have to guide their decisions. Generally one can argue that the more discretion and problem solving needed by the decision maker, the more skill he needs and the higher his costs. Comprehensiveness is a property of rules that bears on the level of discretion needed by the rule user. The higher it is the less discretion is needed, and the lower the cost of the person needed to use the rule.

Proposition: The higher the level of rule fineness, the lower the costs of running the substructure.

Argument: Since increasing fineness reduces the discretion needed by the rule user, the argument here is identical to the previous one.

Proposition: The higher the level of rule explicitness, the higher the costs of running the substructure.

Argument: The logic here is identical to that in the previous argument.

Proposition: The higher the level of user independence, the higher the costs of running the substructure.

Argument: Increasing the level of user independence means increases in the number of users who are also makers of the rules. This increases the total number of people engaged in rule making. It also means that the rules made by these people will be in earlier places in the sequences of consistent rules, and so more difficult. If we are to have more people making rules that are more difficult to derive, then we can expect to pay more for these people.

Proposition: The higher the level of rule durability, the higher the cost of designing the structure.

Argument: All other things being equal, long duration rules imply rule makers will extend the duration of their rules as they acquire confidence in their depth of understanding of the nature of the decision problems and solutions of the organization. This confidence is likely to be the result of learning, whether by experience or in school, and both these involve added costs. It should be noted that in many cases different costs move in different directions. As we do things that increase design costs we may decrease maintenance or running costs. The three costs vary with the design, and also with one another, which is something that adds complications to the process of making the substructures be consistent with one another.

## 11. Costs of the Information Substructure

Costs of designing, maintaining, and running the information and reward substructures are very similar to those of the operating substructure. Since all three substructure are made up of assignments, rules, etc., the cost propositions for all three should be similar. Positive relations between design costs and the numbers of variables, people, allocations, and rules exist for the reward and information substructures as they do for the operating one. Complications in the rules, such as larger domains, more dimensions to these domains, and smaller sets that are elements in the ranges, can be expected to lead to higher design costs of these two substructures. In general, the more elements in the component sets, and the more nearly complete the design, the larger the costs of design and of fitting these two substructures to one another and both to the operating one. Similar arguments can be made for the properties of rule comprehensiveness, fineness, and many others.

Because the information substructure needs to be consistent with the operating substructure, changes in the latter entail changes in the former. When changes in the operating substructure are made, then changes in its costs occur, and changes in the information substructure are entailed. These changes affect the costs of designing the information substructure. As the design of this substructure changes, the design costs change, and the changes are further passed on to the maintenance and running costs of the information substructure. All this then impacts on the design of the reward substructure because of consistency requirements. Small structural changes in the operating substructure have concatenating effects on the other two substructures. The total cost of the small change is larger than the cost of the change without considering the consistency effects on the other parts.

The design of a house can be used to illustrate these concatenated effects and costs. To the design of a house, a room is added. This entails changes in the heating system the design of which must also be added to heat the new room. The same is true of the electrical system; its design has to be added to bring light to the room. Both design additions are consistency requirements of the house design. The costs to the designing process of the room are the costs of all three changes, not just those of the room. Maintenance costs, those resulting from the need to make the actual house the same as the designed one now increase for all three changes. Running costs for the house now involve also all three changes.

Maintenance and running costs for these two substructures are also analogous to those of the operating one. Operating costs of the information substructure can be expected to increase with the number of messages sent, and their frequency. Parameter reading costs depend on the accuracy of the reading, and the nature of the parameter, which determines how easy it is to read. All these cost statements except the last can be restated in terms of the rules, since each message is represented by a rule which specifies what is to be sent and to whom it is sent. Each parameter reading and its frequency are embodied in a decision rule. What is to be read is clearly specified in the rule and frequency can be uncovered from the time dimension of the domain. Accuracy of reading is represented by the sets that make up the elements of the rule's range. More elements in the range imply lower accuracy by allowing more possible values to be sufficient to stand for one real value.

Without the relations between structure and the costs of its design, maintenance, and operation the problem of design would be a much simpler one. This would be a problem of designing the structure that gets the highest level of output. With structure costs the problem involves designing the structure that maximizes or at least takes into account the differences between what it gets, outputs, and what it takes, costs. Also the former problem does not consider efficiencies in the process of design. Since it ignores design costs, it can have no discussion of the process of design. The second form is the one with which we have to deal. This form makes the process of design a necessary part of the discussion. As is shown later, design of the structure and its maintenance and operation are precisely those elements of the work done that distinguish between executives and others. The more the work involves these components, the higher the executive doing it, and the more sensitive the well being of the organization is to his actual decisions. In fact, that is one important component in what is meant by higher and lower in organizations, and by what is meant by the term executive and the reason why some people are paid much more that others in organizations.

Cost relations that are useful to the problem of analysis and design are those stated with substructure properties as domains.

Unless we can state costs in terms of such properties as rule comprehensiveness, or rule domain connections, we are not connected to performance, and outcome. All the cost relations must also be connected to the real decision variables of the structure design problem, that is, the components of the structure. Because the properties are defined clearly in terms of these components, the cost relations described above may be easily restated in their terms. There is a direct connection between what one does in designing the structure and the costs of designing, maintaining, and operating that structure. All the propositions about costs of operating structure rules apply here. However, there are some costs of designing and maintaining the reward and information substructures that are different from those of the operating one. First, we deal with the relations of costs of design and maintenance to the levels of properties defined for the information substructure.

Proposition: The higher the level of parameter inclusiveness, the higher the costs of designing and maintaining the information substructure.

Argument: Reading parameter values costs money, and the more there are to read, the more costs.

Proposition: The higher the level of diffusion, the higher the costs of designing and maintaining the information substructure structure.

Argument: More diffusion means more people are reading parameter values, and more people sending , receiving, and storing values, and they all cost time and money.

Proposition: The higher the level of redundance, the higher the costs of designing and maintaining the information substructure.

Argument: Redundance levels are based on the numbers of people who read values of parameters. Higher levels mean more people are to read the value of parameters. Reading the value of a parameter costs money, and more to read means higher cost of maintenance. Design costs increase because more people are reading the values of the parameters, and that is a cost generating process, especially when it is done with the costs of maintenance and its returns are considered.

Proposition: The higher the level of repetitiveness, the higher the costs of designing and maintaining the information substructure.

Argument: The logic is analogous to the previous one, since higher repetitiveness means more readings of parameter values per unit of time. Here though, design costs may be somewhat less sensitive to the level of the property than before.

Proposition: The higher the level of diffusion, the higher the costs of designing and maintaining the information substructure.

Argument: Diffusion is a property that measures the number of parameters the values of which are in the possession of a person during any given period of time. For the structure, the measure is an average over all people. There are only two ways for a person to get the value of parameter in any given period, and that is to read it, or to receive it in a message from another. Whether we use messages from people within the structure to get people possession of the value of parameters, or we have them read these values, we incur costs. Sending messages costs money as does reading parameters, and as more parameters are put in the possession of more people, the number of times parameters are read or messages sent will increase, and so will the costs of maintenance. Design costs also increase because there are more people to be identified as needing parameter values, and this means more decision rules are to be created.

## 12. Costs of the Reward Substructure

We now turn to those substructure properties that are unique to the components of the reward substructure, and to the components of the other two substructures which may be affected by the needs of consistency. We combine the costs of designing, maintaining, and running the reward structure costs in the same proposition. If the proposition applies to less than all three types of costs, the argument will make that clear.

Proposition: The higher the level of mapping consistency, the higher the costs of the reward substructure.

Argument: Consistency between the domains means that attention must be paid to the reward rule for person A, when a reward rule is being made for person B, and vice versa. Coordination of the two rules to meet certain requirements is the basis for consistency. The rules that are to be followed to get consistency are of the form that two people who do similar work should have domains to their rules that have dimensions that are alike, that these be of similar resolution, and so on. Having to pay attention to these rules costs money, as does the effort needed to be sure that the rules actually used are those specified. The case for the ranges and the mapping itself are analogous to that of the domains. The more consistent the rules, the more coordinated they have to be, and the harder and costlier they are to make.

Reward rule properties of outcome orientation and decision orientation levels may be related to one another. As one property's level is increased then that may or may not imply that the level of the other decreases. It all depends on whether the rule contains dimensions of its domain other than outcome or decision. Such dimensions may be genetic connections, i.e., owner's son, time in service to the organization, and so on. There is not much that one can assert about the relations between the levels of these two properties and their costs of design and maintenance. Insofar as the increases in one may be coupled with decreases in the other, cost movements will be in opposite directions. No generalization about the net effect can be made. Only when the level of increase in one of these properties does not affect the level of the other property, but results in a decrease in the level of the property of arbitrariness, can one make a general proposition about costs. In the special case, then we may state the following:

Proposition: In the special case, the higher the level of the outcome base for rewards, the higher the costs of the reward substructure.

Argument: It is easier to select an arbitrary dimension to the rule's domain than one that is outcome based. In this latter case, some search and decision making is needed; whereas in the former case, very little is needed. Similarly, reading the value of an arbitrary variable should be no more difficult or costly than reading that of an outcome oriented one. After all, it is should be easier to use a rule that had a dimension of being the son of the owner or not, than a rule with that dimension being the variable of the ratio of sales to new accounts created to those of sales to old accounts lost. Design costs of the former should be lower than the latter. It will also be easier to establish that the person is the son of the owner whenever the rule is used, than it will be to measure sales to new accounts and old accounts each time the rule is used. The maintenance costs of the former case are lower than those of the latter. When the process of identifying the position of the person rewarded in the domain is elaborate because it has to be very accurate, for example, then the cost differences between the use of the two dimensions are increased.

Proposition: In the special case, the higher the level of the decision base for the reward, the higher the costs of the reward substructure.

Argument: The argument is identical in logic to previous one and analogous to it.

Proposition: The higher the level of ownership, the higher the costs of the reward substructure.

Argument: As the number of owners increases, so does the variety of goals and reward rules that have to be considered in designing the structure. This increases these costs. Maintenance costs also increase, because of the residual goal conflict that continues to exist after the design is agreed on.

Proposition: The higher the level of receiver orientation, the higher the costs of the reward substructure.

Argument: Consistency is a constraint on the reward rules. It says that various sets of rules must be similar in this or that respect. Constraints increase costs, at least they never lower them, and this applies here to design and maintenance costs.

Proposition: The higher the level of the consistency of range, the higher the costs of the reward substructure.

Argument: The argument is analogous to the previous argument.

## 13. Substructure Costs and Technology Properties

Substructure costs are related to the properties of the technologies which the organization structure will be operating. These relations need to be identified along with all the other cost relations. However, the properties of the technologies which form the domains of these relations are defined in the following chapter. The choice is to state the cost relations after the definitions and have them far away from the others, or keep them with the cost and return to them for the proper meanings. The latter is our choice because the use of the cost relations in design is easier when all the relations are grouped together. In the following set of cost relations, all references to costs will mean all costs of the design, maintenance, and running all three substructures, and the costs of making the three consistent one with the others. In case such generality is not intended, the source of the cost involved will be stated, and the substructure intended will be identified. Propositions on costs have so far been on components of design. They state what happens to costs when components of structures are changed, and so describe the slopes of cost functions. The propositions given next state something about what happens to these cost functions when certain parameters of design happen to change. If the parameters of design change, the slopes of the functions remain the positive or negative, but the functions themselves shift. How they shift when that happens is described next.

Proposition: Costs increase with the level of the technology property of variety.

Argument: Variety is a property defined in terms of the number of technologies which the organization knows will give the same output. As the number of technologies increases, the number of decision variables or the number of parameters must also increase. This in turn implies higher costs of design of all three types for all three substructures as the next two arguments show.

Proposition: Costs increase with the level of the technology property of breadth.

Argument: Breadth is defined in terms of the number of decision variables. More variables means that more of all three kinds of rules are to be created, and more assignments are to be identified for all three. It is likely that there will be complex relations between variables, and the decision rules derived will need to be more connected and complex. This leads to higher costs of designing all three substructures, maintaining them , and running them.

Proposition: Costs increase with the level of the technology property of exposure.

Argument: Exposure is defined in terms of the number of parameters. The more of these, the more rules on reading parameter values, on sending these, etc. Higher costs of designing, maintaining, and running the information substructure are the result. More parameters also mean more dimensions to decision rules, which means more elements in their domains. As shown earlier, this implies higher costs for all three substructures.

Proposition: Costs increase with the level of the technology property of captiveness.

Argument: A higher level of captiveness means that more of the technologies are within the abilities of the organization to operate. This means more variables to be identified, assigned, etc. All these mean more costs of design, maintenance, and running the three substructures.

Proposition: Costs increase with the level of the technology property of randomness.

Argument: The more random the technology, the more outputs there are that are possible from a single set of values of decision variables and parameters. Finding good decisions, and hence decision rules, gets more difficult the more possible outputs there are. Designing, maintaining, and running substructures are thus also more difficult, and hence more costly.

## 14. A Series of Bridges

All the bridges between structure and outcome and between structure and costs have been identified and crossed in the direction of structure to outcome and from structure to costs. Everything needed for designing a structure that has the best pair of outcome and cost associated with it is now available. But how does one find the structure with the right pair? As it stands, the designer would have to design all the structures, find the pair associated with each, then compare all the pairs with one another to find the best one and the best structure. If he were looking for a good structure rather that the best one, he would have fewer thing to do, but the process would still be one of evaluating large numbers of structures. If a logical order could be imposed on the set of structures, the set of outcomes, and the set of costs, then one might be able to find a process of design that does not have to evaluate every structure. The order imposed may be one such that it to allows one to identify and measure differences between elements. If one can make the measures comparable, at least ordinally, then one could develop certain procedures that allow the evaluation of a structure to be used to suggest where the next changes in it might be made to produce a better structure. In short, the creation of orders on the sets and orders on the connections may allow for the development of a systematic or reasonably efficient process of finding the best design, that is of creating it. The process of design is itself the subject of choice. Both the design of the structure and the process of its design are choice problems. Each process of design is based on some logic. Its costs and output are the results of this logic. Since we are interested in the efficiency of this process, we will be discussing the underlying logic which determines the sequence of steps and the ways in which the outcomes of one step are used to determine the next one.

NOTE: Charts that contain the propositions of this chapter are in Appendix I.

# CHAPTER 5

# PROPERTIES OF TRANSFORMATIONS, ENVIRONMENTS AND STRUCTURE PERFORMANCES

## 1. Choosing the Right Properties

One way to get logical order on the elements of a set is to define a property that the elements have, one that is assigned a measure that is logically ordered. The order in which we put three individuals may be that based on the property of distance from soles of feet to the top of the head. We call it height, and we have a measure of it. At the simplest level, by looking at the three standing side by side, we can state that the measure of this property is such that it is larger for this person than it is for that. Theories on organization structures are useful only if they help in the choices of structures that do whatever we want done, and to be useful they must based on the definition of properties that have comparable measures. Most of the work involving the analysis of and prescription for organization structures involves the use of structure properties as the variables of their analyses and prescriptions. If we are to generalize about organization structures, we also will rely heavily on the use of structure properties and on properties of the technologies, the environments, and the performances of the organization substructures. If we are to use these generalizations to design efficient structures, then we will need to define properties that are operational, i.e., only those properties which are defined in terms of real components for which we have measures that are in some logical order. This means that all properties relate directly to variables represented by knobs that can be turned to get the needed values or to dials from which the values can be read. Knobs and dials are metaphors for the ways of making chosen variable values into facts and of making values that are facts into information, or known facts. All properties we define and use in our theory and design are operational. They are not however those commonly found in the literature.

Before we create a whole list of newly defined properties, we need to look briefly at the existing literature to see why we do not intend to use the properties we find there. Since operations analysts, theorists, describers, and designers have often done their work in terms of properties, there are a large number of them. Among them are the properties of organization structures, known as span of control and centralization. Concepts of the properties of the performance, such as adaptability and standardization of the organization, abound in the literature. Environment properties are also commonly used, and we have the concepts of uncertainty and complexity of the environment. The properties of linearity and analyzability are used in the discussion of technology. Even when the work is done in terms of classes, such as, bureaucracy, matrix and the like, the underlying concepts are ones of properties. All such classes of organization structures are defined in terms of values taken by properties, some of the structure itself, specialization, some of the environment of the structure, simplicity, and some in terms of the performance of the structure, standardization and flexibility.

But all this reliance on properties has not produced a commonly acceptable set of properties, a clear distinction between thing and property, and between property of structure and that of performance, of environment, and environment state, and so on.. The properties are not clearly defined, not specifically connected to the components or elements of the structure of which they are properties, and often confused with the things of which they are properties. For example, decentralization is never clearly defined by Mintzberg (1980), who defines it in terms of other properties such as formality and delegation, which are themselves not clearly defined anywhere. Yet he uses the property extensively in his analysis. Meanwhile Robbins (1990), identifies the components of structure as centralization, formalization, etc., when in fact these are not components that define a structure but properties of it. It is also often the case that properties are treated as if their measures were unidimensional, when in fact they are multidimensional. Properties are often defined loosely, and any generalizations made about any property can be supported against all counter arguments by merely shifting from one measure of the many that describe a value for the property to another. The properties in the literature are not operational enough nor clear enough to serve our purposes. We have to develop our own, starting with those of transformations.

## 2. Transformations and Technologies

For our purposes, we accept as given the set of transformations and technologies which the organization chooses and is capable of operating. Strategies and decision about seeking new transformations, or better knowledge of existing ones, are not considered. What the organizations has available in transformations and in their combinations into technologies is fixed. Transformations are what economists refer to as input-output mappings. Though not all transformations involve inputs, things used up, and outputs, things made available for use, many d. Those that do not are analogous to these, with inputs renamed decision variables and outputs renamed resulting variables. It is therefore all right to think of a transformation as an input- output mapping, and a technology as a connected set of input-output mappings, such as production functions, market response functions, and the like. In the example of a previous chapter there were four transformations with which the firm had to operate. Two are $q = f(w, x, y, z, a, b, c, d,)$ and $s = g(u, v, p, k, l, m, n)$. The first is a production transformation, the second a marketing one. Both describe how the decisions made by the members of the organization affect some aspect of the world that is relevant. If we have to use two equations to describe the first transformation, then it would be what we would we term a technology.

Organizations perform tasks and do things which means they change directly by themselves some aspects of the real world. These direct changes then bring about changes in some other aspects of their world. This cause and effect relation describes what we term a transformation. The changes are not necessarily physical, but include those that turn information in the form of advertising into orders. A task may be to make a transaction with a person, to destroy a bridge, to place an order for fuel oil, to design a car, to teach a class in a university, to give medicines to a sick person, to create a table, or whatever. The relation between a set of tasks and a set of outcomes that result from doing these tasks is termed a transformation, and a group of connected transformations is called a technology. The order and the nature of the connections may involve time, logical connections between the domains and ranges of the transformations, or any other relations that are deemed relevant. But basically what organizations do is change some segment of the state of the world. These changes, in their most simple form, are transformations, and a technology is a set of ordered transformations. Cooking a meal is a technology involving a particular combination of transformations, such as, turning the lump of hamburger meat into 6 patties, lighting the gas flame in the barbecue, putting the patties on the barbecue, slicing tomatoes, turning over the patties, etc. The whole process is a technology, where making the patties must precede cooking the meat, while lighting the gas may precede making the patties but is not allowed because it is inefficient, and so on. Making autos, or educating graduate students in business are technologies. In fact, each may be achieved by many technologies which may or may not produce exactly the same outcome. Some technologies are designed by humans, others are found, but all are subject to the laws of physics, chemistry, etc. Organizations have technologies which they choose to have and which they can use, i.e., they can actually make the transformations that make them up, and do so according to the logical order imposed by the technology.

It should not be thought that transformations are all related to "production". Many involve markets where exchange produces changes in the states of those making the exchange. For many organizations there are transformations they cannot control, e.g., those that transform marketing activities such as advertising messages sent into sales. Information, facts and knowledge of facts, and complicated logical arguments are also the subjects of technologies. There are ways of transforming information from one form to another, ways of deriving information from other information, ways of transmitting or exchanging information, and so on. Some technologies are the connecters of the organization to the world around it. To an army these are technologies of killing the enemy, etc. To a firm they are the technologies of selling products, affecting the sales through advertising, or heating steel in order to temper it. In short, technologies are ordered transformations, and these describe a mapping from one segment of the universe to another. These segments may be made up of all kinds of components. Of these there are some that concern the organization and which we classify into sets. Some segments involve things, steel, coal, machines, people, cars, etc. These relate to turning things into other things. Others involve getting facts from other facts. We may combine numbers in many ways (addition, subtraction, differentiation, etc.) and values to get others. We may use logic to derive facts from other facts. Another kind of segment involves the assigning of things or symbols to people or things.

For our purposes of analyzing and designing organization structures, we distinguish between technologies. One of these is that which deals with producing things, selling them, borrowing money, buying things, moving things, and so on. Such technologies we term the operating ones. The second kind of technology is that which deals with information, its creation, reception, etc. This could include, for example, finding out the location of enemy forces, the identity of possible suppliers of parts, the time of the change in price planned by the marketing department, and so on. These we term the information technologies. The last group we call the reward transformations, and these deal with giving things to people in the organization., such as paying salaries or commissions to someone or promoting her. The operating technologies chosen can be used only if certain information, or facts, are available. These requirements are what the information technologies are to supply. To get the values of the parameters defined by the operating technologies, information technologies are needed, and their nature determined in part. Decision rules in the operating structure also determine in part the information needed and hence the technologies chosen.

Transformations that describe people's behavior in an organization must be chosen, or if there is no choice, identified for the people in the organization. These are collected into technologies of behavior. They are technologies because they relate certain conditions such as the rules people make and use, the assignments given them, the money paid them, etc., to the behavior of these people, which involves among other things their choice of variable values, etc. Reward transformations is what we call these. Once they are determined for the organization, they specify another set of parameters on which information is needed.

## 3. Some Properties of Transformations and Technologies

A number of properties may be defined and used in the development of generalizations. The ones we define and discuss next are important ones, but do not necessarily include every important property one may think of.

**Completeness:** For any technology description, this property is defined in terms of the number of tasks or transformations in the description relative to the number that are there in the real case. The more nearly complete the technology, the fewer the tasks that should be a part of its description but are not. The measure of this property is in terms of the ratio of described tasks to all tasks of the real technology. It is an indication of the extent to which the designer understands and knows the technology for which he is designing an organization structure.

**Variety:** This property is defined in terms of the options that are available to get the same end result. It is measured in terms of the number of technologies that produce the same outcome which the substructure chooses and can implement.

**Randomness:** For any technology, this property is defined in terms of the disorder inherent in the transformations that make it up. A transformation is more random the larger the number of outcomes or outputs into which a given vector of input values is mapped. What this means is that the same vector of input values may give any one of a number of outcomes, and the larger this number, the more random this element of the transformation. In this sense, technologies in agriculture are more random than those of modern manufacturing. The measure is the inverse of the results that come about when greater control over the transformations is obtained. The value or measure taken by the property is calculated from the probability distributions of the outputs of its transformations. For each transformation, the amount of an output is distributed randomly when all variables are given fixed values. When all the distributions for this one output variable are calculated, the measure of its randomness is the average of the variances of these distributions. If there is more than one output variable for a transformations, then the randomness measure for the set of all of them is calculated from the variances of the joint probabilities. The measure for this property for a technology is the average measure of those of its transformations.

**Size:** This property is defined in terms of the smallest number of transformations that are logically distinct and needed to describe a technology. It's measure is this number.

**Breadth:** This property is defined in terms of the number of decision variables embedded in the transformation. For a combination of these making a technology, it is the average of the numbers of its component transformations.

**Spread:** This property is defined in terms of the number of parameters embedded in the transformation. For a combination of these making a technology, its measure is obtained in a manner similar to that of breadth with parameter substituted for decision variable.

**Exposure:** This property is defined in terms of the relation of the number of parameters to the number of decision variables or spread embedded in a technology. Its measure is the ratio of the first to the second, or spread divided by breadth. The higher this ratio, the more exposed the transformation, and for a technology the measure of its exposure is the average of the measures for the transformations that describe it. The more highly exposed the transformation is, the more information collection relative to decision making is needed.

**Captiveness:** This property of a technology is defined in terms of the number of transformations that describe it and is implementable by the operating substructure of the organization, and by the number of transformations that are not so implementable. The measure is the ratio of the first to sum of the two. The transformations that are not implementable by the substructure are assumed to be implementable by the substructures of organizations other than the one we are describing, or else exist independently of any activity of any organization.

**Tightness:** This property is defined in terms of the connections between the transformations that define this technology. The larger this number, the higher the measure of this property of tightness. A larger measure of this property means there is less freedom in implementing it, and also there is a need for more information to collect and use.

Logical orders may be given in more detail in terms of connections that exist between transformations, connections that define aspects of the technologies of the firm. We will describe these properties of technologies and the connections between the transformations that underlie them after we work on the connections between decision rules. It is best to do so because the nature of the connections is logically identical in the two cases, and because these same connections can be defined for a rule and a technology. We discuss the intertwining of rules and technologies later under the concept of what we term a decision process.

There are other properties of technologies that may be defined and found to be useful in the choice of the designs of organization substructure. Properties of technologies are defined and connected to the structure of the organization by Perrow (1967), Thompson (1967), and Woodward (1965). Though all three describe classes of technologies, only the analysis of the first is a foundation for the treatment of technologies in this work. Technologies to Perrow (1967) have two properties, each of which may take one of two values. The result is a set of 4 classes. The first property defined is that of task variability, defined in terms of the work done by a person. This is not a property of the technology itself but of how its operation is distributed among people who operate it. This is part of the operating substructure as we defined it, and so there is no one to one relation between this property and any of ours. However, a connection may be made between this idea of task variability and our property of variety. When a set of technologies has a high measure of this property of variety in it, then it has a high level of variability. The second Perrow (1967) property is that of problem analyzability, which may be translated into our properties of completeness and tightness. If the problem is subject to logical analysis, then the task of solving it is considered analyzable. This property relates to our properties of completeness and tightness. The more nearly complete the technology, and the tighter its order, the easier, and hence, more likely would be the use of logic in the solution of problems which embody that technology. Perrow's (1967 craft technologies are those that we would say had low levels of variability and of analyzability, while engineering technologies are those we would say had high levels of both.

Among the more recent work which forms a basis for some the definitions we made above is that of Baligh, Burton, and Obel (1990), and of Volberda (1996) on flexibility and competitiveness. Though the concept of flexibility does not mean exactly the same thing to any two authors, it is basically the same to all in its reference to the ability of the organization to do many different things when asked, and to do so within some time period. The connection between this performance property and the technology property of variety is considered by most to be strong, especially to the property of the technology we call variety.

## 4. Transformation Connections and Technologies

Transformations may be connected to other transformations and to decision rules. The transformation mapping is logically identical to that of a rule, with a domain of n dimensions and range of only one dimension. Economic production functions in their simplest form are what such transformations are. In more complex terms, the transformation or production function may have to be defined by the implicit function. The unit transformation in any given case is an integral mapping or implicit function which may not be represented by two or more mappings. As Georgescu-Roegen (1971) has described it, this transformation is that which cannot incorporate any others without distorting the view of the real transformation. We may, of course, combine transformations in various ways to get technologies that describe real situations. Technologies are sets of connected unit transformations, and we continue combining transformations to create ones that are as complex as needed to describe the real world. For example, in describing the transformation of water from one temperature to another, we may compose a large number of transformations, each describing the production of one degree of temperature into a single function that goes directly to boiling. We don't need the smaller transformations in the case where we are interested in boiling water. If we are interested in water at seventy degrees and at boiling, then we would use two transformation, one to seventy and another from there to boiling.

Once we define the transformations in their simplest form, then we can identify the connections between any two of them. As in the case of connections between decision rules, one transformation may have a domain which is connected to the range of another. This is the case of an output becoming an input. Two transformations may share the same variable as a dimension of their domains. In one case, the input of advertising in the sales function of product A may well be an input in the sales function of product B as well. In general, all connections that could logically exist between decision rule mappings may logically exist between transformations.

Transformations that are only expressible in implicit function form are a little more difficult to treat. All connections between two transformations must be domain-domain ones. Connections between a transformation and a rule may include range-domain connections, but only if the range is that of the rule. We may have as one of the conditions of a rule, the value of one of the components of a transformation. For example, a rule about when to start advertising may be made contingent on some value of output reached in a transformation. A transformation may be started when some rule is implemented. Here the range of the rule is a component of the domain of the transformation. There are in effect many ways of connecting rules to transformations. One can thus create as complex or as simple a network of interconnected rules and transformations as one desires.

A decision process is such a network where every rule in it and every transformation in it is connected to every other directly or through the connection of this other to yet another, and so on. A decision process is a set of connected rules and transformations which is such that it cannot be split into two sub-processes without the removal of at least one connection between two rules or two transformations, or one rule and one transformation. The connections in these two sub-processes are at least one short of those in the original.

## 5. Environments

Growing wheat in ancient times was a fairly simple transformation that turned wheat seeds, land, labor, and the moisture, heat, and sunshine in the area of the land into more wheat at some later time. In this transformation the first three variables are decision variables, the next three are parameter variables, and the last is the outcome variable. Parameter variable is the name we give to an aspect of the world that affects the connection of what we do to what it is we get. One variable is the moisture in the area of this piece of land. It is not moisture ten miles away, and it is not ozone. Parameters relevant to this grower are components of the world that are in the transformation for wheat, and they define his growing environment. Each is a variable, and that means that it has different states, and may logically be assigned one descriptor from a set of such. The set for moisture may be {wet, dry}, and we may say it is wet today. The environment of the grower's operations is defined by two components. First there is the vector space defined by the variables that are the parameters of the transformations involved in the operations. Each dimension of this space is a set of values which a parameter may logically take, and each element in the space is a vector of specific values taken by the parameters. For an organization, the relevant world in which it operates is described by a specific vector space, the environment space. The conditions of this world are described by a vector in that space, the environment state. Over time, the conditions of this relevant world will change, and one may describe this movement from one vector or state to another by a transition matrix which shows the probability of each transition from one vector to another. The relevant world for an organization and the transition matrix that describes its movements from one state to another we call the environment of this organization. Any changes in the space or the matrix is defined as a change in the environment. If a factory locates near the farmer, and it produces gases that affect his crop growth, then the farmer's environment space is changed. It now has a new dimension. If the air temperature is one of the dimensions of the space and actual temperatures increase because of global warming, then the transition probabilities will be different from what they had been. This too is a change in the environment of the farmer's operations. However, changes in temperature without any global warming signify changes in the state of the environment, but not a change in the environment itself. When the argument does not allow for changes in the environment, and there is no likelihood of confusion, we will refer to the environment space as the environment and the vector in the space as the state of the environment.

For the farmer, without the arrival of the polluter or without global warming, a specific vector, (wet, low, no sun), describes a state of the environment, the part of the world that is relevant to the grower, and is beyond him to alter. If the farmer should move, and plant another piece of land somewhere far away, then the environment he now has is defined by variables different from the old ones. Moisture in the old spot was the variable, and that is not the moisture in the new spot, which is what the variable is now. The polluter also changes the environment of the farmer. It is important that the distinction between the environment and the state of the environment be clearly understood. Later, when we work with the relations between properties of transformations, structures, and environments, the distinction becomes critical. We often speak of changes in the environment, and that could mean a change from one environment to another, or a change in the state of the same environment. It makes sense to recognize that a move from the Congo to Siberia is a change in the growers environment, while the shift from the dry to the wet season in the Congo is a change in the state of the same environment. So, the humidity of the air in some area of the world is an aspect of the world. The level of humidity is now a logical concept that refers to the value that this aspect takes. The unit of measure is irrelevant. What is relevant is that this aspect of the world may logically take on a value that is one element from a set of such, each of which says that the level is such and such. The elements of the set are the values which this aspect may take. Each specifies something about this aspect called humidity. To say that humidity is high today is to say that the value of this aspect of the environment takes on a value from the set that contains at least two elements, high and not high. The relation of the one value to the other may or may not contain a logical order such as more than, or a unit larger, or to the left of. The set for an aspect may be degrees Celsius, or it may be the set {funny, not funny}. Any aspect of the world that comes between what the organization does and what it gets is a dimension of the environment of this organization if and only if this aspect is one that takes on a value that is totally beyond anything the organization can do or does. This condition may be absolute or may be assumed for whatever purposes. That the sun comes up or not is absolutely beyond anything anyone can do. That people believe that our product is unsafe, may be taken to be an aspect of the environment now, even if in the longer run we may be able to change this belief. In this case, what we will have to work with is a transformation of some things we do into the level of this belief. As one should expect, this transformation will have new aspects of the environment embedded in it.

As the terms are used in this work, an environment is defined by a set of variables, and the state of the environment is described by a vector in the algebraic space created by these variables and the units by which they are measured. An environment goes from one state to another. This change is termed a change of state. The probabilities of these changes in state may be put as entries in a transition matrix which describes the environment and its behavior. If the dimensions of the matrix remain unchanged, then there is a specific environment, and it goes from one state to another as is described in the matrix. If the entries in the transition matrix itself change, then we have a new environment that is described by the same set of variables as the original, but is different from it because its behavior is different. We also have a new environment if the variables that describe this environment change. One may design an organization structure for conditions that describe a single environment, or for conditions that describe many environments. We might call this case a meta-environment, one with two levels of states. A meta-environment will go from one set of simple environments to another, and each of the simple environments will be going from one state to another. For this meta-environment, we need a meta-structure, which first identifies the structure that works well in each of the individual simple environments. This will be a structure that modifies its performances. Next, the structure that works well in the meta-environment may be defined, and it will be one that changes itself as the meta-environment goes from state to another. One cannot design the latter unless one designs the former simply because the latter structure will be one that changes the set of the former that makes it up. The performance of the meta-structure is made up of decision variables that are structures. In this work we concentrate on the design of structures, and when this process is properly understood, then we may start on the design of meta-structures. A parameter is a dimension of the space that defines the environment. Its value is a component of the state of the environment. The transformations that the organization works with are the sources for the identification of its environment, its decision space, or its parameter space, and its operating space. In the former, a vector describes the state of the environment, and its components can not be affected in any way by the organization. The values may, however, be found out or read by the organization. The state of the environment normally changes over time. and this movement may be seen as describing the behavior of the environment. Thus, there is the space of parameter variables which we call the environment. There is the state of the environment and the movement from state to state in the space which we call the environment's behavior. Similarly, there is the space of decision variables which we call the operating space. A vector in this space is one in which the components are set or made real by the organization. Each such vector may be termed a performance.

## 6. Properties of the Environment

Environment properties may be those of the space itself, that is of the environment , or they may be those of the actual states that environment has been in or is in, or of its movement from one state to another, i.e., its behavior. The first property defined is one of the environment itself.

**Size:** This property is defined in terms of the dimensions of the definition of the environment. The set of values this property may take is that of the positive real numbers. The value is some function of the number of components which define the environment. For example, it could be this number, or it could be a ratio of this number to some other number that describes an environment somewhere else. In either case, the measure is well ordered and easy to observe, once we define the actual environment. The relevance of this property is based on two factors. One identifies how many facts the organization needs to get in order to make good decision, and the other gives the organization one of the facts that tell it something about its ability to control its destiny.

**Variedness:** This property is defined in terms of the set of vectors which describe all the real environments which may be encountered, that is, the number of states which the environment can actually take. The set of values it may take is the set of positive real numbers. The value taken by this property is some function of the number of vectors in the set we call realistic. In defining realistic, e.g., with probability of occurrence of x or more for whatever x we choose, the variedness of the environment may be specified. The set of values is well ordered, and its elements are logically observable or estimable. Variedness is relevant because it is a measure of the extent of the planning space for the organization. It specifies how many different potential performances the organization may have to face, and decides how it is to deal with them. The different states may or may not require the organization to do very different things. The environment of the firm that is global may exhibit a very high level of both variedness and size. This, according to Bartlett and Ghoshal (1990), requires that the firm do very many different things in the different parts of the world. If that is the decision, then they conclude that the organization should be decentralized and have few organizational connections between the parts that do different things. In any case, the firm's decision on the structure must be based on the measures of variedness and size. The measure of variedness in our simple example is infinite because the value of any component of the actual states is a real number and any one of which is realistically possible. But history may very well show that the actual number of states the environment has been in is highly limited. With the measure in hand, the organization can perhaps develop a priority list for the plans it makes. The measure may well be defined in terms of some probability levels of the states, so that only those states with certain levels are included.

**Changeability:** This property is defined in terms of time and the vectors that describe the environment. The set of values it may take is the set of non-negative real numbers. The value is a function of the time that elapses between the environment's being in one state, as given by its describing vector, and its being in another state. We may use average time between shifts from one state to the next, or an average that comes from changes of some "significant" or predetermined size. We could also use some arbitrary unit of time related to our operations, or our reading capacity, or whatever suits our work best.

Obviously this property takes values that are well ordered and observable. It is relevant because it measures something about the speed of change in the environment, and this is relevant to our decisions on how quickly we will want our structure to change its decisions when change is needed. The simple MBC environment of Chapter 2 changes only once every period of production, and it is the length of this period that tells us something about the level of this property. Shorter periods imply increasing changeability of our organization's environment. Whether two different organizations can be compared on the basis of this measure is another issue. What is important is that the measure of this property be customized for each organization, so that it is relevant to the times involved in the its transformations. It is the speed of change in performance the organization needs if it is to keep up with the changes in the environment and survive that would determine the length of this period.

**Randomness:** This property is defined in terms of the logical order that is imposed on the occurrence of the states or on the probability of the occurrence of the states of the environment. The values it may take is the set of real numbers, or a set of vectors with non-negative real number components. Suppose for simplicity we had an environment that takes a finite number of states. Suppose also that history allows us to create a transition matrix of the states of the environment where the entry is the relative frequency, or probability of going from the state in the row to that in the column. Given the fixed period of change of our example we can get a measure of this property of our environment. This measure could be a complex function involving the relation of entries in the diagonal to those off the diagonal, or any other set of operations that are logical and useful we may want to impose on the matrix. If the measure is multidimensional, then of course the function will be replaced by many, one for each component of the vector of measures. Insofar as the measure is a single number, it is logically well ordered and observable. The logical order on the set of vectors of numbers is much harder to specify. It may have to be one that is not completely ordered, and so on. Also, this measure may be restricted to the states that have some minimum level of probability of occurrence of some pre-specified amount. In any case, this property's measure is based only on those states that have such probabilities of ever occurring, which in the limit is zero. Thus, this property and that of variedness are related, and the former should be specified for only those states that are allowed to be those that are used to measure the latter. The relevance of this property is directly related to the organization's capacity to predict the environment, and hence, to take whatever advantage that such time may give it to find new decisions for circumstances which it is expected to encounter in the future.

In the case of an environment which has the property that the probability of its being in any state is independent of its immediate past state, the transition probabilities are all equal. This means also that all states have the same probability of occurring. The randomness of the environment is at the highest value it could be for the states in the matrix. By changing the probabilities in the transition matrix we could describe a less random environment. It is one in which some states are more likely to occur overall, and one in which at various times some states have no probability of occurring. To do this we would increase the entries in the transition matrix to favor some states as destinations over others. The higher the sum of entries in columns, the higher the probability that this state will occur.

**Raggedness:** This property is defined in terms of the set of states that the environment may be in. We use here the same set of states as those we used in our measure of variedness. The level of this property is a function of the difference between one state in which the environment is and the next one in which it is found. Thus we measure something about the distance traveled by the environment in its space as it goes from the one state it is in to the next. Our function might be a measure of the average distance between state vectors, or an average of these distances weighted by the importance of the states, or by their probability of occurrence. We may include only states that have some minimum probability of occurrence we specify. In all cases the ones we use in this measure should be those to which we limit ourselves in our measure on variedness. Our measure should be well ordered since it is one of real numbers, and it ought to be observable, which requires that we be able to identify the state of the environment. This property's relevance comes from its possible effects on the differences between the decisions that the organization may have to make, and the time in which to make them. The raggedness of the environment may best be imagined if we had a space of only one dimension. If we plot the historical series on a graph with time on the horizontal scale and the measure of the one component of the state on the other, we could describe the measure of raggedness quite easily. The more the distance between one measure of the state and the next, the more ragged is the behavior of the environment. Temperatures in the desert show much greater change over time between day and night than do those in the forest, and the former temperature environment is said to be more ragged than the latter.

**Complexity:** This property is defined in terms of the components of the definition of the environment. The value it takes is a set of real numbers. The value is some function of the interdependence of the values of the components of the vector that describe the environment. If the vector space is one of totally independent variables, then the measure of complexity is a zero. The existence of relations between the values of the components of the vectors in the space increases the measure of complexity. This is a measure that is difficult to specify well, and to observe clearly. We may have to rely on impressionistic measures of what it is, and so it is not one we can use strongly in our analysis. It is, however, a relevant property that we are trying to measure here, because it relates to the organization's being correct in understanding and predicting its environment. Our simple case has no connections between the values of any two components of the environment. We could increase this measure if we were to make the prices of the two inputs be dependent on one another, thereby adding a connection which increases the complexity of the environment.

**Independence:** This property is defined in terms of the vectors that describe the environment and those which describe the performance. It would be best if we could have a logical separation of the environment and the performance of the structure. That would make the environment really just that, a true one. Most times this is impossible to do because some variables in the performance have effects on variables of the environment. These effects may not be worthy of attention in the short run, but their cumulative effects may be substantial. It is therefore advisable that one consider this property. The value it may take is one real number or a vector of these, and the more effects the decision of the organization has on the variables which describe this environment, the lower the level of its property of independence. This measure like the one before it is somewhat impressionistic.

## 7. Performance and Outcome

Each of the substructures of the organization structure does something. The operating substructure sets decision variable values, the information substructure reads, sends, records, etc., parameter values and the reward substructure sets values to rewards people get. All three do things, and what they do may be termed their performance. A performance is described by the decisions a substructure makes, and that of the operating substructure is a vector of values which the people have given to the set of operating decision variables. One vector may describe what was done, and a set of these vectors may describe what can be done or what ought to be done, etc. It is shown below that the performance of each substructure is related to the decision rules, assignment, and all the other components that describe it. To show the general relations between structure and performance, one needs to define properties for both. For each substructure, a set of performance properties is defined, and the set is chosen by the anticipation that it would be related to the outcomes of the performance. It should be clearly understood that the term performance refers to what is done, and the term outcome refers to the results of what is done. Performance is not outcome. The former refers to what the organization does, the latter to the relevant effects of what is done. What determines relevance is the set of goals to be achieved by the substructure as determined by the people in the organization, or its owners, or whatever the objectives of a given set of people may be.

## 8. Performance Properties of the Operating Substructure

**Flexibility:** This property is defined in terms of a set of performances. It takes a value from the set of real numbers. The value is a function of the number of different performances which may occur in some given time. This time period is determined by the needs of the analysis, its ends, the conditions of the organization, its environment, and so on. But the basic objective here is to get a measure of the number of different performances that a structure could logically give in some real period of time. The measure of flexibility is the number of performances in the repertoire of the organization. This repertoire is an inventory of performances of some level of quality when chosen for some state of the environment. It can be implemented within some given period of time from the instant it is chosen to the time it is implemented. The measure is clearly well ordered and observable in a logical sense. It is relevant because it impinges on the capacity of the organization to meet its goals when its environment changes, and the changes call for different performances if goals, or even survival, are to be attained.

Of all the logically possible performances in our example, the organization may be limited in its capacity to only a few. We have said nothing on this as yet, but we could limit our organization to the set of performances that is bounded by its capacity to set any one decision variable at any level it chooses. In any case, whether we measure flexibility by a ratio of actual to possible, by the number of possible, or by the number of ones that meet some criteria, the logic is the same. Flexibility increases as the number of performances that are "possible" increases, given the time and whatever else goes into defining "possible"

**Optimality:** This property is defined in terms of a performance and a set of goals. The value this property takes is one of the set of real numbers. The value of this measure for an organization is a function of the distances between the actual performances and the ones that are optimal given the goals of the organization. Simply put, for a given set of goals, there is a set of optimal performances for a state of the environment. How closely the performance of the organization comes to this optimal, the nearest optimal, is a measure of the optimality of that performance. The measure is not based on how close the outcome is to that which results from the optimal performance. For a set of performances, normally those that lie in the organization's repertoire, the measure is a function of all these measures, an average, that may be weighted by the need for the optimal performance.

The optimality of the organization's performance would be measured in terms of the distance between any actual performance and the relevant optimum. In each case the distance is a function of the value of some performance vector minus another, e. g. the difference between the performance actually given and the performance which is identified as the optimal one for the state that describes the environment. Outcomes of performance are used only to identify this latter performance. This property does not tell us anything about the differences in the outcomes of the performances. It tells us something about how far the performance is from the best one. The outcomes are used to identify what the optimal is. The measure on this property tells something about the difference between what is done and what would have to be done to qualify for being the best.

**Coordinatedness:** This property is defined in terms of a performance, specifically the values of pairs of the components of the vector that describe a performance, and an outcome, or goal. The values it may take is one of the set of real numbers. The set is well ordered and observable. The value is measured by a number of steps. For any pair of components, there is the distance of one from its optimal value given the value of the other. For two component values, x and y, we measure the distance from x to the optimal value for this component given the other component is at the given value of y. This is the basis for measuring the coordinatedness of x to y. There is also the similar measure for y given x. For a performance as a whole, a measure of its coordinatedness is given by a function of all the measures of coordinatedness of all pairs of components. For an organization, the measure of the coordinatedness of its performance is a function of the measures for each of its performances, that is the ones it gives in specific cases of environment states. Obviously an optimal performance is maximally coordinated. But a maximally coordinated performance is not necessarily optimal. The relevance of this property comes from the possible advantage of ignoring totally optimal performances, for whatever reasons, and working with lesser or weaker requirements. It is also possible that optimality is best obtained through a process of getting coordinatedness first. Every uncoordinated performance is dominated by a coordinated one, and every coordinated performance may or may not be dominated by an uncoordinated one. Insofar as we allow our simple structure to give different performances that are non-optimal, we can measure the level of coordination for each and use these measures to get an average of the level of coordinatedness for the performances the organization actually gives.

**Responsiveness:** This proper is defined in terms of a set of performances and a set of goals. The values it may take is a set of real numbers. The value taken is a function of the time it takes from the instant of the occurrence of a new state to get from a decision of some specified level of optimality for the old state, to a decision of the same level of optimality for the new state. Time is measured from the time the state changes to the time that the performance changes. For a set of pairs of state and performance we take an average of these times for all pairs to get the measure for the set. Obviously, responsiveness can be measured only after the set of possible performances is determined, the basis for measuring flexibility, and after the goal of an acceptable level of optimality is determined. The point is not to measure the time from decision to any decision, but from one "good" decision to another equally "good" decision. What is good may be defined in terms of closeness to optimality. The relevance of this property comes from the fact that in most cases it is to be expected that the outcome to a decision depends on the state of the environment. If one decision is close to the optimal for one state, it may well be a lot less close to the optimal for another state. Responsiveness essentially measures how quickly the organization can find the performance that fits, or matches at some level, a new state after it becomes fact. The longer it takes to change, the longer we have to live with the old performance which no longer matches the new conditions as well as it did the old ones.

**Controlledness:** This property is defined in terms of a set of performances and a set of goals. The values it may take are a set of real numbers or set of vectors of real numbers. The value taken is a function of the difference between actual performance and that called for by some set of decision rules, somebody's targeted performance, and the probability or frequency of the occurrence of such differences. The measure is a function of the probability that the actual performance will come within some given neighborhood of some targeted performance. If we change the target or the neighborhood, then the measure will change. We can get a two component measure from the set of pairs, (probability, neighborhood), for any given targeted performance. For a number of performances we can get an average single measure or an average for the probability measures for each performance for the same neighborhood. The relevance of this property is obtained from the argument that outcome depends on actual performance, not on that chosen by some who specify what it ought to be but do not actually give that performance. Whenever the performance is that chosen by some group that chooses but does not implement the choices, then controlledness is a relevant measure of what these choosers and non-implementers will in fact get. The structure of the organization affects this measure of controlledness.

## 9. Properties of the Performance of the Information Substructure

Many of the properties of the operating substructure have relevance to the information and reward ones. Some, like controlledness are directly applicable. Others, like optimality, are not meaningful to information except in the context of the operating substructure and its needs for information. This is a problem of substructure consistency which we discuss elsewhere using as a basis the Theory of Teams (J. Marschak, 1959), (J. Marschak and Radner, 1972), (MacCrimmon,1974). It is also logical to assume that information availability to people in the organization may is a strong determinant of the performance of the organization, as is discussed and tested on groups, by Rulke and Galaskiewicz (2000). We will discuss this very issue in terms of the properties that the operating and information substructures need to have in order to be consistent and therefore efficient.

The performance of the information substructure is defined in terms of the actual sets of values which the people in the organization read, transmit, and record. In the simple example, the values given to the prices and all other production parameters are part of the performance. These values are read, are transmitted, and so on. They are the elements of the vector that define the performance of the information substructure of this firm. In effect, the performance of this substructure is defined by the pieces of information brought to the people in the organization. Knowledge acquired is the performance and is described by the set of facts which the set of the people in the organization have. This knowledge is the result of the facts that are read, sent, stored, etc. It is how these things are done that will determine the performance, which is defined as the facts the organization has. Without any claim to being a complete set of all performance properties of the information substructure which are useful to the issue of design, the following set does contain some important ones.

**Accuracy:** This property is defined in terms of the closeness with which the value of a parameter which is read is to the real value. We may apply this also to the values that are sent and to those that are received. For the performance as a whole, the measure is an average of that for each of the many parameters, and for reading, and receiving, and recording. We could have one measure for each of the parts of the performance, namely, values read, sent, and recorded, or we could have a value to all combined. The important thing is the closeness of the parameter values that are used to get the operating performance to those that are the real ones.

**Alertness:** This property is defined in terms of the time which passes between the time a parameter takes a value to the time at which the value is read. We may call this reading alertness, and define an analogous sending alertness property which is based on the time between reading and reception of the value by the person who will use it in determining some part of the operating performance. For alertness in general, the measure is based on the time from a change in the value of a parameter to the time of the reception of the new value by a person who uses it in a decision rule. For the organization as a whole, the measure is the average for all or some subset of the measures for all parameters. The important thing is to get a measure of the time from a parameter change to the time the new value reaches whoever is to use it. For different purposes we may want measures on different combinations of parameters or different combinations of actions. If we have a special interest in the reading part of the problem and of the reading of only some parameters we consider very important, then we can get a measure of the alertness defined in terms of these specifics.

**Awareness:** This property is defined in terms of different parameters the values of which are known by people in the organization. A person "knows" the value of a parameter if he has read it, received it from someone who has read it or from someone who received it from someone who has read it, and so on. The property of accuracy tells us how correct any such knowledge is, while the property of awareness tells us how many people have acquired the knowledge that has this level of correctness. Parameter inclusiveness is the property that is about reading parameters, and its value sets a maximum to the level of awareness that may be reached. This maximum is one dimension of the measure of the property of awareness, while the measure of structure property of diffusion is the second dimension of the property of awareness. Awareness may be increased by either or both of these measures. Its measure refers to the average of the measures of the people subject to the condition that the knowledge is of some average amount of some fixed level of accuracy.

## 10. Properties of the Performance of the Information Substructure

The performance of the reward substructure is the set of decisions it makes which is logically the same concept as that of the performance of the operating substructure. All properties of the latter apply to the former, and the ones that are useful will be used in the analysis. This leaves the properties that are useful in the analysis of this reward substructure that are not in the analysis of the operating substructure, and so have yet to be defined.

**Material Richness:** This property is defined in terms of the economic value of the material things which the organization gives to its members. It is an average figure which may be defined for all members of the organization or for any subset.

**Emotional Richness:** This property is defined in terms of the nonmaterial things that people in the organization are given. It is a measure that comes from the value the recipients put on these things, which may be statements, titles, rank, symbols, etc. The measure is an average for all people in the organization, or it could be defined for any subset of these.

**Interdependence:** This property is defined in terms of the strength of the relation between one person's reward and the work done by others. For two people, the measure of this property would be low when each is rewarded based only on his work and be at a higher value when each is rewarded based on his work and part of the other's work. The more of this part that is used to determine rewards, the higher would be the level or measure of this property. For the structure an average measure would be obtained and serve to describe the relations between of the individual based rewards and team based rewards. We pay team members on the basis of how the team does, win, lose, total score, or we pay each player on the basis of her scoring, or on some combination.

**Fairness:** This property is defined in terms of the material and emotional richness of the things, money, medals, etc., given to individuals who are in the organization. We will discuss this concept of fairness later at some length, but for now, it is simply a property of the performance of the structure. It may be defined in terms of an individual without any reference to any other in or out of the organization, or it may be applied in a comparison of a number of people where the person is compared to others in some predetermined set. The people in the relevant subset may be the set of managers and that of workers, or set of workers who do A and the set who do B. Fairness refers to something about what individuals get from the organization to which they belong. The measure it takes is whatever the individual says it is, or the basis of whatever people in some a culture say it is. It is in this latter sense that is it used in our theorizing until we have a need to redefine it. When we come to a conclusion that some reward situation is slightly unfair or very unfair, we do not reflect the views of any one person involved, or outside the set, whose rewards are being evaluated. Fairness is defined and measured on the bases of general concepts of fairness in the culture from which the organization draws the people it is rewarding for the work they do. What the general view of the culture is about the fairness of a reward system, things, and processes, may differ from that of any individual. But even this personal view of fairness is based on the general concept of fairness in the culture, and the individual view will more often than not be well approximated by the view of the people who have the same culture.

Fairness is a very complex subject, and we will have much more to say on it. This we do below when we inquire into what determines how the people in the organization value things, and what actual organization decisions are involved in the issue of fairness. As might be expected, the decision rules on reward have many components that separately or in combinations form the bases for the conclusions that people have about the fairness of the reward. It is not only what a person gets that may be viewed as fair or unfair, but how the person gets it, who determines it, what he gets, and so on. Fairness may be a property of the performance of the structure and by derivation a property of a number of components of the structure itself. The concept of process fairness and that of output fairness are restated below in terms of the concept of decision rules. the two bases for fairness are broken up into their components and put into a form that relates directly to the decisions on structure design.

## 11. Properties and Master Brewing Corporation

All the properties defined for technologies and so on may be illustrated by parts of the world of MBC when we move away from the simple form for which we designed a structure. First, the firm produces not one but a number of different kinds of beer. Beer is described along many dimensions which results in the identification of properties which the beer has. Color is one such property. A beer may be described in terms of being very dark, or light, or very light in color. Other properties give comparisons on the basis of many other properties, as creamy or watery, sweet or sour, smooth or not, have malted or unmalted wheat, crisp or not, wet or dry, light or heavy, tangy or not, rich or poor in flavor, and so on. There are also the named varieties which are defined in combinations of the above properties. There are beers called lager, ale, pale ale, stout, pilsner, bock, and so on. Some of these types are further broken down into subtypes by properties giving us a pilsner that has a smooth dry finish and one without. For each of these beers there is a process of brewing or transformation that describes the ingredients and their quantities, the processes used on them, the results and quantities of the varieties of beers that emerge after a period of time of this or that length. This is what a brewing process is. Embedded in it are the variables which MBC has to assign to the people in the structure, those who are to make the decision rules, and those who are to use these rules to give the variables values. MBC should also know the nature of the transformations that describe how MBC can change its dollars into quantities of the things it uses to get beer, and the transformation that describe how it can turn the varieties of beer it produces into dollars. Very few of these are the simple single price of the perfect market we had assumed earlier. The inputs purchased may require negotiations over price, quantity, delivery time, and on and on. These transformations are the ones which describe this part of the world of MBC.

In the example of a previous chapter, the environment of MBC was defined in terms of known parameters the values of which changed from one period to the next in a purely random manner. Each of the different organization structures designed for that environment had a set of performances which determined operating profits. The time between changes was not random, and nothing about the nature of the changes was identified. In this simplest form of the environment of MBC, the environment has eight components, each of which is what we called a parameter variable. There are four production ones and four prices to be paid, one for each of the inputs. To make good decisions our organization needs to make sure that it finds out all eight facts. With eight facts and four decisions variables, this organization may be considered to have less control of its destiny than if it had less than eight facts. The work of Ashby (1956) tells us that control over one's ultimate destiny is dependent on the ratio of the number of decision variables to the number of parameters, i.e., the size of the environment. If MBC had also had to move its beers in trucks or whatever, then its environment would contain parameters the are embedded in this physical movement. Gas prices, truck prices, the manner in which the Teamsters respond to and make demands on MBC, government regulations on trucks, all would be part of the environment, which is larger than it was before. This is an environment that makes it sensible to talk, analyze, and decide in term of properties like those we earlier defined, such as changeability, which tells something about how often significant changes occur, or raggedness, which describes how large the changes are, and so on.

The market in which the Master Brewing Corporation operates may also be enriched. Not only are there many beers that MBC may make and sell, there are also many different types of consumers. One segment of the market is loyal to type only, one to type and brand, one to brand only, and one to neither. When MBC sold only one type, it had only the first two segment as its market environment. This was therefore low in the levels of size, variedness, changeability, randomness, raggedness, complexity, and independence. Customers were loyal and were not affected much by what other beer producers did. These loyal customers responded only to changes in the beer MBC made, and there was little other beer sellers could do to affect their behavior. However, when MCB started making and selling a number of different types of beers, all this changed. Other beer makers became competitors when they realized that their actions now had much more effect on MBC sales and conversely. Firms now made decisions seeking to increase market share by taking customers away from MBC, and decisions seeking to prevent losing market share to MBC. The local government regulations on beer alcohol content, retail sales types, hours, etc. that applied to MBC products, grew in number and variety. MBC now has a new environment because things that were not embedded in its transformations are now there. The levels of all seven properties of this environment are higher than those the old one had. The market transformation now has more parameters than it did. The parameters take many more different values than they did, the values they take change more often than they did, the likelihood that any value will happen is more nearly similar for all than it was, the changes in values are greater in magnitude than they were, and the effects of changes in values on outcomes contain many more interconnections that they did. Even if the organization structure which MBC had was a good one for the old environment, it is likely to be a bad one in this new one. Why that is true, and what the new structure should be like, is answered much later when the theory is completed, and the design rules derived.

All these performance properties of the operating substructure are relevant to the structure design problem for MBC regardless of the property levels of its environment and transformations. What differs as these differ, and MBC goes from a business with one beer to a business with many beers, is the relative importance of the properties and their cost. The levels of the properties of the environment determine the effects that the structure's performance properties have on outcomes. Performance properties that MBC should worry about depend on whether the environment is very ragged but not varied, or very varied but not ragged. In the former situation, responsiveness of its operating substructures is the property that MBC should worry about first, and in the latter it is flexibility. This and many pieces of advice will be given MBC after the we have developed the theory from which we can derive them.

For MCB, responsiveness may be measured by the time it takes to get from one optimal performance to another when the state of the environment changes. The lower this time is on the average for the moves between all pairs of performances in the feasible set, the higher the responsiveness measure for the set. If we change this set and change the flexibility of the performance, then we will have to re-measure responsiveness. The relevant time for the measure goes from one to zero. It is highest at 1, when the time from a change in the environment to the change in the performance is zero, and lowest at zero, when this time is the full length of the time for the environment to change from one state to the next. The number assigned to the measure is (1 - s) where s is a proportion of the production period. The proportion s of the period of production represents the time taken by the organization to move to a new performance after the environment state changes. If we were to change the length of production period and make it only half as long as it is, then the real time for which responsiveness with measure (1 - s) applies would be only half as long as it was earlier. Responsiveness is best measured in terms of the periods involved in the changes of the states of the environment. One day may mean a very high level of responsiveness in one case, and a very low level in another case. The actual time of response needed to succeed in boxing is very much different from that needed to succeed in chess.

Controlledness in the case of MBC is the same concept regardless of whether it is a one beer operation or a complicated business. the level of this property may be measured by closeness with which the decisions it makes come to those which are the ones specified by the structure. For each performance specified by the structure there is probability distribution for the distance from it that the real performance comes. The combination of the distributions for all performances gives a measure for the structure property of controlledness.

# CHAPTER 6

# ANALYTIC MAPPINGS: FROM SUBSTRUCTURE PERFORMANCE AND ENVIRONMENTS TO OUTCOMES

## 1. Outcomes of the Operating Substructure

People in the organization choose the kind of outcome that their organization is to realize. It could be waging and winning a war, selling a huge amounts of a set of products, educating people to be good problem solvers, making a positive difference between income and costs, or whatever else. Any outcome is a variable, and each takes on values of appropriate logical form. The values for war may be to win or lose, or the number of enemy killed, or both. Though it is true that in some organizations the outcome is the performance itself, our interest is in those where the performance is not the object of creating the organization. There is no general set of outcomes for the operating substructures of all organizations. The Army seeks outcomes that are different from what the Catholic church seeks, except in the case of the Crusades. Whatever outcome they seek, all operating substructures are faced with functions that relate their performances to the outcomes that they seek. These outcome functions are stated in terms of the output variables of the organization and in terms of variables that are components of the environment of the organization. For outcome oriented, or purposive organizations, these outcome functions are very important, and without knowledge of what they might be, no meaningful design can be created. Some knowledge about the effects that performance variables and those of the environment have on the values of the variable that is the outcome is needed by the organization. Properties of this function may be defined and used to help the organization identify what it needs to do under what circumstances in order to get the outcome it wants. From there it can go to the next stage of determining how it is to structure itself to do these things. We define some properties of the function that maps the performance of the operating substructure and the environment into the outcomes. These outcomes are those that are defined by whatever goals the organization is created to meet.

## 2. Some Properties of The Outcome Function

The operating substructure does things that affect the state of the organization through the connection between performance and outcome. We define next some useful properties of this function that relates the operating structure performance and the environment to the outcomes which the organization seeks.

**Sensitivity to performance:** This property is defined in terms of the changes in outcome values that result from changes of performance values given fixed sets of environment values. What we want to know is what happens to the outcome when the performance is changed and the environment is in some fixed state. Where, as in most real life cases we don't have functions that are continuous and so on, we may have to be satisfied with knowing the results of changes in only some performances. This may be the performance we have now or the performance that is best, or of some quality, given the environment state. We may find it useful to know the effects on outcome of only one or a few components of performance, in a few of the states of the environment. If we do not know the optimum, we could investigate what is happening to outcome when we make changes in our existing performance. The specific measurement of the value taken by this property will be determined by the values of the starting point of performance and environment, but in all cases the value of this property is in terms of so much of outcome for so much of change of performance when the components of the environment are held at some fixed values. The relevance of this property stems from the fact that its value may tell us the returns to our efforts to change our performance, or to our efforts to find the optimum performance when we are pretty close to it. The answer here determines in part the structure we design and the optimality levels we want the performances it produces to have.

Suppose we have a situation in which the outcome is profit, and performance has three components x, x*, and x**, the environment has three components p, p*, and p**, and the outcome function of profit is $0 = g(x, x^*, x^{**}, p, p^*, p^{**})$. Suppose this function were continuous and differentiable. The first thing we do is find the optimal values of the decision variables for each state of the environment. To simplify further, we assume that there are only ten states of the environment which we will encounter. We find ten different performances, each being the optimal in one of the states of the environment. We number the environment vectors from one to ten. We then give each of the ten performances a number that is the same as that given to the environment in which this performance is the best. To get one measure of the sensitivity of this output to performance, we build a matrix with environment states in the rows and the performances in the columns. In the matrix we enter for each square the amount of outcome, or profit, made when the environment is that identified by the row number of the square and the performance is that identified by the column number for the square. The entry in square (7, 5) is the amount of profit made when the environment is in state 7 and the performance is the one given the number 5, because it is the best decision when the environment is that numbered 5.

This matrix may be used to give us some ways to measure the level of this property of the outcome sensitivity to performance. The highest entry in every column is in the diagonal. These are the squares (1, 1), (2, 2).... (8, 8), where the performance is that which is best for that environment. The difference between the profit in square (2, 2) and square (2, 4) is a measure of the drop in profit if the environment were in state 2 and we chose performance 4 rather than the best one which is performance 2. Suppose we calculate the differences in profits for all the squares in row 2. If these are all very small then we would conclude that the level of sensitivity of the outcome to the performance is low when the environment is state 2. When we make the same calculations for all the rows, then we have the measures we use for all environments. The average for all the entries in the squares other than the diagonal may be used as a measure of this property. Another measure one might use is one based on the differences in profits relative to the largest profit. To get it we divide the entry in each square off the diagonal by the highest entry in its row. For each row the highest profit is in the diagonal square, where the profits are those that result from the best performance for this environment that is identified by the row. For row 2 and column 5, the figure we get is the proportion of the profits we could have made had we chosen the performance identified by the number 2 for the environment state identified by the number 2. For each state of the environment we get a ratio for each square off the diagonal. This will be a number between zero and one. The smaller the ratios, the larger the relative drop in profits when non-optimal performances are chosen. Small ratios suggest that big changes in relative profits occur when performances move away from the optimal ones for the environments. Small ratios suggest big outcome changes. The definition of the property of the sensitivity to performance suggests that the bigger the outcome changes, the higher the level of sensitivity. This means that the ratios as defined cannot be the direct measure of this level. To satisfy the definition, we measure this property on the basis of the new ratios we get by subtracting each of the old ratios from the number 1. Now the smaller the old ratio, the larger the new ratio. We could use as a measure of the level of the sensitivity of the outcome function to a performance, the ratio we get when we find the average of all the old ratios and subtract this number from the number 1 to get an average new ratio. It should be clear that what it is that we are not measuring is the absolute amounts of profit made. A high measure of this property of outcome sensitivity to performance might well go with a function that gives very high profits or one that gives very low profits. The measure does not tell us if the profits are good or not. This we get from the entries in the matrix. What the measure tells us is something about how sensitive profits are to movements in performances away from the ones that are optimal for the environment states. It tells us what we lose when our performance is always the same, or is always one of every two and so on, regardless of what the world looks like. The absolute amounts of profit are of course important. They are discussed below. Sensitivity, deals with the differences between what happens when we change the decisions we make, i.e., the performances we choose. If we lose little, then we need not worry about what performance we chose. If we lose a lot, then it matters what performance we chose and when we use it. The operating substructure we need in the first case is likely to be very different from that in the second case. This usually means that the information and reward substructures we need will also differ in the two cases.

**Sensitivity to environment:** This property is defined in terms of the changes in outcome values that result from changes in some specified states of the environment. The measure that this property may take is in terms of the values the outcome and environment take. It is a function from which one can get the amount of change in outcome that results when a specific component of the environment changes, given a starting environment and a given performance. The relevance of this property comes from the fact that keeping track of the environment is valuable to the extent that the changes recorded have effects on the outcome of our present decisions. As a rule, this property is measured by a function of the rate of change of profit with respect to each component of the environment state vector, and evaluated at some environment state, and assuming that performance is optimized in all cases, or at least fixed at some acceptable level. In the case of the simple example with continuous functions we would first find the optimum values of the performance variables in terms of the parameter variables that define the environment. We then substitute these functions for the decision variables in the output function which then becomes a function of the environment components only. The measure of the sensitivity property may be made to depend on the rates of its change with respect to one parameter variable or to the whole set of all parameter variables. We might use the averages of the rates for all environment components. The measure of this property would be the average of the rates evaluated at one specific state of the environment. To get a measure at more than one state, we average the measures we get for the individual states. If we live with our restricted eight environments and eight decisions, then this property would be a function of the differences between the returns to the optimal decision in one environment and the returns to the same decision in the neighboring environment, i.e., the entry in the diagonal minus the best entry in the same row. For all eight states, the measure would be the average for this measure for eight rows If the measure we get for a state is low, it means that one decision that is optimal for this environment state and used for all other states gives us an outcome not far from that obtained from a set of decisions each of which is optimal for a given state. If the measure is low for all eight states, then we have an output function that changes little when the environment changes, even when we do not change decisions. In these circumstances, finding the facts that describe the environment's state would under these circumstances be much less valuable than if the measure of the property were higher. The measure should help the organization determine how much effort it should expend in finding out what the environments looks like now, and what to do about it. But the measure does not say anything about the absolute amounts of profit made, and therefore, does not help the decision on whether the costs of the structure that make and implement these decisions are worth incurring. To get help here, we need the next property.

**Generosity of the environment:** This property is defined in terms of the absolute values of the returns. The value it may take are in terms of those of the outcome. The value taken is a function of the all the returns for all combinations of states and decisions. The relevance of the property is with respect to the decision on the choice of the nature of the operation, the outcome, the kinds of decisions, and the technology.

## 3. Outcomes of the Information And Reward Substructures

Unlike the operating substructure, neither the information substructure nor the reward substructure is directly related to outcome goals of the organization. Performances of these two substructure contribute to the attainment of the outcome goals through the effects these performances have on the operating substructure. What the information substructure's performance produces is information for the operating and reward substructures to use in their performances. Whether this information is used or not is up to these substructures. The nature of this information determines whether or not it is useful. This determines whether it becomes knowledge. When used correctly, this knowledge should produce improved operating substructure performances. As for the reward substructure, its performance is defined terms of what the people in the organization get. The nature of these things determines whether or not they bring about greater goal consistency between goal makers and rule users. It is this consistency that determines the extent to which there is loyalty of the latter to the former. The greater this loyalty, the greater are the inducements of the rewards and the higher the extent to which the rule makers and the rule users will make and use rules that are oriented to the goals of the structure designers. These outcomes of the reward substructure should have positive effects on the performances of the information and operating substructures. Both indirectly and directly, these reward substructure outcomes can be traced to the outcomes of the operating substructure. To design efficient structures by way of defining the substructures, one needs to know the connections between the performances of all three and the outcomes of the performance of the operating substructure. Any such connection ought to be explicitly stated as one from the performance of one substructure to the performances of another. The information that the information substructure produces will affect the performance of the operating substructure when it is used by the latter to get its performance. The way the information is used determines the nature and magnitude of its effects on the performance of the substructure using it.

The direct outcome of the information substructure is the knowledge gained by the operating substructure. When it uses this knowledge, this substructure creates the connection between it and the ultimate goals of the organization. The meaningful output of the information substructure is determined by its use, and the design of this substructure must be guided by this connection. This means that the information substructure must supply what the operating substructure needs, or what empowers it. This connection, and any others which involve any pair of substructures, are the elements of what in general is the problem of designing substructures that are consistent with one another. One specific element of consistency is the value that a piece of information which is given to the operating substructure has (J. Marschak, 1959), (J. Marschak and Radner, 1972), (Rulke and Galaskiewicz, 2000). Value is determined by the difference between the amounts of outcome that result from using the information and those that result from not using it. Given that there is any difference at all, it is affected by such properties of the information as its correctness, that is whether it is knowledge or merely belief. Then there is the timeliness of the knowledge. Regardless of how rich in facts the performance of the information substructure may be, its outcome would be very low if the operating substructure has no decision rules that involve its use. So an important goal of design is to avoid such wasted effort. The outcomes of the information substructure need to be matched with those of the operating one. Whatever the details of this matching may be for any given organization, the outcome function of the information substructure has the same set of properties as those of the operating substructure. This kind of argument is one of the forms that fall under the general subject of consistency as defined in general in Chapter 4.

In all organizations, the outcome of the performance of the information substructure is information that people have that is relevant. This is information held by decision making units for use in the making of the decisions that produce the performance of the operating substructure, which in turn gives the required ultimate outcomes of the organization. Information that is useful is decision rule specific, which means it is information that is required by a rule user to determine the value of an element in the domain of this rule. It is information that is not only relevant but timely, i.e., is person specific, time specific, decision rule specific, and is recognized to be all three by the person who has it. It is knowledge of a set of facts that are relevant because the operating substructure says they are. The knowledge which the people in the operating substructure have determines what the real substructure can and can not be.

Reward substructure performance is defined by the values taken by the variables that are the dimensions of who in the organization gets what and when. The outcome of the reward substructure is the set of the decision rules people in all three substructures actually use. For each person in the structure there are decision rules in which he is the designated user. The rules this person actually uses depend on the nature of the ones in which he is the designated user, and on the reward rules in which he is the subject. The designated user of a rule is more likely to use that rule when his goals are compatible with those of the maker of that rule. The contents of the reward rule for this person have an effect on the degree of goal compatibility and on the rule actually used. Thus reward decision rules have an effect on the outcome through their effects on the rules used in the operating and information substructures. Goal compatibility may be obtained by choosing as rule users the people whose goals are compatible with those of the rule maker, or by doing whatever it takes to develop the belief in the user of a rule that its maker has the goals of the user in mind when he makes the rule. What is of interest here is the compatibility obtained from the design of the reward substructure. Another outcome of the reward substructure is the level of correctness of the use of decision rules. When one person makes a decision rule for another to use, and when this rule is implicit to some extent, then the actual decision made may or may not meet the specifications of the maker. A rule that states that market share is to be maximized leaves it up to the user to find the decision that meets this requirement. Whether the user gets to such a decision depends on skill, knowledge, effort, and so on. All these are things not addressed in the rule, and one person may come up with a decision that he believes meets the logical conditions of the decision rule, when in fact it does not. A different person with more skill or more effort may have produced a decision that is closer to the one the maker wanted. Loyalty may be the term one might employ in describing an outcome of rewards. The degree of loyalty determines the extent to which rule the user puts in the skill and effort which produce the decision that comes as close as possible to that which has the effects required by the rule maker. The extent to which the rule users accept what the rule maker states is to be obtained from the decision governed by the rule determines the level of effort they put into the process of following rules. In turn, this determines the extent to which the rules made are in fact the rules designed to be made. The reward substructure affects these determining factors, which are the skill and effort put into deriving the decision that meets the rule. These factors are therefore considered to be among the relevant outcomes we should consider when we design the reward substructure.

Choosing to split the organization structure into three parts, and to analyze and design each separately, made the job of design easier than it would have been if we had tackled the whole structure as one. However, our process of independently designing each part separately ignores many connections between the substructures. The whole structure made up of these parts will not be the one which would have emerged if we had designed it as a whole. There are two possibilities for avoiding this result. One is to work with the designed parts and rework each in light of the others. The second is to design each part by connecting its performance directly to the outcome of the whole. Both these processes are used in the analysis and design processes which follow. Both are logically dependent for their validity on the theory that produces the specific logical conditions we identified earlier as those which make the substructures consistent one with the other.

## 4. Good and Bad Performance Property Values

The analysis of each of the three substructures is in terms of properties it has as well as properties that other substructures have. The properties of the performances we are going to use are those we have defined earlier. All of them seem to be ones that one would intuitively consider to be good properties. More of a property value means more of the returns. How can more flexibility hurt, or more optimality or more responsiveness? The answers are not obvious until we look carefully at what we mean by increasing some property's values. We need to look more carefully at these relations for this and other reasons. More of a property is certain to cost more at some level of the property, if not at all levels. The values of these properties depend on the structure that performs. Higher property values usually involve structures that cost more to design and operate than do lower values. Secondly, the value of outcome associated with the level of a property value varies with the property values of the environment. An outcome function in terms of properties may be stated in terms of property values of performance and environment as: o = f(k, k*, k**,.......p, p*, .......), where k, k*, are values of the performance properties, and p, p* are values of components of the environment. Since costs rise with the values k, k*, etc, it is not enough to know that f is positively sloped. We need to know things about the partial of o with respect to k and the role played in this function by k*, etc. The work of Malone (1987) carefully analyzes the returns to some properties of the organization which he calls vulnerability, flexibility etc., and makes no unconditional generalizations. It makes no sense to advocate maximum values to properties, e.g., responsiveness in all cases, because its usefulness depends on the nature of the environment, the sensitivity of the output to performance, and on the cost of getting higher property values. The analysis of flexibility that Volberda (1996) makes brings up the issue of the opportunity cost of getting higher levels. It is argued that the best level of flexibility is not the highest, because increasing it lowers the level of the stability of the organization. When the other costs of flexibility discussed above are considered, then this conclusion is even more obvious. Both the returns and costs of a property are relevant.

## 5. Operating Substructure Performance and Outcome

We expect the outcome values to depend in part, at least, on the performance of the organization structure. In all cases, when we refer to the value of the outcome, we are referring to the average value outcome under all circumstances that the organization faces. If these are probabilistic, then the average is a weighted one. Also, in all propositions the outcome is defined in terms that do not include the costs of getting performance property values, i.e., the costs of the structure needed to give the performance that has properties with the values discussed.

Proposition: The higher the level of the operating substructure performance property of flexibility, the higher the value of the outcome of its performance. The higher the level of the environment property of variedness, the larger this increase in the value of outcome.

Argument: The increase in the level of flexibility results from the addition of a performance to any given set of performances that describe the repertoire of the organization. The repertoire is the set of performances that the organization can give after a given time interval of preparation. Adding a performance to this set increases the value of flexibility and gives the organization one performance that is either better than or equally good for some circumstances as any other performance already in the set. In the first case, using this performance in the right circumstances will increase or leave unchanged the value of output. In the second case, the performance will not be used, assuming that increased choice does not produce worse decisions, and nothing happens to performance. This assumes that merely increasing the number of possible performances does not cause decision makers to choose worse performances. Information overload or plain stupidity is thus assumed not to exist.

We have chosen a specific way to change flexibility values. Outcome values are not tied neatly to flexibility values directly. They are tied to a specific way of changing these values, a way that requires a specific starting set. For any such set, except the empty one, the change in outcome value may differ with the set and with the identity of the performance added. Outcome really depends in a unique way on the set of performances, and not on the number of elements in it. There is no single value of outcome to each single value of flexibility. In the absence of such a function, our relation is a useful but not definitive guide to our choice of the best set of performances or repertoire. If we had only the optimum set of performances for every number of performances in the set, then we could have tied outcome directly to this number.

Suppose the organization has an environment that may be in any one of eight states. The best performance, or the performance that meets some quality level for each state, is known for only four of these states. Each performance may be termed the one that is acceptable for a state of the environment. When the environment is not in one of these four sates, then the organization must use one of its four on hand performances. But none of them may be acceptable. Had the organization already identified the acceptable performance for this state and made sure it could implement it, the organization would not have had to use the non-acceptable solution. As the number of performances on hand, or on call, is increase, the number of environment states for which there are acceptable performances increases. Outcome levels are higher because the number of states for which there are higher outcome producing performances in the repertoire is higher. The amounts of increases in the levels of outcome depend on the likelihood that the states for which acceptable performances are put on call is high. Increasing this number can improve outcome levels, or at worst, leave them unchanged. The more likely the state is to occur for which an acceptable performance is added to the set of those on call, the larger the outcome improvements that this addition will produce. What this means is that outcome changes that result from changes in the levels of flexibility are dependent on the likelihood of the environment's being in this or that state.

Probability distributions may be identified for a given environment, and the probabilities of the environment's going from one state described by one distribution to another may also be estimated. The randomness of the environment is a property of these transition probabilities. If we put these into a transition matrix and the entries are all identical, then we have maximum randomness. From the transition matrix one can calculate the steady state probabilities of the states' occurrences. Suppose we had two different eight state transition matrices with the first having entries of 1/8, and the other having entries that vary from 0 to 1. In the first case, the randomness is at its maximum, and in the second case, it at a lower level. The probability of going into some states from all others is higher for some and lower for others. If we were to so reduce randomness, by making some states less likely to occur and others more likely to do so, then the expected returns to adding a performance would be less that they were before the change. This is so in the most likely scenario where the performances are identified first for the most likely states and later for the less likely ones. When the returns are averaged over all states for which acceptable performances are available, the addition of a performance will change the average in some relation to the probability that the added states will occur. The more random the environment states, the larger this probability. The size of the effects of changes in the levels of performances on the values of outcomes often depends on the levels of some of the properties of the environment.

Proposition: The higher the level of the operating substructure performance property of optimality, the higher the value of the outcome of its performance.

Argument: An increase in optimality means that at least one performance is replaced by another closer to the optimum one for the set of circumstances. By the definition of optimality, outcome must therefore increase, providing that the relation between outcome and performance is monotonic as we assumed it was.

It should be noted that we did not tie outcome values to values of optimality pure and simple. If optimality is defined in terms of the average for a lot of performances, then an increase in its value may come from the replacement of some decisions by better ones and others by worse ones. Given the relative importance of the performances in terms of the probability of the circumstances of their use, and given the sensitivity of the outcome to them, average increases in optimality could increase or decrease outcome values. As in the previous case, we cannot get a function from optimality to outcome values, but we can get a relation between the one and a special way of changing the other. Also, cases in which approaching the optimal gives us lower outcomes until we come within some neighborhood of the optimal are excluded by the assumption on monotonic outcome optimality relations.

Proposition: The higher the level of the operating substructure performance property of coordinatedness, the higher he value of the outcome of its performance.

Argument: The argument is analogous to that on optimality.

The same note as in the previous cases applies here with appropriate changes in property name. One added point here is that we don't need coordinatedness if we work with optimality, except that it may be easier to get improvements by looking for coordination than by looking for optimality directly. For structure design purposes, coordinatedness is a much more useful design object than is optimality because it is more efficient to use, and it leads to optimality as well.

Proposition: The higher the level of the operating substructure property of responsiveness, the higher the value of the outcome of its performance. This is subject to the minimum level of optimality that is required of the response performance. The increase in outcome is larger, the higher the level of the changeability of the environment and the higher the level of its raggedness.

Argument: The performances mentioned must, of course, be one of those in the set of those that are on call, or in the repertoire of the organization's performances. And so, this proposition requires an assumption about the repertoire of performances of the organization. Given this assumption, the more quickly we get to the performance of some required level of goodness or higher for any circumstance, the better off we are, or at least no worse off. This is directly the result of our definition of responsiveness. It assumes again a monotonic relation between outcome value and optimality value.

Because the definition of responsiveness is in terms of the averages of many performances, it is not possible to specify a function from values of responsiveness to values of outcome. The reason is that averages may come by increases and decreases of the time it takes to get performances identified and realized, and the result depends on the identity of the performances and the circumstances in which they are used. The relation we specified may not tell us which performance needs to be got in the fastest time, but does tell us that increasing the speed of moving to a different performance is useful, providing the performance moved to is better for the present state of the environment than the one from which we moved. Also, the magnitude of the increase in returns to responsiveness depends on the number of performances in our repertoire. The smaller this number, the smaller the returns to the increase, because there will be fewer cases in which a change is made, and in some cases a change that would have been made if the performance had been in the repertoire, is not made because it is not there. From our propositions on flexibility and responsiveness we can conclude that the returns to any level of responsiveness are higher the higher the flexibility, and conversely. The same is true for the increase in responsiveness.

When the state of the environment does not change often, there are fewer occasion per unit of time for changes in performance. Responsiveness has fewer chances to have an effect on outcome over long periods of time. As the level of environment changeability is increased, more changes in performance per unit of time will be needed, and the returns to the same level of responsiveness will increase. Responsiveness is valuable when a change in performance is called for. The more often the environment changes, the more often will the performance need to be changed, and the more often will responsiveness affect outcome. Hence, the conclusion that the more changeable is the environment, the larger the returns to any level of responsiveness.

It is also true that the bigger the changes in the state of the environment , the worse is the result of staying with the old performance. What was good before the change is more costly to live with when the change is large than when it is small. Consider an environment that goes from state s to state s*. The acceptable performance for s is p, and for s* is p*, and both performances are in the repertoire of the organization. After the state of the environment changes and before the performance changes, the organization is in mode (s*, p) the old performance p in the new circumstances, or state s*. For this state, p* is the acceptable performance and the returns to the mode (s*, p*), are higher than those to mode (s*, p). Responsiveness is a property that describes how quickly the organization goes from the bad mode to the better, and the shorter the time this takes, the higher the level of responsiveness, and the more the returns to the organization (T. Marschak, 1972), (Burton and Obel, 1984). What raggedness of the environment refers to is the difference between the states s and s*. One should expect that in most, but not necessarily all cases, the larger this difference, the larger the difference between p and p*. One should also expect that the bigger the difference between p and p*, the greater is the difference between their returns in state s*. A higher level of responsiveness will increase returns, and the greater the change in the environment, or the more ragged it is, the larger this increase. Responsiveness is a good property to have especially when the environment is ragged.

Proposition: The higher the level of the operating substructure performance property of controlledness, the higher the value of the outcome of its performance. This is subject to the assumption that the performances in the repertoire of the structure are of a fairly high level of optimality.

Argument: It is not very valuable to have very high control over performances if they are not good ones. If the substructure is such that its designated performances are bad, then low levels of control allow the freedom to people to choose different performances which may well be better than the designated ones. Furthermore, as defined earlier, the property of controlledness cannot be connected directly to outcome. One cannot argue that the higher the level of controlledness, the higher the level of outcome without first identifying the people whose control is referred to. We can argue a limited but still useful form of the proposition by first identifying the people who are to exercise the control. Because designing structures is the subject of this work, it is the control exercised by some set of the decision rule makers in the structure that is the relevant one. A measure of controlledness may be obtained for any such group for any given state of the environment. This measure of controlledness would be obtained by measuring the extent to which the actual performance of the structure approaches the performance specified by the rules of the group who made the rules. By averaging these measures over the states of the environment, one can get a measure of controlledness of performance by the relevant set of people. The higher this measure, the closer the actual outcome is to that which would have been attained if the rules made by the relevant group had been in fact those used to produce the actual performance. If this "ought to be" outcome is optimal or close to it, then a high level of controlledness would be associated with a high level of outcome. The value of control depends on the quality of the performances of the controlled structure.

## 6. Information Substructure Performance and Outcome

We assume a fixed level of consistency between the substructures, and accept all the propositions about the operating substructure as true. This allows us to work with one connection between the properties of the performance of the information substructure and the outcome of the operating one. This is logically acceptable given the assumption on consistency. However, if the argument is complex, we may make it without the omission of this step. The information and operating substructures referred to in the propositions are those that belong to the same structure.

Proposition: The higher the level of the information substructure performance property of accuracy, the higher the value of the outcome of the performance of the operating substructure.

Argument: However decisions are made in the organization, they are made on the basis of some set of parameter values. The closer these values are to the real ones, the closer is the mental concept of the decision problem in the head of the decision maker to the real world. A decision maker wants a given level of optimality, or coordination, and so on, for the solution to the real world decision problem. He, therefore, seeks a solution to the concept of the problem that has the same levels of optimality, and so on. This solution will be closer to the former, the closer the concept of the problem is to the real one. This closeness is determined by the accuracy of the parameters used. From the example in chapter 2, it is obvious that any parameter value used to solve the problem affects the value of some decision variable. If this value is not true, then the decision will not be optimal in the real world, and the further the parameter value used is from the real one, the further the solution is from the optimal, and the worse the outcome.

Proposition: The higher the level of the information substructure performance property of alertness, the higher the value of the outcome of the performance of the operating substructure.

Argument: Alertness is the property that is measured by the time from the instant a value of a parameter becomes real to the instant that the structure knows this value. The more quickly the parameter values are introduced into the concept of the decision making problem, the closer this will be to the real world than is that which used the parameter values before they changed. But the real values cannot be used till they are discovered. Alertness reduces the time it takes for a change in a parameter value to be eligible for use in the process of decisions. The higher the level of alertness, the higher the level of responsiveness, all others things being equal.

Proposition: The higher the level of the information substructure performance property of awareness, the higher the value of outcome of the performance of the operating substructure.

Argument: Awareness describes the extent to which people in the structure know the values of the parameters. The more parameter variables the values of which people know, the more likely they are to know the values of the parameters they need in order for them to use their decision rules. These are the parameters that are dimensions of the domains of their decision. When the rule user knows these values, he will make better decisions than when he must ignore them or use a substitute value such as an average. In the structure as a whole, increasing awareness improves the qualities of the decisions, and makes it more likely that the designed structure will become the real one. Also, coordination in the performance of the structure requires that decision makers know more about what others are doing. This is what increasing awareness provides. In structures with rules that are highly implicit or with large measures of user discretion, rule users determine the dimensions of the domains of the rules they use. The increase in the number of parameter variables the values of which they know makes it possible for them to expand the domains of their rules. Their decisions are then more likely to be based on those of one another and so be more coordinated with one another, at least in healthy organizations that do not have fifth columns working to destroy them.

## 7. Reward Substructure Performance and Outcome

Some of the connections between properties of the performance of the reward substructure and the outcome of the operating substructure are discussed next. As in the previous section, the propositions are made under the assumptions that the substructures are consistent one with the other, and that the propositions about the operating substructures made earlier in the chapter are true. This allows us to combine a number of sequential connections into one. It should be clear that the combined connections make sense only in the context of the specific ones in the sequence. One of the important properties of the reward substructure performance, its fairness, is somewhat complicated, and is discussed only briefly in this section and at more length later.

Proposition: The higher the level of the reward substructure performance property of material richness, the higher the value of outcome of the performance of the operating substructure. The increase in the value of outcome is larger, the lower the level of the operating substructure property of rule comprehensiveness, or the lower the level of its property of rule fineness, or the lower the level of its property of rule explicitness.

Argument: Simply put, the performance that is materially rich contains higher rewards, and these attract more intelligent, better educated, more experienced, etc., people into the organization. This can be expected to produce better decisions and better outcomes for any organization structure. These people also have more discretion and greater effects on decisions when comprehensive or fineness or explicitness are lower than when they are higher, and so the effects of their decisions are broader and more salubrious.

Proposition: The higher the level of the reward substructure performance property of emotional richness, the higher the level of the outcome of the performance of the operating substructure. The increase in the value of outcome is larger, the lower the level of operating substructure property of rule comprehensiveness, or the lower the level of its property of rule fineness, or the lower the level of its property of rule explicitness.

Argument: The argument is analogous to the previous one.

Proposition: The higher the level of the reward substructure performance property of interdependence that is based on concord and not on conflict, the higher the value of the outcome of the performance of the operating substructure.

Argument: Higher levels of interdependence in rewards mean stronger effects of what Y gets as a reward on what X does. If these effects are ones of concord, what is good for X is also good for Y. If the reverse is also true, then both X and Y would be encouraged to help one another achieve their goals, and this would produce higher level of coordination, and so better outcomes. Interdependence of this kind rewards teams performance, whereas that based on conflict rewards individual performance. Grandstanding and selfish play are thereby reduced in favor of play that enhances the team's chances to win .

Proposition: The higher the level of the reward substructure performance property of fairness, the higher the value of the outcome of the performance of the operating substructure.

Argument: The effect of a reward on the behavior of the person in the organization is a result of the person's view of the exchange that is described in the reward, decision making, or work in return for something the person values. Balance between inducements and contributions (March and Simon, 1958) and (Simon, 1973) is one way of expressing the different preferences people have for different exchanges. A person puts a value on the inducements, and determines a level of contribution that is appropriate to it. The two levels may be agreed upon or not. A person has a preference ordering on the exchanges, and the rewards determine work done or agreed to, or which is expected to be done. But fairness is not simply a question of what is preferred. It is a question of what exchanges ought to be allowed into the set over which preference is to be identified. The concept of fairness enters into the determination of preferences by introducing the preferences of the person with whom one is exchanging into the preference of oneself. The amount of contribution that is forthcoming does not depend on the inducement alone, but also depends on the exchange offered or set. The fairness, or appropriateness of the exchange as a whole is what matters. One may prefer a reward of a hundred dollars for a day of hard work to fifty dollars for a day of light work when the outcome received by the employer for the day of hard work is at some level. If, however, this level were to double, then one might well find the first option to be unfair, and that there is too much work being exchanged for the reward. The distribution of the outcome between employer and employee is no longer considered to be fair by the latter. The exchange has not changed, but the value to one has, and this may make the other find it to be unfair. Fairness is based on the personal concept which an individual has about who in the world should get what. In any given culture there is are general views on how the wealth of the people ought to be distributed among them. Whereas in the United States CEO salaries that are 1000 times those of the line worker are considered to be a fair way in which to distribute the wealth of the business, in Japan they are not. Both the CEO and the line worker in any culture are likely to hold more nearly similar views of what is a fair way to allocate the wealth of the business. What people in a culture consider to be a fair distribution of wealth and the facts of the reward system in the organization determine their behavior as members of the organization. People's concepts of what is fair and unfair are such important determinants of how people behave in organizations, how they make decision rules, how they use them, etc., that in some cases a reward system that is considered unfair may elicit behavior that is intentionally detrimental to the organization, even if it is also detrimental to the person. Such is the thinking behind cutting off one's nose to spite one's face.

## 8. Complex Performance and Outcome Relations

The function that connects outcome values to performance property values is a complex one. It is not linear in the different performance properties. Changes in the levels of outcomes that result from changes in the levels of one property are often dependent on the level of other properties. A few have been identified, and we now make a few more.

Proposition: The higher the value of the operating substructure property of responsiveness, the higher the value of the outcome associated with any level of its performance property of flexibility.

Argument: It was shown above that as we increase the value of flexibility in a certain way, we increase the value of outcome unless we have stupid decision makers. The reason is that one more performance gives the organization one better chance at getting the right performance for some state. Whatever this new performance adds to outcome will depend on how quickly it is implemented when the relevant state comes to be. Thus, the faster the implementation, the more is added to outcome value. Quicker implementation means a higher value to responsiveness, and thus the higher this is, the more is added to outcome value by the increase in flexibility. It pays to be flexible. It pays even more when higher flexibility is coupled with higher responsiveness.

Proposition: The higher the value of the operating substructure performance property of coordinatedness, the higher the value of the outcome associated with any level of its performance property of responsiveness.

Argument: Responsiveness adds to the value of outcome by shortening the time between the instant when the relevant state comes to be and the instant of the implementation of the new performance that meets the goodness standard. The higher the level of coordination, the higher this standard, and the higher the value of outcome associated with the level of responsiveness.

Proposition: The higher the value of the operating substructure performance property of coordinatedness, the higher the value of outcome associated with any level of its performance property of flexibility.

Argument: Higher values of flexibility mean that more performances are available from which to chose one that comes closest to the best in any given state. The higher the value of coordinatedness, the closer will the best available performance be to the optimal one. Hence the value of the outcome for the given level of flexibility will be higher the more coordinated are the performances available for this level of flexibility

The effect of the value of a performance property of the information substructure on output is often through the effects of the value of this property on values of the performance properties of the operating substructure. In the case of alertness the relation between its value and output is direct. In the case of accuracy, the effect is from it to the levels of the optimality, and coordinatedness properties of the operating substructure. The same is true of reward substructure properties. Fairness levels will have effects on the levels of controlledness of the performance of the operating substructure, and on other properties of optimality, etc. These connections are a logical bases for the concept of substructure consistency. This in turn allows one to develop a more efficient way of designing structures than would have been the case without it. We may design for good combinations of performance property values and then work with each substructure one at a time to identify the values of the properties of the substructure itself. If we know that we need high levels of optimality, coordination, and controlledness in the performance of the operating substructure, then we can conclude that a high level of fairness is the consistent value of this performance property of the reward substructure. When we come to ask what determines the substructure property values that give these performance property values, we may consider each substructure separately. We need not worry about making the components of the substructures consistent since the required performances we identified are already consistent. It is much easier to establish the consistency of the former than it is of the latter.

Proposition: The higher the value of the variability of the environment, the higher the value of outcome associated with any level of the operating substructure performance property of flexibility or with its performance property of responsiveness.

Argument: The more variable the environment, the larger the number of states it has which the organization encounters. More states means that more (or the same) number of performances must be available if each state will be met by a performance of some given level of goodness. In other words, for one state we need no more than one global optimum performance. For two states either the one performance is optimal for both or it is not. If it is, then we need no more, and additions will not improve outcome. If it is not, then the old decision is not optimal for the new state and adding the performance optimal for that state will increase the value of the outcome. For one state no more than one performance is needed, and the value of outcome does not increase with increases in performances in the repertoire. If we add a state, then the value of outcome may increase for this increase in flexibility. The more variable is the environment, the more valuable might be the flexibility of performance because each state is likely to be met with a performance of a given quality. With more environment states to meet and more performances to meet them, the organization can expect to be making more changes in performance over the long run, but not necessarily in the short run. For every change in performance, the improvement in returns increases with the rapidity with which it is made. More variety in environment states calls for more flexibility and more changes in performance in the long run. If there are more states which the environment may take, it will take them sooner or later, and that means changes of state for the organization in the long run. Flexibility allows for changes to be made in performance. In every one of these changes, more responsiveness means higher returns. The more responsive the performance, the more it pays to be flexible, that is, to be able to make these appropriate changes.

Proposition: The higher the value of the changeability of the environment, the higher the value of the outcome associated with any level of the operating substructure performance property of responsiveness.

Argument: The value of outcome improves when we shorten the time between the coming of a state into being and the choice of the matching performance. The more often the states change (higher changeability), the more often we have the occurrences of the changes in performances, and the higher the outcome for any value of responsiveness. Speed is good when there is a change. The more often the changes, the more often we get to make speed pay. If the production period of our example organization transformation of Chapter 2 were halved, the returns to a responsiveness measure of fairly fast would be experienced twice in a period of real time. The argument here is about the frequency of change regardless of the nature of the change, and so it applies to the short and long run conditions. The previous argument deals only with the effect of the number of possible changes on the frequency of change, effects which do not necessarily exist in the short run.

Proposition: The higher the value of the changeability of the environment, the higher the value of the outcome associated with any level of the information substructure performance property of alertness.

Argument: Since the value of alertness of the information substructure's performance determines the length of a segment of the time used to get the value of responsiveness, the argument here is identical to the previous one.

Proposition: The higher the value of the raggedness of the environment, the higher the value of the outcome associated with the any level of the operating substructure performance property of responsiveness.

Argument: Instead of having speed pay more often as in a previous proposition, here responsiveness makes speed pay more per unit. We made this argument earlier.

Proposition: The higher the value of the randomness of the environment, the higher the value of the outcome associated with any level of the operating substructure performance property of flexibility.

Argument: For the same level of variedness, a higher level of randomness means a more nearly equal distribution of the occurrences of the states. More random means all states occur with more nearly equal frequencies. Suppose we had n states of equal probability. With n-1 performances we are short one matching performance once every n times. With the matching performance in the repertoire, (greater flexibility), we gain the same amount, (given responsiveness value), once every n times. Now suppose we reduce the probability of the occurrence of the state for this matched performance, and we increase the probability of other states, thereby reducing randomness. Now, not having the performance that matches this state costs us the same per occurrence of the state, but there are fewer occurrences, and therefore it costs us less overall. Thus the value of the nth performance in the case of lower randomness is less than that in the case of higher randomness, providing the performances in the repertoire are those that match the states with higher probabilities of occurring. If there are some states with very low frequency, and others with very high frequency, the flexibility will be less valuable than if all states were of equal frequency. Ignoring the low probability states and leaving out their matched performances costs us a lot less in the former case that in the latter. It is in the latter case that flexibility is more valuable, or where the value of outcome associated with the value of flexibility is higher.

Proposition: The higher the value of the size of the environment, the higher the value of the outcome associated with any level of the operating substructure performance property of coordinatedness.

Argument: A larger environment has more components than a smaller one. The returns to coordinatedness exist only because the best value for one component of performance depends on the value taken by another component. This translates to the statement that both performance component values depend on the values of some given subset of the components of the environment, or transformation. Coordination is measured by the relation of the value of one variable given the values of all the rest. The more the parameters on which the values of these variables depend, the larger the likelihood that any two will be connected in a way that makes them dependent on the same parameter. More joint dependence of variables on the same parameters means that there are more pairs to coordinate and more ways to coordinate any pair. In general, this means that any level of coordination will produce higher returns the higher the number of connections, which is what happens when the environment has more components and becomes larger.

Proposition: The higher the value of the size of the environment, the higher the value of the outcome associated with any level of the information substructure performance property of accuracy.

Argument: Since higher values of the information substructure performance property of accuracy increase the level of coordinatedness, the above argument applies in this case.

There is an indirect connection between the environment and the performance properties. Through the outcome function, one may trace effects from environment to performance. Linking these two are the properties of the outcome function.

Proposition: The higher the value of the sensitivity of the outcome function to the values of the components of the environment, the higher the level of outcome associated with any level of the operating substructure performance property of flexibility.

Argument: Sensitivity is defined in terms of fixed performance. It means a change in outcome occurs when the environment changes but performance does not. Obviously, a high level of sensitivity and a low level of flexibility means that outcome will change very much, and we can do little about it. The larger the sensitivity, the larger this loss, and the higher the return to flexibility, which is the proportion of this loss which flexibility recoups. More flexibility means more recouped, and more sensitivity means more to recoup.

Proposition: The higher the value of the sensitivity of the outcome function to the values of the components of the environment, the higher the level of the outcome associated with any level of the operating substructure performance property of responsiveness.

Argument: The argument is analogous to he previous one.

Proposition: The higher the value of the sensitivity of the outcome function to the values of the components of the environment, the higher the level of the outcome associated with any level of the operating substructure performance property of coordinatedness.

Argument: The argument is analogous to the previous one.

Proposition: The higher the value of the sensitivity of the outcome function to the values of the components of the environment, the higher the level of the outcome associated with any level of the information substructure performance property of alertness.

Argument: The argument is similar to the previous one.

Proposition: The higher the value of the sensitivity of the outcome function to the values of the components of the environment, the higher the level of the outcome associated with any level of the information substructure performance property of accuracy.

Argument: As for the reward substructure, it too may be made the subject of propositions analogous to those on the information substructure. Insofar as richness of the performance property of the former enhances the value of the operating substructure performance property of the coordinatedness, then whatever is argued about the outcomes of this latter applies to the outcome of the former.

Many relations are described earlier between the values of performance properties of the reward substructure and those of the operating substructure. Through these, one may develop propositions about the relations between the former and outcome by using the propositions about the latter and outcome. It is useful to see both the relations of performance property values and outcome of both substructures, even though one works only through the other. The reason has to do with the process of structure design. If we wanted to raise the value of an operating substructure performance property, then we should explore all the ways to do it, because these have different costs. We usually have a number of ways to do it, only one of which is changing the value of a reward substructure performance property. The cost of this way should be compared to the costs of other ways before we design the whole structure. This is most easily done if we have on hand the direct form of the relation between the level of the performance of the reward substructure and the levels of the different outcomes which the organization is created to get. Through all this, the substructures must be consistent.

## 9. More Needed

To design structures that perform as required, one needs to know how structures perform, and how performance translates into outcome. In this section we have developed the logical basis that deals with this second part. What remains is the analysis that identifies the connection from structure to performance, and there is quite a variety of such analyses available in the literature. There is a great deal of work which argues from various subsets of structure properties to performance. The standard set of structure properties, includes centralization and decentralization, functional and divisional forms, specialization, hierarchical and flat forms, and so on. The works Duncan (1972, 1979), T. Marschak (1972), Mackenzie (1991), Mintzberg (1980), Burton and Obel (1998), Jones (2001), and others are all about this subject. Because most of these works do not analyze connections between structure properties that connect directly to real components of structure, we do not use many of them when this subject of the structure to performance connection is discussed in the next two chapters.

Proposition: The higher the value of the generosity of the outcome function, the less the value of all the above generalizations.

Argument: If the world gave one whatever one wanted, and did so whatever one did, then one would have no need to think about what one did. Here ignorance would be the most efficient state, and any organization structure would be just as good as any other, as far as performance goes. The cheapest structure is the best one. Outcome functions that are very generous are usually those of organizations which offer very new products that the market realizes are valuable. When the attraction of the product is so great and its superiority so telling that the firm has no competitors, the structure of the organization will have little effect on what the firm achieves. But as the superiority of the product begins to weaken as would be competitors get active, then the issue of the structure becomes ever more important, and the innovating firm with its boss, the product inventor, begins to understand that structure is important. It may be that the firm needs a good designer, and the product innovating founder may not be that person, the talents that produce new and exciting products that almost sell the themselves.

## 10. Some Advice for Master Brewing

When MCB had only one beer and its customers were of the kind that stayed with their preferred beer, the outcome function was not sensitive to many elements in the environment that had to do with branding, advertising appeals to dealers, with the fashionability of the beer and its brand, and so on. It was also insensitive to decisions MCB made with the exception of those on the nature and quality of its beer. However, the move to the production and sale of a number of beers introduced into its potential customer set all four kinds of consumers, including those to whom type and brand matter little, such as those newly arrived at the legal age. The outcome function grew larger with more variables, and parameters, and more competing decision makers, and so on. The return function of MBC turned into one that was more sensitive to the performance, (decisions), of MBC, to those of other firms, and to those of the local governments. One might expect that the generosity of the outcome function to be higher when MBC had only one product. That is not, however, correct, since this property is in essence not dependent on any decision that MBC makes, except that on whether it is to be a one beer business, or a many beer one, or a bakery one, or both.

Even though the theoretical analysis is incomplete, there is enough there that could be useful to MBC in the new environment that may be emerging. The firm is now producing a number of different beers and selling to all 4 segments of the market. Very recently a new drink was created and is being made and sold by brewers who are competitors of MBC, and by makers of alcoholic beverages like vodka and whiskey, known generically as liquor. The new drinks are described by the magazine "Consumer Reports" (Aug. 2003), as "Malternatives" that have the "same alcohol content as beer…and the alcohol comes not from fermented grains but from flavorings made of distilled spirit." As malt beverages, the products are being marketed in the US under the laws and tax status that govern beer, not liquor. According to some surveys, the markets the producers and sellers of this new drink seem to be influencing are those markets that are made up of people who are under the age at which it is legal to purchase or consume alcoholic beverages (Consumer Reports, Aug., 2003). There is much political activity on the manner in which these drinks are to be considered as beer or as liquor for purposes of regulating sales. Much economic activity by the sellers in this market has led to tremendous growth in it at the expense of beer makers. Beer brewers are now competing with liquor distillers, and all are searching for production and marketing decisions that give them advantages in a highly regulated industry that is likely to get some major changes in the laws pertaining to this new beverage. Meanwhile, the growth of micro-breweries has been fast. Micro-brewery firms produce very few types of beer, concentrate on quality, often open their own bars and restaurants, and do their selling in restricted geographic areas. They know their small markets, and they concentrate their efforts on them, rather than on entering new ones.

MBC now has some serious strategic decisions to make. Two major changes have occurred in the state of the market environment with the result that competition for sales is getting stronger. Sales of the new drink are mostly to the segment that has no attachments to type or brand of beer, and this is made up primarily of the younger population. Sales are also being made to the segment that has preferences for brands, but not for type. Micro-brewery sales are mostly to the segment with strong preferences for type and brand, a segment made up of the older population, but these beers are also being sold to the segment with strong preferences for type, but not for brand. Malternative sales in 2002 were "$373 million in supermarkets … up more than 38 percent from 2001" (Consumer Reports, Aug., 2003). At the same time, there are changes in the brewing process which allow a beer's alcohol content to be obtained by mixing brewed ingredients. The alcohol content of a beer when it is sold need not be that which was chosen before its brewing began. The new process allows one to get beers of different alcohol levels by blending already brewed ingredients. The new process allows the seller to fill orders for beers with many different alcohol levels in a much shorter time period and from a lower inventory than before. This change in the way in which beer is brewed will also likely change the nature of the channel relations. Post order production is now an economically viable alternative that may impact other components of the transactions between brewers and distributors or consumers (Baligh and Richartz, 1967), (Baligh, 1986a). These and the changes in the assortment that some distillers now offer are a major change in the environment of MBC.

MBC is facing increased competition in all four segments of the market and changes in the nature of its relations with buyers. It must now make new decisions that are appropriate in the new circumstances. If MBC stays with its basic strategy with the one product, it will be operating in an environment that has been changed and with transformations that have been altered. When it decides on whether it is to enter the new product market and on its basic strategic decisions on how it will compete there, then more changes in its environment and transformations will occur. The wellbeing of this firm in the short and long run will depend on and be very sensitive to its decisions and its performance. Its organization structure needs to be designed at the same time that its basic strategic decisions are chosen. Structure must be consistent with strategy, and the costs of the structure must be considered. It needs to design a structure that performs well in the new environment in which the relations are between very many more variables than it used to have, and under which conditions and circumstances change greatly in very short periods of time. The firm's executives need to determine what they are to do to be able to meet future changes, and what the organization structure that makes survival and success in such environments possible should be like.

With what there is of the analysis at this point, one can make some suggestions to MBC executives about what they might consider doing. First, the changes in the environment should be studied to determine what its properties are now and are likely to become. From what is known, it can be concluded that this environment has a high level of the property we defined earlier and called raggedness. A highly ragged environment is defined as one that has large changes in its components happen in a short period of time. Along with this raggedness one can expect the new environment to have a high level of the property we termed variedness, which refers to the number of different states the environment can be in. This is so because there are now more competitors looking for new things to do, and because there are more possibilities in seller buyer relations, that is, in the components of the transactions.

Going through the propositions that have been made and searching for those that refer to levels of raggedness or variedness, one finds that the one performance property that is critical is that of responsiveness. MBC executives should be looking for a structure that changes its performance quite quickly when the environment state changes. MBC must know the performance it needs and be able to implement it in a shorter time than it has been doing. It must also implement the new performances which have to meet some minimum level of quality and be appropriate for the new state of the environment. Alertness levels should also increase because the time it takes to know that a change has occurred is part of the time it takes go to the new performance that responds to it. Finally, it may be the case that the changes that are occurring in the competition may lead to decreases in the level of the generosity of the outcome function, and this means that some increase in the level of the performance properties of coordinatedness and optimality should be considered and with them the property level of accuracy. All these changes will increase costs, and small changes should initially be made in the levels of these properties in order to gauge the cost implications. The advice to MBC executives is to work on responsiveness first. We cannot tell them what to work on till the theory is complete, and the design rules are derived from it.

Consistency between the operating, the information, and the reward substructures is an a important determinant of the efficiency of the whole structure. If MBC makes changes in its operating substructure, then it should consider changes in the other two. So the change in responsiveness which is now an important decision should be coupled with an increase in the level of alertness of the information substructure. This may be obtained through an increase in the level of the information substructure property of redundance. The information to be read contains many facts relating to the markets in which MBC sells its beers. The salesmen who do the selling may be in good positions to detect changes in these facts. They may be given new decision rules on what they are to do about reading and transmitting facts in the markets where they sell. If this is what MBC should do to improve the alertness and diffusion of the information substructure, then it ought to consider how the reward substructure should be changed so that it is consistent with it. Reward decision rules that are purely output oriented would be consistent with decision rules that are outcome oriented. If MBC sales people were involved only in selling, then rewarding them on the basis of sales would be consistent with their work. If they are now to collect information and diffuse it as well as sell, then the reward rules should be changed to make the reward to the individual depend on all three activities. To be consistent with the new information substructure that MBC has, its new reward substructure should have decision rules with the domains of their mappings expanded to contain variables of that describe the manner in which the decision rules are used and on those that describe the outcomes of whatever that use was.

NOTE: Charts that contain the propositions of this chapter are in Appendix I

## CHAPTER 7

# ANALYTIC MAPPINGS: FROM STRUCTURE TO PERFORMANCE, PART ONE

### 1. Decision Rules and Performance

It is now time to work on the morphology segment of our analysis. How form or structure affects function or performance is what must now be determined. The propositions that make these connections from the properties of structure to those of performance are based on theoretical analyses and are about concepts that are operational. This allows the propositions to be used to produce design rules that are meaningful and in a form that makes them useful in the process of designing real world structures. All the structure properties used in the propositions are defined earlier in terms of the components of the structure. The values they take are defined in terms that make it easy to identify them and set their levels in the real world. Because the properties are applied to a structure their levels are averages, but the individual levels that produce these are directly set by the specification of elements of the components that define a structure. The analytic propositions made below refer to such levels or measures and identify the relation between the levels of one or more structure properties and the levels of a performance property of the structure. They imply a causal effect that the components of the structure, or substructure, have on its performance. Each proposition is made on the assumption that all properties not mentioned in the proposition are held at constant levels, that the people in the structure are rational and self interested, and that all three substructures are consistent internally and one with the other.

### 2. Structure Determines Performance

Proposition: A higher level of the structure property of decision rule enfranchisement produces a higher level of the performance property of controlledness.

Argument: This proposition states that a high number of elements in the intersection of the sets of rule makers and rule users causes the difference between the desired performance and the actual performance to be small. When people are involved in making the decision rules they are supposed to use, they are more likely to believe that the rules serve their goals and more likely to use them, than if they were not involved in making them. This assumes a given reward structure. To use the rule is to make the actual performance the same as the desired one. That is what the property of controlledness is all about. Vroom and Yetton(1973) discuss a form of this connection.

Proposition: A higher level of the structure property of decision rule user independence produces a higher level of the performance property of controlledness.

Argument: The argument is analogous to the previous one.

Proposition: A lower level of the structure property of decision rule user orientation and a lower level of the structure property of decision rule enfranchisement produce a lower level of performance controlledness.

Argument: The rules are not made by the users whose goals may be ignored by the makers of the rules. The rules are less likely to serve the goals of the intended users than otherwise, and they are less likely to use such rules and controlledness is at a low level. This connection holds for any reward substructure, although the magnitudes of the effects will differ as the reward substructures differs.

Proposition: A lower level of the structure property of enfranchisement and a higher level of the structure property of user orientation of decision rules produce a lower level of the performance property of coordinatedness.

Argument: For any given number of users, higher user orientation means an equal or larger number of goals to be reconciled when the rules are made. With low enfranchisement, finding people's actual goals is likely to be difficult. With an equal or larger number of goals to consider, finding coordinated decisions for these goals is likely to be more difficult than it would otherwise be. Wrongly identified and conflicting goals make the identification of decisions that "fit" one another difficult to get. This is a case long known to historians as a benevolent dictatorship, or paternalistic organization, which has to get many people to do things that please many other people whose pleasures may be at best guessed at.

Proposition: A higher level of the structure property of user independence produces a lower level of the performance property of coordinatedness.

Argument: Higher user independence means that there are few makers who are not users of a rule. This means that users of one rule are excluded from being makers of any rule of which they are not users. Any two rules involving two different sets of users will not have anyone who is a member of both sets of makers. Barring any other connection between the makers, there is no way to make the two rules into a coordinated pair.

Proposition: A higher level of the structure property of the maker orientation of decision rules and a lower level of the structure property of enfranchisement produce a higher level of the performance property of optimality.

Argument: The more the levels of these two structure properties increase, the more are the mappings of the rules restricted to those that attain the goals of the rule maker. The number of rule makers includes few rule users, and the number of goals of the former set is no larger, probably smaller, than it would be if more users were included, unless enfranchisement somehow reduces the number of goals that individuals have. Whenever the result is fewer goals, the problems are simpler than otherwise, and optimal decisions are easier to find. Mackenzie (1986) calls for unity of vision and strategy. Such unity helps the structure to find optimal choices and to make them into facts. Enfranchisement works against unity of vision and strategy, and if we want such unity we must sacrifice some democracy.

Proposition: A higher level of the structure property of decision rule fineness produces a higher level of the performance property of coordinatedness.

Argument: Coordinatedness is defined in terms of the optimality of the value of one variable given some value of another. We are more likely to get the first value closer to the relative optimal if we were to make the set of variable values allowed for each vector of circumstances small, thereby leaving the rule user less choices. The level of fineness is measured by the inverse of the number of choices , and so the larger it is, the finer the decision rule. Thus, increasing the level of this property should help to increase coordination. Making decisions that fit neatly together is an issue of more order and less entropy and freedom in decisions. Only Adam Smith's perfect markets, involving heroic assumptions as they do, bring the same results out of chaos as could be brought from order. Markets are not organizations, and the transformations they produce are much more limited than those produced by organizations (Baligh, 1986).

Proposition: A higher level of the structure property of decision rule comprehensiveness produces a higher level of the performance property of coordinatedness.

Argument: The argument is similar to the preceding one. Low levels of this property leave the user more discretion than higher levels which cover more circumstances.

Proposition: A higher level of the structure property of decision rule lumpiness produces a lower level of the performance property of flexibility.

Argument: Rule lumpiness comes from having rules that specify heavily overlapping subsets of variable values that are assigned to many different circumstances. The larger the number of elements in the intersection of the sets v and v' for all such sets in the range of a decision rule mapping, the more lumpy the rule. For any given level of rule fineness, the more lumpy the rule, the smaller the number of values prescriptively allowed for the circumstances, or vectors of facts, that are the elements of the domain of the rule mapping. By definition, this means a smaller set of performances, the repertoire, and a lower level of the performance property of flexibility.

Proposition: A higher level of the structure property of decision rule lumpiness and a higher level of the structure property of rule fineness produce a lower level of the performance property of flexibility.

Argument: When both v and v' are made smaller, the rules are made finer. This clearly increases the effects of lumpiness on flexibility.

Standardization as usually defined, for example, in Mintzberg (1980), Hage (1969) and elsewhere, requires high levels of fineness and lumpiness. In the limit you do one thing under all circumstances. This is not, however, the only concept of standardization. Another kind of standardization is increased by an increase in rule fineness and a decrease in rule lumpiness. The result is a performance that is high flexibility, but has a standard decision variable value for each set of circumstances. It also gives very different values to the variable for different circumstances. This is the standardization commonly ignored but is discussed further below.

Proposition: A higher level of the structure property of decision rule fineness and a higher level of the structure property of decision rule comprehensiveness produce a higher level of the performance property of responsiveness.

Argument: Rules with high levels of these two properties give the user very few values to be given the decision variable for each of very many different circumstances. Thus, when these circumstances change, the user has the rule to tell him what to do. The time it takes the decision maker to search for new values for decision variables is reduced if these are already to be found in a rule. Works that extol the value of planning do so because planning produces rules that are fine and comprehensive. Planning identifies for the decision makers the decisions they are to make when something happens before it happens. Also, Marschak's (1972) analysis of centralization would produce very different results if he had allowed the decision makers to get the right rules from a few rule makers, i.e., in centralized structures. It should be noted that responsiveness does not depend on who makes the rules, i.e., centralization, but on the presence of certain kinds of rules. Centralization is not necessary to get responsiveness in a structure as Simon (1976) suggests it is.

Proposition: A higher level of the structure property of domain resolution of decision rules and a lower level of the structure property of rule lumpiness produce a higher level of the performance property of optimality.

Argument: A higher level of domain resolution allows smaller changes in circumstances to be recognized and included in the domain. This means that each element in the domain represents fewer real ones and is closer to the value of the true one. Basing decisions on more nearly correct readings of the world increases their quality. Meanwhile, as the level of lumpiness in the rules falls, the overlap between the decisions allowed for each of any two circumstances becomes smaller, and differences between the circumstances are more likely to be matched by differences between the decisions assigned them. In other words, lowering the level of lumpiness increases the likelihood that the decision chosen for one circumstance will be different from that chosen for another. This is precisely the difference that is needed for better decision choices if it is true that differences in circumstances imply differences in the decisions that are optimal for them. It is logical to make this assumption.

Proposition: A higher level of the structure property of range resolution of decision rules and a lower level of the structure property of decision rule lumpiness produce a higher level of the performance property of optimality.

Argument: The argument here is analogous to the previous one, except that it is now about a large set of values which may be given to the decision variable. Higher range resolution allows more variable values to be chosen than does lower resolution. With low rule lumpiness the variable values the rule specifies are closer to the optima than they would otherwise be.

Proposition: A higher level of the structure property of domain explicitness of decision rules produces a higher level of the performance property of responsiveness.

Argument: The more explicit the domain of the rule, the less time the user needs to determine what parameter it is that is to be read and derive the value that is the true one.

Proposition: A higher level of the structure property of range explicitness of decision rules produces a higher level of the performance property of responsiveness.

Argument: The explicitness of the range reduces the activities that the decision maker has to go through to get the solutions to the decision problem. Since the user must also be sure that the solution meets whatever requirements the rule sets for its results, the process of problem solving gets more complicated the less explicit the decision rule. This time consuming process is reduced as the level of explicitness of the range of the rule is increased. Less time is needed to make the decision, and so the performance is more responsiveness.

## 3. The Effects of Technology Properties

When the properties of technologies are considered, then more can be said about some of the propositions.

Proposition: The higher the level of the technology property of tightness, the lower the level of the structure performance property of coordinatedness that is produced by any given level of the structure property of rule comprehensiveness.

Argument: When the technology has a high level of tightness, there are many more variables that are connected and in need of coordination than when the level of tightness is low. The more variables that are to be coordinated, the more comprehensive must the rules be made. In consequence, the same level of comprehensiveness will produce a lower level of coordinatedness in the case of high tightness than in the case of low tightness.

Proposition: The higher the level of technology exposure, the lower the level of the structure property of controlledness that is produced by any given of the structure property of enfranchisement.

Argument: Higher levels of exposure mean larger numbers of parameters relative to decision variables, and that means that there are many more circumstances under which decisions are to be made. This translates into larger domains of some decision rules, and the same comprehensiveness level covers fewer numbers of circumstances. Thus, there are more circumstances not covered in some rules than there would have been with fewer parameters or lower technology exposure. Performance control is thus lower for the same comprehensiveness level.

## 4. Expanding the Concept of a Rule

Allowing time into the definition of a rule is easily done by pairing variables with time measures. The time measure refers to a time when a parameter takes on the value paired with this time and the decision variable is to be given the value paired with the time. Now the property of comprehensiveness can be split into two kinds, one referring to the circumstances covered by the rule, and the other to the times covered by the rule. Thus the time aspect may cover all time, or a single instant, or very short period. The Ten Commandments apply for all time under all circumstances at any time. The latter tells us that time comprehensiveness is maximum. The former applies to the range of the rule and suggests that we may need to develop a new rule property, that of durability. A high level of rule durability is what we may find in long established structures, such as the machine bureaucracy (Mintzberg 1980). Low durability is what we might find in a new structure, one in which the correct decisions for all circumstances and time may perhaps have not yet been discovered, as in the simple structure of Mintzberg (1980). The real difference between the two kinds of rules has necessarily nothing to do with either the age of the structure or the decisions called for by the rule. In the one case the rule is there for the user to use until a new rule replaces it, and in the other case the rule has to be sent to the user each time the decision variable is to be given a value. Both rules may specify the same decisions, but they do so at different costs. By stressing the ages of the structures in which each rule is usually found, we confuse the issue, since age is not always matched by rule durability. There are many other concepts in the literature that could be usefully redefined in terms of the properties of its decision rules. This includes such concepts as divisionalization, matrix structure, participation, bureaucracy, centralization, and so on.

Proposition: The higher the level of the structure property of rule durability and the lower the level of structure property of rule comprehensiveness, the lower the level of the structure performance property of responsiveness.

Argument: New conditions not in a rule will be considered only when the rules get reviewed. The longer the rules are intended to last, the less frequent the review, and the longer it will take to have the correct response for the new circumstance. The less comprehensive the rule, the more circumstances are not in its domain, and the more often will such correct responses need to be obtained, and the slower the response.

Proposition: The higher the level of the structure property of rule openness relative to the level of the structure property of rule maker orientation, the lower the level of the performance property of controlledness.

Argument: When the rules serve the goals of neither user nor maker, the probability of their being used is not likely to be high. That neither maker nor user goals are to be those the rule produces makes it a rule in which interest is low, or one for which there will be substituted one that serves the goals of varying sets of other people. Unless most members of the organization are agreed on these goals and are truly altruistic, there is no logic why they might use them. This means that the level of controlledness will fall as the lever of this property of openness rises.

## 5. New Structure Properties for Old

Most of the work on structure performance and design in organization theory is in terms of classes of organization structures. Classes are defined in terms of values of fixed combinations of properties. Whether this is the case or whether the work is in terms of properties directly, all generalizations about these classes or properties will be useful as the bases of design rules only if the properties that define classes meet certain conditions. Conditions on the property's operationality, dimensionality, and measurability determine the value of generalizations in which it is embedded. Properties of organization structures about which we theorize in this work are not the same ones as those used in the majority of the work in the literature. Our properties are different, and therefore do not carry any of the names of the old names like formalization, centralization, mechanistic, organic, tyrannical, democratic, bureaucratic, adhocratic, and so on. These are concepts that are rarely well defined and often multidimensional but not recognized as such. If we restate them in terms of our concepts and definitions of properties, the problems of using these old concepts in the analysis will become clear. To do this we need to go back to the concept of an organization and its essential component, the decision rule.

The very reason for creating decision rules is to have some peoples' choices become the choices and the decisions of some other people. This transfer of choices is not necessarily in one direction thereby making organizations one way authority relations. The users of one rule may be the makers of another, the users of which are the makers of the first. What the concept of decision rule does mean is that the choices of the user of a decision rule are restricted by the rule. The user's freedom of choice is reduced by any rule other than the null one. If one is both the user and the maker, then the restriction is imposed by one on oneself. The properties of the rules in an organization determine the extent and form of the restrictions on the choices of the people in it who apply the rules.

The concepts of democracy and freedom clearly apply to all organizations from nations to households. Though often used as if they were the same, they are not the same and they mean different things. It is not that there is one concept with two names, it is that there are two different concepts involved. If we redefine them clearly in terms of decision rules, we will see how they differ. A democracy requires only that people participate directly or through representatives in the making of the rules they are to use, regardless of what these rules are. It says nothing about these rules. Enfranchisement as defined earlier captures this concept well. This property involves only the overlap between the set of makers and the set of users of a rule. Enfranchisement, though somewhat simple and crude, is a property that has only one dimension and is operational. We know how to increase and decrease it's level to serve our purpose.

Democracy, or enfranchisement, does not mean that because the users of rules are among the makers of the rules, the users are free to do what they please or to make any decision they please. Whether the users of any rule are free or how free they are is determined not by participation of users alone, but by the absence of participation of non users, and by the mapping of the rule. If there is more than one rule maker, then any one of them who is to use the rule might well have to do what he might not have done had he been the only maker. Freedom is not democracy. The United States Constitution is a good example of the difference. The realization that the main body of the constitution produces a nation that is a democracy, or at least close to it, but that its citizens are not necessarily free to make any decisions, led to the addition of the Bill of Rights. This is really a set of rules about the making of rules. These special amendments have their own enfranchisement rules, and they are there to help prevent the democracy from making rules that would restrict the freedom of citizens to make decisions of a certain kind. They make the United States democracy more free than the British democracy, where Parliament may make any law restricting any behavior. There are many democracies the citizens of which are less free than those of some dictatorships, especially those that are benevolent and neglectful.

The freedom of a person to make decisions (choice and action) lies in the rules which he uses regardless of whether he joins in making them or not. Given any rule, the more comprehensive its mapping, the less free the user is. The more circumstances the rule covers, the fewer are left unattended for the user to do what he wills. Whenever the rule is not operative, i.e., it does not cover the circumstances by an element in it, the user is free to do whatever he wants, including doing nothing whatsoever. Similarly, the higher the rule fineness, the less freedom the user has. In short, freedom for the user is not related to enfranchisement directly, but only to comprehensiveness and fineness. That these may be affected by enfranchisement does not change this conclusion. In the limit, when there is only one rule maker who is also the rule user, then the definitions of freedom and democracy lose all value.

All this is closely related to the properties of an organization structure which are called formalization and centralization. Both these are really properties of the decision rules of an organization, though that is rarely stated. Also, there are many different concepts that go under each of these two names. These concepts are rarely well and clearly defined. Robbins (1990) in a large number of his works tries hard to bring clarity to the many different concepts that go under these two. His definition of formalization relates to what the rules have to say. His definition of centralization relates to who says it, i.e., who makes the rules. Because the concept of the decision rule is not fully explained by Robbins(1990), he finds it difficult to define centralization as he would like to, only in terms of who says what goes into the mapping of the rules. He then introduces the concept of policies into the definition, so that centralization is in terms of who makes the rules and what policies, if any, these rules express. Policies, as everyone knows, are broad and loose decision rules. But exactly where a rule stops and a policy begins is not clear, so centralization is defined in terms that overlap the definition of formalization.

A clear redefinition of these two concepts can be made in terms of the properties of decision rules we have defined. Formalization would be a property involving comprehensiveness and fineness of rules. Such rules have many elements, and to help the user remember them, they are written. We could add this third dimension to the definition or not. The higher the values of the two or three properties, the higher the formalization. But now formalization is a multi-dimensional concept, i.e., a compound property. When we generalize about it, we cannot specify which if any of the two or three measures is the operative one, or whether it is two of the three, or all three. We do not need this concept since we have the two or three properties that make it up, and we can generalize about whichever combination we need. We can define centralization in terms of enfranchisement only. We can dispense with the distinction that Robbins makes between roles, rules, procedures, and policies. From the definitions it is clear that all are at heart decision rules. A role is a set of rules; rules are comprehensive and fine rules; procedures are rules put together in one of the ways defined earlier; and policies are non-fine rules. The classification is of little value, since these classes are not defined in terms that make them exclusive or exhaustive. We are much better off generalizing about the basic properties of comprehensiveness, fineness, compound rules, and so on. We may even have the elements we need to relate decision rules to the highly sophisticated and precisely defined concept of process that Mackenzie (1986) discusses.

Generally speaking, a large number of the structure properties discussed in the literature may be redefined in ways that capture their essential meanings and connect the properties clearly to the decision rule component of the structure. They may then be related to one another as is appropriate. The redefinition collapses all of them into the properties of decision rules as we have defined them, the rules and the properties. We could redefine centralization in terms of enfranchisement only, or we could make it a compound property by adding to its definition such things as the property of maker orientation, or user orientation. But we do not need this compound property since we can work with the two properties, which would allow us to distinguish between an altruistic dictatorship and a selfish one. Using a different combination of properties we might distinguish between a democracy in which individuals are free and one in which they are oppressed.

Consider the concepts of mechanistic and organic organizations we find in many works (Burns and Stalker, 1961), (Mintzberg, 1980), etc. Whether used as names for classes of organization structures, or as names of properties, the two terms mean the same thing to those using them. What the first really refers to is a situation in which people in the organization are given specific instructions of what to do under most circumstances. Somehow all decisions are laid out and everyone is given what to do under all circumstances. We, of course, know this as an organization with high rule fineness and rule comprehensiveness. Standardization (Weber, 1974), (Hage, 1965), (Mintzberg, 1980), etc., goes along necessarily with mechanistic. There are two kinds of standardizations, as already noted earlier, and one goes with what is traditionally seen as mechanistic, and the other does not. This is the one normally ignored in the literature, which is unfortunate. The standardization of Mintzberg (1980) and Robbins (1990) really refers to rules with high levels of lumpiness and high levels of fineness, rules that say to do the same thing under all or most circumstances.

If mechanistic includes lumpiness, then what do we call the structure that has very fine and comprehensive rules that are not at all lumpy?Here we have high standardization, but standardization of responses to circumstances. The response to each circumstance is standard for the circumstance (fineness); this is true for all circumstances (comprehensiveness); but each response differs from others (non-lumpiness). What is this organization to be termed? Clearly mechanistic and organic are properties of little use. Any generalization about either could have any one of a number of meanings, depending on how we define them. They have so many dimensions (organic is best left undisturbed and totally meaningless), that we can define and redefine them as we wish to make any generalization true or false, provable or disprovable. This is not the case when we work with comprehensiveness, etc., separately or even in combination with flexibility or for any combination of the performance we defined.

## 6. Rule Connections and Performance

The performance of a structure is defined as the vector of values the structure gives to its decision variables. Propositions that show how the connections which the designer makes between decision rules affect performance now follow. The term connection is used here as defined earlier.

Proposition: The values of two different decision variables may be coordinated by connecting the domains of two rules where the rule governing the first decision variable has the second decision variable as a dimension of the its domain, and the rule governing the second decision variable has the first decision variable as a dimension of its domain. What this means is that the value to be given each variable depends on the value given the other one. Algebraic simultaneity is necessary for the setting of the values of the two variables.

Argument: To coordinate the value of one decision variable with that of another is to get the best value for the first, given the value of the second. To coordinate the two is to do so for both. In either case coordination is relevant because the return to a given variable depends on its value and the value of another. Evidence of this dependence exists when functions showing the rates of return to both decision variables, (e.g. partial derivative), have at least one dimension in common. The dimension may be the set of values of a decision variable or of a parameter. In this case, one can make the value of one variable depend on the value of another by making it dependent on the shared parameters. This happens when the domains of the two rule mappings are made to intersect. The values of the two decision variables are made to depend on the same facts, and are thereby coordinated as needed. The war movies have people who synchronize their watches. That way both read the same value for the same variable, time. They need to do so in order that they both do whatever it is, open fire say, in relation to the same parameter value. The coordination is in this case in terms of time only. In general, coordination is with respect to any number of shared values of shared domain variables. From this argument one can conclude that coordinatedness may be increased by increasing the variables the values of which are shared by the decision rules in a structure, or by increasing for any two variables the number of values of parameters in the vectors that are common to the domains of the two decision variables

Proposition: The value of a decision variable may be coordinated with that of another by connecting the range of the rule governing this later decision variable with the domain of the rule governing the former. The variable, the value of which is coordinated, is the latter, which has a domain that has the former as a dimension.

Argument: Here the value of the variable to be coordinated may be made to depend on the value specified for another variable by another rule. In the case of the simple form of MBC discussed in Chapter 2, we could coordinate the decision on the output for factory 2 by making it dependent on the output of factory 1, and conversely. To get the output of factory 2, the manager would be using a rule that contained the value of the output of factory 1 in the vectors of its domain. In the range-domain connection, it is the rule with the domain in the connection that has its decision variable coordinated with the value of the decision variable of the rule with the range in question. That coordination may be obtained in either way is useful to know. If the costs of the two mappings differ, then we have an interesting problem of structure design. Not only do we need to design a structure that has coordination, but we need to do so in a way that has the lower costs. Since the information needs of the two connections that produce coordinated decisions are different, the costs of the two may also be different. The choice of which one to use is then of a standard design form evaluating both the returns of to and the costs of each connection. But that is not where the problem ends, because the level of coordination we get also depends on the values of fineness, lumpiness, and comprehensiveness of the rules connected, and on the number of connections. We might find that there are situations in which the same level of coordination may be obtained from different combinations of the values of all these design variables. We might be able to reduce the level of connectedness and keep the same level of coordinatedness by increasing the level of fineness of the connected rules. There may be cases where the coordination level we get for the same level of connection will be higher when the connection is a range-domain than when it is a domain-domain one. When the size of the difference depends on the level of the fineness of the rule, then trading off fineness and direct connection levels should be considered. Outcome depends on the level of coordinatedness, and we know that costs depend on the levels of all these variables. Good design decisions can be made only if they rest on an understanding of the relations between the values of these design variables and the value of coordinatedness.

Without a perfect match in the domains of two rules we may not be able to get perfect coordination. But we may want to have most values of a variable coordinated with those of another in some cases, and we may not want coordination at all in other cases because it does not pay to get it. We therefore use as much connecting as we need and of the kind that has the lower costs. Inasmuch as optimality of performance requires coordination, all the propositions we made on the latter may be applied to the former. There are, however, other performance properties that are affected by rule connections.

Proposition: A measure of control by the users of rule r over the users of rule r* may be established by connecting the range of rule r with the domain of rule r*. The greater the fineness of rule r*, the greater the level of control.

Argument: Since the decisions specified by rule r* are made to depend on the decisions of rule r, the former are determined in part by the latter, that is, controlled by the makers of this rule. We assume here that the reward system is properly coupled with the decision rule system, and that the rules that are made by set m are followed by set u even when m and u are disjoint.

This kind of connection also makes the makers of rule r, the set m, the controllers of the users of the rule r*, the set u*. Even if m and m* are disjoint, the set m* has abdicated, in some measure, its control over the set u by choosing to connect the range of r to the domain of its rule r*. The users of rule r* act in the way that the makers of the rule r specify. But because of the connection, this act is in fact a react, one in response to the actions that result from the use of the rule r.

Proposition: An amount of responsiveness of performance may be lost by connecting the range of rule r with the domain of rule r*. The slowness that may develop is in giving a value to the decision variable of rule r* when some facts change.

Argument: Because the users of rule r* logically need the value of the variable given in rule r, they may have to wait till that value is actually given to the variable. In some cases the fineness of rule r will determine how long this waiting might be. The less fine rule r is, the less the users of rule r* have to wait for the users of rule r to finish their work before they, the users of rule r*, can use their rule.

Coordinating the performance of a structure may be obtained by connecting the mappings or the makers. Thus, in designing a structure we can get coordination in a number of ways, which in traditional literature were called horizontal departmentalization, lateral and vertical information, etc. Instead of all these loosely defined terms, we now have clean and precise identification of some of the means which may be used to obtain a coordinated performance. The means all involve the nature of the rules that describe the structure that is doing the performing.

The consideration of technology produces propositions which are more complex forms of the ones established.

Proposition: The higher the level of technology tightness, the more domain-domain connections are needed to produce any given level of performance coordinatedness.

Argument: A higher level of tightness means more variables are connected in the technologies, and more variables to be coordinated to get the same level of overall coordination. More variables means more domains that have to be connected to get a given level of performance coordinatedness.

Proposition: The higher the level of technology tightness, the more range-domain connections are needed to produce any given level of performance coordination.

Argument: The argument is analogous to the previous one. It is the existence of a connection that brings about the desired outcome. The designer would be expected to choose the one that has the best combination of outcome and costs. Since both these are specific to the operations of the structure, its environment, and so on, it is not possible to identify in general which connections to make first, but those involved in the tightness seem to be a good start.

## 7. Decision Processes

As defined earlier, decision rules, transformations, and connections between combinations of these two give us the tools by which we can define decision processes in organization designs. In designing an organization one builds up its defining decision process from simple pieces such as parts of the structure, parts of the technology, or some other parts. These may be parts of a structure, parts of a technology, or some combination of the two. The designer works with connections between one rule and another, with connections between one transformation and another, and on connections between a rule and a transformation. If decision processes are created from building blocks, then changes in the former may be made by small marginal changes in the latter. It would be easier and more efficient to design decision processes if these were defined in terms that allow such clear marginal variations. Mackenzie's (1991) concept of a process is put in terms of its building blocks very clearly, and whether or not one agrees with his arguments, one knows what they are about. Other concepts of decision processes are not so clear, and one such example which we discuss in detail is the work of Thompson (1967).

First we show the relationship of Thompson's (1967) 3 classes of technology to our concepts of sets of connected rules and transformations; then we see whether the 3 classes are distinct and cover all possible processes or not. In the process, we show that Thompson's concept of a technology incorporates elements of the organization's operating structure, and is, in fact, a decision process. The structure and the technology are lumped together into what he calls a technology. Thompson's technologies are, in fact, decision processes made up of connected rule mappings, and connected transformations. The difference between rule mappings and physical transformation mappings is that the former connect facts to what is to be done to make facts, and the latter connect facts to facts. The latter describe transformations and technologies that exist in the world, and the way they and the world change, while the former prescribe the changes that are to be made by a person in the world, given a state of that world. These are the operating structure pieces. Together they may be used to describe the organization, but they are not the same thing. The prescriptions of the operating structures need to be realistic if they are to be useful, and that means they must conform to real world transformations, including the users' capacities to be part of such transformations.

The long linked technology of Thompson (1967) may be described in our terms by a set of mappings (transformations and rules) in which the range of one is connected to the domain of the next, and its range is connected to another domain, and so on. This does not restrict the definition as does Thompson to the case where the domain of one mapping is restricted to only the range of the preceding one. Further, our definition need not be time sequenced. Our connections may well be logical only and in reverse order of occurrence in time. The intensive technology of Thompson (1967) is one in which the mappings, rules, or transformations are connected reflexively. The range of one is the domain of the other, and the range of the other is the domain of the first. That is precisely what we have in simultaneity or, in recursiveness, which is logical simultaneity once removed. It is also possible to view this class of technology in slightly different terms. The other name Thompson gives it is intensive technology. Here the technology may be described by mappings that have domains that are made up of the unions of the ranges of other mappings. Such is the case of many people acting on many resources, with the result dependent on all these. By this redefinition, we see that the class is really two classes, and with two dimensions, and perhaps better seen as four classes. Again, the "technology" is really part technology and part organization operating structure, i.e., the processes of making decisions and creating facts.

Finally, Thompson's (1967) mediating technology may be described by two mappings with connected ranges, but disconnected domains. In the limit of this case we have the transaction in which the variables take a value determined by two people, with each choosing a value based on a domain not connected to the other. The term pooled interdependence means that a variable is not given a real value until there is agreement by two people. That is what Baligh (1986a) refers to as a shared variable, a necessary component of exchange and transaction. It should be very clear that Thompson's three classes are not homogeneous classes, and are not exhaustive. Real decision processes may be of any of one such or of any combinations of all of them. In designing a structure one chooses transformations, rules, and connections between them, that is, one specifies decision processes. These decision processes may be built up in a manner that is efficient. The object is to create efficient decision techniques, or ones that produce the appropriate performances. Organizations are combinations of decision processes made up of connected sets of transformation mappings and rule mappings, and of technology and structure. The design of structure must surely take into consideration transformations (technology), and also, the choice of these must consider the structures that would be designed for them. From the set of such pairs of transformation and its structure, one should pick the best one.

## 8. The Set of Assignments

Just as decision rule properties are causally connected to structure performance, so are the properties of assignments. Even if assignments were shown to be somewhat redundant when decision rules are available, they were also shown to be very useful to the analysis. The following propositions make this usefulness clearer.

Proposition: The higher the level of the structure property of assignment commonality, the higher the level of the performance property of coordination.

Argument: By definition of commonality, higher levels mean more variables are assigned to more people, or that more people share responsibility for more variables. When that happens, each person will be solving for the values of the shared and other unshared variables. This produces coordination in the choices of the common set of variables with two or more unshared ones. The unshared ones are coordinated with one another through their coordination with the common set. The level of total coordination is thus higher.

Proposition: The lower the level of the structure property of people inclusiveness, the lower the level of the performance property of controlledness.

Argument: A lower level of people inclusiveness means more people who are presumed to be making decisions are not assigned any decision variables. What variables they give values to are unknown, and hence what values they ought to give them are also unknown. Thus their behavior cannot be controlled, and the level of overall control will fall the more such people there are that are ignored when decision rules are handed out.

Anything less than maximum inclusiveness in people, decision variables, and parameters implies an incomplete structure design. If we assume internal and inter-substructure consistency, failure to include a person means that the decisions of that person are totally unknown. There is nothing in the design to show what it is that this person is to decide. There are no decision rules guiding his decisions since there are none specified. The lower the level of people inclusiveness, the more people there are whose decisions are unspecified and unknown. We now make some propositions that follow from this situation, and others relating to the assignment properties of the operating substructure.

Proposition: The lower the level of the structure property of people inclusiveness, the lower the level of the performance property of coordinatedness.

Argument : With people in the organization with no decision variables assigned to them to give value to, it is impossible to know what decision variables these people will actually set, let alone what values they will give them. Coordination can be expected to be low for this case. In fact, this may not be always true, since people in the structure may be doing their own designing, and may be coordinating things well all on their own. However, one cannot rely on such haphazard outcomes, and it is prudent to assume that coordinatedness is low and to increase it by direct means if we wanted it to be higher.

Proposition: The lower the level of the structure property of people inclusiveness, the lower the level of the performance property of optimality.

Argument: The argument is analogous to the previous one.

Proposition: The lower the level of the structure property of people inclusiveness, the lower the level of the performance property of flexibility.

Argument: The argument is analogous to the previous one.

Proposition: The lower the level of the structure property of people inclusiveness, the lower the level of the performance property of responsiveness.

Argument: The argument is analogous to the previous one.

Proposition: The lower the level of the structure property of people inclusiveness, the lower the level of the performance property of controlledness.

Argument: If a person is not recognized as being in the organization, then there is nothing that can be assigned for him to do, and nothing to control.

The next proposition is on controlledness because we want to put into comparison the inclusiveness levels of people and decision variables. This reverses the order in which we put the previous propositions but does nothing to their meaning. Order is not relevant here.

Proposition: The lower the level of the structure property of variable inclusiveness, the lower the level of the performance property of controlledness.

Argument: If a decision variable is left out of the assignments, then there is either no rule for it or there is a rule with an anonymous user. In the latter case, the argument of the previous proposition is used. If it is the former, then there are no values specified for the variable to take for any circumstance. With no specification for the variable, the variable will be very difficult to control. In fact, the concept of control is meaningless in this case. This is the case referred to by MacKenzie (1986)as that of a virtual position, where a variable is unrecognized by superiors as needing to be given a value, but recognized as a variable by a subordinate who creates the job of giving it a value. If the decision variable is not assigned, and there is no rule for it, then there may be any one of a number of people who may take over the decision variable and give it values. What they give for values under what circumstances is totally beyond the designer who did not assign the variable in his design.

The decision variable set that is made the component of the structure results from the designer's understanding of the nature of the transformations that are to be used and the desired outcomes for which the structure is to be designed. This set may be complete and include every real decision variable which is embedded in the transformation, or it may not be complete. In this case, any omission may be intentional or not. If it is intentional, then it may be because the designer wishes to simplify the structure design problem or that the variable is unimportant in terms of its effects. The result of this omission is a lower level of variable inclusiveness and all the propositions about this property of the structure hold. Bad effects of not including the variable may be too small to counter the lower cost of designing and maintaining the structure. But low levels of variable inclusiveness may be the result of the poor knowledge the designer has of the transformations available. Here, the issue is one of understanding, and if the designer does not understand the nature of the technologies, variables will fail to be included. Not only will the propositions about the effects of this on performance properties hold, but the opportunity costs of these effects may be very high. A critical property of the designer is the depth of understanding she or he has of the nature of the outcomes that the structure is to obtain and of the transformations available to the organization to get these outcomes.

Designing real structures is a process that must be made to include people with an intimate knowledge of the purposes and capacities of the structure that may emerge. Otherwise, variable inclusiveness may turn out to be very costly.

Proposition: The lower the level of the structure property of decision variable inclusiveness, the lower the level of the performance property of optimality.

Argument: If the value given the variable is never specified in a rule, or the rule goes to an anonymous user, actually goes nowhere, then we have no concept of what the values given this variable will be under any circumstance. We therefore assume very low levels of optimality.

Proposition: The lower the level of the structure property of decision variable inclusiveness, the lower the level of the performance property of coordinatedness.

Argument: The argument is analogous to the previous one.

Proposition: The lower the level of the structure property of decision variable inclusiveness, the lower the level of the performance property of flexibility.

Argument: The argument is analogous to the previous one.

Proposition: The lower the level of the structure property of decision variable inclusiveness, the lower the level of the performance property responsiveness.

Argument: The argument is analogous to the previous one.

Another assignment property of the structure is that of commonality. This is a property the level of which is determined by the extent of the overlap between the sets of decision variables assigned to people. The higher the level of this property, the more people there are to whom decision variables are assigned to be given values. This definition of the property fails to distinguish between commonality among a series of rule makers and rule users who are given rules that meet the conditions of rule consistency given in chapter 5, and commonality that comes from overlapping sets of rule makers and has nothing to do with the condition on rule consistency. Even so, a number of propositions may be made about its relations to performance properties.

Proposition: The higher the level of the structure property of commonality, the higher the level of the performance property of coordinatedness.

Argument: By the definition of commonality, higher level means more people are assigned the same variable. If we assume structural consistency of all kinds, then greater commonality will mean that any given variable will be given values in the contexts of other variables assigned to each of the people in the set. Where these assignments are such that some variables are not shared by all, more variables will form the context of the decision on any one of them. This we can assume produces a higher level of coordination than otherwise. Hierarchy in the traditional sense is defined earlier in terms of decision rule consistency, and the more rules in a sequence of consistent rules, the higher the level of commonality. The use of teams in organizations is also the same as designing a structure that has a high level of the property of commonality. In a team a set of people is specified and all members are assigned the same variable or variables. The former kind of commonality has little to do with coordination, but the second kind is that which applies to the proposition. Higher levels of commonality of this kind mean greater use of sets that overlap in some measure in terms of members. The more the overlap, the more people who will be assigned the same variable, and therefore, the higher the level of commonality of the structure. The more the overlap, the more likely are decisions on a variable to be made with conscious consideration for the values to be given other variables.

Proposition: The higher the level of the structure property of commonality, the higher the level of the performance property of optimality.

Argument: If one allows that two brains are better than one at solving problems and making decisions, then the proposition holds. More commonality means more variables are being given values by larger teams, which have more brain power than smaller ones.

Proposition: The higher the level of structure property of assignment commonality, the lower the level of the performance property of responsiveness.

Argument: Whatever improvement in the quality of decision, more people mean slower decisions. This is true after the number of people exceeds a minimal level which produces teams that work well together. More commonality means more people are to set the value of a decision variable, and beyond some point, the more people we have, the more goals are involved, and the more disagreement over decisions. All this means slower decisions, or less responsiveness.

Orderliness is the property of structure that deals with the underlying logic of the assignment of decision variables to people. How the variables assigned relate to one another determines the logic of the result. There is more or less order when the same logic is used and applied to more or fewer assignments. If the logic used is changed for some or all assignments, then it is difficult to talk reasonably of more or less order. Also, unless the logic is based on a sound foundation relating to the decisions that are to be made, then the concept of levels of logic is not meaningful. Suppose, however, that we use as a basis for the order the relationships between decision variables which is derived from the technologies and the outcome functions. Then an increase in orderliness means the application of this logic to more assignments, and it is meaningful to talk of levels of orderliness. When this is the case, one may make some propositions about the relation between this level and levels of performance properties.

Proposition: The higher the level of the structure property of orderliness, the higher the level of the performance property of coordinatedness.

Argument: Regardless of decision rules given a person in an organization, that person will determine the value at which a decision variable is set in the context of the values at which the other decision variables in that person's assignment are set. Any person with a brain is more likely to do that and not to ignore completely such contexts. If the variables in the assignment are logically related in the correct manner, then this person's behavior means more coordination among the values given to the variables. The more orderliness, the more persons in the organization who have such assignments, and the higher the level of coordinatedness for the organization's performance.

The properties of resolution and explicitness of the domain and range of a decision rule are also subjects of causal propositions.

Proposition: The higher the level of the structure property of domain resolution, the higher the level of the performance property of coordinatedness.

Argument: Higher levels of domain resolution allow more values to parameters and variables in decision rules. These contain many more decision variable values that may be chosen, and in turn, this allows the decisions to get closer to the ones that produce maximum coordination.

Proposition: The higher the level of the structure property of domain resolution, the higher the level of the performance property of optimality.

Argument: The argument is analogous to the previous one.

Proposition: The higher the level of the structure property of range resolution, the higher the level of the performance property of coordinatedness.

Argument: As the level of range resolution rises, more values of the decision variable become eligible for membership in the sets of choices assigned to any given element in the domain. More values of the decision variable for choice are likely to increase the closeness with which the value chosen is to the one that gives the highest value of coordinatedness.

Proposition: The higher the level of the structure property of range resolution, the higher the level of the performance property of optimality.

Argument: The argument is analogous to the previous one.

Proposition: The higher the level of the structure property of domain explicitness, the higher the level the performance property of coordinatedness.

Argument: Explicitness is the property that distinguishes between decision rules in which the value of the decision variable, or the parameters in terms of the variable values that may be read, or set, and those in which these are to be derived from some sets of others. For example, there is the statement in a rule that says when the values of some specific parameter are such and such, then you are to do this. There is also the statement in a rule that says for all values of some specific parameter that cause this or that to happen, then you are to do this or that. The latter rule leaves it up to the user to derive the effects of various values on outcomes, and to use his discretion to determine what the element in the domain is, in fact. By being more explicit, the former rule gives less discretion to the user. As the explicitness level falls, there is less likelihood that the users of two rules will arrive at the same element in the domain as the one that describes the facts. The result is that the choices they make will be less coordinated than they would have been had the people agreed on what the facts were.

Proposition: The higher the level of the structure property of domain explicitness, the higher the level of the performance property of optimality.

Argument: The argument is analogous to the previous one.

Proposition: The higher the level of the structure property of range explicitness, the higher the level of the performance property of coordinatedness.

Argument: The two rules of the argument for domain explicitness now involve the users in making inferences as to what decision variable values produce what causes. The rule with the lower level of explicitness is much more likely to produce differences in the inferences made. The values chosen for the two decision variables in this case are ones that have results that are more likely to be different in fact. Coordinatedness is a property that is defined in terms of making inferences from outcomes to choices. Choices made on different concepts of the outcomes that result from these choices cannot be as coordinated as those based on the same or more nearly similar concepts.

Proposition: The higher the level of the structure property of range explicitness, the higher the level of the performance property of optimality.

Argument: The argument is analogous to the previous one.

Mappings that show the causal relations between the properties of the information substructure and the properties of its performance need to be identified. The same is true of the reward substructure. The mappings are described in propositions that use the properties identified earlier.

NOTE: Charts that contain the propositions of this chapter are in Appendix I.

## CHAPTER 8

# ANALYTIC MAPPINGS: FROM STRUCTURE TO PERFORMANCE, PART TWO

## 1. Substructure Consistency

Information and rewards are the mechanisms for making a designed structure become a real one. Earlier we discussed the property of the controllability of the performance of the operating substructure. Now the subject is the issue of control over the structure itself, the structure that becomes a reality compared to the structure that is designed or intended to be the reality. If the design process is to be meaningful, the structure designed should be the structure that becomes a reality. There is no point in designing an organization structure if there is nothing one can do to turn the design into a reality. One thing that one can and should do to get the real structure to be the one that is designed is to design the operating, information, and reward substructures in such a manner that they are consistent with one another. Consistency means that the elements of the three substructures and also some of their properties are matched or fit well with one another according to logic and economic rules. When these rule are met, then the likelihood that the design will become the real structure is enhanced.

**Design Realism:** This property of the design of a structure refers to the extent to which the design can in fact become a real structure. The level of this property that is attained by a design is determined by the extent to which its three substructures are consistent.

Though discussed earlier, the subject of consistency needs more analysis in order to make the property of design realism clear and useful in the process of creating designs. Consider the case of the user of an operating decision rule. To use the rule she needs information on the values of the components of the domains of its mapping. If the information substructure has decision rules which meet this requirement and can get this information to her, then it is consistent with this one rule of the operating substructure. The extent to which such fact requirements for the use of any decision rule are met may be used as a measure of the consistency level of the information and operating substructure for this one rule. An average level for all operating decision rules is then a measure of the consistency between the information substructure and the operating one. The higher the consistency, that is, the higher the level this measure for the operating rules of a structure, the higher the level of the realism property of the design of the design.

Team Theory (J. Marshak and Radner, 1972), (MacCrimmon, 1974) deals with the issue of the economics of information and its use in making decisions. In using the mapping of an operating decision rule, the user first determines the true value of each component of the domain of that rule. When that is established, the user may then apply the mapping to get the value of the decision variable. The set of information decision rules that is consistent with this operating decision rule is that which gives the user the relevant information or the values of the components of the domain of the mapping of the operating decision rule. One set of decision rules in the information substructure that would be consistent with this operating decision rule is one that tells the operating rule user to read the values of the parameters that define the domain of this rule. Another such set is that which has the rule for some person to read this information and another set that has rules that require that the information be sent to the user of the operating rule. The set of information rules which is a component of the designed information substructure will affect the ability of the people in the organization to use the set of operating rules which is the component of the design of the operating substructure. Substructure consistency is the concept that refers to the capacity of the former to supply the information needs of the latter. The extent to which the design of the information substructure is consistent with the design of the operating substructure will determine the extent to which this design will be realized. The issue of realism also involves the timing of the arrival of the information to the relevant users of operating decision rules, its accuracy ,and so on, and arguments about their effects on realism may be made.

Finally, all arguments made for these elements of information and these two substructures may be made for other elements of any two of the three. A design of a reward substructure with higher levels of the property of decision orientation is more nearly consistent with a design of an operating substructure with lower levels of user independence, and with higher levels of comprehensiveness and of fineness. Low user independence means that users do not have much say in making the operating rules. If these users are also given little discretion because the rules they are given are comprehensive and fine, then the outcomes caused by the use of these rules have very little to do with their user. There is no logic in making the user's reward depend on outcomes for which he bears no responsibility. Here, a reward rule based on the decision, that is, on the use of the rule, makes more sense to its users and so makes the realization of the designed structure more likely.

Higher levels of the reward substructure property of arbitrary orientation is not consistent with any operating substructure, and the level of realism is low for all designs of these latter. If what the person receives as a reward is independent of the operational, informational, or reward rules she uses, then there is no logic that could underlie her choice of any rule except, perhaps, the rule which minimizes effort on her part, i.e., do nothing. On the other hand, the design of a reward substructure with higher levels of the property of outcome orientation is more nearly consistent with the design of an operating substructure with higher levels of user independence. As the level of user independence increases, so does the level of effect they have on the making of the mappings in the rules. Because of this increase in the magnitude of the causal connection between the mappings they create and outcomes, the logic of rewarding them on outcomes becomes more meaningful. They are thus more likely to use the mappings in the designed structure, thereby increasing its level of realism.

## 2. Information Substructure Properties and Its Performance

Performance properties of the information substructure include those that have been discussed for the operating substructure. There is not much to say about these, because the concept of substructure consistency allows us to go directly from the properties of the operating substructure to the properties of the information substructure. The same is true for the reward substructure. However, there are some performance properties of the information and reward substructures that are unique to each. They are useful in the analysis and will be used, but because they do not connect directly to the outcome of the performance, they have to be shown to connect indirectly. It will be shown that they do connect to the properties of the operating substructure and from there to the properties of its performance. Whether connections of the first kind exist or not will depend on whether the two substructures are consistent, and so consistency must be explicitly considered before the existence of these connections is established. Connections between the information and operating substructures are discussed first. Information performance properties that are unique to it are alertness, accuracy, and awareness. They need to be shown to be connected to outcome by way of their connection to the properties of the performance of the operating substructure. From the full definitions of these given earlier, they may be briefly described. Alertness deals with the time it takes the information substructure to read the value of a parameter after that value has become a fact. The shorter this time period, the higher the level of alertness. Accuracy deals with the closeness with which the read value comes to the real one, and the closer the values, the higher the level of accuracy. Awareness refers to the proportion of environment defining parameters the values of which are known to the people in the organization. To be known, the value of a parameter must first be read by somebody.

Proposition: The higher the level of the information substructure property of redundance, the higher the level of its performance property of alertness.

Argument: The more people who are assigned the job of reading the value of a parameter, the higher the probability that at least one will read it within any given period. When we increase the number of readers, we increase the likelihood that someone will read the new value within x units of time after it comes into being.

Proposition: The higher the level of the information substructure property of repetitiveness, the higher the level of its performance property of alertness.

Argument: If the rule says that the parameter is to be read every x units of time, instead of every 2x units, then there is more repetitiveness. It also means that on average, the time it takes between a change in value and its called for reading is shortened. If one reads the meter every ten minutes one will catch a change in its value in ten minutes or less. If one read the meter every twenty minutes, then one could go for much longer than ten minutes before knowing the change, and so one would not respond as quickly to the change as one would have if the readings had been more frequent.

Proposition: The higher the level of the information substructure property of parameter inclusiveness, the higher the level of its performance property of alertness.

Argument: If parameters are excluded from any assignment for reading, then they may never be read or they may be read, but rarely. No one knows when they will be read, and it is fair to assume the time between readings will be higher than otherwise. This increases the average time between readings for the set of parameters and lowers the level of alertness, which is the result of the lower level of inclusiveness.

Proposition: The higher the level of the information substructure property of parameter inclusiveness, the higher the level of its performance property of accuracy:

Argument: Any parameter not assigned specifically to one or more persons to read may not get read at all. One also does not know what the result of its reading will be if it is read. The accuracy level can be expected to go up as more parameters are assigned.

Proposition: The higher the level of the information substructure property of redundance, the higher the level of its performance property of accuracy.

Argument: The higher the level of redundance, the more people on average are assigned to read a parameter. The more people who read it, the more likely one reading will come within some specified distance from the real value. So we can expect this distance to be smaller for at least one reading the more readings there are.

Proposition: The higher the level of the information substructure property of fineness, the higher the level of its performance property of accuracy.

Argument: Fineness is the property of a decision rule on reading a parameter that specifically states the size of the neighborhood around the real value of a parameter in which readings must fall. The finer the rule, the smaller the neighborhood and the closer the reading to the real value.

Proposition: The higher the level of the information substructure property of repetitiveness, the lower the level of its performance property of accuracy.

Argument: It is assumed here that familiarity may breed contempt. The more often a person reads the value of a parameter, the less likely he is to worry about the accuracy of the reading. One reason is boredom, and another is the thought that there is no need to worry about accuracy this time since one is to read it again very soon and get it right that time.

Proposition: The higher the level of the information substructure property of range resolution, the higher the level of its performance property of accuracy.

Argument: The increase in resolution allows the reading to get closer to the real value, and so to be more accurate than it would otherwise be.

Proposition: The higher the level of the information substructure property of parameter inclusiveness, the higher the level of its performance property of awareness.

Argument: If a parameter is left out of those assigned to people who are to read them, there is a much lower likelihood that it will be read at all. People in the organization are thus less likely to know what their values are.

Proposition: The higher the level of the information substructure property of diffusion, the higher the level of its performance property of awareness.

Argument: The argument follows directly from the fact that the second measure of awareness is directly derived from that of diffusion. As we increase the means by which people get the values of parameters, by reading them or by getting messages which tell them what they are, we increase the number of people who know the value of one or more parameters.

Proposition: The higher the level of the information substructure property of redundance, the higher the level of its performance property of awareness.

Argument: The more people who read variables, the more variables the value of which people know.

The performance property of awareness that is relevant is that relating to the knowledge the rule users have of the values of the variables that define the domains of their operating or reward decision rules. Only the awareness of the value of the variables relating to operating and reward rules is relevant. This is the awareness that affects the level of consistency between the operating substructure and the other two. Whenever the term awareness is used without any modifier, it refers to this awareness, that is, that which relates to consistency.

## 3. Performances of the Information and Operating Substructures

When we made the propositions in which we showed the connections between the levels of the properties of the operating substructure and the levels of its performance properties, we did so under one important assumption. This was that the operating substructure was to be accompanied by an information substructure and a reward substructure that were consistent with it. The effects of comprehensiveness and fineness on coordinatedness will not be as we said they would if the information substructure did not supply the rule users with the information that would allow them to use these rules. Consistency in this case means that the information substructure must be designed to supply exactly that information. We again assume this consistency when we tackle the next set of propositions. There are two more sets for the information substructure. The first involves the direct relation between the properties of this substructure and the performance properties of the operating substructure when the two are consistent. The second set involves the relations between the performance properties of these two substructures, again assuming they are consistent. The first set is not needed if we do two things. First, we show how the information substructure properties are related to its performance properties. Secondly, we show how the performance properties of the information substructure relate to the performance properties of the operating substructure. We have just done the first for all the information substructure structure properties and its performance properties. Now we make propositions of the second kind. All the propositions will be used to derive design rules that produce consistent and efficient substructures.

Proposition: The higher the level of the information substructure performance property of awareness, the higher the level of the operating substructure performance property of coordinatedness.

Argument: Higher levels of awareness means that the values of more parameters are known by people in the organization and used in decision making. This means that more people know the values others are giving to their decision variables. Knowing what others are doing allows the decision maker to adjust his choices of decision variable values to fit better those given other decision variables by other people. He has the capacity to make the adjustment that coordinates his decision with those of others. Whatever coordination is obtained in this case is left to the rule users to determine, and how much one actually gets is not as clear as it was in the case of specific operating rule properties used to get coordinatedness. One can hope that the greater awareness will prompt the users of the operating decision rules to expand them by incorporating the new information.

Proposition: The higher the level of the information substructure performance property of alertness, the higher the level of the operating substructure performance property of responsiveness.

Argument: The level of responsiveness is determined by the time it takes the operating substructure to get the new performance activated after the environment changes. This time is made up of two segments of which the first is the time from change to the reading of the new condition, and the second is from the time of this reading to the time at which the new performance is activated. The higher the level of alertness, the shorter the first time segment, and also the total of the two.

Proposition: The higher the level of the information substructure performance property of alertness, the lower the level of the operating substructure performance property of coordinatedness.

Argument: As we stated earlier, the levels of some information substructure performance properties that produce high levels of alertness also produce low levels of accuracy. This in turn reduces the level of coordinatedness, as shown in the next proposition.

Proposition: The higher the level of the information substructure performance property of accuracy, the higher the level of the operating substructure performance property of coordinatedness.

Argument: Higher levels of accuracy mean more nearly correct values of parameters. This in turn makes the values given to the decision variables closer to the most coordinated set than otherwise. Truer facts make for more real coordination.

Proposition: The higher the level of the information substructure performance property of accuracy, the higher the level of the operating substructure performance property of controlledness

Argument: Knowledge of the values of decision variables is necessary for whatever process is needed to make the values what they ought to be. To control the values of decision variables, it is necessary to know what they happen to be now. The feedback of control theory is the content of awareness.

Proposition: The higher the level of the information substructure performance property of accuracy, the higher is the level of the operating substructure performance property of optimality.

Argument: The argument is analogous to the previous one. Truer facts make for better decisions.

Proposition: The higher the level of the information substructure performance property of awareness, the higher the level of the operating substructure performance property of coordinatedness.

Argument: The more parameters values are known to people in the structure, the more likely are the decisions made to be based on other decisions, and hence to be coordinated with them.

Proposition: The higher the level of the information substructure performance property of awareness, the higher the level of the operating substructure performance property of optimality.

Argument: More information, the result of more parameters the values of which are known, should lead to better decisions. Since outcomes depend on parameter values and decision variable values, the optimality of the latter depend on the former. Knowledge of the values of more parameters should allow for decision variable values that are closer to the optimal. Awareness is what results from the distribution of knowledge that Rulke and Galaskiewicz(2000) studied and connected to performance, and distribution is what we defined as diffusion. This substructure property along with others, such as redundance, determine the substructure performance property of awareness, as we have shown in previous chapters.

Proposition: The higher the level of the information substructure performance property of awareness, the higher the level of the operating substructure performance property of controlledness.

Argument: The basic theory of control developed earlier shows that knowledge of the values of the variables not under control, i.e., the parameters, is critical to the process of control which involves the setting and resetting of the values of the variables under control, i.e., the decision variables. The more parameters the values of which are known, the greater the number of decision variables the values of which may be brought under a positive level of control.

## 4. Reward Substructure Properties and its Performance

That rewards affect the performance of the operating substructure goes without saying. Properties of the reward substructure along with those of the other two substructures are closely related to the performance properties of the operating substructure. What it means to get the reward substructure to fit with and be consistent with the other two is to design all three to get as much out of these relations as possible. As it was with the information substructure, there are two kinds of relations that need to be explicitly identified and explained. First, there are the connections between the properties of the reward substructure and its own performance properties. Secondly, there are the connections between the performance properties of the reward substructure and the performance properties of the operating substructure. Connections of both kinds are established and discussed. However, we cannot strongly support the connections without discussing at length the nature of humans, something that is beyond the scope of this work. All we can do is identify some propositions that specify and explain the connections of either kind on the assumption that humans are self interested and capable of reasoning when they make decisions.

Proposition: The higher the level of the receiver orientation property of the reward substructure, the higher the level of its performance property of emotional richness.

Argument: The performance property of emotional richness is directly defined by the choice of the ranges of the reward rules and by the values assigned to these by the rule mapping. The only things one can say without great analysis of human behavior, is that the richness of the rewards is obtained by specifying the dimensions of the range based on the dimension of the receiver's goals, the things he values.

Proposition: The higher the level of the receiver orientation property of the reward substructure, the higher the level of its economic richness.

Argument: The element of the range is in the form of a vector of rewards: money, time off, health benefits, accolades, or whatever. If these components are those which the reward receiver values, and if they are set at values according to the receiver's goals and preferences, then they will have a higher economic value. Thus, the person whose goals are heavily weighted in favor of money would get more here and less time off. It is also true, and obvious, that increasing the amount of any one of these, money or benefits, or whatever, will lead to increases in the performance property.

Proposition: The higher the level of the of the reward decision rule domain-domain connection of the reward substructure, the higher the level of its performance property of interdependence.

Argument: The interdependence property of performance makes rewards to one person dependent to some extent on the rewards given another. One way to get this connection is to make the reward rules of the two have mappings with domains that intersect. One may put in the domain of one any variable from those defining the domain of the other, such as, what the other does, or what the outcome is of what the other does.

Proposition: The higher the level of the reward decision rule range-domain connection of the reward substructure, the higher the level of its property of interdependence.

Argument: The argument is analogous to the previous one.

Proposition: The higher the level of the reward substructure property of ownership, the higher the level of its performance property of emotional richness.

Argument: Ownership entails the participation of the receiver in the making of the rule. This reduces the likelihood that her goals are misconstrued when the rule is made. The participation is also likely to increase the level of the receiver orientation of the rule. Both these effects reflect on the level of the emotional richness of the reward rules of the receiver who is involved in making them.

Proposition: The higher the level of the ownership property of the reward substructure, the higher the level of its performance property of economic richness .

Argument: The argument is analogous to the previous one.

Because of the importance of the fairness property of the reward substructure, we will discuss how to get it and how it affects operating substructure in a section all its own, and even then we will not do it full justice.

## 5. Performances of the Reward and Operating Substructures

In relating the information substructure performance properties to those of the operating substructure, we make the assumption that the two substructures are consistent. We make the same assumption for the next set of propositions relating reward substructure performance properties to those of the operating substructure.

Proposition: The higher the level of the reward substructure performance property of material richness, the higher the level of the operating substructure performance property of controlledness.

Argument: Unless there is consistency, there will be no connection between what people get and what they do, whether that be the making of decision rules, the using of decision rules, or any combination of both. Given there is consistency, then higher reward material richness means greater opportunity costs to noncompliance, and self interest would produce higher levels of compliance and control. However, if rewards get very rich, the marginal value of these costs to the person receiving the rewards diminishes, and higher levels of richness would then lose their connection to compliance and to control.

Proposition: The higher the level of the reward substructure performance property of emotional richness, the higher the level of the operating substructure performance property of controlledness.

Argument: The argument is analogous to previous one.

Proposition: The higher the levels of the reward substructure performance properties of interdependence, the higher the level of the operating substructure property of coordinatedness.

Argument: When rewards depend on outcome, and at the same time the rewards are interdependent, then reward receivers will find it to their advantage to help their cause by helping the causes of others. They will solve their problems in the contexts of the solutions of others, and that will produce coordinated behavior.

Proposition: The higher the level of the reward substructure performance property of fairness, the higher the level of the operating substructure performance property of controlledness.

Argument: This argument is developed at some length in the rest of the chapter when we discuss the concept of fairness in some more detail.

## 6. The Fairness Property of the Reward Substructure

One property of the reward substructure performance that is of great importance is that of fairness. The concept refers to the state of one or more persons and to something about what that state is and what it ought to be. It always carries some such moral element, which may or may not include a comparisons basis. Most uses of the concept involve a comparison of the states of two or more persons. In this usage, to say that one person's state is unfair is to say that this state is not what it ought to be, given that the state of some other set of people is what it is. A set of people is required in this use of the concept. The make up of this set is a decision that has to be made by the maker of the statement about fairness. It is often the case that the set of people included in the comparison is not identified explicitly, but the existence of some such set is implied. In this latter case the meaning of fairness is not clear. Meaning is clear only when the set is identified, and the relevant states of its members specified.

Interestingly, the choice of this set is itself subject to a claim of fairness. One might argue that the fairness of the state of person W should or should not be established in the context of the state of person Y. Something about the fairness of the use of the concept of fairness is implied here, and a concept of meta-fairness may well be what we need to capture this use of the term. More on that later. But for now, the identity of the people in the comparative set and the dimensions of the states identified for each are critical elements in the meaning of the concept of fairness when used comparatively.

Much information on fairness is available in the works of Thibaut and Walker (1978), Earley and Lind (1987), Lind and Tyle (1988), Tyler (1990), Folger and Konovsky (1989), Baron and Cook (1992), Boettger and Greer (1994), Brockner and Cooper-Schneider (1992), Van den Bos, Lind, Vermunt, and Wilke (1997, 1998). In this literature the object is to uncover the way people evaluate the fairness of their rewards and the effects these evaluations have on their behavior. A basic concept underlying this research is the distinction between the process by which the reward is determined and the reward itself. Both are subject to fairness evaluations. These are uncovered in theory and experiment. How people respond to various fairness evaluations is also explored. Examples of analytic functions which the designer of an organization structure may get from this research is the effect of the adversary system on fairness perception (Walker, LaTour, Lind, and Thibaut, 1974). Another source would be the work on the fairness perception of the jury system (Davis, 1980). Also useful is the work that combines a number of different variations in the process and looks for the fairness evaluations of these many forms of elements of the reward procedure or process (Folger and Kosovsky, 1989). The combination of the fairness of the process with that of the outcome is producing more realistic descriptions of the way people assess the fairness of the rewards they get (Van den Boss et al, 1997, 1998). This information is all of great use to our designer, but he needs more.

What the designer needs is the information on how and why a person evaluates the fairness of each of the designer's design variables, and of various combinations of these. The conclusion on the measure of fairness of a person's state is derived from the reward rules. All the components of the rule are involved, and so by extension this property called fairness may be applied to the rule's components. Fairness is a property of the performance of the reward rules, but is so directly connected to the rule components, that people may use the term as if it were a property of one or more components of a reward rule. Its use in this sense of a structure property is metaphoric, but correct. By basing the property of fairness on the reward rules, it becomes a property of the components of these rules. Below we give an operational definition of the property of fairness for each component of the rule and analyze the connection between the nature of the component and the measure of its fairness. From these connections a set of rules for designing the reward substructure are derived and stated in terms of real and identifiable design variables.

Connections between reward rule components and the level of fairness are often quite complex. It may or may not be that the fairness of one component is independent of the fairness of another. There is no reason to believe that people don't trade off the fairness of two components and experiments on only one piece of the process, such as the jury form will not show these tradeoffs. Unless it is shown to be otherwise, one has to assume that the reactions that people have to the reward process are complex and not describable by linear functions. The relations needed by the designer must come from experiments where the effects of one component are measured in the context of control over the others.

An example is the case of the manner in which the values of the variables which define the domain of the reward rule are determined. How are the "facts" relating to the dimensions of the domain of a reward rule to be identified, and how does the answer affect people's view of the fairness of the reward? If we are to get the correct relation from some experiments, we have to have experiments that control for the effects of other decision rule components. An experiment to find the relation between the use of the jury system to establish the facts and the level of fairness of the rule needs to control for the effects of the domain definition itself. As designers we need to know the tradeoffs between a jury system and the adversary system that produce the same level of fairness for the process as a whole. Would one's evaluation of the fairness of a jury system with adversarial presentation of evidence be the same as that for the same jury system but the presentation of all the evidence by a single source that is legally competent? Surely, the fairness of the jury system is dependent on the presence or absence of an adversarial system. What this says in simple terms, is that the fairness level given by a person to a process with both these elements may well be more than twice that given to each of the processes, that with only a jury and that with only the adversary system. Without some understanding of such tradeoffs, one would be hard pressed to design a reward system that is of some level of fairness, and is also efficient, or moral, or whatever other property one wants it to have. The distinction between process and outcome and the analysis of the fairness of each separately is only the beginning of what the process of designing a structure needs. By basing the concept of fairness on the reward rule components, and on the components of the information rule that governs the establishment of the facts of the reward rule, we have deconstructed the concept of fairness. Organization rewards are of a level of fairness derived from the levels of fairness people apply to the components of the reward rules. What a person receives and the way this is determined are both elements in how that person and others come to a conclusion on the reward's level of fairness. Most people have a concept of fairness and have no trouble making meaningful statements about the fairness of the performance property of the information substructure and about the fairness of a property of the substructure itself. People also consider the level of fairness to be an important issue, and have no problem conceiving of ordinal levels of fairness. The level of fairness they ascribe to a reward affects strongly their behavior (Sashkin and Williams,1990), (Harder,1992), and (Boettger and Greer, 1994). A designer must rely on the reward substructure of the organization to get control over it and so make it perform in the manner intended. The response of people to rewards is dependent on the fairness they ascribe to these rewards. This fairness evaluation that people have of rewards is sometimes so important that they react to the unfair rewards in a contrary manner (Greenberg,1990). If a reward is seen as grossly unfair by its recipient, he might perform in a manner that is actually contradictory to the one intended by the designer of the reward process.

Fairness need not contain a comparative element and may be applied to the state of an individual without reference to the state of anyone else. However we define state as personal, or economic, or educational, fairness may be defined as a property of that state. A state has many components. One set of these most associated with fairness is economic. Elements of this set refer to variables in the state of the universe which an individual controls, which means that the individual can change their values according to certain rules of transformations, or through exchange. In this case, two persons exchange units of these variables so that the components change values according to specific rules of the conservation of energy and matter. These components of the state of the individual are allocatable, which means that what one controls cannot be controlled by another, and that this component cannot be increased by exchange alone without reducing its level in the state of another. One set of components of a person's state are those the person may use but does not control. Public goods are an example. These too are allocatable, and what one uses another cannot use at the same instant. But not all components of an individual's state are allocatable. There is no reason why increases in one person's control over facts or knowledge held must mean the reduction of knowledge of another.

It is logical and meaningful to apply the property of fairness to the state of a single individual without any reference to any other. It may be said that it is not fair that X suffers such pain. This may be an absolute statement that implies nothing about any other person or thing. It does imply something about the moral value that the speakers assign to the state of person X. The notion of the fairness of a state also implies the existence of some power which brings about the state and is also capable of transforming it into one that is better and more fair. An essential element of the concept of fairness is the belief that some decision is made and that that decision affects the state to which the concept is applicable. The decision is made by some person or persons, or by some other power. Another essential element of the concept is that the state that is unfair can be altered to one that is more fair. The fairness of a state of a person may be the result of how he is treated and changing the fairness of treatment will change the fairness of the state. Thus to say that a person's state is fair, is to say that the person is treated fairly by some power.

Most uses of the concept of fairness involve the states of two or more persons. In this usage, to say that one person's state is unfair is to mean that it is unfair relative to the state of some other set of people. A set of people is required in this use of the concept. The make up of this set is a decision that has to be made by the maker of the statement about fairness. Though the set is often not explicitly identified when a comparative fairness is the concept, it is implied. In this latter case, the meaning of fairness is not clear. Meaning is clear only when the set is identified and the relevant states of its members specified. Interestingly, the choice of this set is itself subject to a claim of fairness. One might argue that the fairness of the state of person W should or should not be established in the context of the state of person Y. Something about the fairness of the use of the concept of fairness is implied here. An issue of meta-fairness may well be what we need to capture this use of the term. More on that later. For now the identity of the people in the comparative set and the dimensions of the states identified for each are critical elements in the meaning of the concept of fairness when used comparatively.

## 7. Fairness of Decision Rule Components

The term fairness may be meaningfully used in reference to any one or combination of the reward rule components m, s, u, and f. The mapping f may be itself subject to fairness evaluation as may its domain, its range, and their association with one another in the mapping. The term fairness may also be used for the analogous components m*, s*, u*, f* of the rule in the information substructure that determines how the values of the dimensions of the reward rule are to identified when the rule is used. It is true that people are mostly interested in the outcome of the use of some reward rule. The range of the reward decision rule is where it all ends. To a horse, that is all that matters, and all that affects its behavior. People, however, are smart enough to want to find out why this outcome came about, or whether this outcome is one in a pattern or is an isolated case. People can predict future rewards much better if they know how they are determined. Reward fairness is a concept applicable to the elements that produce any outcome, not only to the total process by which the reward is determined, but to each and every component of it. These are the components of the reward rule and its information rule. A smart person evaluates the fairness of each component of the reward and information rules, and then combines these evaluations into a concept of the fairness of the whole process. What combinations are made, or how complex they are should be the subject of research into behavior. Until we hear from these researchers, nothing may be ascribed to this personal mapping ex ante other than that it is personal but subject to cultural (Baligh, 1994, 1998) and social forces, and that it is complex and non linear. It involves complex interactions among the variables, interactions which make the effect of the fairness of one component on the fairness of the whole to be dependent on the fairness of other components. We expect this mapping to allow for tradeoffs whereby a change in the fairness level of the domain of the mapping may be coupled with a change in the level of the fairness of the user set that leaves the fairness level of the whole reward substructure unchanged.

Reward rules are defined in terms of components, the first of which is the set of its makers. The make up of this set and the way it is chosen, and so on, are part of the reward process used by people to determine the level of the fairness of the rule's performance that is the reward actually received. The properties of this set of rule makers is subject to a fairness evaluation. For a number of rules, a reward substructure say, the evaluations of the fairness of every rule making set in there determines the conclusion on the fairness of the whole. It is logical to argue that person Y should not be in the set, and to support the argument by reference to one of many properties of this person. The person is not qualified or not entitled to belong, is biased for or against those to whom the rule applies, and so on. The set may be fair or unfair because its members are or are not the correct ones according to some higher rule governing membership. Endless is the list of supports for fairness arguments regarding this set. In law and in organizations this element of fairness gets little attention. Under conditions of democracy, the fairness of reward substructures becomes a non-issue. After all, the set of rule makers is made up of everybody, and what could be more fair than that? The democratic process is used to stifle any discussion of fairness by referring to the fact that the set m is made up of all eligible voters. This argument is especially strong in a democracy that does not constrain the majority by a bill of rights, a constitution of meta-rules. In organizations, property rights may be used to remove any but "owners" from being eligible to be in this set, and so fairness of rewards in an organization is transferred to fairness of the concept of ownership, and so, moved from the specific to a much more general plane of social living. Fairness of the set of reward rule makers of an organization's substructure remains very important with or without attempts to subvert it by using the ownership gambit. In one interesting study it is shown that the social status of the chair of the compensation committee of the board directors relative to the social status of the CEO has an effect on the reward given the latter (Belliveau, 1996). The level of the fairness of the reward is logically tied to these properties of the social standings of the people who make the rules. Social status is carefully defined here in terms of university, clubs, etc., but it is obvious that issues of race, ethnicity, etc., also enter into the perception of this set's fairness.

Just as the set of people who make the rules is subject to a fairness measure, so is the set the people who make the information rule that goes with the reward rule. The argument here is directly analogous to that of the reward rule makers. But this is not the end. We have the set of people to whom the reward rule applies, the set whose rewards are determined by use of the rule. Members of the set may be considered to be too dissimilar one from the other, or may contain no consideration for handicapped people, or may not be a logical fit with the reward mapping. Then there is a fourth set that is also subject to fairness evaluations. This is the set that uses the reward rule. A fifth set also subject to fairness evaluation is that which uses the information rule that goes with the reward rule. Makeup of either of these is fair at some level or another based on bias, race, or whatever. This set is the one that establishes what the facts are according to the information rule it uses. Then with these facts, the set uses the mapping of the reward rule to get the reward. The user set is the one that establishes the one vector among the many in the rule's domain that is the one that is true, the one that is factual . This vector contains the actual values taken by the dimensions in the domain of the mapping. If the mapping has as dimension total sales made by Y, then it is the user set which determines what this amount is in fact, in any given period.

Facts are critical in the reward process. Whatever the decision rule on information may be, it cannot remove completely the discretion that the set that uses the information rule has in determining what the facts are. Reading the facts is the job of this set, and reading the facts is not always a simple act. It can be too easily turned into making the "facts". Lying, or simply erring, are always possible whatever the information rule. The identity of the members of this set is very important to its fairness, and this to the fairness of the whole process. Anglo-Saxon law puts almost all its efforts to get fairness on this part of the rule. The members of the set are chosen after a process that allows for exclusion of people by the sides in the dispute. The object of these rules is to remove bias, or keep it in one's favor, predetermination of facts, etc. Fairness in law is the object of these rules. This set is given the power to determine what the facts of the case are.

The process by which the facts are determined affects what are accepted to be the facts. A jury does not uncover the facts by observing the real world, or by running tests on what it finds, or by asking questions of people. It hears statements about what the facts are purported to be. It hears them from two groups, each interested in giving only those facts which when used by the jury in the rule mapping produce the reward outcome which the fact presenter desires. The jury is part of the set that uses various information decision rules to decide what the facts are, or the place in the domain of the reward rule that is to be mapped. It may also apply the mapping and get the reward, or it may stop there and other members of the rule user set apply the mapping to the spot in the domain chosen by the jury. The jury does not get to determine the dimensions of the domain of the reward rule mapping, that is the kinds of facts it is to determine. The judge determines what purported facts the jury is to hear and determines which are so and which are not so. In fact, the set of users of the reward rule is divided into two sets, the judge and the jury. Again, the idea is to promote fairness and to make for an expert determination of the domain of the mapping and the process of reading facts. These last two refer to the relevance of evidence, and given its relevance, its admissibility. The problem deals with the determination of what reality is.

Using a jury is just one among the very many ways of going about determining which vector in the domain of the rule mapping is to be the one used when the mapping is applied. To measure the effects of using a jury against those of no jury on the fairness of the rewards gives us a measure of only one aspect of a reward rule. It does so without controlling for other components (Davis, 1980). This information is of limited use for the designer who is interested in the individual and combined effects of all the fairness evaluations of the components, and in the rates of change of these measures. Thus, one might well ask how people are to evaluate the jury system when they are not told anything about the mapping of the reward rule that uses the facts established by the jury. The jury system may coupled with a mapping that takes each element in the domain, the one the jury specifies, into a small set of rewards that differs from the sets specified for other elements. The same jury system may be coupled with a rule that maps most elements in the domain into the same set of few rewards. In the first case, the decision rule has a high level of fineness and a low level of lumpiness. In the second, the decision rule has exactly the opposite of these levels. It matters what the jury decides what are to be the facts in the first case, but matters very little in the second. One would hardly expect that a person asked only about the fairness of the jury system in the two cases would give the same answer as she would if she is told that one case has high levels of rule fineness and low levels of rule lumpiness, and that the other case had the opposite.

The domain of the rule mapping is an obvious subject of the fairness argument. An example of what people conclude about the fairness of the domain of the rule mapping is that of a very highly regarded public school and the choice process used for the admission of students. The present system uses an examination that is a multiple choice one. The subjects of the multiple choices are chosen by some set of rule makers. The specific nature of these subjects and the answers given them in sets of multiple choice tests define the domain of this reward rule. One administrator says that such tests are unfair to certain groups. The implication is that the choice of subjects is not fair. He could also have argued that the multiple choice restriction is unfair to some groups, but he did not. The counter argument by another administrator is that nothing could be more fair than a simple multiple choice test, because it is objective. The arguments cover two aspects or properties of the domain of this rule on admission. Neither argument contradicts the other, and the second in no way counters the first, as intended by its formulator. The two people are not talking about the about the same thing. They are both talking about the same decision rule, but about different components of the rule. One is talking about the set of variables that make up the dimensions of the domain of the rule, the contents, and subjects of the test questions, and the other is talking about reading the values of the variables. In summary, the domain of the rule mapping consists of a set of components, and of sets of values one for each component. There is one set for each component, and each set contains the values which the component may take. In the case of the test, the components are the specific questions asked, and the values which each component may take are only two, correct or incorrect. These are then "added' in some ways to give number scores which then make up a vector which is one element of the rule's domain.

At the heart of the reward substructure is the mapping of the rule which is subject to fairness evaluations. A mapping describes how the vectors in the domain are transported into the range. It may do this in one step, or two. In this case the first rule takes the vector in the domain into a vector in another domain. For example, it takes all the evidence the jury hears into the range of guilty or not guilty. The second rule takes this domain to the sentencing one. Here, the rule first describes what we have to do to the values of variables in the first domain to get us an element in the second. It may describe the basis for associating an element in the domain with one in the range. In its simplest form, it is a list of pairs. Whatever form it is in, it states a logical order to be imposed on the elements of the set that is the domain, an order that pairs each with an element in the set that is the range. One may find the order explicitly stated, or one may infer it from the list of pairs that describe the mapping in extensive form. If no order exists in some or all of the mapping, then we have a random one with no order. One may subject a logical order to a fairness evaluation. When the mapping is random, then of course, its very randomness is an appropriate subject of a fairness argument.

One mapping may be fair or unfair to whatever degree because it weights one factor more than another. It may be fair or unfair because it associates some domain dimensions with some range dimensions in different degrees of strength. An example of the first case may be an argument over the fairness of the heavy emphasis given by the mapping to the measure of time in system. People with more years in the organization are given very large salaries, or very low ones, with work quality being given much less or much more weight by the mapping. Of the second case, we have the example of a mapping that gives work attendance very heavy weight in public commendations and very low weight in money, while giving work quality the inverse weights of low in commendation and high in money.

Fairness may be focused next on the range of the mapping of the reward rule. Most issues of fairness seem to be about this part. It is after all the part that seems to count most in a world where what one gets, has, etc. matters a great deal. This is the part excluded by the literature from the process or procedure and is called the outcome. We may still call it the outcome, but we need not separate it from the process. If the mapping is in the process, then so is its range or the outcome of the process. This is where the focus on actual allocation comes in. It is where most people think fairness is all about. Despite the fact that such is not the case, as we have already shown, this is still an appropriate subject of fairness. It is a simple one involving comparisons of the outcomes of the mappings application. It merely compares who got what. Used by itself, this subject needs only a definition of a set of people among whom the comparison is made. Any set will do. Disagreements on the fairness of outcome may be applied to the outcome given a specified set, or may be about the nature of this specified set. Once the latter becomes the issue, it becomes no longer meaningful to talk of the fairness of the allocation.

Reward fairness is a concept that is fundamentally about what is given by the organization to a person, i.e., about the performance of the reward substructure of the organization. Its use in the process of designing an organization is in its derived meaning. It is what it connotes rather than what it denotes that matters. It is when fairness is connected to the specific components of reward rules that it becomes useful to the designer. Once we identify the reward rule and its matching information rule, then the reward actually given in a specific case is directly obtained from the use of the two rules. Everything about the reward which is the outcome of using the rule can be traced to one or more of the rules' components. It is best, therefore, to take any issue of fairness of outcome and break it down into one or more of the issues of fairness of the rule making set, the rule using set and its rules of reading facts, the domain of the mapping, the mapping, and the range of the mapping. Any person who is interested in the fairness of one and only one reward need worry only about the outcome. Though this case may be important for one accused of murder, it is inadequate even for him if he has some mechanisms for appeal. Most people look on the fairness issue in terms of more than one application, and are interested in the use of the reward and information rules over time (Brockner, 1992). Since the same rule may give different outcomes, many of these may be needed for people to decide on the fairness of the rule. In organizations, members are usually given their rewards a number of times over their careers. The fairness of their treatments can only be determined by them if they evaluate the rule itself and the series of outcomes.

## 8. Organization Rewards and Fairness

Fairness of rewards in an organization is very likely to influence the decision making in all substructures. That is why the subject is important to designers. Regardless of the intent of the reward givers, perceived fairness will affect the performance of those rewarded (Harder, 1992), (Boettger and Greer,1994). Culture determines in part the magnitude of this effect. One can argue that fairness is a concept understood in most if not all cultures. The concept that a person has some level of control over the outcomes of what he or she does, causation, is also common to most cultures. Performance is related to outcome. The introduction of the decisions of third parties into this relation brings up the concept of fairness. This is true especially when the third party is a set of humans, but also when it is a set of gods or spirits or energies. We assume this to the case, and if it is not true of all cultures, then we assume it is true of most.

In organizations, rewards are the main tools of control over behavior. In terms of decision rules governing the operating variables of the organization, rewards are the mechanisms by which rule makers affect the probability that the rule users will use the decision rule mappings of the three substructures. When an operating decision rule mapping is not comprehensive or fine (Baligh, 1990), it allows the user a degree of discretion, meaning that he could do many things and still be following the operating rule. In this case, the reward may be used not just to get the user to use the rule correctly, but also to get him to use his discretion in a way that serves the goals of the organizations. Rewards are mechanism that can be used to get higher levels of performance optimality and coordinatedness. In order to get any such effects, reward rules must be designed in the context of the operating rules the control of which the reward rule is targeting. If the person who is the object of the reward rule considers it unfair, then that person may intentionally disconnect the rule from his/her use of the operating rules. The person may also respond in a contrary way and subvert the operating rule (Greenberg, 1990), (Harder,1992). The argument is that the effect of a reward rule on behavior is determined by the understanding of that effect by the person who is the object of the reward rule. Whatever the rule maker's intentions and explanations of the rule may be, the rule's effects on the behavior of its object person depends on that person. If, therefore, this person considers the rule to be unfair, she would behave in a way that makes its effects different from what the rule maker expected. However well designed the reward rule is and however closely it fits the operational decision rules, its fairness may be cause for turning the good fit into a bad one. It may do so or not, depending on the extent to which the person whose reward the rule covers considers the rule to be unfair, and on the component of the rule which that person considers to be the source of the unfairness.

Whether any reward rule will be considered unfair is a function of both the culture of the society (Baligh, 1994, 1998) of the person rewarded, and also of the psychology of this individual. This might be the result of personal feelings of persecution, or whatever. The effects of culture may rest with such concepts as that of ownership, or be the result of the belief that God determines all earthly rewards, and He is not subject to fairness measures on this since He rewards piety, and these rewards are only in the after life and are guaranteed by God's promise. Even though fairness is in the mind of the person to whom a reward rule applies, understanding the components in the rule that produce the conclusion in this person's mind is useful to the design decision. We may change the bad parts of the rule or replace the person. For one or two people in the organization this may be adequate. It is not so for designing a number of rules for people in general, rules that don't need changing to fit this particular person or the other.

Unfortunately, such generality is not too easily obtained. It is very difficult to get general agreement on fairness because people differ and because the fairness of the rule is some personal function of the fairness of all the rule's pieces. Suppose we set up an experiment in which we identify a set of people and a reward rule for each of them. We then show the set and the rules to some experiment subjects and ask them to tell us the degree of fairness of one specific rule applicable to one specific person in the set. Are we likely to get all kinds of different responses? Could the responses differ even if the set of people is accepted by all respondents as being an appropriate one? Would we get any answers that would change if a comparison of two reward rules for two people in the set were being evaluated? What does it mean to say that this reward rule for X is fair to a high degree, but is fair to a low degree when that rule is used for Y? For example, is it meaningful to say that Harry should be hanged for his crime, but that Harry should not be hanged for that crime if Bill is not hanged for his crime? Is fairness a concept to be found in all cultures. How does it differ from one culture to the next? Are there reward rules to which the concept is not applicable, as for example in the case of the reward rules that stem from perfect markets and democracy? If the answer is yes, then are the two systems themselves subject to the concept? Could one argue that though the outcome of a perfect market cannot be fair or unfair, it is correct to argue that the perfect market itself is a fair or unfair basis for reward rules? Do nonhuman animals ever exhibit behavior that could logically be considered to be based on some concept of fairness? Much work needs to be done on this general topic of how people conclude that a reward rule in an organization is fair, or quite fair, or unfair, and so on.

## 9. Fairness and Reward Substructure Design

Results from the different experiments that have been conducted and reported in the literature mentioned above give much insight into how specific elements in the process by which the reward is determined relate to a person's conclusions about the fairness of the reward itself. Knowing these connections is of help to the designer of the structure, but she needs more. She could put to good use knowledge about how the levels of fairness which a person ascribes to these design variables are put together by that person to get him to a conclusion on the level of fairness of the whole reward system. She needs to know how people trade off the fairness level of one component of the reward rule for the fairness level of another component. She needs to know how reward fairness affects the behavior in response to that reward. The reason this information is needed becomes clear when we look at what the designer does. The general problem she has is to design pairs of rules, one reward rule and one information rule that matches it. It is understood that both rules are the subjects of fairness evaluation by those rewarded and their conclusions on this affect their behavior in ways that are yet to be understood at the high levels needed. The designer needs information on the complex interactions and tradeoffs that are used by people to determine the fairness of the reward they get. It is important to know something about these, so that one might use the most efficient combination that will get any given level of fairness. Both the performance of the reward substructure and its cost are important to the designer (Baligh, 1998). The problem for the reward part of the structure is to get such an efficient design. To get this design, it is necessary that fairness, along with other properties of the reward substructure be linked to both performance and costs. As mentioned earlier, the information on these links that exists today (Zenger, 1992), (Boettger, and Greer, 1994) is not yet in the proper form for use in the design of organization structures.

In summary, the designer has the job of identifying a set of reward rules and matching information rules with the object of getting a performance from the organization structure that is a good one in terms of its outcomes and its costs. That might mean maximizing some function of performance and costs, or it may mean the best structure for the costs, or a good structure for the costs. The rules the designer creates affect the costs of the operation of the organization's structure in ways which the designer needs to uncover for his particular circumstances. He must do the same for the relation between performance and outcome. For the reward substructure alone, the problem is to make a design that fits some given operating substructure, i.e., one that minimizes the cost of the fairness level specified or one that maximizes the fairness for a given cost. General analytic treatments of these relations and their use in the process of designing organization structures may be found in the literature (Burton and Obel, 1998). The designer of a structure is interested designing rules that have the right balance between performance and costs and needs to know what costs are incurred in designing and maintaining different rules. He needs information on the relation of costs to the specific rule components chosen and to the combinations of components.

## 10. The Elements of Fairness

The term fairness may be meaningfully used in reference to the mapping of the rule, the domain of the mapping, the range of the mapping, the set of makers, the set of users, and to all the components of the rules that are used to establish the specific value of each element in the domain that is used in the use of the rule. Ultimately, people may be interested in the outcome of the use of some reward rule. However, they are also smart enough to want to find out why this outcome came about, or whether this outcome is one in a pattern, or is an isolated case, or whether what they are told are the reward rules really are the ones used. Because the concept of fairness involves so many dimensions, its evaluation by one person in a specific case may well be very different from that of another. The set of makers of a reward rule is subject to fairness evaluation. On person may argue that it is unfair because person Y is in it. To support this conclusion the evaluator can argue by reference to one or more of the many properties that one might apply to the person Y. The person is not qualified or not entitled to belong, is biased for or against those to whom the rule applies, and so on. The set may be fair or unfair because its members are or are not the correct ones according to some higher rule governing membership. Endless is the list of supports for fairness arguments regarding this set and endless may be the number of evaluations of the fairness of this rule.

Despite these possible variations in the evaluations of fairness, it is possible to uncover some similarities in the bases of the arguments various groups of people use. These bases are embedded in the complex and strongly interrelated values taken by properties of the culture of a people. Baligh (1994, 1998) argues that cultures, characteristics of people and their behaviors, may be analyzed in terms of components, such as fundamental beliefs, values, etc. and that many if not most of the characteristics of a culture may be logically derived from combinations of others. One may use this argument on the concept of fairness to explore the conclusion that because people have the same way of evaluating fairness in general, they will show substantial similarity in their evaluations of the fairness of the set of makers of reward rules. In some cultures the concept of fairness and the bases for its evaluation issue are derived from some basic specific beliefs that people have, some specific basic values they adopt, and the specific logic they use to translate the first two into action. Suppose people believe that they have a high level of control over transformations in the real world. They also believe that it is possible to identify the specific segment of the output of a group that is the result of the presence of each member of that group. And, they believe that the output of the group working together is larger than the sum of the outputs of the individuals working separately. These people use a logic based on a concept of truth that is comprehensive, exclusive, and binary. They value control over material things very highly, and they value the condition in which each individual is in control of his actions. All this leads to some compromises, one of which involves very different levels of participation in the making of different rules. Operating rules and their attendant reward rules, which government creates in order to allow people to live in close proximity, satisfy family and social values, and get the advantages of group work, are the rules which people want. Participation in the making of such rules is preferred by the people who are to use these rules. Every one wants to participate, and all of them value fairness to all involved. Both requirements are met by the democracy form of government. So that is what is chosen and is applied to all rules. Each individual, however, does not value fairness and participation at the same levels for all rules. There are some rules he wants to control. He prefers that he participate, and that no one else does. If a person wants to participate, it does not mean he wants others to do so, but fairness says that it does mean just that. There are rules which the user wants to control and that means excluding the participation of others in making them. Here control over the rule is the goal. That translates into the concept of ownership and more generally freedom. The high importance of such control, a strong concept of ownership, coupled with a high value of material things, may be what people value. This is freedom, the removal from the set of rules, makers of others than the users. Capitalism is a structure where rule used by a person on the fate of elements of a set of material things he owns does not have anyone other than that person participate in making it. What determines the set is the concept of ownership which is accepted by people. The set of decisions that a people allows to be the objects of rules that have participation by users in their making determines the extent to which the people have participation and freedom. The larger the set, the more democracy the people have. The smaller the set, the more freedom. The people's concept of what fairness is and what is fair or not in this or that case is related to the levels of democracy and freedom which the people choose..

In the case of the fairness of the user set of a reward rule for a person, the arguments are on the concepts involved in determining what the facts are and on the level of participation in this process. The user set of a rule is the one that establishes the actual values taken by the dimensions in the domain of the mapping that is given by the rule. If the mapping has as dimension total sales made by y, then it is the user set which determines what this amount is in fact in any given period. Reading the facts is the job of this set. What it concludes are the facts determines the vector in the domain of the rule it uses, and this determines the reward. There are two aspects of the user set. They are independent of one other. There is the makeup of the set of users, and there is the process by which they are to establish what the facts are. The first is an element of the reward rule; the second is an element of the information rule that accompanies this reward rule. An example of such a pair is the "jury" system of Anglo Saxon law. The members of the set are chosen after a process that allows for exclusion of people by the sides in the dispute. The object of these rules is to remove bias, predetermination of facts, etc. The resulting set is the jury which is given the power to determine what the facts of the case are. But it does not read nor does it uncover the facts for itself. It is given what are purported to be facts by two groups, each interested in giving only those facts that produce the required outcome when the mapping is applied. The jury also does not get to determine the dimensions of the domain of the mapping, nor the facts on the dimensions of the domain that it may be told are so. The judge does that, and the facts of a case are determined from a set of users made up of two nonintersecting subsets, the judge and the jury. The judge determines what variables are in the domain of the rule, and the jury determines the values each of these variables has. Again, the idea is to promote fairness by making the user set have no one from the maker set in it.

In organizations this aspect of rule fairness is a special case of the general one because the interests of the maker and the person to be rewarded converge. It is recognized that the rule user is the facts reader, and therefore, ought to be in the appropriate position to read them correctly. Correctness is important to the maker, and to the person rewarded. What is appropriate is defined in terms of access to the facts and the expertise to measure them. All the baggage of how to read the values of variables comes in here. Since these rules may affect what facts emerge, they too are subject to fairness measures. The domain of the rule mapping is an obvious subject of the fairness argument, as in the case described earlier of recent discussions of the choice process used for admission to a very highly regarded public high school. The confusion in the arguments of the people show that fairness in indeed a complex matter. In summary, the domain of the rule mapping consists of a set of components, and of sets of values, one for each component. Each set contains the values which the component may take. In the case of the examination, the values for each choice are only two, correct or incorrect. These are then "added' in some ways to give number scores which then make up a vector which is one element of the rule's domain.

Next we have the mapping itself. This too can be the subject of fairness. A mapping describes how the vectors in the domain are transported into the range. It may describe what we have to do to the values in each vector to get the subset in the range with which we pair it. It may describe the basis for associating an element in the domain with one in the range. In its simplest form, it is a list of pairs. Whatever form it is in, it explicitly states a logical order, or else one can infer the order from the list. If no order exists, then it is a random mapping. It is the logical order that may be subjected to a fairness measure. When the mapping is random, then of course its very randomness is an appropriate subject of a fairness argument.

One mapping may be fair or unfair to whatever degree because it weights one factor more than another, or because it associates one component of the range elements with one or another dimension of the domain. An example of the first case may be an argument over the fairness of the heavy emphasis given by the mapping to the measure of time in system. People with more years in the organization are given very large salaries, or very low ones. Of the second case, we have the example of rewarding lower absenteeism with public commendations, and rewarding lower errors with money.

Finally, there is the range of the mapping of the rule. Most issues of fairness seem to be about this part and it is after all the part that seems to count most in a world where what one gets, has, etc., matters a great deal. This is where the focus on actual allocations comes in, because it is what most people think fairness boils down to, what one gets from the reward substructure. Fairness here is a simple concept involving comparisons of the outcomes of the mappings application. It merely compares who got what. Used by itself, this subject needs only a definition of a set of people among whom the comparison is made. Any set will do, but the argument on allocation needs a specified set. Disagreements on the fairness of outcome may be applied to the outcome given a specified set, or may be about the nature of this specified set. Once the latter becomes the issue, it becomes no longer meaningful to talk of the fairness of the allocation. There are, however, no a priori restrictions on the nature and membership of this set.

Despite the fact that this subject of fairness is the most obvious and the most used, it is the least useful for purposes of analysis and design. Outcome is the result of a decision rule. The designer works with the latter to get the former. Everything about fairness of outcome can be traced to one or more of the components of the reward rule. It is best, therefore, to take any issue of fairness of outcome and break it down into one or more of the issues of fairness of the set of reward decision rules. The fairness of the rule making set, the rule using set and its rules of reading facts, the domain of the mapping, the mapping, and the range of the mapping should be the things to which the concept of fairness is attached.

Proposition: The higher the level of the mapping consistency property of the reward substructure, the higher the level of its performance property of fairness.

Argument: Despite the fact that fairness is in the eyes of the beholder, it is not independent of what he beholds in fact. The analysis of the sources of fairness made earlier argues that to all people including minimally rational ones, fairness is the result of the recipient's evaluation of the nature of a number of components of the rules in a reward substructure, and that the evaluation does follow some rules of logic. One basis that is logical involves the relations between the various components of reward rules and the consistency that exists between them. When people who are given similar operating rules are given similar reward rules, there is consistency in the reward substructure.

Proposition: The higher the level of the ownership property of the reward substructure, the higher the level of its performance property of fairness.

Argument: Ownership allows the receivers of the reward to participate in making the reward rule. Higher levels of it produce rewards more closely matching those the receiver wants. Without any comparisons between receivers, this should make the individual consider the reward to be more fair than one in which he had less say.

Proposition: The higher the level of the involvement property of the reward substructure, the higher the level of its performance property of fairness.

Argument: Before a reward rule is used, the vector in the domain of the rule that describes the facts must be determined. Higher levels of involvement mean greater participation by receiver in the determination of this vector. This participation should increase his/her confidence in the correctness of the facts which the rule decides on. The claim of unfairness based on incorrect facts is removed.

There are connections between the levels of some reward substructure performance properties, and between these levels and those of some operating substructure performance properties. We identify some of these under the assumption that the reward substructure is internally consistent, and that it is also consistent with the operating substructure.

Proposition: The higher the level of the reward substructure performance property of fairness, the higher the levels of its performance properties of emotional and economic richness.

Argument: The argument is best understood when it deals with lower levels of fairness. As the level of the fairness of the reward substructure falls, the values of any given set of rewards fall, and this leads to a fall in the levels of the motivational effects of these. It is not just the reward itself that determines what people do in response, but it is both the reward and what its fairness is considered to be. What people give to the organization is not directly connected to the reward. The balance is between inducements and contributions as March and Simon (1958) state. This is true only if the term inducement means value to the receiver of what the organization contributes to him. Absolute value of the reward to its receiver, whether it is considered by itself or in the context of other people's reward, is determined by the receiver. It is the result of the individual's characteristics and the culture to which he belongs. The level of fairness of the reward rules is in the eye of the receiver. As this level falls, so does the likelihood that the receiver will use the decision rules that define the designed operating and information substructures. The lower the level of fairness that people assign to the rewards they get, the more different will the real structure they create be from the one designed. Not only will this created real structure differ from the designed structure, but the former may be intentionally created to produce performances and outcomes that are contrary to those that would have emerged from the designed structure. Low levels of fairness may lead people to sabotage the organization.

Proposition: The higher the level of the reward substructure performance property of fairness, the higher the level of the operating substructure property of optimality

Argument: Higher levels of fairness increase the levels at which the users of the operating decision rules use the designed rules. However, when the design has rules that are less than maximally comprehensive and fine, they leave occasion for the user to use rules which he creates. The likelihood that these created rules are consistent with designed ones is higher, the higher the level the reward substructure property of fairness. This means a higher level of the performance property than would have occurred if the created rules were less consistent with the ones in the design. The lower the level of fairness, the more likely that people will make less than optimal decisions whenever the designed ones leave the user some discretion. Less fairness means contributions of less effort, etc., in creating these, and hence less optimality.

Proposition: The higher the level of the reward substructure performance property of fairness, the higher the level of the operating substructure performance property of coordinatedness.

Argument: The argument is analogous to the previous one

## 11. Advice on Properties of Master Brewing Structure

When last we spoke with Master Brewing executives, we told them that the performance of the structure they should have was to be much more responsive and alert to changes in the state of its environment, and a little better coordinated and appropriate for that state. This advice is as useful as telling a driver whose neighborhood has grown, and that those who drove cars in it have become more erratic, that he should change his behavior. He should react quickly to what is happening, know what other cars are doing, and try to do the right thing when he is suddenly confronted by change in circumstances. Now we need to tell him what he needs to be in order to be able to do what we tell him to do. We tell him that he needs eyes that focus light onto the retina or very close to it, eyes that are placed to allow big peripheral vision, a large brain, and so on. If the motorist cannot be the person who has these properties, then he might hire a chauffeur who does. We have moved from the needed properties of the performance to the properties that the structure that is to perform in this way is to have. Similarly, we can give MBC advice on the properties of the organization structure it has to have in order for its performance to have the desired properties. Unlike the motorist, the firm can structure and restructure itself, and we can give it a little more help to do it well.

Analytic propositions that describe the relations between levels of structure properties and levels of performance properties are given above. One that is relevant is the one that states: a higher level of the structure property of decision rule fineness and a higher level of the structure property of decision rule comprehensiveness produce a higher level of the performance property of responsiveness. Recall that a decision rule is what people in the organization use to make decisions. It contains statements of the form: if the circumstances are such and such, the specified decision variable is to be given one of the values in some given set. Higher levels of comprehensiveness mean that more circumstances are included in the rule. More fineness means that the values from which the choice of one for the variable is to be made are fewer. A rule is the result of solving problems and storing the solutions. When the decision made meets a basic standard of quality, optimality or coordinatedness, then a record is kept of the circumstance and the decision made for it. When the circumstance occurs one makes the choice on the basis of the list. One may choose the one in the list or make some improvements on it, or whatever. The more the circumstances for which this rule has such a record, the fewer the times the rule user has to solve the problem from scratch to find out what he has to do. If it is also true that the rule has a high level of fineness, the acceptable set of choices is smaller, and the rule user has fewer values from which to choose. Both these conditions mean that over time, more and more circumstance will be in the list for which the solutions are recorded. There will be more of circumstances for which decisions are identified, with fewer and easier options for the user to evaluate, and as a result, the choice of a decision of a given quality should take less time to identify. That is one way of increasing the level of responsive. Another is to decrease the time between the instant when the circumstance became a fact and the instant you describe what it is. How then does the motorist or the executives of MBC get such rules? How do they identify what is to be done when x occurs, before x occurs? The answer is by generalizing from experience, by generalizing from theory and problem solving, and by generalizing from a combination of the two. The motorist goes to school and develops generalizations about what happens to the movement of the car when the brakes are slammed. He may later realize from an experience that what happens depends on the slamming of the brakes and the wetness of he pavement. By generalizing, he develops rules that contain more and more circumstances, and fewer and fewer choices of what to do in each. MBC executives need to develop a structure with analogous decision rules, ones with higher levels of the properties of comprehensiveness and fineness. Other properties of decision rules they should aim for are higher levels of explicitness, ones that require less thought from the user. The salesman may have a rule that states that if the competitor's price falls by an amount that reduces our sales by 4% or more, then set our price at the value that reduces this effect to 3%. This is a rule that is much less explicit than that which states that if the competitor's price falls by $5, then reduce ours by $3. The response time in the latter is shorter, than in the former where there are calculations to be made.

Higher levels of responsiveness are also produced by shortening the time it takes to describe the circumstance after it becomes that. This comes from structure properties such as alertness. There is a proposition that states that higher levels of the redundance property of the information substructure produces higher levels of the performance property of alertness. Another states the same for the property of repetitiveness. Redundance is a property of the assignment component of the information substructure, and repetitiveness is a property of the decision rule component. The first refers to the number of people who are assigned the same parameter variables and so given the job of finding out the values taken by these components of the environment. The second refers to how often a person is to find or read the values. MBC should now consider these two ways of increasing its alertness by reducing the time it takes to realize that a change has occurred. It is advised to design a structure which has a performance with a higher level of alertness than that of its present performance. Over time, MBC should make adjustments in the structure and in the level of the alertness property of its performance. It should obtain some measure of the order of magnitude of the effects of increased alertness on responsiveness and the structure costs of getting that level. It is also strongly advised that substructures designed be consistent internally, and with one another.

NOTE: Charts that contain the propositions of this chapter are in Appendix I .

# CHAPTER 9

# THE EFFICIENCY OF THE DESIGN PROCESS

## 1. Decisions that Precede the Design Process

In Chapter 4 and elsewhere in the preceding analysis, the issue of the consistency between the components of the vector that describes an organization structure and the substructures are discussed at some length. The issue of how to make the designed structure become a real one is to be discussed soon. What we discuss now is the important issue of designing structures that are to make the decisions that will solve a specific set of problems which some group wants solved. The very purpose of the design is to create a structure that performs in a manner that produces an outcome which the designer wants for himself, or for whatever group is involved. The structure is the mechanism for giving values to decision variables which describe a performance that produces an outcome desired by the group. The connection between the performance and the outcome is a set of transformations. If the structure is to perform in a manner that produces the real required outcomes, then the transformations which the designer uses to identify the decision variables and the parameter variables that make up the second and third components of the vector he is creating must also be real. Whether or not the designer gets the real outcome he wants, depends on whether or not he knows the real transformations and uses them when he makes design decisions that specify the fourth, fifth, etc., components of the vector that describes the structure. If the sets of decision variables and parameter variables are not derived from the real transformations that are relevant to the people for whom the organization structure is to be designed, then the efforts of the designer are meaningless. His design is worthless. You cannot design a good structure if you don't understand the nature of the business.

Any process of designing organization structures must start with a given set of decision variables and a given set of parameters. The designed structure is that which gives the former their values, given the values of the latter, and does so for some group of people X with desired outcome Y. If the design is to be useful, then both of these sets must be those which are in the real transformations which the group identifies as describing the real world manner in which they may get their required outcomes. The most basic of all strategy decisions are the choices of the outcomes and the set of connections between what is done and what results. The identification and choice of the real transformations is no easy matter. It involves the understanding of the real world causal relations and the choice of combinations of subsets of these for the organization to operate. This knowledge is the result of the analysis of the nature of the world and of the connections between its components and the determination of which components have values that can be set, which have values that can only be read, and those that have values than can be neither set nor read. All this is useful to anyone if he has some preferences on the values for some of the components of the world. The designer of the organization structure does not necessarily have to do all the derivations of the connections. It would be better if the designer did the derivation himself, so that he may be sure that components two and three of the design vector contain the variables from the real transformations that would produce the world desired. If he derives the transformation himself, then he may be better able to choose from them the sets of decision variables and parameter variables which he is to use. This decision may allow the simplification of the design by excluding some variables which are judged to be of small consequence in their effects on outcomes. The designer may judge both the relevance of a variable and the effects of its exclusion on the design problem, or he may work closely with a transformation expert who does the former while the designer does the latter. If one is to be an expert designer, one who can create designs for different transformations, outcomes, etc., then it is likely that one will not have the time to master both subjects, and working with an expert in each case is probably best. Whatever the connection of the designer to the people who want a structure, the designer must have at hand knowledge of the transformations which the structure will be operating. The detail which the designer can obtain for his design is limited by the detail in which the transformations he knows are given.

If components two and three of the vector which describes the structure must be realistic for the design to be relevant and useful in the specifics circumstances for which it is created, so must be the first component, the set of people. There are a number of considerations that need to be kept in mind when one chooses the people who make up the first component of the vector describing a structure. They cannot be just any set of people, because they are integral parts of the elements of components four, five, etc ., of the vector that describes a structure. They have to be people who have the capacities to do what these components specify for them to do. The people in this set must be able to make the decision rules of the rule component. They must be capable of deriving decision rules that are consistent with those they are given to use. They must be capable of deriving from implicit decision rules explicit rules that are consistent with them. They must be capable of using decision rules that tell them to read parameter variables, and so on. The designers of the structure need to know something about this component before they specify others. One cannot discuss efficient designs without recognizing that a design may never get to be a real structure because the people in it are incapable of making it real. What the designer needs is knowledge about the relationships between people brains and their capacities to do what the design specifies. Only then can he design a structure that is within the capacity of the people in it to realize. The derivation of these relations is needed for the structure to be relevant to the specific case and to be useful. The issue of people and these relations, capacities, etc., is vast and is probably best left to the experts in that field with whom the designer may work to match the design created with the people available, or specified, or whatever. The important thing to recognize is that the structure designed must be such that the people in it have the capacities to make the design become a real structure.

An efficient process of designing organization structures starts by identifying properly its people, its decision variable, and its parameter components. The elements of each of these sets must be real, and as many of them as are needed, be included. Each of these three components is to have elements that are derived from a correct understanding of the real transformations and people that are involved in the specific case before the design is created. There is no such thing as an efficient structure design or a useful one that is not tailored to a specific set of people capacities and realistic transformations. It is important that the transformations that the designed structure is to use be understood by the designer, at least at the level of detail which the design is intended to have. An efficient process of design starts with the decisions on technologies and environment already made and to be treated as givens for which a structure is designed. Once the process of designing an efficient organization structure is complete, or even before then, the decisions on transformations may be revisited, and perhaps changed, or not. If they are changed, then the structure would be redesigned for the new circumstances. The process of designing organization structures is often involved in a series of choices of transformations, environments, and efficient structures. A series of structures may have to be designed in this process of adjusting the pieces to fit one another. Efficiency of a process is certainly desirable, and in these circumstances of its repeated use in any given case, its efficiency is even more valuable. We want the process to design an efficient organization for the set of circumstances and to do so in an efficient manner.

The decision on the technologies that the organization is to operate is really the decision on the basic identity of the organization, determining in general terms what the organization is to do, and specifying what it is and what it is not, and what goals it has. The decisions on what the world should be, on desired outcomes or goals, are followed by decisions on the transformations that exist and include the outcome variables which the organization is to operate. Those are the outcomes containing transformations that include variables the values of which the organization has the power to set. The technologies chosen determine what the environment of the organization is, and so determine in general form what is part of it, and what is not. So the firm that makes a decision to buy a part rather than make it, identifies in general that its connections to the world that lies outside are to include the set of decisions on buying this part. The structure will choose the details of these transactions, and we would want it to do so well. Should the decision be made that the part is to be made, not bought, then the connections of the organization to the world are changed, the transformations are changed, and the structure will also change, and with it, the details of the connections it has with the world.

Even a small change from transporting the organization's product to the location of the buyers to letting them pick it up at the organization's plant and transport it is a change that could have major implications. All aspects of the old environment relating to transportation are no longer in the firm’s new environment. All the decision variables that are related to transportation are no longer so for the organization. Its structure may need changing by removing people, decision rules, parameters to be read, rules on these, etc. The organization's immediate environment is changed. Its identity in terms of what is in it and what is not is also changed. The nature of the set of technologies is the basis for the process of structure design. The efficiency of this process is an appropriate goal as is the goal of an efficient structure. The efficiency of the process of design is well worth investigation.

## 2. Designing for Pieces of Environment

Technologies that the organization chooses to operate determine two sets of relevant variables. The first is the set of decision variables, those the values of which are set by the organization structure. The second is the set of variables the values of which are set by forces outside the organization, and independently of what it does. This set we called the set of parameters. Its elements are the dimensions which define a space we call the environment. A state of this environment, or a description of the part of the world, is a vector of values of the set of parameters. The state of the environment is thus an element of the space defined by the relevant set of parameters. We have often referred to both the space and a state or element in this state as the environment. No confusion exists, however, if the context is clear. Environment properties refer to the environment as a space and are determined by the relation of the elements in the space to one another.

If one had identified an environment with n dimensions referring to n parameters, then one can identify any segment of this space. Such a segment would be an environment that is a piece of the bigger one. Any subset of the original n parameters may be used to define a piece of the environment, which piece is itself an environment that is logically describable in terms of any of the properties defined earlier. Instead of calling an environment changeable on the basis of all its dimensions, or component variables, one might split it into two pieces, one of which is highly changeable, and the other not so. The one average figure for the whole is replaced by two averages that describe more accurately two pieces of the whole. In choosing the variables or parameters to the organization structure that define pieces of the environment, one should have as one's goal the development of an efficient process of design in which the organization is designed in pieces, each of which is created to fit best a piece of the environment. It all starts with the technologies and the total environment.

Suppose the organization operates two technologies that have no parameters in common. In simple terms this means that the two technologies have two environments that share no variable. The environment of the organization is made up of two totally separate pieces. To design a single set of substructures for the one environment of the two technologies taken together would clearly be unnecessary. Whatever the property values that describe this environment may be, it would be much more precise to describe the two pieces separately than to describe them as one. For example, a measure of medium for the property of raggedness for the whole environment might turn out to be two measures of high for one segment and low for the other. The responsiveness in the piece of the structure that the former may require is not required in the second. Two pieces of the structure, one for each piece of the environment, may be more appropriate. It would certainly be better to design two pieces of structure for two pieces of environment if the two technologies shared no decision variables and no parameters.

The first step in an efficient process of design is to identify non-connected and lightly connected technologies, and on this basis create the pieces of the environment that match these technologies. An obvious example is the well studied case of two sets of products that are used to create two divisions in the organization. Two technologies are not connected when they share no parameter or decision variable. They are lightly connected when they share a small number of the parameter sets that are embedded in their definitions. The degree of disconnection is determined by the proportion of parameters shared. This measure of connectedness is necessarily determined by the number of parameters shared by the technologies and not by the number of decision variables shared. Even when they share no decision variables, the environments of the technologies may still be connected.

One basis for having an organization structure with largely independent divisions, is the disconnected environments of two product sets. This does not mean that the technologies of the two products are disconnected in decision variables. If they are so disconnected, then the two divisions or segments of the whole structure can remain independent without any loss of efficiency. If, however, the two technologies share one or more decision variables, then the two divisions created on the basis of disconnected environments cannot remain independent without loss of efficiency.

Nonetheless, as a first step in the process of design, it is efficient to identify technologies with low levels of parameter connection, and on that basis to identify the pieces of the environment that go with these technologies.

Environmental pieces that go with the low level of parameter connected technologies need not be totally disconnected themselves. Design process efficiency may be obtained from using pieces that share a small proportion of their dimensions. Obviously, the less connected the pieces, the more useful they are, and the more efficient their use. When there is a complete sharing of dimensions, or parameters, we are back with the whole environment. As we move from complete disconnection to complete connection, our pieces become less useful. However, the usefulness does not disappear as soon as we leave the extreme.

Each piece of environment will be associated with a set of decision variables. Each of these sets now make up the first component of what we have called a structure or a substructure. Along with this component there needs to be designed the other components or decision rules, etc., and the other substructures. The first component of the information substructure for this environment piece is, of course, the set of parameters that make up the environment piece that goes with the decision variables of the operating substructure. For each piece of the environment we can design an operating substructure piece and the information and reward substructure pieces that go with the operating piece. In all cases, we are talking of designs that are best or of high quality for the purposes desired and for the given environment.

In summary, the process of design begins with the definition of pieces of the environment. Each piece is defined in terms of parameters, most of which are embedded in one or more technologies, and are not embedded in others. Each piece of the environment goes with a set of decision variables, the ones embedded in the basic technologies of this environment. This set of decision variables is the basic component for the other components of the operating substructure that is designed to be efficient for the environment piece. In turn, this substructure forms the basis for the other two substructures, those of information and rewards.

When all the environment pieces are defined and their structure pieces are designed, is the job of design finished? The answer is that it is not necessarily finished. Even if each structure piece is made up of three substructures and is optimal for its environment, the whole may not be optimal. The reason is that the environment pieces are based on technologies that do not share all parameters. But not sharing all parameters does not imply that the technologies do not share decision variables or that they do not share some parameters. The sets of decision variables that are associated with environment pieces are not necessarily disjoint. We are designing structure pieces that are not really pieces, because they share decision variables. Any structure pieces obtained in the first phase of design using environment pieces need to be redesigned and reintegrated. The issue of their fit one with the other needs to be considered.

Even so, it may well pay to start the process of design by looking for pieces of the environment and designing for each a piece of the structure, and then fitting these pieces together by changing their designs at the margins. The more disjoint the environments, the smaller the margins of the changes needed to fit the separately designed structures. The efficiency of this process of defining pieces of environment and designing structures for them is determined by the amount of redesign that is to be made when the pieces are fitted together. These changes are determined by the margin sizes in which they are to be made, which are determined by the degrees of disconnection between the pieces of the environment.

Given a total environment of n dimensions or parameters, what is the best number of pieces of the environment that one should choose in order to make the process of design efficient? Except for the case of some unique set of pieces that are totally disconnected in both parameters and decision rules, the answer to the question is not obvious. As we've said, the answer depends on the degrees of disconnection of both parameters and decision variables. It also depends on the design cost of fitting the structure pieces together, which depends on the number of pieces of structures and on the sizes of the components that describe these pieces. The answer also depends on the returns to the fitting of the structure together, that is, on the degree to which the structure pieces are made to fit one another. What we get for fitting the pieces together at any level depends on the return function that describes the outcomes from different structures. Some functions are such that small improvements in design produce huge changes in outcomes, while others are such that huge design differences produce small changes in outcomes. In the latter case, the fitting process is unimportant, in the former it is important.

Nothing can be said in general about what design process is most efficient. What can be said is that a number of factors determine the extent to which the process should be one based on identifying pieces of the environment, designing for each such piece a piece of structure that is efficient for it, and the fitting all the pieces together to form an efficient total structure for the total environment. These factors are the degrees of parameter and decision variable connectedness of the environment pieces, and the sensitivity of outcomes to total structure quality shown in the outcome function. The higher the first and the lower the second, the more efficient will be the piece by piece process which is followed by fitting the pieces together.

AT&T's decision a few years ago to break itself into three separate pieces might be explained in a number of ways. Management has determined that the three businesses, the transformations and technologies that define them, have three environments that differ a great deal one from the other. Furthermore, all three environments are strongly disjoint. One conclusion is that the best structure for each environment also differs a great deal from the others because the environments are so different. Another conclusion stems from the disjointedness of the environments. It is that fitting the three different structures together is not likely to increase the outcome by much, and is likely to be costly. If further, the three sets of transformations are strongly disjoint, that is they share few decision variables, then the conclusion that fitting the structure pieces together would affect outcome by a negligent amount is further strengthened. Under the circumstances it makes little sense to have one structure instead of three independent ones. To give stockholders maximum flexibility, it makes sense to make the three separate structures or organizations three separate businesses.

## 3. Designing for Pieces of Technology

A technology is an ordered set of transformations, and these are descriptions of parts of the real world. A technology that belongs to an organization, or could belong to it, is one that can be realized by the people in the organization. That technology contains within it the decision variables and the parameters of this organization and its people. Just as the parameters of technologies may be used to create small design pieces, so decision variables may be used to do the same. All the technologies are broken down into sets, each of which has no, or very few, decision variables in common with any other. The cleanest break up would produce subsets each of which is only one technology, and each of these shares no decision variable with any other. But if such neatness is not possible, other overlapping pieces may still be used to improve the process of design, just as environment pieces that were not disconnected may be so used.

Each technology subset may now be considered alone, and a piece of the total structure designed for it. An environment piece will go with this subset of technologies, though this piece is not chosen for its disconnection. In any case, now one can design for a subset of technologies, do it for all the subsets, and then put the whole together, making the adjustments as called for by the fitting process. The more clearly disconnected the technologies, the less an increase in outcome will be produced by the fitting process, as we stated in the case of A T and T. Also, the more disconnected the environments, the less the increase in outcome brought about by the process of fitting together the pieces of structures. Before starting the design process, one would do well to search first for pieces to be designed separately and then fitted together. A good piece, one that will take the least effort to fit to others after being separately designed, is that structure that has a technology set that is as close to being disjoint from any other technologies as possible. The same is true for the structure that has an environment that is not connected to any other environment of the organization. Any time the designer finds a case of disconnection or disjointedness, he would do well to design the substructure for it separately, and then fit it with the others which are designed separately also. The complexity of the design process increases exponentially with the size of the structure to be designed. Any time the opportunity for designing in parts and then putting them together and adjusting them to be consistent with one another occurs, it should be considered quite seriously. What goes into the process of consideration, and how one is to decide which process to follow, needs to be discussed.

## 4. When to Design Pieces and When to Design Wholes

Whether it is more efficient to design pieces of structures separately, and then put them together, or to design the whole structure depends on the magnitude of the task of putting the separately designed pieces together. Bartlett and Ghoshal (1990) state that in the case that one decides to recognize the differences because they are large, and it is profitable to be flexible and do those things that are good in that piece of the environment, the best organization structure is the "Transnational". This is an integrated network of the pieces of the structure each of which operates in one of the separated environments. Whether this organization structure is the best way to put the pieces together into an integrated whole or not, there still remains the problem of designing the structures of the pieces of the whole "Transnational" organization. There is no discussion of this subject, and the authors' conclusions imply that the recommended way of putting the pieces together is independent of the structures of these pieces (Bartlett and Ghoshal 1990). If we are to break up the environment into pieces, then we should design structures for the pieces, and then design the structure that is made up of all of them. If we are worried about the size and variety of the environment and think it is best to break it into pieces, then we should first design the structures for these pieces. Next, we design the structure that is to put the pieces together, and then perhaps change the former, and so on, till we find the best combination of structures for the pieces and the structure that puts them into a structure for the whole environment. What we intend to discuss first is whether or not we should split the environment into pieces, design the structures for them, and then create a structure that contains them. The alternative is to keep the environment whole and design the whole thing at once. In either case, the resulting structure for the whole environment may or may not be anything like the "Transnational". It will likely depend for its form on the properties of the environment, its variedness, size, complexity, and so on.

The decision on designing for pieces first, then for the whole or directly for the whole, depends on a number of factors. First, we must have a logical basis for putting the parts together into a whole before designing the parts. This issue is covered earlier when we discussed the issue of consistency, fit, and match. There we referred to the basic logic of structure addition (Baligh and Damon, 1980) and (Baligh,1990). The discussion of consistency is relevant only if we have a logical basis for matching or fitting pieces of structure. We have discussed this and some of its forms (Baligh, Burton and Obel, 1990, 1992), (Burton and Obel, 1984). The next factor is the degree of disjointedness that exists between the technologies or environments of the separately designed pieces of the structure. Suppose we have decided on two pieces of the total structure that might be eligible for separate design, followed by the design of the elements that will fit them together. One's choice is to follow this piece by piece process, or the one that designs the total structure as a unit. Call them the piecemeal and the one shot process, respectively. How much disjointedness between the technology sets of the two pieces makes the piecemeal process more efficient than the one shot process? The same question may be asked for the disjointedness of the environment, and for both environment and technology at the same time.

Answers to these questions depend on two factors. The first is the process of design one uses for any given single piece of structure for any given technology set and environment. The second factor is the nature of connections that were ignored when the piece was designed separately, but have to be considered when this piece is to be fitted into other pieces. The decisions on what pieces are to be defined separately, and how much retro-fitting is to be done, depends on the facts of the case. The more efficient the process of design, the less advantage there is to designing pieces separately and then fitting them together. The greater the disjointedness of the technologies or environments and the fewer the connections ignored in designing the pieces separately, the greater the advantage of this separate piece design. Each case needs some estimates of these facts before the design process is chosen. But whatever the process one choose may be, what constitutes the piece or whole to be designed are three substructures. They are the operating, the information, and the reward substructures. In turn, each of these has its component elements which are the decision variables, rules, etc. Designing a piece of structure involves the choice of the specific elements of all the components of each of the three substructures. A complete design specifies all the elements of all the components of all the substructures. Less than complete designs are obviously possible, and in most real cases they are the ones sought, and indeed the only realistic ones. Call this the finished form or the one that comes as close to the complete form as we want. However close the design is to the complete form, the decision still has to be made on the sequence of designs that are actually to be identified or created, where each is a modified form of the previous one. Each change is the result of additions to or subtractions from, the previous structure. There exists some way of determining when one has arrived at an acceptable one, the finished form.

Whatever process of design we choose, it has to be a sequential one. Any design must be created one element at a time, one element in the set that is an element in one set that is a component of one substructure at a time. The sequence may or may not have loops in it, places where the move is to a less nearly complete a structure rather than to a more nearly complete one. Here subtractions and additions may alternate. Such changes must be logically possible, and making them must not make the result something that is not a structure. The algebra developed by Baligh and Damon (1980) shows that such additions follow strict logical rules. The process is thus an orderly one of going from one structure to another and getting to the finished form No human or artificial brain can do the whole thing in one shot. No painting, no literacy work, no house design, etc., is ever specified except in units of brush lines, or letters, or lines, etc. A novelist may have the whole novel enter her head in one blinding flash of self revelation. None the less she still has to write it one letter at a time. The issue now is to see whether there are certain sequences of design that are more efficient than others.

A process is more efficient than another if it can get one to a finished form of some required level of quality or efficiency in fewer steps than the other, given some starting structure. Fewer steps means a smaller number of designs made in the sequence that ends in a finished form. But this definition of design efficiency requires that we identify the smallest logical move from one design to another. In terms of the elements of the components, that move is a single element, added to an existing set or removed from it. Since these elements themselves may be made up of elements, the design steps should first be seen in terms of adding elements to what we called the elements of our component sets. A decision rule is an element of the latter kind. The pair that states if a, do b, is an element of a rule and one of the former kind.

The efficiency of the design process comes from the choice of its steps, that is, the specific alteration made at each step. Given the starting point, the structure with empty components, the null structure, or a non-empty structure, each step in the designing process involves an addition or a subtraction of one element. The result is a new structure very much like the one before. In a sense, the two structures may be thought of as being in a logical neighborhood of one another. The efficiency of the process will be determined by the efficiency of each of these small steps. What is needed is some way that tells one what elements added or subtracted get the structure closer to the desired finished form, and what this needs is that something be known about the finished form. In a process like this one, the Simplex method in Linear Programming identifies the finished form by defining the optimal solution. It gives a set of rules the make it possible to make the change from one solution to the best one that lies in the neighborhood of the one at hand. The logic of this process is that each solution may be changed in a way that takes it to the best solution that lies in the area defined by the minimum changes in the existing solution. Here, the steps that are needed to identify the best move are precisely defined, and the optimum solution is determined by a precise set of operations. We cannot hope to get anything like this precision in the process of designing organization structures, but we can use the same logic to develop ways of making efficient the moves we make in the process of design. All we can say here is that if each step, or even each small set of steps, were made to produce a better structure than the previous one, then the process would be more efficient than if that were not the case.

This does not say much, until one recognizes that all those structure properties may be used to ensure that each step is an improvement and to help make that improvement larger than it might be otherwise. These properties if used to define the finished form, will supply the mechanism that one uses to identify the small changes in a given structure that will produce one that is more nearly alike the needed finished form. Knowing that we need more decision rule fineness helps us replace one rule with one that is more fine. Knowing what fineness means allows one to make the change in fineness larger, thereby making the rule being created closer to the finished form and the structure more nearly similar to its desired form.

All the analysis made earlier may be used to guide the micro-steps in the process of design or redesign. The detailed definitions of the elements of rules, of messages, etc., and of the elements of the components of the three substructure are the sources for identifying the specific changes that are available at each step. Meanwhile the use of properties allows the evaluation of these micro-alternative steps and the choice of the more efficient change. Finally, the precise definitions of the elements and their relation to properties allow one to identify what it means to add to or subtract from a structure a piece that turns it into another structure. It gives one the operational definition of what the process and its steps are, and what you may do when you are designing.

Why is it that the process of breaking up the structure into pieces according to some logic, designing each piece separately, then designing the connections between the pieces is more efficient than designing the whole structure as if it were a single piece? Again, the clue may be in the example of linear programming. In some cases, the total L.P. problem may be broken up according to some well defined rules into a number of smaller problems, these problems are solved separately. Then these solutions are adjusted to give the solution to the whole. Decomposition is the term given to this process. Its efficiency over the process of treating the original problem as a whole is established under certain conditions (T. Marschak, 1972) and (Burton and Obel, 1984). This process has been used to analyze organization structures to determine the circumstances when the structure that is made up of highly disconnected pieces, or divisionalized, is more efficient than the structure that is a highly interconnected whole, or is centralized (Baligh, Burton and Obel, 1990). For us the general issue is whether or not it is more efficient to design, say two structures, and then connect them into a single structure, than it is to design this single structure directly. Call the first the piecemeal process and the second the one shot process. Unless it is more efficient to design two pieces without connecting them than it is to design the whole made up of these two pieces, then the piecemeal can not be more efficient than the one shot one. It is the existence of diseconomies of scale in design, problem solving, etc., that make the piecemeal process possibly more efficient than the other one. Such diseconomies are known to exist in many processes, for example, in L.P., in the solution of sets of equations, and so on. At heart, the issue is one that rests on the fact that twice as big means more than twice as complicated. Or, twice as many things in the structure, variables in equations, variables in the operating structure, means more than twice the possible number of connections.

The piecemeal process has two main stages. First the pieces are designed separately, then a design is made of the connections between the pieces. Scale diseconomies allow us to argue that the first stage costs less than the one stage of the one shot process. If this cost difference is an amount greater than the cost of the second stage of the piecemeal process, then it is the more efficient of the two. If the amount is smaller, then the one shot process is the more efficient of the two. Which process one uses will depend on the cost of the piecemeal process's second stage. This cost, in turn, will depend on the effort needed to design the elements that will reconnect the pieces of the structure. The complexity of this problem is determined by the numbers of shared decision variables and parameters there are among the technologies and environments we identified as the bases of the pieces we designed separately. The more interconnections we ignored in these bases, the more costly the second stage of design. The more damage to the whole the deconstruction of technologies and environments does to the real world, the more the cost of the piecemeal process, and the less likely it is to be the more efficient of the two.

We are back at the discussion of how one identifies the technology and environment subsets for the pieces to be designed. It is a question of the degree of separability of these in fact. It is for the designer to study the real world, and then identify the subsets of environments or technologies that are in fact such that their intersection with other subsets is small enough. How small is small enough cannot be answered here. All one can say is that the less the subsets intersect, the more likely will the piecemeal method be the more efficient design process to use. Finally, it is clear that the more complicated the world, the fewer subsets there will be that have small enough intersections. But even in such cases, the piecemeal process may be more efficient. The pieces would be few and big relative to the whole. One may, in fact, define the degree of complication in the relevant world by the number of subsets that one can find that have intersections of some minimum size. The designers must decide this minimum level and define the basic subsets which then tell them how many pieces are to be designed and give them some estimate of the cost of the second stage of the process. As the minimum level goes up, the number of pieces goes down. As the minimum level goes up, the cost of the second stage of the piecemeal process goes up. As the number of pieces goes up, the cost of the first stage goes down.

A classic economic problem is what we have just described for the choice of a process of design. If we just allow the piece meal process to have any number of pieces, including only one piece, what we earlier called the one shot process, the problem of the choice of the most efficient process of designing an organization structure can be stated simply. We have defined clearly technologies and the environment derived from them. The process of designing an organization structure begins with the identification of these. We have identified the logic one may use to identify those things about the structure that make it a desirable one, i.e., one we can consider to be eligible to be an end product of design, a finished form. We have derived the logic and the steps needed to create the technology and environment subsets for which pieces are to be designed separately. We have also identified the concepts needed to define the operational steps that the designer makes to design a piece efficiently. Finally, we have identified the problem of the efficiency of the process in terms of the number of pieces to design separately. When all these concepts are understood, and the design steps are followed, the result is an efficient process of designing efficient organization structures. What now remains are the details needed to make the process of design produce an efficient design, one that is desirable, one that will behave in a way that produces the desirable outcomes. The details are not in the theory developed earlier, but they cannot be derived without it, and can be derived from it. The details are the measures of the structure properties that produce a performance with the set of property measures that produce the wanted outcome. The details are the mappings from outcome to measures of performance properties, from these to measures of structure properties, and from these to structure components and their elements. These mappings are inverses of a sort that must be derived from the analytic mappings of the theory developed earlier.

## 5. Design Efficiency and Designing Efficiency

It is not enough that one recognize that it is important that the design be that of an economically efficient organization structure. It is also useful to know that designing that structure is a costly process, and that the one used should be the low cost one, or at least one of the lower cost or more efficient ones. Most of this work has been on the theory of the structure's efficiency. It is a theory which shows which structures are more or less efficient under given conditions of technology and environment. This chapter shifts the attention to the efficiency of the process by which one designs an efficient structure. The process of design is actually a process of searching for designs. Each step is made up of two activities, generating a set of feasible options, and searching this set for a structure that meets some conditions. The first activity may be subject to efficiency consideration. There may be rules one can devise that can be used to produce this set. Searching the available options, as has been argued earlier, may be made by rules that guide it at each step. These rules replace a complete search which involves the identification of all permutations of steps and their evaluation in terms of the efficiency of the resulting structure. Guiding the search is the clue to efficiency. An example that really fits the case is the chess playing computer and the chess playing human. How does the one compete against the other?

Speed in identifying all of the moves made alternately by each player is one advantage the computer has over the human. Given a position and the rules of moving pieces, the computer can generate a huge number of possible sequences of future moves in a period of time billions of times smaller than can the human opponent. This human opponent can, however, derive rules that restrict the set of future permutations of moves to a small subset of the whole. These rules may suggest that only permutations that have certain sequences need enter the feasible set. At one point, one may exclude all permutations involving the loss of a queen in the second spot. Such rules may save the human player huge amounts of time, but save the computer very little time, and may not be efficient for it to be given them. At each step, each player now has a set of permutations from which to choose. One way to evaluate the permutations is to use one single rule. It would be the rule that evaluates the last step by identifying whether it was a win, lose, or draw step. Simple computer operations would use this method, but generating all options at each move and evaluating all of them may be too much for even the computer to finish in the allotted time. Certainly, this search method is not available to the person, given brain speeds. The alternative for both is to develop rules that allow evaluation of only some of the permutations, excluding some and keeping others. A series of rules may be applied to allow this process to measure only a very few permutations actually defined beyond the first few entries. These rules must come from such theory as that which ranks board positions by analyzing their properties. These have to be created by the theorist. Rules may be ones that say any board position with the property of having a bishop in a square on the edge is excluded. Another rule may refer to some measure of control of the center board as defined in terms of the pieces which can move to these squares in one move. These rules are only as good as the theory from which they derive, and the theory is only as good as the person who created it. Rules may be given the computer, but again it is still only as good here as its rule giver, and its only advantage over the person is speed in generating and evaluating options. The human advantage is in theory, the rules it produces and their use. Technical speed of search, the evaluating of alternatives, which the computer possesses is much more valuable when it is coupled with search efficiency, the choice of alternatives to evaluate which the theorist supplies. That is why the very best theorist, rule generator and user, can still beat the incredibly fast move sequence evaluating computers whose rules come from persons of lesser theorizing capacity. Obviously, the most efficient process is that which combines the human theorist and the rules of design he gets from his theory with the speed of the computer that is to use the rules to reduce the size of its search space (Burton and Obel, 2004). We now need the derivation of structure evaluation rules from the analytic theory and the identification of the relative magnitudes of effects their use has on the efficiency of different design processes under different circumstances of structure size, environment, transformations, sizes, and complexities, and so on.

## 6. The Work of Collecting the Facts for Design

Properties of structures will need to be measured if we are to be sure that their values take on the measures the design rules we used said they should take. Since these properties are defined in terms of actual design components, they should be easy to measure. For this reason we will go through them only briefly, starting with those properties of the assignment components. The first properties deal with people, decision variables, and parameters. For any design, all assignments are collected, and every person given an assignment is listed. Comparing this list to that of all people intended to be in the organization structure gives us a basis for a measure of people inclusiveness. The measure may be the ratio of the numbers in the two lists. From the collected set of all assignments, a set of variables is created. It is the union of the sets of decision variables that makes up the second component of the assignments. When compared to the basic set of variables that is the second component of the design, the union set can be compared to this set. Variable inclusiveness is measured by the ratio of variables assigned to at least one person to the number that are identified as needing to be given values. That is the ratio of the number in the union set to the number in the set that is the second component of the vector that describes the design. When the measure is less than one, then there are variables missing in the former, but they are in the latter. These missing variables may be those that allow the development of the "virtual positions" which Mackenzie (1986) discusses. People will assign them to themselves or others, thereby increasing the measure for this property by adding to the incomplete original design. But whether this happens or not, for any design this property has a measure which could be the ratio of the number of elements in the union set to the number in the original set. If we wish to distinguish between decision variables on the basis of their importance, we can create a measure based on a ratio that weights the presence of some differently from others.

Measuring the value of the property of commonality is a straightforward but lengthy one. For any n assignments there are n people, each of whom is assigned a subset of the set of decision variables that is the second component of the vector which defines a design of a structure or substructure. First, we count the total number of variables in the union of all these subsets and multiply it by n. Call this number D. Next, we count the number of subsets in which each variable appears and add these numbers together. Call this number N. Now, the measure of the property is the ratio of N to D. If every variable appears in every subset, then H is the number of variables times the number of subsets (assignments) N, and N is equal to D. The measure of commonality is one, since every variable is common to all assignments. If every variable is in only one subset, then the number N is equal to n, the number of assignments. The measure of the property is still N divided by H, where N = n. This is the minimum value the property could take, so the measure of this property has a lowest value that depends on the number of assignments in the substructure, and its highest value is 1.

Orderliness is measured only after the set of all decision variables of the substructure is sorted. Once we sort this set, we create a number of subsets the union of which is the original set, and the intersection of any two of them is empty. We call each of these a sorting subset. The basis of the sort will determine the subsets we get. If we change the basis, then we might change the resulting subsets. The bases for the sort may be any set of dimensions, such as product, function, type of customer, activity, etc. In any case, for the sort process we choose we get a set of nonintersecting subsets. Define the number of these subsets as S. Each decision variable in an assignment will belong to only one of these subsets. For each assignment, we count the number of different subsets that contain at least one variable in the assignment. If all the variables of the assignment subset fall into one sorting subset, then this number is 1. If there is at least one variable in the assignment subset that falls in each of the sorting subsets, then this number will be equal to S. We now get the appropriate number for each of the n assignments and add them all together. Call this number L. It goes from its minimum value of n to its maximum of S. The ratio of S to L is the measure of the orderliness of the assignments of the structure. When S = L, then the number is 1, and we have the lowest level of orderliness for this substructure. When L is equal to n, then the ratio of S to L is at its highest. The actual number will depend on the sort we use to begin with, and so this measure of orderliness should be accompanied by a statement of the basis for the sort that underlies it.

If a user of a decision rule is also one of the set that makes the rule, then that maker is enfranchised for this one rule. In measuring the level of this property of enfranchisement we start with all the rule users in the set of people that makes up the first component of the vector that defines the substructure we are designing. For each person in the set we count two numbers. First, there is the total number of rules the person uses. Second, there is the number of these rules for which this user is also a maker. The ratio of the latter to the former measures the level of enfranchisement for this one user. The number goes from 0 to 1. When we calculate this ratio for each rule user, then we can calculate the average ratio for all. This gives us the measure of the level of this property of enfranchisement for the whole set of rule users. As an average, this number suffers the weakness of failing to distinguish between cases of high enfranchisement for only a few users from cases of low enfranchisement for many more users. It also fails to capture cross enfranchisement, or the cases where users not only help make the rules they use, but also help make the rules that others use. So, to capture this feature of maximum democracy, or really maximum interference of people in the work of others, another measure and meaning to enfranchisement is needed.

Enfranchisement could be given a meaning that applies it to a specific rule maker or user. For this person we count the total number of all rules used by all people in the structure of which this person is one of the makers. The ratio of this number to the total of all rules used gives a measure of the level of this concept of enfranchisement of this one person. The average of this measure for all people in the structure gives the property's measure for the substructure we are designing. One might call the first property enfranchisement in one's work, and call the second property enfranchisement in the work of all the people in the substructure. Normal concepts of democracy involve this second kind of enfranchisement for the group that is relevant, such as, all factory workers, all sales people, all people above 18, all executives, all members of the organization, and so on.

Maker orientation is a property that attempts to describe the goals which the rules in the organization structure are intended to achieve. To measure its value, one needs the goal set used to make the rules. This set is not defined as a component of the structure, and so it has to be obtained from whoever it is who makes the rules. For any one rule, the value of this property is obtained from the number of maker goals used to make the rule and the total number of goals used to make the rule. The measure is the ratio of the first to the second. If we argue in this manner for the property of user orientation, then we have two non-independent measures. If only maker goals are used to make the rules, then the measure of maker orientation is one and that of user orientation is zero. If all the goals of both users and makers are used to make the rule, then the two measures will be some numbers between zero and one. This last is always the case if rules are goal based. To get an understanding of what a substructure is like, we need both measures and knowledge of who the users and makers are, and what their goals are. Since the set of makers and that of users intersect, the two orientation properties may be referring in part, or whole, to the same thing. The larger the number of people in the intersection of the two sets of makers and users relative to the total number of users and makers, the more will the two properties be like one property only. For the whole structure this is a large amount of information, and the two measures would be averages for all the rules. These two properties are therefore rather vague in measurement, but they serve to give one some idea of whose goals the rules are designed to achieve. One should use the two properties for analysis and design with care, because they are not independent of one another in definition.

Rule openness is another crudely defined property. It needs not only the identity and goals of users and makers, but the identity and goals of people who are neither. Unless there are no such people and goals, then finding them may be difficult. The property measure would be obtained analogously to the previous two, but the argument about the lack of independent definitions of these does not apply to rule openness and either of the goal orientation properties.

Comprehensiveness is a property defined in terms of the domain of the mapping of the rule. Suppose the domain of the rule has elements defined in terms of some n dimensions. Every element in the domain is thus of the form of a vector of n dimensions, where each component is a value taken by a specific variable, which in this case is a parameter. Every one of these will be given a value in at least one vector in the domain. Given this one value, the smallest set of values which this variable may logically take is determinable. For each component variable there is such a set. For example, we may have as elements in the domain vectors of four components. Let us assume that given the actual rules, we conclude that the minimum number of values which the first component may logically take is 2, that for the second is 4, and for the third and fourth the numbers are 3, and 9. For these possible values of the four components there are 2 x 4 x 3 x 9 different vectors. Comprehensiveness of this one rule is measured by the ratio of the actual number of vectors in the domain to this total number that could logically be in the domain. The larger the number, the more comprehensive is the rule. Increasing the measure of comprehensiveness means adding vectors which are not there, but could logically be there given the dimensions over which the vectors are defined. For a group of rules, the measure of their comprehensiveness as a group is the average of the measures of the comprehensiveness of each of the rules in the group.

This measure of comprehensiveness is that which is relevant to our analysis and design. Whenever the term comprehensiveness appears in this work, it refers to the property measured as defined above. We may at times need slightly different views of the rules, something that gives us a property similar to comprehensiveness, but yet not the same. We call this property absolute comprehensiveness. We start with a fixed set of dimensions and possible values which each may logically take. Once these two sets of numbers are given, the total number of vectors in the domain is obtained. The ratio of actual vectors in the rule's domain to this number is a measure of absolute comprehensiveness given basic components, etc. This property starts with an arbitrary set of dimensions for the domain of the rule, whereas the other one derives this from the elements of the actual domain.

In a sense, comprehensiveness is analogous to the explicitness of the rule. It tells us whether a given element or vector that could have logically been in the domain is covered by the rule, or is not. If rain is the only dimension, and there is only one element, rain, in the domain of the rule, then the minimum number of elements is two, rain and no rain, and the second is missing from the rule. The rule's comprehensiveness could be increased by adding the element of no rain to its domain, and so making the rule more explicit in a sense. Finally, one can measure the partial comprehensiveness of a rule based on only one or more of the dimensions of its domain. In this case, one would need to specify the dimensions of interest and get the measure for them in exactly the same way one would get it for all of them.

Rule fineness is a property of the range of the rule. This range is a set of sets, each of which has as elements values of a decision variable. For every such set there is a number which measures the elements in it. The average number for all the elements of the range of the rule could be the measure of the fineness of this rule. The finest rule is then that with a measure of one. But this makes things a bit confusing, since making things more fine means reducing the measure of fineness. So we define what we called fineness as the property of grossness. Then the property of fineness is the opposite of this grossness. Its measure is the inverse of that of grossness. Its measure is obtained by first measuring the average number of elements of the sets that make up the rule. Then, we divide this into the number one, and this ratio is then the measure of a rule's property of fineness. The highest measure is now one, and the lowest is less than one and larger than zero. For an example, we may have a rule with three elements in its range. Each element is a set, and the number of elements in them is 6, 4, and 9. The measure of this rule's fineness is 1 divided by 6 + 4 + 9, or 1/19. The measure of the fineness of a group of rules is the average of the measures for its members.

Every element in a rule's domain is a vector of values of some variable. A choice of a value for this variable determines a set of values which it may logically take. If we give the variable in one vector the value 5, then the set of values it may take is the set of all positive integers. We may restrict this set to all positive integers between 1 and 30, for example, if the variable is never found to be larger than this number. In any case, for each variable some such set of logical values it may take is obtainable from each actual value it is given in a vector in the rule's domain. This is this variable's resolution set. It has all the values which the variable may logically and realistically take. There is one such set for each of the component variables of the vector that is an actual element in the domain of a rule. The average of the numbers of elements in these resolution sets is the measure of the property of the rule's domain resolution. The measure is a number that could be infinite, and even an infinite number that is smaller than another, i.e., the number of positive integers or the number of positive real numbers. In all cases, this number measure is identifiable.

Increasing the resolution of a domain means smaller differences are allowed between the values which it may take as a component of a vector in the domain. It means that we are making sharper distinctions between the values that are logically possible. This means that we hold the extreme values for a variable fixed and increase the number of elements in the resolution set. So, we may measure temperature in values of hot and cold or increase the resolution to hot, less than hot, more that cold, and cold. For a given rule then, there is a measure of it's domain's resolution which may be obtained from the resolution sets of the variables that define the dimensions of its domain. The extreme values for each of these resolution sets are held fixed. The measure for each variable level of resolution is obtained. The average resolution measure for all variables is then the resolution measure of the rule. For a group of rules, the average for all is the group's resolution measure. It is not the absolute value of this measure that is what we use in the process of design. It is the relative value it has, and the results of changes in it that are of use. One can always design with more or less resolution in the domain of a structure's rules. The only thing one has to keep in mind is that the extreme values used in making the measures are the same in all cases.

The measure of the property of range resolution of a rule is analogously obtained, except that here there is only one variable for each rule. This measure for a group of rules is the average of the measures of the members of the group. Both measures of resolution refer to the precision with which the variables of a rule are measured for those in the domain and set for those in the range.

When one studies the elements of the range of a rule ,one may notice that the elements of one set are very different from those of another, or not. The rule may have elements that are all the same, which means it says to give one of the same set of values to a variable regardless of what the element it is attached to in the domain may be. This rule states that the circumstances change, but the values allowed the decision variables do not. In a sense, the mapping lumps all elements of the domain into one set of values. The range of the mapping is a single element in this case. It is like the mapping of 0 multiplied by y, which is 0 for any real number y. At the other extreme, there is the mapping of 1 multiplied by y, which is equal to y for any real number y. There is no lumping at all here. For a rule then, the measure of its lumpiness is the ratio of two numbers. The first is obtained as follows: for every value that appears in at least one set that is an element of the domain, we find the total number of times that it appears. If the domain has 20 elements, then this number is anywhere from 1 to 20. The total of these measures, one for each value that appears at least once, is calculated. From it an average figure is obtained for all the values. This is now the average number of elements of the range in which any value appears, for those values that appear in at least one element. The number also goes from 1 to 20 in a rule with a range of 20 elements in it. When we divide this number by the number of elements in the range of the rule, we have a measure of that rule's property of lumpiness. The measure is one of the similarity of the elements of the range. A rule with maximum fineness and maximum lumpiness has a range in which each element is a set made up of only one value for the relevant decision rule. That value is the same in all elements of the range. The rule has a range in which every element, which is a set of values which may be given to a decision variable, has only one value. This gives maximum lumpiness to go with the maximum fineness. If this rule, however, still had every element with only one value in it, but the value in every element appeared only in that element, then the rule would still have a maximum fineness measure but a minimum lumpiness measure.

Two rules are domain-domain connected if they both share at least one dimension, and there is an element in each domain that has the same value for this dimension. For more than two rules, the definition would be analogous, and the measure of this property would start by counting the number of times a value for one dimension occurs in the domains of this set of rules. Dividing this number by the number of rules in the set gives us a measure of the connectedness for this one value. Repeat this process for every value for this dimension and average over all values. Do the same for all the dimensions of the domains of all the rules. Now, we have the average number of times a value of a dimension occurs in all the rules of the our specified set of rules. For each value of each dimension that occurs anywhere in a domain, there is one such ratio that goes from zero to one. When we average all these ratios, we get the measure of the domain-domain connection for this set of rules.

For the range domain connection, we note first that the order of range and domain is critical here. First, we pick one decision rule which by definition has a range made up of sets of values of one decision variable. Next, we choose another rule in which the variable that is the range of the first is one of the dimensions of its domain. We count the number of times a value for this variable that occurs in an element of the range of the first rule occurs in an element of the domain of the second rule. Divide this number by the number of elements in the domain of this rule, and we get a ratio between zero and one. This is a measure of the range-domain connection between the first rule and the second. There may be many rules in the substructure under analysis and design that could be the second rule in the above measurement. For any substructure that includes the first rule, and has a total of n rules altogether, there are n-1 rules eligible to be the second rule in the measurement. For our first rule, we get the n-1 ratios and average them, getting a measure for the range-domain connection for our first rule. We then make every rule the first one and get the relevant measure of its range-domain connection with all the others. The average of all these ratios, one for every rule in the structure, is the measure of the r-d connection property of this substructure. If the average measure is too gross, then we can make a number of average measures, one for each segment of the substructure. Segments must be logically defined if the refined measures are to be better than the single gross one.

## 7. Facts on Information Substructure

The properties of operating substructures are also properties of the information and reward substructures. But these have other interesting and useful properties that are unique to them. These need to be measured. Working first with the information substructure, there is the property of diffusion. All decision variables and parameters are elements of the second component of the definition of an information substructure. For everyone one of these, we identify all the decision rules in this substructure that have this variable as the subject of its range. Next, we identify all the people mentioned in these rules who read, receive , or retrieve the variable. We count the number of such people and divide it by the total number of people in the substructure, i.e., the organization. This ratio tells us the proportion of all people who know the value of this variable. When we get the ratios for all the variables, we average them. The result is a measure of the diffusion property of the information substructure.

Parameter inclusiveness is measured by the ratio of the number of parameters which are to be found in the assignment component of the substructure to the total number of parameters to be found in the set of variables that describes another component of the substructure. The same variable may appear many times in the assignment component, but for this measure it is counted only once. If the number is one, then every parameter is assigned for someone to read. Otherwise, there are some parameters the values of which are supposed to be known as the design specifies, but no one is given the job of finding out what their values are.

Redundance is the property that has something to do with how many times a parameter appears in the parameter reading assignment component. We count the number of times a parameter appears. This tells us how many people are to read its value. We divide this number by the total number of people in the substructure. This is the proportion of all people who are to read the value of this one parameter. When we have this ratio for all parameters, we average the set and get the measure of redundance of the information substructure. The higher the ratio, the more people on average are asked to read the parameter values, and the more redundant is the substructure.

In any given period of some fixed length, a parameter may be read x times. To measure the value of the property of repetitiveness, we need to fix the length of this period. The length would be an appropriate one for a subset of variables, which set identifies for us a substructure of the information kind. It could be that for the whole substructure of a subset of it. The important point is that the time period length be appropriate for all the variables, decision or parameter, of this substructure. Next, we count the number of times the variable is to be read by someone during this period and identify the largest such number. The domains of the rules of the substructure is where we find these numbers. Read rules will have mappings that identify when the value of a variable is to be read under various circumstances. From these clock times we can get the number of occurrences of the reading of the variable in a period of some given length. When we have this number for all the relevant parameters, we get the average figure. That gives us a measure of the repetitiveness of the substructure we are working with.

For an information substructure we redefine the property of rule fineness. What we need here is a different meaning or property from what we defined for the operating substructure, even though we will use the same name for both. In this case, rule fineness refers to the number of acceptable values that are to result from reading the variable value. Acceptable is here defined in terms of the real value. For the temperature of something that is to be read, we specify as an acceptable reading under some circumstance any figure within 2 degrees of the real one. In a sense this property is about the accuracy of the readings, which depends on the measures allowed by the rule. These ranges are defined by the elements of the range of the rule. For each real rule, we count the number of values in each element of its range and get an average. When we do this for all variables, we average these averages. The number one divided by this last figure is a measure of the fineness of the real rules, that is, of a substructure. The larger the number, the smaller the denominator. The smaller the denominator, the more fine the readings are to be, the rules have smaller sets making up their ranges. And so, we have a ratio which measures the rule fineness of the information substructure, and the larger the measure, the finer the decision rules on reading the values of variables.

## 8. Facts on the Reward Substructure

The first of these is that of the domain consistency of the reward substructure. What this property measures is the sameness of the bases on which people are rewarded. To start with, one must specify a substructure of the reward substructure with a given set of people in mind. This is the set for which we wish to compare reward bases. Next, one calculates from the rules of this substructure, the total number of elements in the domains of all the rules. For each rule we calculate the ratio of the number of elements in it to the total in all rules. The average of all these ratios gives us a measure of the domain consistency of the rules in the relevant reward substructure. If all the domains are identical, then the measure will be one. As the differences between the domains of the reward rules increase, this number will decrease to a minimum equal to the average number of elements in the domains divided by the total number in all the domains reward substructure defined by a set of people whose rewards are of interest. The property of range consistency is defined in terms that are related to the sameness of the ranges of rules. But it is not simply a case of the similarity of ranges, because what we really need is an idea of the similarity of the rule mappings. These are person specific and have domains and ranges. Similarity between ranges is worthless as a concept if the rules' domains are not similar. So, the way we measure range consistency will be meaningful when this is incorporated in the measure. Together this and the previous measure will tell us something about the sameness of the reward mapping for different people.

We start the process in the domains of the set of rules that define the reward substructure for a set of given people in whose rewards we are interested. Suppose we had n such rules. There are n domains and one set that is the union of all these. The number in this set we call k. For every element in this set, we calculate the number of domains in which it is found. Each element will be in some number of domains from 1 to n. We have then up to k such numbers, one for each element of the union. For a specific element, let this number be m. Next, for each one of these elements of the union of domains, we count the number of different elements into which this domain element is mapped. For an element in n domains, this number will be any of 1....n. Call this number t for this element and calculate the ratio m/t. If this specific element is mapped into the maximum possible number of different elements of the ranges, then this ratio is one. Maximum mapping difference exists in this case. As the number t falls, sameness of mapping increases, and the ratio m/t also increases. Next we wish to weight the importance of this element. We do so by the relative number of rules n in which it occurs. This weighting is obtained in the ratio of the number of rules in which it occurs, m, divided by the total number of rules n. For this specific element, we now have the weighted measure of sameness of the mapping's ranges. That is m/t multiplied by m/n. To get the measure of the property of range consistency, we take the average of this measure for all k elements. If the mappings are identical, and sameness is at its maximum, then m will equal n and t will be one. The measure for all k elements will then be m = n, the largest measure possible. As sameness decreases, t gets larger and m/t gets smaller, as does the measure of the average.

Orientation of the reward rule mappings is a property that tells us something about the bases of the mappings. If a reward mapping has a domain in terms of only profit, then it is said to be outcome oriented. It rewards the results of the decisions of the person rewarded, and not what she actually does. If the domain has a dimension defined in terms of the decision variable assigned in the operating structure to a person, then that introduces the orientation of decision, or action into the rule. So, for each of the reward rules for the n people who are relevant, we count the number of dimensions in its domain. Let this number be k for some specific person and his or her rule. Next, we count the number of these dimensions that are outcomes, the number that are decisions, and the number that are arbitrary. Let these be o, d, and a, respectively, For each person and reward rule, the three measures of the properties of orientation are o/k, d/k, and a/k. For all n people and rules, the outcome orientation property measure is the average of o/k for all people, and analogously for the decision and arbitrary orientation properties.

## 9. Operational Property Measures

Many of the property measures of the three substructures are complicated and perhaps costly to get. But they are all operational, that is each is described in terms of the actual things to be counted, the mathematical operations to be performed, etc. Without such detail, the properties are really worthless for analysis or design. It makes no sense to state that the centralized organization is low in its speed of response, unless we can at least distinguish, in fact and from observation, between the measure of centralization of two organizations and between their response times. If we cannot measure these properties, then a design rule which says that the organization should be fast in its response and should therefore be designed to be low in centralization is useless. Unless the designer knows how to make the organization low in centralization, and to figure out when the responsiveness of his design has reached the right amount of responsiveness, she cannot use this design rule.

Whatever the objects of analysis and design may be, there is a need for operational and measurable definitions of the things connected by the analysis and the things that actually have to made facts in the design. All variables should, therefore, be defined and have labeled dials or digital readouts that give them measures of clear meaning. All parameter variables have only these, but decision variables, the heart of designing, need also knobs. In a figurative sense, the decision variable should be identified by a knob which can be turned to give it a value. This means that the knob must have markings of the variable's values and the definition of whichever is the one that is the set value. It also means that there should be a dial that reads out the actual value the variable takes. Only then can one set a value for a variable and check to see whether the set value is that which actually holds. Connections of analytic form should be represented by two connected readouts, and when decisions are involved, by one knob and two readouts, one for what the knob is set to, and the other for what the resulting value is. To be useful, analysis and design must have measurable variables, hence- the long definition and specifications of the way to measure properties. It is at this point that the rules for designing organization may be extracted from the analytic statements.

# CHAPTER 10

## DESIGN MAPPINGS: DESIGN RULE DERIVATION AND USE

### 1. Mappings and their Inverses

Theory supplies statements that are analytic and categorical, while design needs statements that are conditional and prescriptive. How then do the latter derive from the former? An analytic statement is of the form: if a is true, then b is true. It asserts that the truth of a makes b also true. As the conclusion of an analytic theory, it asserts that a causal relation exists between the two truths, or that the truth of a causes b to be true. From this statement, if a then b, (which is its short form), one can easily derive the statement: if you want b to be true, then make a true (if b then do a is its short form). There is no complicated issue here. It is also clear that one cannot properly derive the rule: if you do not want b to be true, then make a not true. From theory to a rule of behavior is one simple step. If however, the theory contains other statements involving a and b and maybe c and d, then the step from one analytic conclusion to a design rule becomes a little more difficult.

Suppose the theory has two conclusions as follows:

1. If a then b
2. If a then c.

One can still derive the action or design rule which states that if you want b then do a (if b, then do a). But what if the one wants b to be true and c to be not true? Now the first part of the derived prescriptive rule that is relevant is: if b and not c. From the theory it is clear that to follow this with do a is not possible, that is, it is a bad rule, because following it will produce b and c, which is not wanted, and will not produce b and not c , which is wanted. If the two conclusions were all the theory we had, then no action rules of use to the actor who wanted b and not c could be derived from it. This actor may now return to the theory and work on expanding it. A new conclusion might be:

3. If k then b.

Now, of course, from the theory we can get the prescriptive rule if b then k. This addresses the need for b, but does not do anything for the need for not c. The theory is still not adequate for the needs of the action taker. One can get a rule of use from the theory, but one cannot get all the rules from it that one wants to.

Suppose the theory had the two following conclusions:

5. If a then b
6. If m then not c.

From this one can derive two rules that are useful to the actor who wants b and does not want c, that is, wants not c:

If b do a
If not c do m.

As a last simple case, imagine the theory to have the two conclusions:

If a then b
If k then b.

The actor is interested in b. Two rules may now be derived:

If b do a,
If b do k.

Now the actor has a choice and realizes that doing a or doing k is not a matter of indifference to him. The theory is not adequate for his needs.

When a theory has a large number of analytic and categorical conclusions of the if-then kind, it is a rich source for prescriptive statements or rules of behavior. But the more the conclusions there are in the theory, the larger the combinations of these which may be used to derive rules. From conclusion to rule is no easy step. Our theory does have many conclusions at each step from structure to performance and from there to outcome. It is not easy to use the theory to derive the design rules we seek.

## 2. Deriving Rules of Structure Design

The theory developed earlier has many conclusions at each stage. It is also a partial theory, in that conclusions are simple ones with only one or two of the many possible variables included in any one conclusion. There are very few of them that have complex forms, such as, one which states: if a and b, then c and not d, for example. Most conclusions are unitary ones that say if a then b. Even so, combinations of conclusions may yield design rules not obtainable from each considered alone. Sequences of mappings are complex with shared domains and shared ranges. This makes concatenated design rule derivation a complicated affair. A less than complete listing of all conclusions that could be derived from the basic theory makes it likely that an incomplete set of design rules with some contradictions may result.

## 3. Facts on Technology

The theory developed earlier distinguishes between the nature of what is, and the nature of what may be done. Statements of the first form are the facts available to the designer to use. What the designer has to choose are the variables identified in the statements of the second form. In the theory of organization structures, the facts the designer is given are the values taken by the defined and relevant properties of the environment and the technology. Some of these facts may be simple uni-dimensional ones that are directly observable, while others may be functions of such simple variables and must be derived from these observable ones. To read these facts, the designer must know what these functions are, must read the values of the variables in their domains, and then go through processes of transforming these into the facts that are needed. The designer needs to know how to measure the technology property values, and whether such measurement is to be direct, or indirect through the use of various functions and logical procedures. The same is true of the environment.

Facts the designer needs about the technology are the measures of the values taken by the properties which are to be used in the process of design. Among these is the property of completeness, which can be ascribed to the technology which is relevant to the organization to be designed. The designer needs to count the number of transformations in that technology that is known, or can be known, to the set of people who are to be in the organization that is to be designed. Members of the organization must be surveyed to ensure all known transformations are identified. The state of knowledge about transformations may have to be studied to determine what is now known, to whom it is known, and maybe even to whom it could become known. The unknown transformations are those known to be part of the technology, but with their nature not yet described. It is known that some cells are changed from normal to cancerous ones, but the elements that describe the transformation are not known. In some cases the elements may be known, but the mapping is not. Designers have to do the best they can in identifying the un-described transformations, a rather difficult task. It involves recognition and knowledge of what is not known. Measuring the property of technology completeness requires the assembling of the knowledge of what transformations are known and described, and also what transformations are known to be in the technology but are not described because of ignorance. The proportion then of the one to the sum of the two gives a measure of completeness. It must be obtained for all technologies. When these are segmented into subsets for the creation of segments of the total design, an average figure for each set is to be calculated.

Variety is a property the measure of which is the number of technologies that are different but have the same ultimate range. These may be the number of different ways in which paper may be produced. All the technologies have as their ultimate range some measure of paper output. The same concept involves identifying all the different carriers and routes which may be used and taken to get from here to there. Again, this measure of variety exists for each different technology the organization knows and is capable of using. For any segment or subset of technologies, all the knowledge of people in the organization needs to be collected, and the average for the set calculated.

Control over transformations comes from control over input amounts and control over the mapping itself. If inputs are decision variables, then they are assumed to be under control of somebody in the organization. Randomness may still exist here for those who make, but not necessarily use decision rules. Ignoring this issue for the moment, we want to know how much control over the output of a transformation the organization has. Control here depends on control of the non-decision variables in the transformation, on the parameters. For any transformation, the organization may estimate this measure of randomness. It comes from the distribution of output measures for every combination of decision variable values specified. If for every such set one and only one output is obtained, then randomness is zero. If for every such set of decision variable values any number of output levels are of equal probability, then randomness is infinite. For each transformation, some such measure of randomness needs to be estimated by the designer of the organization's structure. For each technology, the measure is obtained from the measures of the transformations that define it and the logical order imposed on them by the definition of the technology. If a technology is defined by two transformations in which the output of one is an input of the other, then the randomness of the technology is obtained from the randomness of the first, now randomness of an input, and the randomness of the second. The result is derived from the joint probabilities of the two transformations. For a set of unconnected technologies, a segment defined for design purposes has as a measure the average of the measures of the technologies in that set.

Size is a technology property that is easy to measure once the technology is deconstructed. When a technology is broken down into a set of transformations, none of which is separable into more than one transformation, then the technology is fully deconstructed. Its size is merely the number of its constituent transformations, and for a set of technologies, the size is the average for all. Just as size is easy to measure, so is the span of a technology. There are two kinds of span, one for decision rules and one for parameters. Decision span is measured by the number of decision variables that are represented by dimensions of the domains of its transformations. For a set of technologies, the measure is the average of its elements. Parameter span is measured analogously, with the term parameter here referring to true parameters and to the variables that may be the decision variables of other organizations, and perhaps dependent to some degree and in some way on the values the organization gives its direct decision variables. When we divide this latter measure by the former, we get the measure of the exposure of a transformation, or a technology. Exposure is a property that now reminds one of the basis for the famous dictum on control being dependent on whether or not the number of parameters is exceeded by the number of decision variables (Ashby, 1956). The ratio of the two goes into determining the highest level of control by the organization over a technology, and perhaps may also be used to measure how difficult it is to get any level of control. To refine further this idea of what the organization has that allows it control over technologies, we have the property of captiveness. It is measured by the ratio of the number of decision variables directly given values by the organization, to the number of these plus the number of those parameters the values of which depend on the values the organization gives its decision variables. The remaining parameters are the real ones, ones the values of which are totally independent of the values given the decision variables of the organization. Thus, the measure of the property of captiveness tells us something about what the organization can do directly, compared to what it could do if it could tell how other organizations may respond to the values it gives it own direct decision variables. In some sense, this is the part of the organization's environment that it might be able to change within the constraints of the responses of other organizations to its own behavior (Baligh and Richartz, 1967), (Baligh, 1986a), (Volbreda,1996).

Finally, there is the measure of the tightness property of a technology. It is a difficult property to measure because it requires the mapping of different logical orders into some number scale. There is no way of doing this in a manner that truly represents the effects of logical order on what can be done. Therefore, the measure on this property is to be a somewhat subjective one. What it needs is an understanding of how restrictive is the logical order which the irreducible transformations that make up the technology must meet if the result is to be a technology that is real. Logical sequence is one order, connected domains and ranges are others, necessary and sufficient requirements between transformations is yet another order. In creating a technology one may use any one logical order or a combination of logical orders. Of these combinations, some are feasible and do give a technology with relevant outcomes, while some others do not. Each combination of logical orders defines a specific technology with its own levels of the relevant outcomes and operating costs. The number of choices gives one a measure of the tightness of the technology. The fewer the choices, the tighter it is.

## 4. Facts on the Environment

Environment and technology meet or overlap at the point of size and parameter span. The property of environment size is measured in the same way as that of the property of the span of technology. Counting the number of parameters is, however, only the beginning of the measuring process. Realistically, finding the parameters to count is not easy. It is a fact that the places where one is to look for the parameters is not something that is obvious. Not all parameters are equally important, and knowing the values of one may have much greater returns than knowing the values of another. In order to take account of these issues, and to get a pragmatic and useful way of estimating the environment's size as this relates to our problem of deriving rules on structure design, we identify a mapping that produces this measurement. The things to count are as follows: the number of competitors, of decision variables (weapons) that each uses in its competitive strategy, of market segments where we and they compete, of different transaction types made in each segment, of government regulations that are pertinent, and the elements of the natural environment that are pertinent. This last refers to such variables that are not in any human's ability to set, such as weather or population movements, etc. At this point, we should have segmented the environment on the basis of the technology segments created. Everything that follows about identifying the components of the environment and about measuring the values of its properties refers to any and all segments created.

Size is a function of these parameters, but it is not a simple one. As the number of competitors increases from zero, we expect size to increase. But after, say, the number 8, the relevance of the number drops. It becomes less important that we know this number or other numbers associated with what the competitors do. Beyond the number 15, we are in a perfect market, and the number of competitors becomes irrelevant. Not only does going to sixteen not increase size, but it brings us closer to market perfection, and so decreases size. This component of size is zero if there are no competitors, and 1 if there is 1 only, and so on, till it comes back to being 0 where there are say 9 or more. Not only that, but competitor strategy variables collapse into one single one, price. Size is measured by the parameters listed, but the function that is actually used should be created to give the number of parameters the organization needs to know. This is, therefore, a relevant fact to structure design.

A decision has to be made on the basis of the value of information to the organization and the cost of getting that information. Decisions on these issues must be made prior to designing the structure, even though neither the value of information nor its costs can be known before decisions on how to get it and use it are made. These are structure decisions, and so we are in a double bind. We need one to make the other, and we need the other to make the one. The solution is first to start with specific values given to the elements of one set, values based on experience and understanding. Next, values are derived for the elements in the second set. In the context of these values, new values are derived for the elements of the first set and the sequence is then continued until we notice that the derived values for the elements of both sets show some convergence. Stopping the process is then decided on the bases of the nature of this convergence and the cost of making another iteration.

In terms of our specific problem, we start with a good understanding of the general economics of the problem. Next, the aspects of the environment that are relevant are identified and counted, and the mapping is specified. The result is a size of the environment which we then use in creating our first design. We then use this design to re-measure size, which we then use to redesign, and so on. In any case, the size of the environment is the number of components of a vector which we call the state vector. When filled in, each component of this vector is given a value, and the vector then describes the environment at some point in time. It describes the state of the environment, the size of which is n, and for which each component represents a measure of the value of one specific fact, a specific variable such as the temperature, or the price charged by a competitor.

The question still remains regarding the standard or set of values one is to use to describe the value of a variable. Price may be measured in dollars and entered as such, or it may be measured vaguely in tens of dollars and entered as very high, high, etc. Here again, the issue is one of determining the detail in which we are to design, and the effects of changes in what we measure on what the design does. It is to be solved for each case individually, given the things we expect from our design. A large number of sequential decisions on value followed by design, and then by a new set of decisions on value, may be necessary. There can be no absolute answers, since what we want from our design process may differ from one time to the next. Everything said about the property of size of the environment may applied to any segment of it. If we choose to segment the environment in the process of design, for reasons discussed earlier, then we can measure the size of each segment in exactly the same way we do the whole.

Size tells us something about the number of dimensions we need to describe the environment in a realistic and useful, as well as a parsimonious way. We now know we have a number of facts about the environment which the organization structure which we design will need to determine. But it is not yet known how often the facts will have to be read and so on. Hence, we have the property of variedness, which is a measure based on the number of different values each of these facts does in fact take, or can in fact be reasonably expected to take. Suppose that temperature is one of the relevant environment facts. In one environment the temperature actually ever recorded may be anywhere between -30 and 120. Another environment may have this range be from 80 to 120 . The first environment can now be said to have much greater value of variedness of temperature than the second one.

For an environment of size five we have a vector of five components that describes it for us at any given time. The larger the range that the value of some one component may realistically take, the more varied is this aspect of the environment. For this component, variedness is measured by the number of different values we can reasonably expect it to take. This number depends on the scale we choose to measure the value of this component variable. When we choose a balanced set of scales for all the different dimensions of the state of the environment, then we can measure its variedness. For the whole vector, its property of variedness may be measured as the average of the measures of all five of its components.

Care must be given to the choice of scales for the measures of the vector's components. For each entry the measure must first be in appropriate terms. If the parameter is temperature, then it is in terms of degrees Fahrenheit, or in terms of very high, high, etc. If the parameter is competitor advertising, then we must decide on whether the measure is some function of total television time per week, a measure based on this number and an analogous one for radio, space in newspapers, etc. Whatever we choose, the variedness may be measured by past history, by absolute impossibilities, or by some expected logical set of boundary markers. If advertising is measured rather simply in dollars spent by competitor, then the range can be two numbers which we have very good reason to believe our competitor will never over or under-spend, respectively. Variedness, then, is a measure of the total number of states we can expect the environment may be in at any time. It is a measure of the real environment, but the value it takes is determined by the standards we use to measure the facts as well as by the actual values the facts take. It is a measure that holds for a given set of vectors chosen to be adequate to describe the environment. If in our sequential describing, measuring, and designing process, we change the definition of the environment and so change the vector that describes its states, then we must reconsider the process of measuring all the components of the vector, and then measure the value of its property of variedness.

If the measures of variedness of the components are very different from one another, then an average figure for the environment is a bad descriptor of it. In this case it may be reasonable to segment the environment into sub-environments, each of which has measures for its components that are more nearly alike. The result would be a set of pieces or segments of the initial environment. Each segment would be chosen on the basis of this similarity. The result might be one segment with a very high measure of variedness, another with a medium measure, and the third with very low measure. As we discussed earlier, the segmentation of the environment is a decision that is to be made on the basis of the similarities of the measures of the properties of its components.

A very important property of the set of state vectors that are used to measure variedness is that of changeability. As variedness identifies the number of states the environment could be in, changeability identifies something about how often our environment changes its state. The measurement of this property requires that we first identify the set of states we use to measure variedness, which requires that we specify the general set of vectors which defines for us where the state of the environment might be. Next, we measure the time it takes the environment to go from one state to the next. After a very large number of such measurements is made, the average time elapsed between one state and the next is the basis of the measure of the changeability property of the environment. The shorter the time, the higher the measure of changeability, which is then measured by the ratio of some base length of time to the actual. If the average is three days, and the base length is thirty days, then changeability is thirty divided by three, that is, ten. If the elapsed time is one day, then the property measure is thirty. Each organization must choose the base length to suit its purposes. What is needed is the measure of the property which will be used in design. Whatever base is used to measure this property is used in the design process. The actual base time chosen is irrelevant as long as it is properly matched in the measures of those properties of the structure's performance when the design rules are derived. In the case of a continuously changing environment, the measure of time is zero, and the property of changeability has as a measure a number approaching infinity.

In some cases the time considered relevant may be that between states that differ by a relevant amount. What makes a change relevant is a decision that comes from the nature of the organization, the measures on other aspects of the outcomes it seeks, and so on. Once the minimum change size is chosen, then the time that is measured is that from one state to the next state that differs from the first by the minimum allowed. Here again, a circular and sequential process of measuring first the environment, using the measure to get a design, then recalibrating the measuring standard, and re-measuring, may be necessary. Also, when the property values of the components differ markedly from one another, one should consider creating segments of the environment. Each segment would have components with similar values of their changeability. We would then have an average measure for each segment that would be a better approximation than what we had for the un-segmented environment. The segments would then be used to design segments of the structure as we have shown earlier.

Changeability is a property that deals with the rate of change in the values taken by the components of the environment. Randomness is a property of the order, or lack of it , which the changes in the values exhibit. Any component of the state of the environment vector is given its identity when the environment is first identified and the property of size is determined. For a component, the set of values it can take is determined when the property of variedness is measured. The elapsed times between the different values that the component takes give one the basis for measuring its changeability and that of the environment. The pattern that may exist in the sequence of values taken by this component gives us the basis for measuring the value of the property of randomness of this variable. With the analogous patterns for the other components, we get the basis for measuring the value of the property of randomness of the whole environment. As an example, consider the case of the environment component of the consumer price index, the value of which is given monthly. If a long sequence of values observed show a pattern in which every value in that sequence is followed by a larger one, then one can conclude that the probability of a value going down from one period to the next is zero. In the case of maximum randomness, the probability of a given value being followed by any other value is the same. This holds for all values. It is the transition matrix of the values of a component that will be the basis of the value we give its property of randomness. The idea is not necessarily to have number measures for the entries of the matrix, but to have some concept of their orders of magnitude. When it is here, where does it go next? Is there a set of places where it always goes from here, and how big is the set relative to the complete set of numbers? When this is done for all components, then some order of magnitude for the whole vector of components may again be estimated on the basis of the similarities of the measure for the components.

While changeability deals with how often the environment changes its state, raggedness is a property that deals with the magnitude of the changes that occur in the values of the components of the environment. It deals with the size of the difference between one value and that of the next one taken. It is a measure of the magnitude of the change. If the temperature component of the environment goes from one value to another twenty degrees away in a given time of, say, three minutes, and if this is true for all the changes, then one would call this component more ragged than it would be if the difference were ten degrees. To measure raggedness, we need a basic time period during which the largest amount of change would be measured. Next, we measure many such changes for each component value, determine the average, and make that the measure for this component. When we do this for all components, we get a measure for the raggedness property of the whole environment. If the values for the components' raggedness properties differ from one another a great deal, then again we may well consider the definition of segments with components that have more nearly similar measures of raggedness.

We have to have this fixed time as a basis for measuring the value of this property. The appropriate time for each component may differ from that for others. Segmentation must be used here. The time period used as a base is one of choice. The measure of the raggedness of the values taken by a component is a relative one. It can be changed by changing the base time, which needs to be chosen to fit the component and the organization we are designing. Here too, we may have to go back and forth from calibration and measurement to design, and back and start again. Segments of the environment may be useful to create at each stage of design and calibration if the measure of raggedness of each component is similar to some others and very different from some others.

Randomness is the property of the environment that tells us something about the probability that the environment will be in any one of its possible states. If there were 200 possible states, and the probability that the environment is in any one is the same for all, then this environment is very random. To measure this property, we need the probability distribution over the states of the environment. The variance of this distribution is the measure of randomness of the environment. Being highly random does not mean that the environment is also highly changeable or highly ragged. The first refers to the relative frequency with which the environment is in this or that state. The second refers to how often the environment changes from one state to another. The third refers the magnitude of the change in state, when it does occur.

Is the environment as defined such that the values taken by its components are independent of one another? If the answer is no, then we have a positive measure of the property of the complexity of the environment. Suppose we discover that one component is so defined that its value may be obtained from the values of a set of other components. In this case, we do not need this component to describe the environment. We should drop it from the vector of states. But what if the value taken by this component depends on that of some others, but is not obtainable from these others? Knowing these may tell something about the value of this component, but does not tells us exactly what it is. If what it tells us is close to what it is, we may find the approximation close enough and still drop this component from our vector. If the approximation is deemed to be not close enough, then we must keep the component, but we must also recognize that its value does depend in a particular way on these other values.

Complexity is the property of the environment which describes this interdependence. To give it a measure, one must first identify any and all connections that exist between the components. The mappings that describe the relations of the values of the components to one another also need to be identified. The value taken by this property is based on the nature of these mappings. One measure of this property could be defined as the ratio of the number of components that are connected to at least one other to the total number of components. Perhaps this is too crude a measure, and we want one that captures the strengths of the relations. To get such a measure, the ratio would be altered by some factor that measures strength. In general, this measure is a rather subjective one, and its use is problematic.

Also problematic is the measure of the last property of the environment, that of independence. The assumption that underlies the argument that environment and performance are two different things is that the values taken by any component of the former are independent of the values taken by any component of the latter. The logical separation of environment and performance is the result of the distinction between decision variable, a component of performance, and parameter, a component of environment. Ideally, in the analysis the two should be clearly separated, thereby making the process of design that takes the environment as fixed useful. However in the real world, such separation may not be possible to get, and there is some residual dependence which needs to be considered. It is this residual, and hopefully minor dependence, that this property describes. To measure it, we will need to make some subjective judgments on how we are to deal with the interactions.

## 5. Facts on Outcomes

The last set of property measures needed to complete the basic facts to be used in designing organization structures are those involving outcome mappings. Once the organization determines what it is to do, it determines its technologies. Once this is done, then what we called the environment may be described. When the organization chooses the outcomes it wants to get from what it does, then the relation of these to what it does and to the environment may be described. These mappings are really a part of the environment but are required goals and not just operating choices before they are identifiable. So we treat them as a group, or special segment of the environment.

Sensitivity of the outcomes to performance is the first of this last basic set of properties to be measured. If we had one simple mapping in real number space, and it was continuous and differentiable, then the partial derivative of outcome with respect to a component of performance, a decision variable, would give a function that measures sensitivity. In the real world none of these requirements is likely to be met. Nonetheless, it is always possible to ask how outcomes are likely to change if some one component of performance were changed. If an order of magnitude were obtained for each decision variable, or component of performance, then some average may be estimated for performance as a whole. Two cases are of interest and require some estimate of this measure. The first is that of estimating the measure when performance is changed in specified directions from what it is now. The second case is that of making the estimate for movements in the performance as it moves towards the best one, given all other components of technology and environment were constant. If neither is possible to get, then we have no basis for making any design decisions, since we could not translate the performance changes of any design decisions into actual outcomes. We need these sensitivity measures to tell us when changes in performance are worth the effort of the redesign we have to make to get them. So, the measurement of the order of magnitude of this property is essential if design is to be a meaningful activity. In many cases, good estimates of the property of outcome sensitivity are not hard. A company interested in the profit outcome may find that even minor design changes lead to greatly increased profits. Such an estimate may be very simple to get.

Outcome mappings may also be analyzed for their sensitivity to parameter values. Everything said about the measurement of the previous property applies here. A measure of the order of magnitude of the two together tells us what to expect when both the environment and the performance are changed, as in case where the latter is changed to match the change in the former. Some idea on the values taken by these properties, given the choice of outcomes is made of course, is needed before one can tell whether design efforts or redesign efforts are even worth starting.

Finally, we come to the very last fact we need for design, the value of the property of richness of the outcome mapping. The two sensitivity properties refer to changes in the ranges, when changes are made in the domains of these mappings. Richness refers to the absolute values of the range of the mapping at any set of points in the domain. Very high measures or very low ones may obviate the need to worry about structure design altogether. If richness is very high where we are and in surrounding conditions of environment and performance, then no one would care about any changes in the organization's structure. If richness is very low where we are and in surrounding conditions, then again no one cares about changes in performance and structure. In this case, we need new technologies and new environments. It does not pay to worry about design when everything is great. When everything is bad, then a change in the whole nature of the business is what is needed. In between these two extremes, an estimate of the order of magnitude of the value of this property is invaluable to the process of design. The higher the level of this property of richness, the lower the utility of the marginal returns to improving the structure and the less the effort on design should be.

## 6. Facts on Performance

Rules of substructure design are of the same logical form as decision rules, with an if segment and a do segment. The design rule for an environment segment may be made up of various combinations of properties of technology, environment, and outcome. One such design rule might state "if the environment property of raggedness is high, then the value of the performance property of responsiveness should be made high". To use these basic design rules one would need to find out what the facts are that make the statement the correct one, and hence, the one relevant. The facts in this case are only to be measured. They can not be set because they are beyond the power of the designer or the organization. They are what they are and nothing can be done about it. These facts can only be read, and cannot be set. Since performance is defined in terms of decision variables, its components are set by people in the organization. Whatever the property of this performance may be, it is given a value by the first set of decision rules. This value is what the rule says it ought to be. Reading this value gives us the feedback we need to make sure that the design rule is followed. But performance properties are also used in the if part of a set of rules, those based on the outcomes of the first set of rules. Without a measure of the values of these properties we cannot check to see whether or not the structure we design is the one we need. It is what we need if it gives us performances that have properties with the values we wanted. We need these measures to be sure we are using the right rules, i.e., that our underlying analytic theory statements are true. Measuring the properties of performances is an integral activity of designing organization structures.

Flexibility is one property of performance that needs to be measured. It is, in fact, a property of a subset of performances, and this set needs to be defined if the property is to be measured. A repertory company puts on plays. The more plays it can put on, the more flexible it is. That is what flexible in the nonphysical sense means. But how much time does the company need before it can put on a play? What quality of acting can be achieved in the performance of this play in this given length of preparation time? Two theatre companies can each put on any one of 29 plays. The first one can put on any play with one day's notice, the second within 10 day's notice. If we allow ten days to be the standard time, then the two are equally flexible. If the standard time is two days, then they are not equally flexible. If both take one day, but the quality of the acting by one company is far superior to the other, then there is no meaning to the statement that both are equally flexible.

What a unit can do can only be meaningful in the context of some quality level and some time frame. The problem for us is to determine the time frame and quality level that are relevant to the circumstances of the organization whose structure we are to design. In choosing the appropriate time frame, the organization's technology and its environment must be considered. First, there is the total set of performances that could be given in some long but finite time, which is determined by the technologies. Given these, there is some minimum time period needed for a performance to be brought into existence. This is the smallest time period that the technology requires to go from one performance to the next. But an organization structure may need much longer than this time because it may not know how to specify this performance. The time it takes to choose a performance may be longer than the time needed by the technology to make it possible. For flexibility of performance then, the time frame we choose must be as large as that required by the technology. If quality of performance is important, then this time frame must be that which is the minimum needed to make the new performance in the new environment at least as good as the old performance was in the old environment. The time frame we choose must be comparable to that used in defining the changeability of the environment.

An analogy helps us here. A hunter who uses arrows has a quiver full of them when he's in the field. There is no way this set can be changed without returning to camp, making new kinds of arrows, etc. There is some time period during which the hunter is limited to a specific number of kinds of arrows he may use in the field without returning to the village to get the kind he needs but does not have with him. Suppose the quiver can carry 20 arrows, and each kind of arrow represents a performance. The number of different kinds of arrows is limited by technology to 20. In this case, one might conclude that the maximum measure of flexibility is this number, 20. One kind of arrow means no flexibility. Suppose that the best kind of arrow to use is different for each of 20 types of game. The location of each game can change in 10 seconds. How long does it take the hunter to draw the right arrow for the game spotted? Now for the hunter with 20 arrows and a draw time of 8 seconds, the measure of flexibility is 20, the very highest. If he had only 10 different arrows and the same draw time, then the measure would be 10. If he had twenty arrows but had a draw time of 8 seconds half the time and 12 seconds the other half, then on the average he will get half the best arrows needed within 10 seconds and the measure of flexibility would be 10. The time frame chosen here is 10 seconds, because that is the time frame in which the environment, defined in terms of the location of the game, needs to change.

A measure of 20 performances and the requirement of best arrow within ten seconds is the very highest level of flexibility in this case. Another way to measure flexibility is to use the ratio of the actual to this maximum. But whichever one we use, its meaning is dependent on the time frame and the given quality. For this same hunter, the time frame used is that which is limited to the time it takes to get an arrow out of the quiver. If we changed this time to three days, the relevant number of different kinds of arrows is what is already in camp, or might be fashioned during that time. However, in this case the measure of flexibility is not relevant to the outcomes today, but only to outcomes four days from now. Quality ten seconds from now is irrelevant in this case, and quality in four days is meaningless in the previous case of the ten second time frame. The time frame chosen to measure flexibility is that relevant to the environment of the organization, and to the outcomes it chooses.

The measure of flexibility tells us what performances of some given quality the organization is capable of in a given time period. The question now is how fast can it actually produce the performance of the needed quality. In the case of the hunter with 20 kinds of arrows and a draw time of 8 seconds, we can argue that he can get so many numbers of game of a certain kind in a day. If this hunter had a draw time of three seconds, then the measure of his flexibility is still twenty. But now he can be expected to get more of each kind of game in a day than before. This actual draw time measures what we call the responsiveness property of the hunter's performance. It is the time it takes to actually realize the performance that is in the set available in a given period of time and meets the quality requirement for all performances in the contexts of their environment's states. The state is that which holds now, and the time of response starts when this state of the environment first came to be. For the hunter, the response time is that between the instant when the game came into his sensory range, and the instant he fired the arrow. This time measures responsiveness.

Responsiveness for an organization is a property that is akin to speed. It involves the speed with which an organization spots changes in the environment, and then chooses and implements a set of decisions that is appropriate to the new state of the environment. Once we define what appropriate means, responsiveness is measured in terms of this time period. We may use pure time, e.g., five days, or we may use time in units of environmental changes. In either case, we take the average time to get the appropriate performance. In the second case, we take the average time between minimally significant changes in the environment, and measure responsiveness by the ratio of the first to the second. Responsiveness may thus be five days, or one half, which is the ratio of five to the time between environment changes, which is ten.

To measure responsiveness, we need to define what we mean by a performance that is appropriate to the environment. One definition is that the performance be the best, or that it be a good one, or that it be as good for the present circumstances as the one before was for its circumstances. Here again, we might have to experiment with one choice, and use the results we get in design to make another choice of what is appropriate. The richness of the environment and the sensitivity of outcome to decisions should play a role in our choice of appropriateness. After all, if both measures are low, we may not want to design costly structures that produce low returns to quality of performance or the speed of its implementation. In any case, both flexibility and responsiveness are meaningless without the specification of a time frame related to environment change and a quality level of performance that is considered acceptable.

Quality brings us to the next property of performance, what we have called optimality. If we knew the optimal performances for differing environments, we would certainly implement them. If we did not know what is best, then we could not measure how close to the best any performance might be. How, then, do we measure optimality? If we can not measure it in absolute terms, we can measure it in terms of some ordinal relation. We may not be able to say that performance 1 is close to optimal, but we can say that it is closer to optimal than performance 2, and that we might find performance 0 that is closer still. In this sense then, optimality of a performance may be said to be high when it is higher than that of many other known performances, and lower than only a few. As more performances become known, our measure may have to revised. And yet once more, we are confronted with the need to measure and design and re-measure and redesign.

Fortunately, coordinateness is not quite as vague and hard to measure as optimality. The level of coordination of a performance can be said to be at its highest if no change in the value of any one component produces a better performance. If one can change the value of one component, and there is a better outcome, then the performance just changed was not maximally coordinated. If one is unable to change the value of any component and get an output improvement, then one has a perfectly coordinated performance. The level of coordinateness may be estimated by the number of components which may be changed one at a time and bring about a higher level of coordination. If performance had 16 components, and we establish that there is only one component which when changed would produce better coordination, then we would call that performance highly coordinated. If 11 component value changes made one at a time improve coordination, then our present performance can be measured as being very low in coordinateness. It would be best if we could use the measure suggested earlier, that is, in terms of the amount of improvement in output that these changes made. But this requires that we know the output of each performance, something that is logically possible, but realistically remote. In design we use whichever gives us better results. One is easy to use, but gives vague conclusions on the best level of coordinateness. The other is expensive, but gives clearer and logically stronger conclusions. Trial and error in designing may be our best alternative here.

To measure controlledness, we need the performance specified by the operating structure, and the one actually implemented. Since control is in terms of some decision maker, then one, or a group of these, must be chosen before we can measure the value taken by this property. We are talking of control of performance by some specific set of people. Once we identify this set, then the decisions this set of decision makers expects from the structure is established by the decision rules the set makes. The rules made by this group identify a set of performances that are expected. Among these are those that are thought to be best. Controlledness is measured by the difference between the actual performance and the closest performance in the set considered to be expected and best.

Control is measured by two values. The first is that of the difference between the actual performance and the specified one. The second is a probability measure of getting any specified difference between the actual and the desired performance. When these two measures are used, the result gives a better basis for determining what needs to be done to change the level of control. However, this is a difficult measure to get. The first one we defined is much easier. We use whichever measure gives us what we want in the light of what it costs us to get it. If we want to know the measure control of various performances, given a single desired one, this second measure is adequate. If we want to measure control of various performances given any one of a number of desired performances, then we have to use the first two component measures of control.

# CHAPTER 11

# DESIGN RULES FOR ORGANIZATION STRUCTURE PERFORMANCE PROPERTIES

## 1. A Process of Design

In a task as complex as that of designing effective and efficient organization structures, an efficient process of design is likely to be one made up of a series of steps. First, the technology and outcome function are identified, and the components of the environment are derived and segmented in the manner described above. The parts of the technology of the whole and of the outcome function that are relevant to each segment are identified. At the end of this step there should be an environment, a technology, and an outcome function for each segment of the structure. The second step is to derive from these and the rules of design, which are themselves derived from the propositions of the analysis, the levels which one wants the properties of the organization structure's performance to have. The third step of design is to identify the set of structure property levels which the structure needs in order to perform as desired. The fourth step is to take these derived levels of the structure properties and derive from them the design or specification of the components of the structure itself. Because the properties of the structure are defined in terms of its components, the move from the levels of the properties to a design of a structure is one of translation rather than derivation. What we now have is a set of levels of desired performance properties, and a set of properties of a structure that has the performance that has the desired property levels. Because this set of structure properties is obtained without consideration of structure costs, there will be a series of steps that include the repetition of this fourth step. We call these two sets the "starting" sets of the design process.

Let us call the set of desired performance property levels the P/set, and the set of structure property levels designed to give that performance the S/set. We now have the starting P/set and the starting S/set that is derived from it. The fifth step is to consider the costs of this S/set and adjust it. The object is to search the neighborhood of the

S/set we now have from the previous step for other sets that cost less money, involve lower structure costs, and yet yield a P/set that has outcomes very close to those of the set we started with. This is a process of making marginal variations in the S/set and estimating the changes these bring about in the P/set. Next, the change in cost of the changes in the S/set are compared to the changes in the outcome of the P/set. If these cost and outcome changes are acceptable, the whole process starts with the new S/set. If the changes are not acceptable, the process starts again with the original S/set. When the variations no longer produce changes large enough to pay for the next variation, we stop the process and adopt the P/set and S/set we have. These are the "ending" sets of the process.

What we now have is a set of performance property levels and the fully adjusted set of structure property levels that is derived from it. Next, we go back to the initial P/set obtained in step three, and search its neighborhood for other sets. The search starts somewhere close to the original and derives from it a set of structure property levels. Next, the search involves a series of adjustments on this set that are analogous to those done on the first set of derived structure property levels. This means that step four as described above is now repeated. These marginal changes are used to derive the changes they imply need to be made in the S/set, and the outcome and cost changes that result are estimated. If the these two changes improve the relation between outcome and cost, and are acceptable, the new P/set is used to start the process all over again. If the changes are not acceptable the process then starts with the first P/set. As in step four, results of marginal variations in the set on which we are of focusing, the P/set, become such that further variations in it are no longer worth making.

In summary, the design steps for one segment of the environment are in a sequence where the earlier step produces the facts to be used to perform the next step. Performing the activities of each step involves using design rules which turn the required results of the previous step into another set of required facts. Design rules which are derived from the analysis made earlier are derived below. These rules guide the acts involved in the steps of the design process. They are:

1. Identify an appropriate segment of the environment, the relevant segments of the technology and the outcome function, and the levels of the properties of all three.
2. Derive the desired set of performance properties for the organization structure. We call a set of performance property levels a P/set .

3. Derive a set of property levels of an organization structure which has a performance that meets the outcome of step two. We call a set of structure property levels an S/set
4. Given the outcome of the result of step three, make changes in the set of organization property levels, the S/set, derive the changes these produce in the P/set, estimate changes in the cost of the former and the outcome of the latter. If changes in these are acceptable, go through the whole process again, starting with the S/set that resulted from the changes. If the changes in outcome and cost are not acceptable, make further changes in either of the two S/sets and redo the acts of this step. When changes in S/set no longer produce changes of any magnitude, step four stops. Changes made at each stage may be in either of the two sets. It does not have to start with changing the S/set first. Whether we change this set or the other first does not affect the logic of the process. Also, one may change one set many times before changing the other. This too has no effect on the logic. What is important is to make each stage start with changing one of the two sets and end in changing the other set. Every stage has a pair of matched sets where the S/set is logically derived from a specific preceding P/set.
5. We may stop after any stage in step 4, or we may stay in it and go through another iteration. The decision to stop is made when the next stage does not produce much change in its concluding P/set and S/set, or when it does not produce much change in the returns and costs of the two sets. To stop means that the last S/set derived is that of the structure we want, and the last P/set is the performance we are going to get. Given the definition of structure properties, this S/set can be directly translated into specific components of structure. This then is the design of a structure, one that is best for the given circumstances of environment, technology, outcome function, the structure cost function, and the design process cost function. The actions taken within each step are guided by rules, as are the transitions from one step to another. These rules are given in this and the following chapters.

## 2. Design Rules

A good design rule might state that if the environment property of raggedness has a measure of 64, then the performance property of responsiveness should be given a measure of 38. But the requirement of number measures is too much to ask for when one is dealing with complicated concepts like environment raggedness, and so on. Whatever the measure, the best rule would do this for every value taken by the property of raggedness. Better still, the rule would be accompanied by the algebraic process by which it is to be combined with another rule that involved the value of responsiveness. So, the rules we get are simpler ones (Baligh, Burton and Obel, 1987), (Burton and Obel, 1998). An example would be a rule from the artificial intelligence design program of Burton and Obel (1998, 2004). A rule is given as: if the environmental uncertainty is low, then centralization should be high (cf 20). Here, the rule does not have number measures for the values of the properties. Since uncertainty is measured in broad categories of high, medium, and low, centralization is measured in terms of high, medium, and low. The rule is not as precise or as good as it might be. The term cf 20 is the component of the rule that gives a measure of the strength or importance or intensity of the admonition to follow the rule. This measure also allows one to combine this rule algebraically with another of the form: if the environment complexity is low, then centralization should be high (cf 30). The required level of centralization for both rules is defined by the equation: $20 + (100 - 20) \times 30/100 = 20 + 24 = 44$. There are also rules of the form: if the environment property of equivocality is high, that of complexity is low, and that of uncertainty is low, then centralization should be set at a measure of low. Here complex nonlinear relations between the values of many properties can be incorporated within the rule, but the combination of two such rules with one dimension of domain cannot be combined in the manner of the equation described above.

Unless we have the actual equations that describe the functions of the firm for which we are designing a structure, no design rules that specify values to design variables are derivable. Even if we know that the more coordination we have, the higher the outcome for any organization, we do not know how much the increase would be for any organization. For such an organization, the facts of the case are necessary to establish how much outcome increase we get with any improvement of coordination, and the reason is simple, coordination is costly. We know that higher levels of coordination have higher costs. We cannot say how much coordination we should have unless we know the actual number relations between costs and coordination levels, and between outcome and coordination levels. For each organization, there are such relations that are unique to it, or at least organization specific. Given the complexity of the determination of the cost of coordination and the identification of such a relation, there is no point in establishing what it is until we know the set of levels of coordination we might want. These relations are not equations in real number space, but functions for which there is no describing equation. Even if we were to argue that their slopes, or what would be their slopes if they had been in equation form, are generally positive, or whatever, and we use this knowledge to guide the search, we would not be able to avoid the search itself. This is the reason that the design process circles on itself, as in step four. To create a design process of general applicability, one for a general theory, would be analytically neat but functionally useless.

The design rules which are to be derived for the general case of design are therefore as precise as the underlying conditions allow. They are of the form that alerts the designer to a property as one that is important to consider in the circumstances because of its effects on outcomes. Others will specify the structure property that is most likely the one on which to operate to get a certain level of a performance property. Wherever possible, the rule will combine as many dimensions in its domain as the theory warrants, so that intricate causal connections may be captured. Combining rules algebraically will lack any detail number operations, and will merely suggest possibilities of tradeoffs or identify the nature of the effects of one variable on the effects of another. In short, without the numbers representing relations between property values and outcomes, and between these values and cost, an artificial intelligence system is not of great use. If the functions differ from one design case to another, then an artificial intelligence process must be created for each set, and the efficiency of this method of design is weakened. If an artificial intelligence design program has to be adapted or recreated for each case, then the returns to it are much smaller than if it had been usable in all or many cases. If the details on return and cost functions are not available to the designer, then they cannot be included in the artificial intelligence program, and it is of little use to the designer. If the facts on cost functions are obtainable in small segments only, and are estimated from past moves, then the artificial intelligence program would have to be used many times to get the final design.

## 3. Nature and Meaning of the Design Rules

Performance properties might be good or bad. Those we have chosen are all good. Higher levels of flexibility, optimality, coordinatedness, responsiveness, and controlledness would always lead to more desirable, or at least as desirable, an outcome than would lower levels. Earlier analysis has shown that. Why not have one design rule that merely states that we should set the level of each property at its highest? The answer is that the levels obtained come at a cost, the cost of the structure that will produce them and the cost of designing this structure. We know before we start designing that these costs are likely to make it unprofitable to set performance property levels at their highest. Furthermore, the analysis has shown that the costs of getting any level of one property may well increase as the level of another performance property is increased. All these cost relations make it clear that the best levels of performance properties are not determined by outcome alone. The best set of levels for these six performance properties is not the maximum for each, but is one to be derived from the outcome and cost functions that are specific to the operations for which a structure is being designed. There is a decision problem in which the solution is the optimum or good set of structure performance property values. The design rules are intended to start the process of determining the levels desired, given the outcome and the structure and design costs.

The rules for design that will be derived have special meanings and a specific algebraic nature. Organization structures are made up of people connected in a particular way. People, unlike machines, do not have fixed or standard ways of making decisions, or describing facts, or understanding rules, or sending information. The performance of the structure and its environment are heavily loaded with components that have no number measures. Even though one may have some idea of the magnitude of the value of a variable, and be able to identify some order on a number of these magnitudes, one could not logically think of these magnitudes as cardinal. All this makes precision of design not meaningful. The best we can hope for is to design what might be termed impressions of structures. Somewhat fuzzy but discernable organization structures is the best we can hope for.

The complexity of the object of design, three substructures with issues of consistency connecting them, large numbers of different pieces of the structure to be connected by large numbers of many different kinds of connections, restricts one's choice of the process of design. It is suggested that the most efficient process is one that works with pieces of the environment, pieces of the technology, pieces of the outcome function, and with pieces of the cost function and designs pieces of structures to go with them. Next comes the designing work of fitting a few of these pieces, which means redesigning some of the pieces. The first combination of pieces is not random, but is based on some concepts of the general neighborhood of values of properties of performance and structure. Once the first sub-piece is designed, it may be used to identify where changes in it might produce a better design. This redesign process is also governed by the basic rules of design. The whole process is based on segments, fitting, redesign, refitting, redesign once more, and so on. Design rules guide this process by identifying at each step the neighborhoods of property values where the values are to be set. As the process of design moves through its many stages, the rules also help identify the directions in which the values might move to get better fits and better redesigns.

A rule is then of the form: the higher the value of property X, the higher you are to set the value of property Y. Another rule would be that which states that the higher is the desired value of property Y, the higher the value at which the property Z is to be set. The first rule is used when X is a property of the environment, the transformations, or the outcome functions, and the second rule is used when Y is a property of performance. The first kind of rule is used to get the set of desired values for Y, which then makes the second set of rules usable. Both may be used at all stages of the process, except the first. Here, we need a starting point for X and Y values. To get these we will assume that the design rule is in absolute form, that is, it states that when X is high, set Y at a high level. This issue is discussed in much detail in the next chapter, and suffice it to say for now that this starting point is in a form which allows the correct use of the rules in comparative form. During the continuing process of design, one works away from the starting point as changes in outcomes and costs resulting from the use of the rule are evaluated. A new set of rules is derived for use in the next step. High costs discovered in getting a value for X suggest reducing it in the next stage of design. The use of the next rule might suggest that a different way of getting this value of Y is available. It might be considered as one of lower cost. This would lead to further movement of the present value of Y to a higher one. There may also be a rule that indicates that there is another property Z, the value of which calls for a high value for Y. Since there are two reasons for the value of Y, we should combine the two rules to get the value for Y. There are different ways of combining the rules, and the outcome depends on the one we choose.

Combining design rules is an important determinant of the design we get from using the rules. Suppose there were two design rules that have the variable Y as the design variable, the one in the then part of the rule. Suppose also we are at a stage where both rules are stated in terms of specific values for the shared design variable. This will occur in the very first step and in any potential last step. The logical manner we choose to combine them will produce different rules to use in the next step of the design process, and consequently will lead to different designs. When one compares the values of the shared design variable called for by the two rules, then only one of two conclusions can be made. Either one rule calls for a higher value than the other, or both call for the same value. In both cases the rule we choose to use in the design process will be one of the two. In the case of equal values, we may use either. In the case of unequal values, we use the rule that specifies the higher value for the design variable. We call the rule a dominating one. We use only it because it meets the requirements of the other rule. After we use the dominating rule and complete the step in the design process, a new rule about the design variable shared by the original rules will appear. It is then compared with the rule that was dominated, and the one that dominates the other is that used in the next step of the process.

Some rules may have two components that describe the element of the domain. They might be of the form: the higher the value of the property X, and the higher the value of property Z, then the higher the value at which the property Y is to be set. Such a rule is the equivalent of three elements: the rule for X, the rule for Z, and an algebraic connection between the values of X and Z. This relation is defined as follows: the value set for Y is the higher value of the two rules augmented by a factor that is in proportion to the lower value. Suppose the X rule asks for a higher value for Y than does the Z rule. The combination is the value of the X rule increased by a factor proportionate to the value in the Z rule. The larger this value, the larger the factor. Combined rules of this form acknowledge the impact of the property X on the property Z, and conversely. The combined rule acknowledges the fact that combinations do have an impact on what is to be done with the value of Y. When two rules remain separate, and when they are merged into one, depends on the analytic statements from which they are drawn. The analytic mappings derived earlier in this work tell us when two prescriptive rules may be combined, in which case they will be. Such combined rules state that the rate of increase of what the value of Y is to be with respect to either of the values of the two properties X and Z is larger than it would be in a similar rule with only one property in the if part. Combining rules in this way is based on the analysis of the theories that produce the individual rules. More on this issue is found in the next chapter.

## 4. Design Rules for Performance Property Values

The outcome function relates the performance of the organization to the outcomes that are valued by the organization. An army wants to win wars and destroy enemy armies, a social organization wants to raise money for research to eradicate cancer, and the computer software company wants to get the largest share of the world market. Each of these functions has as its decision variables the components of the organization's performance, and as its parameters the components of the environment. Our first design rule is derived from the nature of the outcome function that is monotonic in both decision variables and parameters. The rule does what a first rule should do. It tells us whether to go through the process of design or let it, the structure, just happen. Unless a rule on performance property levels is explicitly stated to refer to the reward or information substructures, it refers to the operating substructure.

Rule 1. The higher the level of the generosity of the outcome function, the less time and effort are to be invested in designing the organization structure. The lower this level, the more important it is to pay attention to the structure of the organization and its the performance.

The sense of the first rule is quite obvious. If outcome is great regardless of what your structure does, then why incur costs of designing and costs of structure to get properties that get you very little improvement in output. In this case, there is no need to worry about the properties of the performance, and hence, no need to design an organization structure. If however, the outcome is not always great regardless of what we do, then it pays to begin studying the outcome function. If the outcome is sensitive to the decision variables, that is performance, then outcome may change in huge amounts when performances changes. It may fall dramatically when the decision moves way from one good performance to one slightly less good. Performance quality is important in this situation. So this property of optimality is to be desired. We should know this early in our design process. The same argument holds for coordinatedness. If quality of decisions and performance are important, then it pays to make sure that they are implemented. This is what a higher level of controlledness gives us. Finally, higher levels of responsiveness reduce the time of moving from one performance to another. When the outcome changes a great deal when the environment changes, then some of these large outcome changes may be expected to be bad ones. The longer the structure takes to produce a different performance, the longer we have to live with this bad level of output. Hence a higher level of responsiveness can be expected to improve outcome over time by larger amounts and should therefore be sought after.

Designing an organization structure becomes important when the properties of the performance affect outcome greatly. The outcome function is in considerable measure a result of some fundamental decisions the would be designers of the organization make. Strategy is the term used to define such decisions. We have not done much with strategy in this work. It is too vast a subject and deserves a work on its own. But it is important to mention the points at which strategy and organization performance and structure come together. One aspect of strategy is the set of decisions that determines the choice of the outcome function. Strategy determines in some measure the outcome function by determining the nature of the outcomes it seeks, and the technologies it will employ to that end. In doing so, strategy identifies the decision variables of the organization, that is, what it is that the organization is to do, what technologies it is to use, and what it is to get out of all this. If the strategic choice is that this be a fire fighting unit with a specifically defined output of minimizing death by fire in a given area, then the set of decision variables to which this organization is to give values is in part determined, as is the outcome function. This side of strategy may then be used to develop the strategy that creates the mechanism that will actually choose the values for the decision variable of the output function. This part of strategy is that which produces a structure design. Given the result of this sequence of strategy making, the process may be repeated by altering the outcome function, then redesigning the structure that fits it, and so on.

Rules of design should state what the designer ought to do when certain circumstances hold. When the rule is about a performance property, then the rule tells the designer what the level of a specific performance property ought to be. The complete set of such levels forms the basis for the design of a structure. From these levels of performance properties, the levels of the structure properties are derived. These links are the outcomes of the theory and the analysis which showed what performance property levels are obtained from what combinations of levels of structure properties. Because all properties are defined operationally, these levels are directly transformable into a design of an organization structure.

There are two kinds of design rules on performance properties. The first kind of rule is that which states what the level of a performance property is desirable as a starting point in the design process. The second kind of rule states something about how levels of two or more of these desirable levels are to be adjusted before the next step of design is started. We now derive the set of rules of the first kind.

Rule 2. The higher the level of the outcome function property of sensitivity to its parameters, the higher the level of environment property of variedness, and the higher the level of environment property of randomness, the higher the level at which the performance property of flexibility is to be set.

Rule 3. The higher the level of the outcome function property of sensitivity to its parameters, the higher the level of environment property of changeability, and the higher the level of environment property of raggedness, the higher the level at which the performance property of responsiveness is to be set.

Rules 2 and 3 deal with the adaptability of the operating structure. Flexibility relates to having a performance that fits the state of the environment that exists. Responsiveness relates to how quickly the operating structure can get that performance going after that environment state begins to exist. The more environment states we have to face, the more flexible we need to be. Also, the more nearly equal are the probabilities of these states, the less we can ignore some states because they are very rare, and concentrate on the less rare. Meanwhile if the states change very often, then we need to respond with our performance changes quickly, or we'll find ourselves implementing performance y for state x at the time x has long since become w, or whatever. Also the bigger the differences between the states, the worse will our performance for the old state be in the new state. We need to shorten the time we live with this old performance. Of course if our outcome function is such that outcome changes a great deal for the worse when we don't adapt and do it fast, then we need to do it fast.

Rule 4. The higher the level of the outcome function property of sensitivity to its decision variables, the higher the level of the environment property of size, and the higher the level of the technology property of tightness, the higher the level at which the performance property of coordinatedness is to be set.

Rule 5. The higher the level of the outcome function property of sensitivity to its decision variables, the lower the level of the technology property of randomness, and the lower the level of the environment property of randomness, the higher the level at which the performance property of optimality is to be set.

Rule 6. The higher the level of the outcome function property of sensitivity to its decision variables, the lower the level of the technology property of randomness, and the lower the level of the environment property of randomness, the higher the level at which the performance property of coordinatedness is to be set.

Rule 7. The higher the level of the outcome function property of sensitivity to its decision variables, the lower the level of the technology property of randomness, and the lower the level of the environment property of randomness, the higher the level at which the performance property of controlledness is to be set.

Tight technologies are heavily ordered. That means that failure to recognize these orders is equivalent to using very different technologies, and hence getting much worse outcomes. With an environment of large size, one with many components, the amount of variation in the technology that is likely to occur when one ignores the logical orders is greater than in the case of fewer components. Sensitivity of the outcome function to the decision variables also enhances these effects. In these circumstances, coordination level increases mean higher levels of marginal returns of the level of the outcome. It is worthwhile to incur the marginal costs of designing a structure which has the properties that give it a higher level of the performance property of coordination. Rule four makes good sense.

Randomness of the technology weakens the connection between what the organization does, its performance, and the outcome. The same is true of randomness in the environment. This makes higher levels of optimality much less valuable in terms of outcome than they would be if randomness were lower. What we optimize is the solution of that part of the problem that is not random. Actually one should say that one's capacity to get better outcomes is restricted by the size of the segment of the problem that is random or by the degree of randomness embedded in it. As these two levels of randomness fall, then the effects of increasing the level of optimality increase, and we set its level higher. The sensitivity of the outcome function to performance enhances these effects. It makes optimality effects on outcomes much stronger than they would be otherwise.

Rule 8. The higher the level of the technology property of variety, the higher the level at which the performance property of flexibility is to be set.

Rule 9. The higher the level of the technology property of variety, the higher the level at which the performance property of responsiveness is to be set.

A higher level of the technology property of variety makes the decision space of any structure bigger. This means a higher level of the quality of the match between performance and structure can be expected. The best match between structure and environment will be better or no worse when the structure has more ways of getting it. Any level of flexibility will have a higher return if the elements in it have returns higher or no lower than every element that is its analogue. Flexibility is more valuable in the one case, and so should be set at a higher level.

Rule 10. The higher the level of the technology property of captiveness, the higher the level of the technology property of completeness, and the lower the level of the technology property of exposure, the higher the level at which the performance property of optimality is to be set.

Rule 11. The higher the level of the technology property of captiveness, the higher the level of the technology property of completeness, and the lower the level of the technology property of exposure, the higher the level at which the performance property of coordinatedness is to be set.

When one thinks about the three properties of technology discussed in the preceding two rules, one finds that all three are related to the pieces of the technology which the organization can actually operate. Regardless of the randomness of any technology, some parts of it may be beyond the capacity of the organization to operate. This may be because the world happens to be that way, or because strategic considerations led this organization to give part of its technology to another organization to operate. In either case, the more pieces the organization can actually operate, the larger will be the good effects of improved performance quality on outcome. If the payout of increasing the level of optimality increases with the extent to which the performance covers all elements of the technology, then rule 10 makes sense. The other rule may be supported similarly.

Rule 12. The higher the level of the technology property of captiveness, the higher the level of the technology property of completeness, and the lower the level of the technology property of exposure, the higher the level at which the performance property of controlledness is to be set.

The reason for this rule is that the conditions of high captiveness, and completeness, and low exposure leave little of the technology out of the logical reach of the organization. The smaller this uncontrollable segment, the higher the probability that any given effort to control the controllable segment will carry to the whole. In other words, the bigger the segment that is controllable, the more effect on the whole will any level of control on this segment have.

## 5. Substructure Consistency

Some design rules may be stated about the consistency between the performances of the three substructures. Consistency issues will also arise in the case of substructure properties. The rules on these are stated below. But for performance consistency, we have rules involving information substructure performance properties of alertness, and accuracy, and one reward substructure performance property of fairness. Alertness is defined earlier in terms of the time elapsed between the occurrence of a change in the value of a parameter and the reading of the new value by a member of the organization. When we average these times for all variables, then we can establish a measure of alertness. Accuracy refers to the nearness of the reading of the value of a parameter and the actual value. Again, when we average these for all parameters, we can develop a measure of this performance property. For the reward substructure, we defined at length this property of fairness. Its measure for the organization is based on the averages of measures given it by all members of the organization for the rewards given to all these members.

The design rules on these properties will be given in terms of the desired levels of the performance properties of the operating substructure. A desired level is one that is set by the use of one or more of the preceding design rules. Since the logic of substructure consistencies connects the substructures directly, by making the information and reward ones depend on the operating one, there is no need to connect the first two directly to environment, technology, etc.

Rule 13. The higher the level of the performance property of responsiveness desired of the operating substructure, and the higher the level of the performance property of optimality desired of the operating substructure, the higher the level at which the performance property of alertness of the information substructure is to be set.

Rule 14. The higher the level of the performance property of responsiveness desired of the operating substructure, and the higher the level of the performance property of coordinatedness desired of the operating substructure, the higher the level at which the performance property of alertness of the information substructure is to be set.

Rule. 15 The higher the level of the performance property of flexibility desired of the operating substructure, and the higher the level of the performance property of optimality desired of the operating substructure, the higher the level at which the performance property of alertness of the information substructure is to be set.

Rule 16. The higher the level of the performance property of flexibility desired of the operating substructure, and the higher the level of the performance property of coordinatedness desired of the operating substructure, the higher the level at which the performance property of alertness of the information substructure is to be set.

Rule 17. The higher the level of the performance property of controlledness desired of the operating substructure, and the higher the level of the performance property of optimality that is desired of the operating substructure, the higher the level at which the performance property of accuracy of the information substructure is to be set.

Rule 18. The higher the level of the performance property of controlledness desired of the operating substructure, and the higher the level of the performance property of coordinatedness that is desired of the operating substructure, the higher the level at which the performance property of accuracy of the information substructure is to be set.

Relations between the substructure properties in these six rules are not of equal strengths. All six rules are also independent one of the other, and hence are not to combined in any algebraic way. Whichever rule demands the highest level of alertness dominates two other rules, and similarly for accuracy. In any given designing process, only one rule will determine the level of alertness at which we start the process, and only one rule will determine the level of accuracy at which we stop the process. Each of the rules has two properties defining their domains. This means that the two levels are to be combined algebraically. The way this is done is explained earlier and essentially involves the augmentation of the effects of the level of one property by some amount that increases as the level of the other property increases. The rule states that there is a positive interaction between the two variables of the domain.

The level of responsiveness is based on the time it takes from environment (parameter) change to performance (decision variable) change. This time is made up of the time it takes to realize a change has occurred and to get the new facts, and the time it takes to choose the new performance for these new facts. By shortening the former we shorten the total time. That is, by increasing the level of alertness, we increase the level of responsiveness. If we want this to be high, we should set the first one at a high level also. The higher the level of optimality desired of the new response, the better the outcome. That means that time is even more valuable. To take into account the interactions between responsiveness and optimality levels, a rule is created into which they are embedded, rule 15.

The rule on the accuracy levels to set are sensible because we expect the outcome to responsiveness to depend on whether or not we are responding to the correct state of the world. The more accurate our description of the environment, the more "true" the response, and the more valuable the time it takes to get that response. Thus, accuracy makes responsiveness more valuable. The higher the level of the former we desire, the higher we should set the level of the latter. Meanwhile, the higher the level of optimality we require of our response given whatever the reading of the environment may be, the better the outcome we get when we get it. Then it must be that we would get an even better outcome if our response were "true" to the correct facts. Thus, the higher the level of responsiveness and optimality we desire, the higher the level of accuracy we should set. The effect of accuracy is to enhance the effects of desired levels of responsiveness on the levels of accuracy that we ought to require of the information substructure.

The arguments for flexibility and controlledness of rule 17 and 18 are analogous to the arguments for responsiveness of rule 16.

Rule 19. The higher the level of the performance property of controlledness desired of the operating substructure, and the higher the level of the performance property of coordinatedness that is desired of the operating substructure, the higher the level at which the performance property of awareness of the information substructure is to be set.

Rule 20. The higher the level of the performance property of controlledness desired of the operating substructure, and the higher the level of the performance property of optimality that is desired of the operating substructure, the higher the level at which the performance property of awareness of the information substructure is to be set.

Awareness is a property of the information substructure that tells one something about the knowledge that people in the organization have. This is knowledge about the parameters the values of which are known. These parameters are those that come from the organization's technology and its environment. The quality of the decisions in real terms is dependent on this knowledge. The more people in the organization know about the facts, the more likely they are to make better decisions, and also decisions that are more coordinated. Meanwhile, the controlledness level over these decisions requires information on what they are. If the awareness level is high, the information on the parameter values is more widespread, and so more likely to be known to those who need it to obtain the needed control. Higher levels of control are more valuable the higher the level of optimality. The same is true of coordinatedness. If we want higher values of these two performance properties, we should make the level of the performance property of awareness also higher. This is what rules 19 and 20 tell us. Meanwhile, higher levels of awareness are of no value if they are not coupled with higher levels of accuracy. Knowledge is valuable in making better decisions if the knowledge is correct. Knowledge is valuable only if it is knowledge of what is. The parameter values known to people in the organization must be the correct ones if they are to enhance optimality, etc. The rules on awareness are valuable in the context of the rules on accuracy which preceded them. To make the performance properties of the reward substructure consistent with those of the operating substructure, we need to derive rules on the levels we are to set on the performance properties of the reward substructure.

Rule 21. The higher the level of the performance property coordinatedness of the operating substructure that is desired, the higher the level at which the performance property of awareness of the information substructure is to be set.

Even though this rule seems to be implied by the previous one, it is not. This rule states that awareness is helpful to coordinatedness, regardless of the level of control, and the relation is important to warrant its own rule. Coordination requires that decisions be made in the context of one another. Whether this is to be achieved by highly explicit, comprehensive, and fine rules, by implicit rules, or by decision rules that are range-domain connected, it means that more information is needed by the decision makers. Linking the decisions together to get coordination in the values chosen for decision variables requires information that is not needed if the links did not exist. The more the linkages, the more information each decision maker needs, the larger the domains of the decision become, and the larger the number of parameters the values of which the rule user needs to make his decisions. When the rules he has do not include all of these parameters as dimensions of their domains, then the rule user will add them into his rules if he has access to the values the parameters take. The level of the of the performance property of coordinatedness of the operating substructure is affected by the level of the property of awareness of the information substructure. This rule calls for a specific connection between the property levels of two substructures. That is the same thing as calling for consistency between the two. We now turn to the subject of the consistency of the operating and the reward substructures, and the performance property connections that bring it about.

Rule 22. The higher the level of the performance property of controlledness of the operating substructure that is desired, and the higher the level of the performance property of optimality that is desired of the operating substructure, the higher the level at which the performance property of fairness of the reward substructure is to be set.

Rule 23. The higher the level of the performance property of controlledness of the operating substructure that is desired, and the higher the level of the performance property of coordinatedness that is desired of the operating substructure, the higher the level at which the performance property of fairness of the reward substructure is to be set.

Control levels of performance are defined in terms of probabilities and ranges. The issue of control is one of the nearness of the performance we actually get to the one we specify as the one we want to get and the probability we get any level of nearness we may want. Greater control means the same levels of nearness at higher probability levels, or higher levels of nearness at the same probability levels, or both. In the organization, control involves people, those who specify what performance is to be, and those who make it what it is. One way to give the former, the specifiers, control over the latter, the performers, is to make the attainment of goals that the latter have compatible with the nearness their performance comes to the one specified. Hence, rewards by the specifiers for the doers should be based on this principle. The analysis made earlier also states that the higher the level of control you want over some group, the higher the level of fairness you must show to all you wish to control. Fairness here is used in its broad sense, as the performance measure that results from the combination of the measures given to the fairness of reward decision rule range, mapping, users, and so on. Also, the rules suggest that this relationship is enhanced when the desired quality levels of the specified performances, optimality or coordinatedness, are increased.

Rule 24. The higher the level of the operating property of controlledness of the operating substructure that is desired, and the higher the level of the performance property of optimality that is desired of the operating substructure, the higher the level at which the performance property of material richness of the reward substructure, and the higher the level at which the performance property of fairness of the reward substructure are to be set.

Rule 25. The higher the level of the operating property of controlledness of the operating substructure that is desired, and the higher the level of the performance property of optimality that is desired of the operating substructure, the higher the level at which the performance property of emotional richness of the reward substructure, and the higher the level at which the performance property of fairness of the reward substructure are to be set.

The bases for these two rules are the arguments that both kinds of richness attract better decision makers, and so on. The coupling of fairness with the two properties is based on the argument that unless the distribution of the richness is fair, higher levels of richness do not produce better decisions or work from many in the organization. Fairness is a requirement for richness to have an effect on outcome.

Rule 26. The higher the operating property of the coordinatedness of the operating substructure that is desired, the higher the level at which the performance property of connectedness of the reward substructure is to be set. As the level of connectedness rises, people in the organization respond by increasing the number of decisions made by others in the organization. If they ignore these decisions by others, then they ignore important bases for their own rewards, and so fail to do whatever enhances these rewards.

## 6. Balancing Performance Property Levels

After establishing the levels of performance properties to start the process of design, one proceeds to the design of the structure that is to give such performances. When that is done, then it might be well to go back to the starting set of performance property values and see if adjustments might be valuable. Such adjustments involve a balancing of the levels we started with, something that might indeed be valuable, and therefore included as an action in one or more of the five design steps identified earlier. In the example of the hunter, it is of less value to the hunter to have in the quiver an arrow of the right kind for the quarry, the longer it takes to get the arrow identified and loaded. It is a case of the need for balancing the levels of flexibility and responsiveness. Effects on outcome that any level of flexibility has will vary as the level of responsiveness varies. It may be recalled that flexibility and responsiveness were explained in simple terms as the number of different arrows the hunter has in his quiver and the speed with which the right arrow is chosen. It does a lot more good to have the arrow there in the quiver when the response is fast. Hence, we need to state rules that are to be used in step six, where the facts used come from the completion of step five.

Rule 27. If the level of the performance property of responsiveness (flexibility) that is set is higher than the level of the performance property of flexibility (responsiveness) that is set , then the latter is to be increased by a fraction of the difference, or the former is to be decreased by a fraction of the difference. The fractions are to be set at values between zero and one.

This rule and all others stated in this form, where one property is open and one is enclosed in parentheses, is equivalent to two rules as follows:

a) If the level of the performance property of responsiveness that is set is higher than the level of the performance property of flexibility that is set, then the latter is to be increased by a fraction of the difference, or the former is to be decreased by a fraction of the difference. The fractions are to be set at values between zero and one.

b) If the level of the performance property of flexibility that is set is higher than the level of the performance property of responsiveness that is set, then the latter is to be increased by a fraction of the difference, or the latter is to be decreased by a fraction of the difference. The fractions are to be set at values between zero and one.

The statement that one is to be increased and one is to be decreased means that all or any of the following is to be done: change only the higher level by decreasing it; change only the lower level by increasing it; make both of the preceding changes. Which one should one do, and what fractions should one set? The first question is answered by the absolute values of the two levels. The higher in absolute terms is the higher of the two levels, the more should one decrease it. The lower the absolute value of the lower of the two levels, the more one should increase it. No changes are to be made when the two levels are close to one another in value. The rules are to be used to balance the two levels. From the argument, the balancing adjustment is to bring them closer together, but we do not know the costs of doing so. Hence, one should choose a fraction that one thinks will not add more in costs than it would in outcome. Having done this once, the fraction may be changed in the next iteration based on what one learned in the first one. The choice of the first fraction may be guided by two things. First, there is the information on costs and returns obtained from steps four and five, which may be used to give an idea of the gains to reducing the difference. Secondly, there is argument from which the rules come which suggests that the bigger the difference, the bigger the unbalance. This suggests that the starting fraction should be larger, the larger the difference. But whatever the fractions used, they are to chosen to produce only marginal variations. Changes of no larger than ten percent are what the fractions should produce. It is probably best to investigate the end results on outcome and costs of the use of fractions that are equal to or less than 5 per cent.

Other performance properties may also be the objects of the balancing work of step five. An organization may consider whether to have a few very good performances ready for a few states, or to have many mediocre performances ready for many states. The large outcomes it gets when these few states exist, and the bad outcomes it gets when they do not, may well add up to the mediocre outcomes it gets for all these states. Being very well prepared for a few circumstances may be as good as being less well prepared for many circumstances. Also, one may argue that an organization may respond to changes very quickly at low levels of optimality, or it can take more time to respond and do so at higher levels of optimality. What is gained by the quick improvement in the first case is made up for in the slower but better improvement in the second. This applies to coordinatedness as well as to optimality. And so it is clear that we need even more balancing rules for the performance properties.

Rule 28. If the level of the performance property of optimality (flexibility) is higher than the level of the performance property of flexibility (optimality), then the latter is to be increased by a fraction of the difference, or the former is to be decreased by a fraction of the difference. The fractions are to be set at values between zero and one.

Rule 29. If the level of the performance property of optimality (responsiveness) is higher than the level of the performance property of responsiveness (optimality), then the latter is to be increased by a fraction of the difference, or the former is to be decreased by a fraction of the difference. The fractions are to be set at values between zero and one.

Rule 30. If the level of the performance property of coordinatedness (flexibility) is higher than the level of the performance property of flexibility (coordinatedness), then the latter is to be increased by a fraction of the difference, or the former is to be decreased by a fraction of the difference. The fractions are to be set at values between zero and one.

Rule 31. If the level of the performance property of coordinatedness (responsiveness) is higher than the level of the performance property of responsiveness (coordinatedness), then the latter is to be increased by a fraction of the difference, or the former is to be decreased by a fraction of the difference. The fractions are to be set at values between zero and one.

Rule 32. If the level of the performance property of coordinatedness (controlledness) that is set is higher than the level of the performance property of controlledness (coordinatedness) that is set, then the latter is to be increased by a fraction of the difference , or the latter is to be decreased by a fraction of the difference. The fraction are to be set at values between zero and one.

Everything said earlier about the fraction applies here when we are talking about control levels, which are measures of the extent to which the organization can make what is actually done be what it was decided it ought to be. If the ought to be performance is of a high level of optimality, then making it happen can be expected to yield a much better outcome than would be expected in the case the ought to be performance were of a low level of optimality. Control pays off better, the better the decisions to be controlled. Since control costs are independent of the quality of the performance, the rule on control being high when optimality is higher is reasonable. The same argument applies to coordinatedness.

The two performance properties that were defined for the information substructure may need balancing. Here are the rules for them:

Rule 33. If the level of the performance property of alertness (accuracy) that is set is higher than the level of the performance property of accuracy (alertness) that is set, then the latter is to be increased by a fraction of the difference, or the former is to be decreased by fraction of the difference. The fractions are to be set at values between zero and one.

In all rules that involve the raising of one level or the lowering of another, the underlying argument is that they may be traded one for the other without any lowering of outcome. Whether we raise one or lower the other or do both depends on what we anticipate the costs might be. In general, one can assume that the rate at which the costs of a level of a property increase as the level increases to be greater the higher the level. So for two levels, one very high and one very low, it would pay to increase the lower by a high fraction and decrease the higher level by a fraction lower than the first. If the two values are close to one another, then no change in either is needed. If both rules are at low levels, then one might increase the lower one by a high fraction and leave the high unchanged.

Each of the balancing rules deals with only two properties. However, each property may be in more than one rule. Is the end result for all the properties dependent on the order in which we use the rules? The answer is yes. It depends on whether the second rule used takes its facts from the major rules as did the first rule used, or from the result of the use of the first rule. It is easiest to do the second, since the level that comes from using the first balancing rule might make the use of the second unnecessary. The results will differ slightly, based on the order in which the rules are used, but the differences are too small to matter. The important point to recognize is that each rule requires for its use a fraction of change that is estimated, given some concept of outcome and costs. Also, the fractional changes are small to begin with. They are to be used to tweak levels obtained from the major rules, and not to set these levels.

## 7. Ordering the Rules for an Efficient Designing Process

In going through the process of design, one should be concerned about its efficiency. Efficiency of the process itself is what is meant here. It is likely that such efficiency may be gained if one were to work a set of rules that have the same variable, that is the same variable for which a value is specified. Once this design variable or property is done with, all the design rules for the next property are then used to derive the level it is be given. One starts step 2 by using all the rules for one property only. With all the rules for deriving the level of this property together, it would be relatively easy to use one after the other, and to compare their results to see which one dominates. That is the rule which gives one the desired value for the one property. When step two is finished, there is a desired level for each of the properties which may now be used as the facts for step three. In giving a summary of the rules, we will group them on the basis of the properties of their ranges, those the levels of which are to set by the rule, that is the designer. We will also use short hand to refer to things. Thus for the level of a performance property of optimality we will use P/optimality, for an outcome function property we will use O/......., for technology T/.... , and for environment E/..... . For the terms "the higher" we will use H, and for the term "lower" we will use L. For the difference in levels of two properties we will use optimality - controlledness, and for the if then separation we will use columns. Rule 1 is used to determine if it is worthwhile to go through the process of design. Rules 2 to 26 are the major rules, and are to be used to determine the levels of the performance properties in an iteration in the process of designing a structure. In this iteration, each property level will remain in the neighborhood of this one initial one even after the use of the balance rules and the consideration of the costs of the structure needed to get each level. Balance rules 27 to 33 are to be used only to modify at the margin the levels obtained from the use of rules 2 to 26. In the two summary tables below, the order of the rules is one which puts together rules which are to be used to derive the level of the same performance property. Rule 2 is stated earlier as “the higher the level of the outcome function property of sensitivity to its parameters, the higher the level of the environment property of variedness, and the higher the level of the environment property of randomness, the higher the level at which the performance property of flexibility is to be set.” It appears in short form in the table. It is followed by all major rules which set the level of flexibility, those for responsiveness, and so on. What these rules do is tell the designer the property levels which the performance of the structure to be designed is to achieve.

TABLE I: MAJOR DESIGN RULES

OPERATING SUBSTRUCTURE RULES

| Rule# | Domain Components IF | Range Component SET |
|---|---|---|
| 1. | H. O/ generosity | L. Design effort |
| 2. | H.O/ sensitivity to parameters | H. P/ flexibility |
| | H. E/ variedness | |
| | H. E/ randomness | H. P/flexibility |
| | 8.H. T/variety | |
| 3. | H. O/sensitivity to parameters | H. P/responsiveness |
| | H. E/changeability | |
| 9. | H. E/raggedness | |
| | H. T/variety | H. P/responsiveness |
| 4. | H. O/ sensitivity to decision variables | H. P/ coordinatedness |
| | H. E/ size | |
| | H. T/ tightness | |
| 6. | H. O/ sensitivity to decision variables | H. P/ coordinatedness |
| | L. T/ randomness | |
| | L. E/ randomness | |
| 11. | H. T/ captiveness | H. P/ coordinatedness |
| | H. T/ completeness | |
| | L. T/ exposure | |
| 5. | H. O/ sensitivity to decision variables | H. P/ optimality |
| | L. T/ randomness | |

| | | |
|---|---|---|
| | L. E/ randomness | |
| 10. | H. T/ captiveness<br>H. T/ completeness<br>L. T/ exposure | H. P/ optimality |
| 7. | H. O/ sensitivity to decision variables<br>L. T/ randomness<br>L. E/ randomness | H. P/ controlledness |
| 12. | H. T/ captiveness<br>H. T/ completeness<br>L. T/ exposure | H. P/ controlledness |

## CONSISTENCY RULES: INFORMATION & REWARD SUBTRUCTURES

| | | |
|---|---|---|
| 13. | H. P/ responsiveness<br>H. P/ optimality | H. I/ alertness |
| 14. | H. P/ responsiveness<br>H. P/ coordinatedness | H. I/ alertness |
| 15. | H. P/ flexibility<br>H. P/ optimality | H. I/ alertness |
| 16. | H. P/ flexibility<br>H. P/ coordinatedness | H. I/ alertness |
| 17. | H. P/ controlledness<br>H. P/ optimality | H. I/ accuracy |
| 18. | H. P/ controlledness<br>H. P/ coordinatedness | H. I/ accuracy |
| 19. | H. P/ controlledness<br>H. P/ optimality | H. I/ awareness |
| 20. | H. P/ controlledness<br>H. P/ optimality | H. I/ awareness |
| 21. | H. P/ coordinatedness | H. I/ awareness |
| 22. | H. P/ controlledness<br>H. P/ optimality | H. R/ fairness |
| 23. | H. P/ controlledness<br>H. P/ coordinatedness | H. R/ fairness |
| 24. | H. P/ controlledness<br>H. P/ optimality | H. R / material richness and fairness |
| 25. | H. P/ controlledness<br>H. p/ coordinatedness | H. R/emotional richness and fairness |

| | | |
|---|---|---|
| 26. | H. P/ coordinatedness | H. R/connectedness |

**TABLE II BALANCING RULES**

| Rule # | Adjusted pair of properties |
|---|---|
| 27 | P/ responsiveness - P/ flexibility |
| 28 | P/ optimality - P/ flexibility |
| 29 | P/ optimality - P/ responsiveness |
| 30 | P/ coordinatedness - P/ flexibility |
| 31 | P/ controlledness – P/ responsiveness |
| 32 | P/ optimality - P/ controlledness |
| 33 | P/ coordinatedness - P/ controlledness |
| 34 | I/ alertness - I/ accuracy |

Since all balancing rules deal with the difference between the levels of two properties, and since they all indicate the same kind of change to the larger and lower values, we need only list the pairs of properties that need adjusting one to the other. Recall also that every rule has two conditions in which the property positions are reversed, so each pair in the table refers to the order given and its reverse

After the adjustments to the property levels obtained from the major rules are made, these levels are then used as the desired levels of the performance properties. The structures must now be designed, i.e., the levels of their properties that make their performances have the desired levels must be identified. The rules of design that show how to move from desired levels of performance properties to the levels of structure properties that perform in a manner that meets these desirata are the subjects of the next two chapters.

# CHAPTER 12

# DESIGN RULES FOR ORGANIZATION SUBSTRUCTURE PROPERTIES AND COMPONENTS: PART A

## 1. Rules to Design the Structure Itself

Only the rules to be used to design the structure itself remain to be identified. Design rules will be stated in terms of structure properties. Because these are defined in terms of the components of the structure, the design rules are easily connected to these components. Properties stated in terms of the former are easily transferable into the latter. Forms the rules take will be dictated by the analytic statements from which they are derived. Not every design rule will come from one analytic statement. It may be necessary at times to combine a number of these to get the one meaningful design rule. Also, a rule may tell the designer to choose from a number of equally acceptable values of different structure properties, or it may specify a required combination of values of different structure properties. When all the rules of design are specified, their use will involve a number of steps and a process of iterating these steps. The steps and the iterations are the means by which one can get the design of a structure with an output to its performance and a cost of its operation, which are an optimal pair. In a design problem of this magnitude and complexity, there is no way of getting the best in one single move from output to performance properties to structure properties to the design of a structure, and the specification of the components of a structure. That is why we have an iterative process which uses the design rules over and over in an adjustment process. At the end of this process there emerges a design of the structure that is efficient, given the circumstances of environment, technology, and the costs of the structure. These costs may be quite significant and play a major role in determining the efficiency of the different structures. They must be included in our process of creating such designs, even though most of the literature on organization structure design ignores them as elements of the problem of designing efficient structures. Before the rules of design are derived, the general problem of combining the analytic propositions and the general form of combinations to be used are discussed. Also, the logical steps to be taken in combining these rules together is discussed, and the basis for determining the order in which the rules are to be used to get a design is defined. Finally, the issue of determining the number of times that the whole sequence of design steps is to be used is taken up.

Subsets of design rules will be created on two different bases. First, the rules will be grouped on the basis of outcome. The subset will be that of all rules that deal with the level of a given performance property. All rules involving a performance property will be in one subset. For example, those that get us the performance property of flexibility will be together in one subset, those that get us responsiveness in another, so on. We will also create another sorting procedure which will group design rules on the basis of a design variable which is a dimension of their range spaces. One group will be made up of all the design rules that deal with the choice of the level of decision rule comprehensiveness, another on the decision rule explicitness, etc. The rules that make up the elements of these sets are to be derived from the analytic propositions. The forms these take determine the forms the former may take, and these determine the ease with which the designer may use them. As we now turn to this issue, we will find that the clarity and correctness of the analytic propositions are obtained at the cost of complexity and repetitiveness in the use of the design rules derived from these propositions.

## 2. Rule Mappings: The Relation or the Slope

Rules of design can be in any one of many forms. The form taken determines the ease with which they may be used and the quality of the results they give. Simple rules are ones that are defined in real number space by mappings that are in the simplest algebraic forms, such as, set the value of design variable X in terms of the values y and z of variables Y and Z to be that given by $x = f(y, z)$. All values are in real numbers, and using the rule is a simple process. Next, one might have to deal with rules that are less clear. There are rules, for example, that are in terms of design variables the values of which are not real numbers, but are well ordered and in identifiable form, such as set x at a low level if both y and z are at low levels. If the variable levels are observable and controllable, then this rule is useful, but not as precise as the preceding one. Weaker still and even less useful are rules that map only rates of change of values of the kind that are ordinal only. Such rules state that the higher y is, the higher x should be set. The rules we get depend on the form in which we state the analytic propositions from which we derive them. In the theory created earlier there are well proven and well founded propositions. Because we wanted to work with variables that are clearly defined and realistic, and because of the complexity of the interactions between these variables, the only clear and rigorous theory we could use was that which produced propositions that dealt with directions of changes in the values of variables. Given the realism and operationality of the descriptions we needed of the environment, the technology, and the structure, the only way we could get propositions about variables that had values that were comparable and meaningful was if we were to restrict our propositions to this form. If we were to develop a theory that produces more precise propositions, we would have to restrict the generality of that theory. This is the result of the fact that each individual organization structure is a unique case with a unique environment, a unique technology, a unique set of costs, and so on. There is no way in which we can get any generalizations about such subjects, because there is no logical order on the set of structures, or environments, or transformations. By working with properties of these entities, we managed to create a number of logical orders. By using properties with operational logically ordered levels, we were able to make analytic propositions about the relations between the levels of the various properties. Even so, the levels of the properties are not real numbers, and there is no way to create propositions that are mappings in real number space. Instead of the propositions being in the form of an equation in real number space, they are in terms of higher and lower levels. The uniqueness of the circumstances of organization structures makes it impossible to argue in general for all cases that if the value w of the variable W is high, then the value v of the variable V is to be set at level called high. It may well be that in some cases this would be correct, but in others it would be incorrect. The correct level is the one below the high, the one we call moderate. To get the generality for the rules, we work to get propositions that state only the relation between the directions of change between the values w and v. The propositions are in the form of the comparative, and identify the slope of a function rather than a function.

Design rules derived from comparative propositions can at best be in the comparative form. Our design rules will not say that to get a given v, set w at such a level, but will say that if you to want to increase v, then make w larger. The loss of precision between the two forms is simply the result of the fact that there are many functions that have the same direction of slope, and giving only the latter slope is much less specific than giving the former. But the design rules are useful and operational when used in the iterative manner of designing structures which is described in the last chapter. This iterative process of design makes excellent use of the rules and produces a design that may not be optimal, but is quite good. Not only is it a high quality structure design, but one that is derived from rules that come from a realistic model of the problem, and therefore one in which we can have confidence. By using the iterative process, we can have the rules be realistic and stated only in terms of the direction of change in each step of the iteration. The size of the change may be estimated using knowledge that may be derived from the effects of the of the last change. So our design rules are thus general and quite useful when used in an iterative process of design.

One problem still remains. That is the problem of where to set the levels of variables which define the starting points for the iterative process. Once we have a set of levels of the design variables determined, the rules are very useful in finding a next better set. But the rules are useless without such a starting set, and it cannot be obtained using our rules. Fortunately, our iterative process is efficient regardless of the starting point. True, its efficiency, the number of iterations used to get the end result, improves the closer the starting set is to the end point, but the improvement is not really that great. In any case, to use our rules and the iterative process, we must have a starting set or a first design. Rather than pick one randomly, we will get one by assuming, only this once in the iteration process, that our rules are in terms of absolute values of variables rather than in comparative terms. They are stated in terms like high, not in terms like higher. To get the first design, we take the design rule that states that to get a higher v, set w at a higher level to mean that to get a high v set w at a high level. From that point, we drop the assumption and use the rules to give us only the direction of change and the effects of the last change to give us the magnitude of the change.

When we derive the starting levels in the iterative process, we treat the design rules as being more specific than they are. Here we assume, incorrectly but usefully, that the rules are stated in direct relation between levels of the variables. We assume that the mappings we have which define the sign of the slope of a function to be describing the function itself. The (higher, higher) becomes the (high, high) rule. This is to be used only in setting, for the iterative process of design, the starting levels of the design variables. Even then there is still another problem, that of determining the relation of dominance that exists between rules. This relation exists when the use of one rule obviates the use of another, because using the first meets or exceeds everything called for by this other. That dominance relation defines a rule that allows some instructions about a design variable to be eliminated from consideration. Fewer rules have to be worked with in our iterative process, which is now more efficient than it would have been. Since the dominance relation is defined in terms that compare the values of two variables, it cannot be established from rules that do not specify such values but refer only to the direction of the change in a value. When we use this relation, we must assume that the rules are stated in direct relation between levels of the variables. Because dominance, once applied, removes the dominated rule and its design variable from the analysis, its use in an iterative process is dangerous. Rules removed in one iteration may not be dominated in later iterations, and so should be reconsidered later. Dominance decisions are best not made until late in the iteration process. How late is to be decided when the differences in levels set at the end of the iteration make it clear that further iterations would not be likely to change them much. The later in the iterations we do this, the less efficient the process, but the less likely we are to remove a rule erroneously. Where we do it is thus a problem which the designer must solve in the context of the sizes of the differences in levels and the direction in which they have been moving to that point. The form of the rules we give achieves a high level of generality, while the dominance rules and the iterative process of design make their use more efficient than it would otherwise be. There is still the problem of deriving the design from the analytic propositions.

## 3. From Analytic Propositions to Design Rule

One of the rules states that high levels of performance coordinatedness are produced by high levels of decision rule fineness. It is easy to derive the rule which says: to get more coordination into your performance, you should increase the level of rule fineness. One then needs to know how high this level of fineness is to be for any level of the performance property. If we had only this one proposition and its attendant rule, the answer would be given in the context of the multi-step adjustment process. It would mean that you start at a fairly high level and work up or down in reasonable increments which would be based on the sizes of the effects of the last change on outcome and costs.. Though not very accurate in specifying how high the starting level of fineness ought to be, the rule does give a point that is different from the low point or a medium point. This starting point is such as to make the future changes in the adjustment process smaller than they would have been, and the stopping point nearer to what it would have been if we had started somewhere else.

There is another analytic proposition which states that high levels of the performance property of coordinatedness are produced by high levels of decision rule property of comprehensiveness. Do we now derive a design rule analogous to the one we got from the first proposition? If the effects of the levels of the two properties on coordinatedness were linear, the answer would be yes. However, it is clear from the analysis underlying the two analytic propositions that the effects are not linear. We would contend that the higher the level of one structure property, the higher the marginal effect of the change in the other. The two feed on one another for their effects on the performance property. The two propositions together would produce a rule for design of the form: the higher the level of coordinatedness specified, the higher the combined levels of both the properties of comprehensiveness and fineness should be. Whereas the two separate rules might imply that one might have a high level of only one property, and that might allow one to ignore the second rule, the combined property rule does not. It clearly states that the levels of both properties should be combined, and that the level of this combination should be higher, the higher the level specified for coordinatedness.

To combine the rules, we first assume them to be in absolute and not comparative form. Next, we study the fundamental analysis that produced them to establish whether or not this analysis ignored some logical relations between the two rules. After all, the analytic propositions are argued one at a time, and though this makes for clarity of analysis, it does not take into account more complex mappings. In studying propositions together, we might find that two structure variables feed off one another in their effects on a performance property. The increase we get in the performance property level when we increase the level of one structure variable may depend on the level of another structure variable. If we can theoretically establish such a relation, then only one design rule for the two design variables is to be derived from the two propositions. The rule is to be understood to mean that the levels of the two variables are to be set simultaneously. They are to be balanced by adjusting changes called for in the level of one by substituting for some of them changes in the level of the other. To get a high level of coordinatedness, we may manipulate the level of decision rule fineness alone, we may manipulate the level of decision rule comprehensiveness alone, or we may manipulate both levels. From the concepts that underlie the definition of both these properties of the decision rules of a structure, one can derive the following conclusions: a) the increases in the level of coordinatedness of the performance get smaller for the same increment in the level of decision rule fineness; b) the same as in a) is true for decision rule comprehensiveness; and c) the two structure variables work in a nonlinear fashion, so that an increase of an amount x in the level of each produces a larger increase in the level of coordinatedness than does an increase of 2x in either one alone. This last conclusion comes from an understanding of the nature of the variables and the relations of structure to performance. It cannot be obtained from the analytic propositions alone. Rewriting these propositions to capture this interaction of the effects of the structure variables values would produce a highly complicated analysis that would be very difficult to comprehend. In any case, the use of both propositions in the light of the three conclusions produces something of the form: to get high levels of coordinatedness, set the levels of both structure properties at a fairly high level, one that is high, but not as high as it would be if you were using only one of the two variables to get the required level of the performance property. The combination is a pair of levels that are balanced in some ratio, and with absolute values that are lower than those that would have had to be given to either property if it had been the only one to be used to get the specified level of coordinatedness.

Once all propositions are studied and decisions made on combinations, we can derive a set of design rules. They will all be in comparative form, i.e., the higher the level of performance property Z that is desired and set, the higher should be the level of the combinations of structure properties X and Y. Some rules will have values for two or more properties to be set, others will have only one.

This set would be obtained after all variables that are included with others in a rule are balanced. Variables X and Y are balanced by a process that involves testing the effects on the performance property levels of changes in the two variables. Noting the amounts and directions of change, a pair of levels may be obtained after a few iterations. We now assume that all rules are in absolute form. We use them to get a set of levels for all structure design variables. A starting set is what we have when the iterations changing variable values produce pairs that make very little difference in result wherever pairs occur. All such rules involving the balance of the levels of two or more design variables X and Y will be stated in one of the following terms: the higher the combination of the levels of X and Y, the lower the combination of the levels X and Y; the higher the combination of the levels of X and 1/level of Y (or 1/level of X and level of Y). This last means that we get the right balance with a combination of a high level of X and a low level of Y, or conversely. At times we use the phrase "level of property X or level of property Y" by which we mean one of the following: "the level of X alone", "the level of Y alone", or " the levels of both X and Y". The word or is used in its strict logical sense.

At the conclusion of each stage of step 5 in the iteration process, a set of levels of the design variables or structure properties is in hand and ready for use to start the next stage, or to be modified by the application of the dominance and balancing rules. It is now time to consider in some detail what the dominance rule is, and how it is to be used. When there are two propositions concerning one design variable and two performance properties, then our derived design rules would follow the logic we discussed earlier in deriving the levels of performance properties. If performance property X demands some level of structure property Z, and at the same time performance property Y demands a different level of property Z, then the value chosen for structure property Z will be the higher of the two. In this case, one rule would dominate the other. The dominant one would be used first and perhaps also uniquely in the process of design. If the lower level of structure property Z comes from a rule in which it is the level that is in balance with a level of some third structure property W, then the higher level for Z is the one chosen. The balanced pair of levels is to take as fixed the higher level for Z, and find the level of the structure property W that goes best with it. That is the value which gives the same level of the performance property generated by the combined value of Z and W. We do this for all cases where dominance occurs.

An example will show this use of the dominance relation. Suppose that the required level of coordinateness gave a pair of levels for comprehensiveness and fineness that when balanced are at the moderately high level. Suppose also that the specified level of controlledness asks for the level of the structure property of comprehensiveness to be high. Because high dominates moderately high, the level of the structure property of comprehensiveness is to be set at high. Suppose that because of substitutability, we can get the same level of coordinatedness if we lower the level of fineness and pair it with the new level of high for comprehensiveness. The two design rules now combine to produce these two levels for the properties of the designed structure. This process would be followed for all structure design variables to obtain the levels used to start step 3 and all remaining steps of the eight iterations we go through in designing a structure.

Dominance is a relation between two rules which deal with the same structure design variable and different objective variables, performance property ones. Another relation to consider is that between two rules that have the different structure design variables and the same objective variable. For example, one rule may state that the higher the desired level of optimality, the higher is to be set the level of comprehensiveness. Another rule say have the same about optimality, but refers to the level of domain resolution. The two design variables are not in one rule, and therefore, they are not closely related as those that are. They may however be substitutes for one another at the total level. That is, in the first case one substitutes small values of two variables, and in the second case, one substitutes the whole of one rule for another. In this latter case, there are four possibilities. The first is that there is rule dominance relation, and one uses only one of the two rules or design variables. The second is that there exists a relation between the two design variables that is the same as that which would have put them in the same rule, but the relation is very weak. The third is that both of the first two relations hold at different levels of the variables. Lastly, the relation may be one of rule consistency.

In the case of the first relation, both rules would be tried. The one that gives the highest difference between effects on the performance property level and the cost would be used, and the other one ignored, except in one situation. This is one where the marginal cost of the variable in the rule used exceeds its marginal returns before we get to the initially specified level for this variable. If we continue to ignore the rule that is dominated, we ignore the possibility that the marginal returns from this rule and those of the first rule may together make it possible to reach the level for the variable specified in the dominating rule before marginal cost exceeds marginal revenue. We use the dominated rule in this case, and continue to use further dominated rules, if there are any, until we get to the end. This is where we have reached the high level for the design variable of the first dominating rule, or we run out of dominated rules to bring into our design process. Dominated rules may be relevant and used to determine whether the combined effects resulting from their consideration justify the cost of the higher of the levels for the variable. In the second relation, we may use both rules, but only to make only small tradeoffs which we know will improve the result very slightly. In the case where the third relation exists, one has first to determine where the levels are and which of the first two cases holds for these levels, and then either ignore one rule or make small tradeoffs. Since the process of design is an iterative one, it allows one to try various rules and combinations of them at each step of the five and at each stage of the fifth step.

Throughout the design process, the operating structure must be matched by consistent reward and information substructures. The design rules we develop will be those involving the operations of the whole structure, which means they apply to the design of the operating, the reward, and the information substructures. Added to these rules will be the rules for designing a reward substructure that is consistent with the operating substructure, and analogous rules for the information substructure. These design rules are grouped on the basis of what they are intended to produce, which are desired levels of performance properties. All design rules are derived from the analytic propositions or the consistency theorems proved earlier. Some design rules are derived from a single proposition. Some are derived from a number of propositions which are combined in some logical manner which is specified. Each such rule gives instructions about a number of design variables and about the combination of levels at which these variables are to be set.

## 4. Structure Design Rules

Before the rules of designing the structure are derived, it is best if we revisit the sequence of designing activities we have already been through. To get to where we are, we had to work through the process of identifying the required levels of the performance properties of the structure we are to design. To get to this point of using the rules on performance properties, we went through a process of breaking up the entire environment of the unit for which we want to design a structure. Each piece is defined in terms of parameters, most of which are embedded in one or more technologies and are not embedded in others. Each piece of the environment goes with a set of decision variables, the ones embedded in the basic technologies of this environment. This process gave us a set of environments, each of which was a segment of the whole, and each of which had a distinctive space, set of dimensions, and a pattern of changes in the levels of the variables which are its dimensions. Both the environment and these patterns were described in terms of properties which were created to capture their essential features. Size was a property defined in terms of the environment, and variedness, raggedness, etc., were properties defined in terms of the behavior of the state of this environment over time. Any subset of the original n parameters may be used to define a piece of the environment, which piece is itself an environment that is logically describable in terms of any of the properties defined earlier. Instead of calling an environment changeable on the basis of all its dimensions, or component variables, one might split it into two pieces, one of which is highly changeable, and the other not so. The one average figure for the whole is replaced by two averages that describe more accurately two pieces of the whole

Each segment of the environment had its own decision variables and parameters, all of which belonged to the whole from which the segment came. The choice of the segments was based on similarity in the levels of the properties that describe the technology and the environment derived from it. Every piece or segment we define in this manner is a logical basis for the first two components of the vector which describes an organization structure. Each segment is the starting point for the use of the design rules that are derived below to create a piece of the whole structure for the unit. For every segment or piece of the technology and its environment, we may proceed to design the organization structure that gives values to the decision variables and read the parameters that belong to the segment. For each piece of the technology and environment an organization structure with required levels of performance properties may be designed. Each such structure is itself a combination of three substructures, operating, information, and reward. It is true that a structure designed for a piece of the environment may have to be fitted with another designed for a different piece to get the appropriate total structure that would apply to the total of the two pieces. We discuss the nature of this fit and how to get it below, but it should be clear that the problem of design is independent of whether one is designing a piece or a whole, because they are logically identical concepts. The last set of rules in the process of design are those that produce the design of an organization structure, and are derived from the analytic propositions of the earlier chapters. Each rule starts with a conclusion from the preceding step of design, namely, a desired level of a performance property of the structure to be designed.

Design rules may be ordered for exposition or for use in any number of ways. To make their use easier, we first derive and explain all the design rules for the operating substructure, then do the same for the information substructure, and then for the reward substructure. For each substructure, the design rules are grouped into subsets on the basis of the performance property of the substructure to which they refer. Every rule about the operating substructure says something about what ought to be done to get a desired level of one specific performance property of this substructure. For example, all rules that do this for the operating substructure performance property of coordinatedness will go together into a section identified under the heading of coordinatedness of the operating substructure. Now we have the groupings based first on the identity of the substructure, then on the identity of one performance property of the substructure. The rule will thus be one relating to substructure X, then to the performance property Y of this substructure. The first grouping is for the operating substructure. The first subgroup of this group contains the design rules that produce desired levels of the performance property of the coordinatedness of the relevant operating substructure.

All the rules will be numbered consecutively, starting with the operating substructure, followed by the information substructure, and then reward substructures. We will start with the operating structure and with its performance property of coordinatedness. Each structure design rule is identified by the substructure to which it applies and is numbered. A design rule for the operating substructure is termed an OD-Rule, where O stands for operating substructure and D stands for design. Similarly, the rules for the other substructures are termed ID, for information and design, and RD, for reward and design. Because each is identified by the substructure to which it applies, the name of that substructure will not be mentioned in the rule itself. The reference in a rule is to a substructure identified by the designation, O, I, or D. The reference within the rule to a desired or required level of performance property X is a reference to that level which is obtained by using the set of design rules that are given in Chapter 8. The reference in the rule to the level at which property Y is to be set is a reference to a property of the designated substructure itself.

The logic of the substructure design rules is one of four kinds. The first is a kind of rule which states the levels at which a combination of substructure properties is to be set. What this means is that the designer is to set the level of each of the properties at that which is specified and then to adjust the levels by increasing some and lowering others to find the combination of levels that does what is required. These rules are made for structure properties that have complex nonlinear effects on some performance property. The same level of a performance property may be obtained from many different combinations of the levels of some structure properties. One might increase the level of one and reduce the level of another and still get the same level of the performance property. The structure properties are interactive in complex ways and are also substitutes for one another.

Secondly, there are the rules that specify what is to be done to the level of only one substructure property. In each iteration of the process of design, the designer is to set the level of this one property without regard to the levels he sets for other structure properties. This rule is reasonable when the effects on the given performance property of the change made in the level of this one structure property is independent of what changes are made in other properties. The third type of rule specifies what is to be done to the level of substructure property A or to the level of substructure property B. What this means is one of three things. First, it means that the designer is to set the level of structure property A without regard to what is set for structure property B. Second, the designer is to set the level of structure B without regard to what is set for what is set for structure property A. Third, it means that the designer is to set combinations of the levels of both A and B. In each iteration, the designer may accept the meaning that is more reasonable. The first and second are the more reasonable if in the specific iteration the changes made in each property have effects that are more or less independent of one another. The third meaning is more reasonable if the effects of the two changes are not sufficiently independent. The reasonable meaning may change from one iteration to the next. If the design rule has more than two properties in it, then the first meaning applies to a property if and only if it applies to that property when it is paired with every other. In all other cases, the designer can take the rule to be equivalent to a rule of the third type.

The last type of design rule refers to what is to be done to a vector of levels of a number of structure properties. This means that all the levels of the vector components are to be changed in the manner specified in each iteration of the design process. The reason for this is the nature of the analytic relation between the structure properties and performance property of the rule. The relation that is of this type is one in which the level of the performance property may be changed only if the changes in the level of structure properties are in some fixed proportions one to another. To get one more car produced, the manufacturer needs four more wheels and one more brake pedal. If the increases were 12 wheels and no brake pedal, the car is not complete, and no change that matters in output has occurred. An increase of 12 wheels and 1 brake pedal would allow an increase of one car. Similar relations exist between structure and performance relations. They are not necessarily as tight as that of the car example, but they have the same logical nature. A change in the level of a performance property is much smaller when the level of only one structure property is changed than it would have been if this had been accompanied by a change in the level of another structure performance. When the rule specifies a change in the value of a vector of levels, it does so to avoid going through iterations that are known to have very little effect. A smaller set of structures for the designer to search cannot be but more efficient than a larger one, especially if it is smaller because it does not contain any designs that are known to be ineligible for choice because they are dominated by others that lie in their neighborhoods and are not much different.

In summary there are four kinds of design rules. They relate to:

a) Setting the combination of two or more substructure property levels;
b) Setting the level of only one substructure property level;
c) Setting the levels of substructure property A or B;

d) Setting the level of a vector of levels of substructure properties.

## 5. Design Rules for Substructure Consistency

All the design rules that are to be derived next are meaningful only if we make the assumption that the substructures they produce are internally and externally consistent. A design rule states that the higher level of performance property X of the substructure that is desired, the higher the level at which property Y of the substructure is to be set. Every property of a substructure refers to a component of it, and the component is made up elements. The level of the property of the component is derived from the levels of these individual elements. The level assigned to the set is unique and may be the average of the levels of the elements or some such combination. However, this mapping has no inverse, and the same level of the property of a component can be obtained from very many different sets. Any level of the property obtained from a set that makes up a component will have be the same as that of many other sets. If the design rule tells us that the level of property X of component Y is to be set at a higher level, it does not tell us what the elements that make up the component with higher level are to be. Implementing this rule by identifying the levels of the property of the individual elements is the last step of the design process. For every design rule that sets levels for properties of a component, we derive a design rule to implement it. This implementation design rule is based on the concepts of the economic consistency of a substructure. There will be one to accompany every design rule for a component as a whole. Consistency rules tell us how to choose the elements of the component so that these elements meet two conditions. First, the levels of the property which these elements have give a level for the component as a whole that is that set for it by the companion design rule. Second, the elements must be those whose membership in the set that makes up the component meets the consistency assumptions that allowed us to map the level of the property of the set as a whole to the level of the performance. If a design rule calls for a higher level of the decision rule component property of domain-domain connectedness in order to get a required level of the performance property of coordinatedness, then the consistency rule to accompany this design rule will state that the decision rules that are to be domain-domain connected are those where the connection increases the level of coordination between the variables that are governed by these rules. There are some decision variables where the connections of the rules between them does nothing or very little to the level of coordination between them, and there are rules where it does a great deal. Decision rules that have the comparatively large effects on the property level are those that are to be connected to get the higher level sought by the decision rule for the component. These same rules are those that are to be disconnected in the case where the rule calls for lower levels of the property. On the way up, we start connecting rules with the bigger effects and move down, and in the case of lower levels we reverse the order.

When we made the analytic connections between the level of a property of the component as a whole and the level of a performance property of the substructure, we assumed that internal consistency existed. The design rule derived from this analytic connection is meaningful only if this assumption is correct. Consistency rules satisfy this assumption and identify the manner in which the design rule for the component is to be implemented. The last step in the design is that where the elements of the components of the structure are set, and consistency rules make that step. Every design rule which sets a level for a property of the component needs a consistency rule to carry it into setting the elements of the component.

External consistency between substructures requires its own set of design rules. Such rules would tell the designer that the use of this or that design rule for one substructure is to be accompanied by the set of such and such design rules for another substructure. Design rules for one substructure may require that other rules for other substructures be used to maintain the level of consistency between them. External consistency conditions can be met by complementing the rules on one substructure with rules on other substructures. For example, among the consistency criteria are those that result from the relation between the performance properties of the operating substructure and those of the information substructure. There are a number of reasons discussed earlier why the performance property of the information substructure affects the level of coordinatedness of the operating one. For each set of design rules derived for a substructure we will attach a set of performance properties of other substructures to which the designer is to pay attention. At some point, the designer is to use the rules relevant to these properties to produce the required level of consistency between the substructures.

## 6. Design Rules for Coordinatedness of the Operating Substructure

It is argued earlier that technology tightness is a property that has effects on the returns to the level of coordination. Coordination increases give much better results when the technology property of tightness is high than when it is low. The returns to any increase in the level of coordination are larger, the higher the level of technology tightness. As this level increases, the opportunity costs of not coordinating increase. Coordination is more valuable, and the returns to any level of it we set is higher than it would have been. This holds true for any combination of the design variables we use. But more tightness means that more decision variables are interrelated, and that means that any level of coordination we get will require a higher level of the combination we use to get it. In turn, this means higher cost. So the added returns and the higher costs must be considered and a conclusion reached when we make decisions on the levels we want the property to have. From arguments like this one, we derived a host of rules for use in the first stage of design. These tell the designer how to determine the levels of performance properties that are desirable to start the process of design and redesign. When the iterative process rule on a structure property is used for the last time, its specification will need to be translated into decisions on the components of the structure itself. Because this translation has to be made, we will acknowledge it when the rule is stated, even if it is to be used only when the rule is used for the last time. Every design rule will be followed by a rule which translates the levels of structure properties into specific components of the structure itself.

OD-Rule 1: The higher the level of the performance property of coordinatedness that is desired, the higher the combination of the level of comprehensiveness and the level of fineness that is to be set in any iteration of the design process.

OD-Rule 1*: The higher levels of the comprehensiveness and fineness properties of the decision rule component are to be obtained by replacing some of its decision rules with others that have higher levels of these properties. The decision rules of the structure that are to be changed are the ones where higher levels of these two properties produce larger increases in the level of coordination of the decision variables they govern than would be produced by changes in other rules. Where lower levels of the structure properties are sought, the elements are chosen in reverse order.

Two analytic propositions were combined to get the first rule. Increasing the level of comprehensiveness increases the size of the domains of decision rules, and hence the likelihood that these domains will intersect with one another, and therefore increase coordination. Increasing the level of decision rule fineness also has the same effect because it reduces what may be chosen in any circumstance. The reason the two are combined is that the increase in the level of comprehensiveness will have much weaker total effect on coordination if rules allow huge sets of choices for each circumstance. Similarly, it is clear that decreasing the sizes of these sets will have weaker effects if they apply to very few circumstances. In a sense, the partial derivative of the level of coordination with respect to the level of comprehensiveness falls for any level of fineness. The same is true for the partial of coordinatedness with respect to fineness. Therefore, keeping the two balanced makes sense and should be considered each time the rule is made. This is even more sensible if we consider the likelihood of the truth of the assumption one might make about costs, to wit, that marginal costs of both design variable levels are increasing. This assumption is not necessary for the rule to be very useful in choosing the directions of movements from one iteration of design to the next. If it should prove to be false in any situation, then it is discarded, and the balancing process continued, but at a lower rate of substituting the level of one variable for that of the other.

Setting the decision rule component property levels of comprehensiveness and fineness at higher levels comes from making its elements have higher levels of the two properties. To change the levels of a rule's property of comprehensiveness and fineness, one changes the domain and the range of its mapping. When these are changed for two or more rules, the level of coordinatedness of the variables the rules govern will then change. However, this change may well vary a great deal from one variable to the next. Coordination levels may not increase at all for variable 1 and 2, but greatly for variables 3 and 4. Therefore, the consistency rule says that you should change decision rules governing variables 3 and 4 by increasing the level of comprehensiveness and the level of fineness of each. Changing these two rules produces a larger increase in coordinatedness than would changing the other two. The criteria of choice are the same for all consistency rules. Every one of these rules is about the elements of the component identified by the design rule it accompanies. The consistency rule will refer to the same performance and structure properties of the rule it accompanies.

OD-Rule 2: The higher the level of the performance property of coordinatedness that is desired, the higher the combination of the level of the domain-domain connection and the level of range-domain connection that are to be set in any iteration of the design process.

OD-Rule 2*: The elements that are to be changed are the rules where more connections produce relatively higher levels of coordinatedness of the decision variables they govern. For lower levels of the structure properties, the elements are chosen in reverse order.

In this rule, the trade off between these two levels is the result of what we assume about their costs, rather than their effects on the output of coordination level. What one can derive from the analytic propositions on costs is that the use of range-domain connection involves lower costs than does the use of the domain-domain connection. The reason is that using the latter allows one to collect the effects of many domain variables levels into a much smaller set, which is the level of the one variable of the range of that rule. However, since the use of the latter delays the first rule decision maker from any decision until the second finishes using his decision rule, we can expect the time it takes to make both decisions will be longer in this case than when the domains were connected. Time costs are really costs of lower levels of responsiveness. So these connection costs are to be determined after the level of this performance property is determined. In any case, as we trade off variable levels, some costs go up, others go down. This is precisely why we need to combine the two levels when we are going through the process of design. Arguments in support of this consistency rule are analogous to those made for the previous one.

OD-Rule 3: The higher the level of the performance property of coordinatedness that is desired, the higher the combination of the level of domain resolution and the level of range resolution that is to be set in any iteration of the process.

OD-Rule 3*: The elements that are to be changed are the rules where higher levels of domain and range resolution produce relatively higher levels of coordinatedness of the decision variables they govern. For lower levels of the structure properties, the elements are chosen in reverse order.

OD-Rule 4: The higher the level of the performance property of coordinatedness that is desired, the higher the combination of the level of domain explicitness and the level of range explicitness that is to be set in any iteration of the process.

OD-Rule 4*: The elements that are to be changed are the rules where higher levels of domain and range explicitness produce relatively higher levels of coordinatedness of the decision variables they govern. For lower levels of the structure properties, the elements are chosen in reverse order.

Combining the levels of the two structure variables in each of the four rules is based on arguments from the analytic propositions. For example, the coupling of domains of decision rules does little good if fineness is low. The first ties decisions together by making them depend on the same set of facts. Everyone's decision to open fire on the enemy is based on the time shown on a given clock, while the low fineness tells each to do whatever he pleases. This extreme case shows that for large impact on coordination, both domain connection and rule fineness must be set in a logically simultaneous manner.

One very important point about all the above rules needs to be mentioned. That is that they are in some sense complementary, and should be considered in a logically simultaneous manner. After using the first rule, the second is then used, and the effects of its use on the power of the combination of levels of variables of the first rule checked. There is likely to be an element of substitutability between using the first combination and using the second one. This results from the fact that each alone does produce coordination, and we would use a much higher level of one if we used no other. The same argument may be made for analogous rules that follow, which means that all of them should be used in an iterative manner where the use of the second modifies the use of the first, the third modifies the use of the first two, and so on. The sequence in which the rules are used, and the attention given to each should be based on the impact on coordination that each has. The magnitude of the impact on coordination of a fixed increase in the level of the first is the same as that of the second combination, all other things being equal. This impact is larger than the impacts of the variables in the third, fourth, and fifth combinations. The rules should be used in an iterative manner in the same order as they are given. Consistency rules paired with these structure rules should be used in the same way.

OD-Rule 5: The higher the level of the performance property of coordinatedness that is desired, the higher the level of assignment commonality that is to be set in any iteration of the design process.

OD-Rule 5*: The elements that are to be changed are the assignment elements where higher levels of commonality produce relatively higher levels of coordinatedness of the decision variables that the assignments have in common. For lower levels of the structure properties, the elements are chosen in reverse order

By raising the level of the property of decision variable assignment commonality, it is more likely that the decisions made on one variable will be made in the context of others in the same assignment set. In the limit, the design can assign one variable to each individual, or all variables to all. In the first case, one would expect a lot less consideration of the value given to a variable not assigned to an individual when he gives a value to the one assigned to him, than in the case where he and everyone else are assigned both variables.

Design Note: The information substructure performance properties of accuracy and awareness and the reward substructure property of interdependence have direct effects on the coordinatedness level of the operating substructure. The design rules that relate to the accuracy and alertness of the information substructure should be considered for use when the operating substructure property of coordinatedness is the object. The same is true of the design rules that affect the reward substructure property of interdependence. This note derives from analytic propositions we made earlier about the effects performance properties of one substructure have on the performance properties of another. The arguments for the two substructures are analogous. Whatever argument we make about the information substructure applies to rewards, and so we will discuss only the former.

We proposed earlier that the properties of accuracy and awareness of the information substructure have effects on the levels of the performance property of coordinatedness of the operating substructure. We argued earlier that if the information used to give values to the decisions variables is not close to the real facts (low in accuracy), then any coordinatedness level attained using this information will produce an outcome that is lower than that produced by the same level of coordinatedness attained using information that is closer to the real facts (higher in accuracy). In the case of the performance property of awareness, we have argued that the higher its level, the higher the level of coordinatedness that is likely to emerge from any given operating structure. To capture these effects of the performance levels of one substructure on the performance levels of another, the rules on the design of the operating substructure that have some desired level of the performance property of coordinatedness are to be used in conjunction with some of the rules on the design of the information substructure. Rules that require that the performance properties of accuracy and awareness of the designed substructure be at some specified levels are the ones relevant here.

Whatever the structure of the organization, the people in it make the decisions which in turn determine the outcome. How good the decisions are depends on the information the decision makers have, on the goals they are asked to achieve, on the connections and forms of the decision rules they use, on their rewards, and so on. Any structure could produce a host of different decision sets. It is the people who ultimately determine which one actually comes about. Thinking processes determine how people make decisions in any structure. The better these processes are, the better is the decision maker. The quality of the people sets the upper bound to the quality of the decisions made. The actual decisions depend on the extent to which the people use their highest quality processes. How coordinated or how close to the optimal a decision we get depends on what the best the decision maker can do in the structure, and how close the processes he uses are to the best ones. Fairness of rewards and their material and emotional richness have effects on the effort, care, etc., with which people in an operating substructure make rules, use them, etc. One property especially strong in its effects on coordinatedness is that of interdependence. As that increases, we expect people to pay attention to what others are doing when they make a decision. Rules of reward substructure design that relate to these performance properties are to be considered as complementary to those of operating substructure design when these are used to get a required level of coordinatedness. Later, we identify all the design rules for the information and reward substructures.

The design of an organization structure is not complete until the three substructures are consistent one with the other. Because consistency is determined by the relations between the components of the substructures, it cannot become a design decision for the designer until he has identified some of these components, that is, done some designing. It is best to delay the derivation of the rules for obtaining this consistency until we are done with all rules of designing the substructures. No mention will be made to either reward substructure design or to consistency until we are done with the derivation of all the design rules.

## 7. Design Rules for Optimality of a Structure Performance

Increasing the level of coordinatedness increases the level of optimality. One may well argue that increasing the levels of many of the properties of the performance of a structure increases the level of the optimality of its performance. There are ways to get increases in the level of optimality which may cause a decrease in the level of coordination. One way deals with information, another with the domain resolution, and so on. Here we are interested in the structure properties that affect optimality directly. We can make good use of design rules which are derived from the propositions which deal directly with the level of optimality. These rules are those in which the relation between the design variable and the level of performance optimality is direct and not necessarily through effects on other performance properties. Some design variables affect optimality indirectly, some affect it directly and indirectly, and some affect it directly. In this section we identify only those rules that involve at least one design variable that affects optimality directly. Rules involving variables of the other two kinds will be stated in terms of their effects on the intermediate performance variable. The effect of levels of comprehensiveness and fineness on coordination, and through that on optimality, means that rules about these design variables will not appear in this section, but will appear in the section on coordination and anywhere else they may have effects. Some of the rules of design for optimality will involve only one design variable. Others will involve more than one variable.

OD-Rule 6: The higher the level of the performance property of optimality that is desired, the higher the combination of the level of maker orientation and the level of the inverse of the level of enfranchisement that is to be set in any iteration of the design process.

OD-Rule 6*: The elements that are to be changed are the decision rules where a combination of a higher level of maker orientation, and a higher level of the inverse of the level of enfranchisement produce relatively higher levels of optimality of the decision variables they govern. For lower levels of the structure properties, the elements are chosen in reverse order.

Rather than making the objective of the rule 'the level of enfranchisement', we have made it the 'inverse of the level of enfranchisement' or 1/level of enfranchisement. The same substitution may occur later for other properties in order to keep as many of the rules as similar in form as possible. To make the inverse of the level higher is to make the level lower. As to its content, this rule is derived from the propositions that show that decision rules are better when the goals on which they are based are those of the rule makers. Such goals do not get misunderstood as they might if they had to be identified and transferred from the rule users to the rule maker. Also, keeping the number of makers small, setting the level of enfranchisement at a low level, reduces the complexity of obtaining the one set of goals to use as the base for the decision rule. This set does not need to come from the many different sets of goals that the participants in the rule making have. The interaction between the effects of the two levels is assumed to exist because what is gained in clarity by keeping the goals restricted to the maker set is lost in the problems of getting one set of goals from the large number of these.

OD-Rule 7: The higher the level of the performance property of optimality that is desired, the higher is to be set the level of the vector made up of the level of the domain resolution, the level of the inverse of the level of decision rule lumpiness, and the level of fineness in any iteration of the design process.

OD-Rule 7*: The elements that are to be changed are the decision rules where a larger vector made up of the each rule's level of domain resolution, the level of the inverse of the level of decision rule lumpiness, and the level of fineness produce relatively higher levels of optimality of the decision variables they govern. For lower levels of the structure properties, the elements are chosen in reverse order.

Higher levels of domain resolution allow for finer distinctions between its elements. This means that we can distinguish between amounts in ones, rather than only in tens. Decisions made may now be different for two circumstances, when earlier the two circumstances were only one, and there would have been only one decision. This gives a better chance to get a decision that is nearer the optimal for either set of parameters or circumstances. However, the returns to this improvement will be smaller as the level of lumpiness gets higher, and especially so if fineness is at a high level. A higher level of resolution increases the number of circumstances that are recognized, and so also, the chance to get a different decision for each, one that fits better each circumstance. But higher levels of lumpiness remove any advantages to this by assigning the same set of decisions to larger sets of circumstances. The finer distinctions that higher resolution brings to decisions are weakened by lower levels of lumpiness. If the fineness level is low, then the choices left in the sets of decisions available for each circumstance is large, and the effect of lower lumpiness is weakened. The levels of these three structure design variables need to be set as a triple. As the resolution level is increased, the level of lumpiness should be decreased and the level of fineness should be increased, thereby enhancing the effect of the first. To get decisions that fit better the circumstance, we distinguish between these in a finer manner, and we allow the decision for any circumstance better chances to be different from that for another. The lower the level of lumpiness, the more will increases in fineness increase the levels of optimality. This rule should be seen as showing that high levels of the latter are good when those of the former are low.

OD-Rule 8: The higher the level of the performance property of optimality that is desired, the higher is to be set the level of the vector made up of the level of range resolution, the level of the inverse of the level of decision rule lumpiness, and the level of fineness in any iteration of the design process.

OD-Rule 8*: The elements that are to be changed are the decision rules where a larger vector made up of the rule's level of range resolution, the level of the inverse of the level of decision rule lumpiness, and the level of fineness produce relatively higher levels of optimality of the decision variables they govern. For lower levels of the structure properties, the elements are chosen in reverse order.

Arguments for this rule are analogous to those made for the previous one. Essentially, a higher level of range resolution makes it possible to distinguish between values of a decision variable that are closer together. One can distinguish values that are pennies apart instead of dollars only. This in turn makes it possible to get closer to the optimal decision. But a higher level of lumpiness again makes it less possible to change decisions anyway, and this negates the advantages of higher range resolution. This effect is strengthened if the level of fineness is high.

OD-Rule 9: The higher the level of the performance property of optimality that is desired, the higher is to be set the level of the vector made up of the level of domain explicitness, the level of the inverse of the level of decision rule lumpiness, and the level of fineness in any iteration of the design process.

OD-Rule 9*: The elements that are to be changed are the decision rules where a larger vector made up of the rule's level of domain explicitness, the level of the inverse of the level of decision rule lumpiness and the level of fineness produce relatively higher levels of optimality of the decision variables they govern. For lower levels of the structure properties, the elements are chosen in reverse order

OD-Rule 10: The higher the level of the performance property of optimality that is desired, the higher is to be set the level of the vector made up of the level of range explicitness, the level of the inverse of the level of decision rule lumpiness, and the level of fineness in any iteration of the design process.

OD-Rule 10*: The elements that are to be changed are the decision rules where a larger vector made up of the rule's level of range explicitness, the level of the inverse of the level of decision rule lumpiness, and the level of fineness produce relatively higher levels of optimality of the decision variables they govern. For lower levels of the structure properties, the elements are chosen in reverse order.

Both these rules come from arguments similar to the previous two. As the level of explicitness, of either domain or range, is made higher, the rule user is faced with less uncertainty as to what the facts are or are to be. The result is that we get a decision that is more clearly specified, and therefore more likely to be closer to the optimal one than otherwise. Again, higher levels of lumpiness increase the probability that the same decision will be made over and over, which makes ineligible many of the more clearly specified decisions and so weakens the returns we get from being able to use them. Again, the effect is made stronger as the level of fineness is increased. Hence, raising the level of explicitness should be accompanied by lowering the level of lumpiness and that of fineness, but again as the former gets smaller the bad effects of the latter on optimality weaken. We can increase its level to get better coordination.

Design Note: There are design rules for the information substructure that are to be used to get a required level of optimality of the operating substructure. These design rules are those that relate to the two properties of the accuracy and awareness which have positive effects on optimality. Analogously, the reward substructure performance properties that affect optimality are those of material richness, emotional richness, and fairness. Design rules for these are derived below and should be used in conjunction with the design rules of the operating and information substructures. Higher levels of the information substructure performance properties of accuracy and awareness produce higher levels of optimality of the operating one. Accuracy levels determine the extent to which the goodness of the decision made on the basis of the information used is translated into goodness of this same decision when the real facts are used. The lower the accuracy, the less likely is a very good decision to be made, given inaccurate information. There are two goodness measures involved. The first is that of the decision given the information used to get it. Next, there is the goodness of the decision that would have been made, given the real facts. The first may be very high, but it may be very far from the second. In the real world, the decision that was very good, given its information, may turn out to be very bad. As we increase accuracy, we decrease this difference. Meanwhile, improving accuracy would have weaker effects if we were to have high levels of lumpiness and fineness, and so restrict the choices made for different sets of information and reduce the chances for decision that are good, given the information we have and have just made more accurate. So when we use the design rules to get an operating substructure with the appropriate levels of its performance property of optimality, we should also use in conjunction with them the rules to design information substructure to get the correct levels of its performance properties of accuracy and awareness. An argument can also be made for using some of the design rules for the reward substructure when these design rules of the operating structure are used. Levels of the emotional, economic, and fairness properties of the reward substructure have an effect on the levels of thought and effort that people put into the making of and using of the operating and information decision rules. In turn, this affects the level of optimality of the performances of these two substructures. The design rules for these reward substructure properties should be used in conjunction with those on the operating substructure property of optimality.

Note: Charts that contain the rules of this chapter are in Appendix II.

# CHAPTER 13

# DESIGN RULES FOR ORGANIZATION SUBSTRUCTURE PROPERTIES AND COMPONENTS: PART B

## 1. Design Rules for Flexibility of a Structure Performance

An organization structure is more or less flexible according to the number of performances that meet some given conditions and so defines a set. First, a performance in the set meets some predetermined level of optimality for some circumstance which the structure may realistically encounter. Second, each performance is implementable within some finite length of time, measured from the time the performance is chosen to the time it is actually done. Both the level of optimality and the length of time for implementation are chosen within the context of the overall nature of the states of the environment and states of technology that be may encountered. For any given pair of optimality levels and length of time, there is a set of performances that meets them. This set may be used to create another set, that of circumstances, each of which is one for which a performance in the first set meets the optimality conditions. If the number of circumstances in this set is to be made larger, then the number of performances in the other set must be increased, or at least remain the same. In other words, increasing the number of performances in this set may increase and will never decrease the number of circumstances in the other set. Once the level of optimality and time period are set, then it follows that a structure that is to increase its flexibility must increase the number of performances that meet the conditions. A set of performances, each of which meets the optimality condition for one or more circumstances and the time limit for implementation, is the set we may term " arrows in the quiver". We may measure flexibility by the number of performances in this set. Flexibility measures the number of performances which are implementable within a given time period and which are of some minimum quality level for some circumstances. Along with each such set, there is a set of circumstances that are covered, so to speak, by at least one performance that is at least of the optimality level specified and can be implemented in the specified time.

For the flexibility measure, the optimality level is for performances held in reserve. This means that they are there to help direct the search for the performance in the set that meets the level of optimality for actual implementation. What we have is a set of performances, each of which is described in some level of detail and marked as the starting point for identifying the performance that meets the required level of optimality and is to be implemented within some fixed time period. The more detail in the definition of the performance, the shorter the time to complete the detail required and implement that performance. The fewer the number of circumstances identified as that for which a performance is marked to be used to start the process of deriving the performance that meets the required level of optimality, the shorter the time it takes to make the derivation. The higher the level of optimality required in the implemented performance, the longer the time it takes to make the derivation. When these two are set, then the number of performances that the are in the set that meet them defines the level of property of its performance we call flexibility. Over time, a structure that learns is one which uses its experience to increase the detail of the performances in the set, reduce that number of circumstances for which the performance is the search starter, and reduce the time of deriving the performance that meets the optimality level for implementation.

Before we go into the learning structures, we work with the case where no learning occurs. The starting set that meets our conditions is considered to be that which remains unchanged unless it is changed into another that becomes the fixed set of performances that meet the two conditions. This is the set of reserve performances, so to speak, available for use as is or as bases for generating ones that are. They are arrows in the quiver, one of which is to be drawn and used as is, or modified and then used given the game sighted. The optimality of the performances so held in reserve need not be as high as that needed for actual use. It is more costly to make them all meet the higher condition. The time it takes to get one that does meet the conditions of optimality is shorter than that needed if there were none there, and we had to start from scratch.

To be in the set that makes for flexibility, a performance must meet conditions for some set of circumstances. Suppose a structure starts with such a set and one implemented performance. Each such performance is associated with a set of circumstances for which it is identified as implementable in a given time and for which it meets a minimal level of optimality. This association is precisely that which describes the ones in decision rules. In these, a set of values for a decision variable is chosen for a circumstance, and the performances in the quiver are nothing more than a combination of a number of rules. As the rules of the structure are used over time, performances from the storage are used as is or to generate better performances. This means that the number of performances acceptable for any circumstance become fewer and fewer, and that decision rules will be getting more fine, and the level of optimality that the performances in reserve have will also be higher. The result is that we have the same number of performances, and therefore the same level of flexibility, but a higher level of optimality which the performances attain for the set of circumstances. Organizational learning is the improvement in the quality of the performances that are in the set of stored performances that determines what we called flexibility. As it matches performances to conditions, the organization's decision rules should be getting finer, and the level of optimality of the rules should also be rising. If this is what happens, then the organization may be said to be learning. Along with this learning, and as an integral element in the process is the recording of the associated pair, performance and the circumstances which it covers. As rules get fine, the latter can be expected to decrease, and the total number of performances to increase. Learning is the process of getting better matches between a performance and the set of circumstances which it is intended for. This process is that of becoming experienced, a process that involves not just the creation of the set that defines flexibility, but also that produces the definitions of responsiveness, optimality, and so on. We will return to this learning process and investigate the relations between it and the organization structure.

Now we return to the rules of design that produce structures that have the required level of flexibility. Our first rule is on comprehensiveness.

OD-Rule 11: The higher the level of the performance property of flexibility that is desired, the higher the level of the vector made up of the level of comprehensiveness, the level of the inverse of the level of lumpiness, and the level of fineness that is to be set in any iteration of the process of design.

OD-Rule 11*: The elements that are to be changed are the decision rules where a higher level of the vector made up of the each rule's level of comprehensiveness, the level of the inverse of the level of decision rule lumpiness the level of fineness produce relatively higher levels of flexibility of the decision variables they govern. For lower levels of the structure properties, the elements are chosen in reverse order.

Flexibility begins with planning. Planning begins with the identification of what the world of the organization might get to be. For each state of the world that is considered to have some high enough probability of occurring, a set of decisions is identified. The higher the number of circumstances considered, the larger the different performances are likely to be needed to meet the level of optimality required. More states of the world identified and included in the plans means decision rules with larger, and therefore more comprehensive domains. If the plan allows the values which may be given a decision variable for each state, or circumstance, to be similar to that which may be given in many other circumstances, then fewer performances will be identified than in the case where different circumstances were identified with different sets of decisions. The structure that is prepared to implement any one of a large number of performances that meet some minimum levels of quality is one that has decision rules with high levels of comprehensiveness of domain and low levels of lumpiness of range. Plans that produce flexibility are those with rules that cover many circumstances and differentiate between the sets of performances that are acceptable in each circumstance. By its very nature, lumpiness is such that as its level increases, it assigns more and more performances, values of decision variables, to each set of circumstances, values of parameters. The result is that fewer performances are recognized as ones that might be required, and that defines lower levels of flexibility. The inclusion of fineness levels is based on the arguments made earlier about their effects on optimality being high when lumpiness is high, and being low when it lumpiness is low.

The conditions on minimum time for change and for some level of optimality for the changes also affect the measure of flexibility which the plan calls for. That is why the definition we gave for flexibility requires that these be set before the decision on flexibility is made. In real terms, the flexibility measure that results from a plan with any given level of comprehensiveness would fall if the level of the performance optimality were to be raised, or the time of implementation were to be reduced. Both these requirements are to be determined within the context of the environment and technology of the organization. Their levels, and the level of flexibility, are to be determined in a logically simultaneous manner. This produces the required level of flexibility and the contextual measures of time and quality which the structure is to be designed to meet. In the iterations of the process of designing the structure, cost considerations might require changes in any of these three requirements. Thus, as optimality is increased, the cost of any level of flexibility will increase. In general, all three should be set as adjusted in terms of one another.

OD-Rule 12: The higher the level of the performance property of flexibility that is required, the higher the level of the combination of the level of domain resolution and the level of range resolution that is to be set in any iteration of the design process.

OD-Rule 12*: The elements that are to be changed are the rules where higher levels of the combination of the level of domain resolution and the level of range resolution produce relatively higher levels of flexibility of the decision variables they govern. For lower levels of the structure properties, the elements are chosen in reverse order

Arguments for this rule are analogous to the ones before them. Greater resolution of the domain will show more variations in the conditions, and hence, give impetus to changes in decisions. Higher levels of range resolution mean finer variations in decisions, and hence, an increase in the number of these on hand, and that means higher flexibility. If one does not see differences in circumstances, one will not have different decisions. If one can not distinguish between differences in decisions that are smaller than some amount, one can not have as many choices of decisions as one would otherwise have.

Design Note: There are design rules for the information substructure that are to be used to get a required level of flexibility of the operating substructure. These design rules are those that relate to the performance property of the awareness. These rules are identified below when the design of this substructure is discussed.

## 2. Design Rules for Responsiveness of a Structure Performance

Finding a performance which matches a given circumstance is a process that starts with a search of the set of performances which the organization has identified as meeting the optimality requirements, etc., for some circumstances. This is that set which we used to define a measure for the property of flexibility. The term circumstance is used to define a state of the environment and the technology. Match refers to the optimality and other conditions which the performance must meet, given a circumstance. The set of performances that make up the set used to measure flexibility are those performances that are of some minimum level of optimality for some realistic environmental circumstance, and are ones for which the time it takes from choosing the performance to implementing it is below some given length. If performance x is in the set, then once we choose to do it, we can do so before some amount of time elapses.

Responsiveness is measured on the basis of the time it takes from the moment a circumstance becomes real to the moment that the structure implements a performance that is of some level of optimality. This level is the same for the measure of responsiveness as it is for that of flexibility. However, the time for this latter is a measure of the length of the interval of time from the moment of the choice of a performance that meets the optimality condition to the moment of the implementation of this performance. For responsiveness, the relevant measure is of the interval from the instant a circumstance becomes the real one to the instant of the implementation of a performance that meets the optimality conditions for this circumstance. This length of time is the sum of three intervals, the first of which is the period of time from the instant a circumstance becomes real to the instant that its realness is recognized. The time elapsed from the instant of recognition to the instant at which the performance that meets the requirements is identified is the second interval. Finally, there is the period of time it takes to implement this chosen performance. Since choosing a performance must follow the reading of the circumstance, and implementation must follow the choosing of a performance, the implementation time is the sum of all these three.

What happens in an organization structure is as follows. There is a recognition that a new circumstance has come into being. Next, the circumstance is identified, by having its components read and recorded. Next, the performance that meets the requirements for the circumstance is chosen. The choice may found by searching a mapping in the organization's information structure. This is the mapping that identifies the performance that matches the circumstance. If there is no such element in the mapping, then the performance will have to be obtained through a series of problem solving activities. Lastly, this performance must be implemented and turned from we ought to do to we are doing things to make it real, things such as transferring information on the circumstance, or transmitting new decision rules, or new elements to be inserted into old rules. If the matching performance that is identified is already in the set that we used to define flexibility, then it will be a component in an element of an existing mapping which may be stored in the information substructure. If the mapping is stored, then finding that performance should take a lot less time than if the performance was not in such a mapping, and so had to be generated through problem solving activities. The organization might find it most efficient to search for this performance in the mappings from which the set of performances that determine flexibility is derived. Searching this set first will tell us whether a mapping that contains it exists. But unless this set is connected to the set of circumstances in an orderly manner, this search will not be efficient. Given this connection is present, the efficiency of the search or time it takes to find the mapping is lower than that of starting from scratch.

In discussing responsiveness, the interval of identifying the performance for any circumstance is defined as the time it takes to search the set of performances used to measure flexibility for the performance, and then searching the mapping that matches it to the circumstance, and the time of generating a matching performance from scratch if it is not in the set searched. Only if the performance is not in there, and the search is unsuccessful, would the organization go through the process of developing the matching performance from scratch. It is here that learning may occur. We will come back later to elaborate. Ordering the performances and developing the mappings from circumstances to the matching performances will determine the efficiency of the search process, and the conditions in which it might be more efficient to develop the performance from scratch rather than do the search. One may assume that this set of performances and the set of circumstances for which it contains a match are put into the form of a mapping, from the set of circumstances to the set of performances that are a match. This is a requirement on the information substructure, as the rules will show later.

Responsiveness is a property of the performance of an organization. The level it has is the result of the elements of the organization's structure that determine three time intervals. The first is the time it takes the organization to realize that a new circumstance exists and to read its components. The second is the time it takes to find the performance that matches the circumstance. Lastly, there is the time it takes to implement the performance. Each design rule that will be identified is there because its choice variable is an organization structure property, defined in terms of the elements of this structure, which affects one, or more, of these three periods. Each design rule in the set that increases responsiveness is about a structure property that reduces the length of one of the three intervals. Each rule will be connected to its relevant interval, which we will designate as the facts interval, the decision interval, and the implementation interval. Response time is the sum of these intervals if they do not overlap. If there is a logical possibility that one may be started before the previous one is finished, and if this is in fact the process followed, then response time will be shorter than the sum of the three intervals. After we first consider the simple case of no overlap, then we will examine the second more complex one.

OD-Rule 13: The higher the level of the performance property of responsiveness that is required, the higher the level of rule comprehensiveness that is to be set in any iteration of the design process.

OD-Rule 13*: The elements that are to be changed are the rules where higher levels of rule comprehensiveness produce relatively higher levels of responsiveness of the decision variables they govern. For lower levels of the structure properties, the elements are chosen in reverse order

This is a rule about the second or decision interval. Once a state of the environment is recognized, then the shorter the time it takes to specify the set of decisions that are of the required optimality, the appropriate one for it, the more responsive the organization. Decision rules identify the values of the decision variables or the set of decisions for various environmental conditions, namely the ones in their domains. When the state of the environment is in the domain of a rule, then to find the appropriate decision variable value for it, the decision maker has only to consult the rule. When this is true for all the decision variables that make up the set of decisions, then the time it takes to identify this decision set is that of consulting the rules. Given that the rules are recorded and stored in ways that makes them easy to reach, this time is considerably shorter than that needed to generate the value of any one of the decision variables of the appropriate set. When the state is not in the domain of a rule for one of the decision variables, it would be necessary to go through the process of generating the appropriate values. In general, the more states of the environment are in the domains of the decision rules, the faster the identification of the variable value appropriate for it is found, and the more responsive the organization is. Meanwhile, the measure of rule comprehensiveness refers to the sizes of the domains of decision rules, and hence to the likelihood that an environment state is in there. So, the more responsive we want the organization to be, the bigger the domains of its rules have to be. In addition, the information substructure must be designed to take advantage of the these rules. This is a requirement that we discuss under the heading of making the operating, information, and reward substructures consistent with one another.

OD-Rule 14 The higher the level the performance property of responsiveness that is required, the higher the level of rule fineness that is to be set in any iteration of the design process.

OD-Rule 14*: The elements that are to be changed are the rules where higher levels of rule fineness produce relatively higher levels of responsiveness of the decision variables they govern. For lower levels of the structure properties, the elements are chosen in reverse order

Finer rules have smaller sets of decision variable values assigned to each element in their domains than do rules that are less fine. Smaller sets mean less choice to the decision maker, and less choice means less time needed to find the value in the set that is appropriate for the state of the environment. The higher the level of optimality that is specified by earlier rules, the more time it will take to find the appropriate decision variable value, and the lower the level of responsiveness of the organization for any level of fineness. For any given level of optimality, the less fine the rule, the longer the time and the lower the level of responsiveness. The returns to the organization as it increases its rule fineness will be higher, the higher the level of comprehensiveness it has. This would suggest that the higher the level of comprehensiveness decided on, the higher the level of fineness that should be chosen to go with it. However, the cost of any level of fineness will also increase with the level of comprehensiveness chosen. So the effect of the level of the latter on the required one for the former is weakened but not eliminated.

OD-Rule 15: The higher the level of the performance property of responsiveness that is desired, the higher the level of the combination of the level of domain explicitness and the level of range explicitness that is to be set in any iteration of the design process.

OD-Rule 15*: The elements that are to be changed are the rules where higher levels of the combination of the level of domain explicitness and the level of range explicitness produces relatively higher levels of responsiveness of the decision variables they govern. For lower levels of the structure properties, the elements are chosen in reverse order

Whatever the qualifications on the kinds and goodness of the performance we set, i.e., the time it takes between the beginning of the new circumstance to the new performance, is the main issue. The more explicit the domain of a decision rule, the less analysis and derivation is required to translate the new values of the components that describe the world into the values of the components of the decision rules associated with them. It takes less time to change the decision which is based on competitor price which we read directly from the world, than it does to change that which is based on the effects of the new price on market share. This is true even if we don't have to wait for the latter, but merely calculate it from some formula. The less computation and derivation based on the new circumstance there is before the rule can be used, the quicker it will be used. As for the range explicitness, the argument is analogous to the one for domain explicitness. It takes much less time to use the rule which states that for every competitor price x, explicit domain, our price is y, explicit range, than it does the rule which states that for every competitor price, the effects on our market share must be estimated, and our price is to be that which makes this competitor's market share at no more than 1.1 times our share. The second rule moves from explicit numbers for x and y to the effects of prices numbers x and y. The world we see shows the price number x, and the decision we make is on the price number. To use the first rule instead of the second is to have a rule that takes longer to use once the number y is ascertained. When the of level of the one property is considered in combination with the level of the other, any enhancement of the effects of one by changes in the other are more likely to be recognized and obtained.

OD-Rule 16: The higher the level of the performance property of responsiveness that is desired, the higher the level of the combination of the level of domain resolution and the level of range resolution that is to be set in any iteration of the design process.

OD-Rule 16*: The elements that are to be changed are the rules where higher levels of the combination of the level of domain resolution and the level of range resolution produce relatively higher levels of responsiveness of the decision variables they govern. For lower levels of the structure properties, the elements are chosen in reverse order.

These rules come from the realization that increasing resolution implies more possible values that a parameter may take, and that a decision rule may specify. There are larger logical spaces to consider in both cases. One may expect that it would take more time to search these spaces for the value taken by a parameter, or the value to be given a decision variable.

D-Rule 17: The higher the level of the performance property of responsiveness that is desired, the lower the level of range-domain connectedness that is to be set in any iteration of the design process.

OD-Rule 17*: The elements that are to be changed are the rules where lower levels of range connection produce relatively higher levels of responsiveness of the decision variables they govern. For lower levels of the structure properties, the elements are chosen in reverse order.

A connection between the range of one rule and the domain of another means that use of the second rule is logically dependent on the use of the second. The second decision cannot be made, and certainly cannot be implemented, until the decision from the first rule is made, or identified. This logical dependence means that the second decision cannot be made until the time it takes to make the first is over. There are organizational ways in which this time may be shortened, but it cannot be eliminated. These effects on responsiveness of using range-domain connections to get coordination exist.

Design Note: There are design rules for the information substructure that are to be used to get a required level of responsiveness of the operating substructure. These design rules are those that relate to the performance properties of alertness and accuracy. The same is true of the reward substructure properties of material and emotional richness, and also of fairness. These rules are identified below when the design of these substructures is discussed.

Analytic propositions established in previous chapters show that alertness is the determinant of one segment of the time from a change in the circumstance to the response made. It is only after the organization realizes that a change has occurred and then finds the correct values of the changed components, that it can begin to decide what its response is to be. The effect of accuracy is however the opposite of that of alertness. It may not be a strong effect, but logic suggests that the closer to the real value of the parameter that one wants the measure one has of that value to be, the longer time it will take to get it. Higher levels of accuracy may require multiple readings of parameter values and may require more elaborate procedures. Multiple readings required may be sequential or not. If they are, then they will involve more time than fewer readings. If the readings are done by many people simultaneously, then some time will be needed to put all the readings together to get the appropriate accuracy sought. We will return below to these two properties and the design rules that give us information substructures that fit with the operating substructure obtained from the use of the design rules on responsiveness. Similar arguments are made above to support the inclusion of the three relevant performance properties of the reward substructure.

## 3. Design Rules for Controlledness of a Structure Performance

Control of performance means two things. First, there is a performance that is specified as required. Second, there is a set of probabilities with one element that gives the probability that this performance will, in fact, be the one that is chosen. The issue of control is relevant to design only if there are connections between the structure of the organization and this set of probabilities. There is such a connection, and the designer may use it to do just that. How structure is connected to control of performance is the subject of the next set of design rules and the arguments that prove the logic on which they are based.

OD-Rule 18: The higher the level of the performance property of controlledness that is desired, the higher the level of enfranchisement or the higher the level of user orientation that are to be set in any iteration of the design process.

OD-Rule 18*: The elements that are to be changed are the rules where higher levels of enfranchisement produce relatively higher levels of controlledness of their user sets. For lower levels of the structure properties, the elements are chosen in reverse order

If the rule user participates in the making of the rule, or if the rule is intended to achieve the goal of the user, then that user is more likely to use this rule than if she had neither participated in making the rule nor found the rule to be compatible with her goals. Higher values of these two structure properties do enhance the control over performance or use of the rules. Enfranchisement is defined in terms of the participation of the rule users in the making of the rules, which means that a person participates in making the rule he uses. It does not say anything about participation of people in the making of all or some of the rules. This use of the term is somewhat different from the normal one where it is used to mean participation of people in making all rules, whether the rules apply to what decisions they make or not. Here then, enfranchisement is not quite democracy.

OD-Rule 19: The higher the level of performance property of controlledness that is desired, the higher is to be set the level of the vector made up of the level of people inclusiveness, the level of variable inclusiveness, and the level of parameter inclusiveness.

OD-Rule 19*: The search should be for what one considers to be those variables, etc., that have the most effect on control when they are incorporated into the structure.

It is hard to imagine that any person in the organization may be left with no task, that is with no decision variables to which he is to give values. But if such a lapse of inclusiveness should occur, then it can be expected that a very low level of control can be exerted over this person's decisions. The same is true of variables and parameters. However, ignorance does exist and the results are precisely lapses in inclusiveness. Also, including a previously ignored variable will have much less effect on control, if a parameter strongly related is not included.

Design note: The reward substructure performance properties of material richness and emotional richness have direct effects on the level of controlledness of the operating substructure. The same is true of the property of fairness. Design rules for reward substructure that have any of these performance properties are derived below and should be used when one is designing for the controlledness property of the operating substructure.

General rules to be stated in the next section call for the inclusion of all people, all decision variables, and all parameters in the design

## 4. Design Rules for Inclusiveness

Every performance property of the operating substructure is affected by one or more of its properties of people, variable and parameter inclusiveness. It is clearly the case that the level of people inclusiveness affects the level of the performance property of controlledness. In fact, the other two inclusiveness properties also affect it. Control is exercised over what people do, and what people do is set values of decision variables or read values of parameters. If some person is not recognized as being in the organization, or if a variable is assigned to no one, then it makes no sense to talk of the level of control that the designer has over either. The role of inclusiveness in the property of controlledness is very strong. It is explicitly recognized by making a design rule about it.

Each performance property of the operating structure should have a rule on inclusiveness. When one talks of the level of coordination, one talks of decision variable values and the relations between them. If a decision variable is not in both the sets that make up the two components used to define inclusiveness, then it does not exist in the structure. Coordinating the value it is given with that given another decision variable is meaningless. The same logic applies to the other performance properties, and the three inclusiveness properties have pervasive effects and are therefore important design variables. They are also properties that may be obtained at very high levels, at costs that are relatively trivial compared to the costs of other properties, such as domain explicitness, or whatever. The cost of getting the maximum level of people inclusiveness is the cost of making certain that every element in the set that is the people component of the vector which describes the substructure is a component of at least one pair that is an element of the assignment component of that vector. The same is true of the effects and costs of the property of variable inclusiveness. In light of the pervasiveness of their effects and relatively low cost of setting their levels at very high values, we may identify design rules for the operating substructure that are not conditioned on the need for any one performance property. The issue of inclusiveness is relevant to all three substructures. The rules on inclusiveness are considered as applying to the whole structure. They are designated as D-Rule 1, etc., where letter D stands for design, and the absence of a letter before D means that the rule applies to the whole structure and to any of its substructures. For this reason, we need to identify them just once and state them in terms of the whole structure, that is the organization. These rules are not conditional imperatives like all the rest, but absolute ones to be used under all conditions. The reason is that these rules relate to the components that define the boundaries of the structure. If a person is not in the set people that is the component of the structure, then that person will not be in any assignments, decision rules, etc. Since the cost of meeting the inclusion requirements are relatively insignificant, the inclusion rules are not conditional. The structure designed will be for whatever these three components contain.

D-Rule 1: The level of the people inclusiveness property of the organization structure should be set at the highest level in the beginning of the design process and left there.

D-Rule 2: The level of the decision variable inclusiveness property of the organization structure should be set at the highest level in the beginning of the design process and left there.

D-Rule 3: The level of the parameter inclusiveness property of the organization structure should be set at the highest level in the beginning of the design process and left there.

## 5. Design Rules for Information Substructure Performance

So much for the design rules which are to be used to design the operating substructure. The rules tell us what the structure components are to be if the substructure is to have a performance with some given level of this or that property. It is time to do the same for the information substructure for which the design rules are designated, ID-Rule 1, etc., where D means design, and I means the information substructure. First, there are the rules that relate to the performance property of alertness.

ID-Rule: The higher the level of the performance property of alertness that is desired, the higher the level of repetitiveness that is to be set in any iteration of the design process.

ID-Rule 1*: The elements that are to be changed are the rules where higher levels of repetitiveness produce relatively higher levels of alertness of the parameters they govern. For lower levels of the structure properties, the elements are chosen in reverse order

ID-Rule 2: The higher the level of the performance property of alertness that is desired, the higher the level of redundance that is to be set in any iteration of the design process.

ID-Rule 2*: The elements that are to be changed are the rules where higher levels of redundance produce relatively higher levels of alertness of the parameters they govern. For lower levels of the structure properties, the elements are chosen in reverse order.

The more often a parameter value is read, or the higher the level of repetitiveness, the sooner will a change in its value be noted, which is what a higher level of alertness means. This is a reference to the increase in the average number of times that all parameters are read. One can raise that number by increasing it for only one or two parameters. How to get the increase in alertness to all the parameters to whose values we should be alert is a problem that is discussed when the rules on consistency that have to hold between the operating and the information substructures are discussed. The rule on alertness assumes that this consistency exists. Meanwhile, the second rule recognizes that the more people who are assigned the job of reading a variable, the sooner a change in its value is noted.

Design rules on getting the needed levels of the information substructure performance property of accuracy are also given under the assumption that the consistency problem is solved.

ID-Rule 3: The higher the level of the performance property of accuracy that is desired, the higher the level of redundance that is to be set in any iteration of the design process.

ID-Rule 3*: The elements that are to be changed are the rules where higher levels of redundance produce relatively higher levels of accuracy of the parameters they govern. For lower levels of the structure properties, the elements are chosen in reverse order.

The more people who are assigned the job of finding out what some parameter value is, the more likely that its real value is the one that is read by somebody. Which of all the readings is the correct one can only be obtained by logical operations on the set of readings. Various statistical operations may be devised and decision rules developed to make use of such operations. This is an issue of the internal consistency of the information substructure and is discussed later.

ID-Rule 4: The higher the level of the performance property of accuracy that is desired, the higher the inverse of the level of repetitiveness that is to be set in any iteration of the design process.

ID-Rule 4*: The elements that are to be changed are the rules where higher levels of repetitiveness produce relatively higher levels of accuracy of the parameters they govern. For lower levels of the structure properties, the elements are chosen in reverse order.

This rule results from the argument that repeating an action tends to bore the actor, and the quality of the work falls. There is no contradiction between the two rules. What the second rule does is to point out that it is not enough to use the first, but one has to consider how to do so. One gets many readings by having many people each of whom reads the value a few times, rather than a few people each of whom reads it many times. Here again, is a design decision dictated by the need for the internal consistency of the substructure.

ID-Rule 5: The higher the level of the performance property of accuracy that is desired, the higher the level of rule fineness that is to be set in any iteration of the design process.

ID-Rule 5*: The elements that are to be changed are the rules where higher levels of fineness produce relatively higher levels of accuracy of the parameters they govern. For lower levels of the structure properties, the elements are chosen in reverse order.

ID-Rule 6: The higher the level of the performance property of accuracy that is desired, the higher the level of range resolution that is to be set in any iteration of the design process.

ID-Rule 6*: The elements that are to be changed are the rules where higher levels of range resolution produce relatively higher levels of accuracy of the parameters they govern. For lower levels of the structure properties, the elements are chosen in reverse order.

In the case of information decision rules, range fineness refers to the freedom of the rule user to accept a reading of the parameter as the true one. The higher the level of fineness of the range, the smaller the distance between a reading and the true value of the parameter that must exist before the reading is accepted as close enough to the correct one to be accepted as in fact the correct or true one. A user cannot meet such a requirement without some concept of what he might do to estimate how far a reading is from the true one, or what the probability might be that it is at least this or that distance from the true one. Some of the things that can be done relate to the manner of making the reading, the logic of the process by which a reading is determined, and the property of fineness is meaningful only if some of these things are done. Greater fineness requires the use of any such means to determine the probability that a reading lies within some distance of the true one and to accept as correct a reading only if there is a such a high probability that it does so. Greater levels of fineness ask for greater accuracy of the readings that are accepted as true, and therefore to be ones that are used in the decision rules of the operating substructure. Meanwhile, the rule on the level of range resolution determines how closely a rule user may estimate the distance between a reading and the correct value. For the rule user, an increase in the level of resolution means that the set of readings that meet the rule requirements of fineness is enlarged and the difference between one element and the next one is decreased. The rule user can thus get readings closer to the real measure than he could get before. It is reasonable to expect the accuracy of his readings to improve. Fineness and resolution are complementary. The effects of changes in their levels are likely to be greater than linear.

Awareness is the last performance property of the information substructure that remains to be to be connected to the design variables of which the first to be discussed is the substructure property of diffusion.

ID-Rule 7: The higher the level of the performance property of awareness that is desired, the higher the level of diffusion that is to be set in any iteration of the process.

ID-Rule 7*: The elements that are to be changed are the assignment pairs, (person, parameter set), meaning that this person gets the value of the parameters in the set, where larger sets of parameters produce higher levels of awareness in the person with whom they are paired. For lower levels of the structure properties, the elements are chosen in reverse order.

ID-Rule 8: The higher the level of the performance property of awareness that is desired, the higher the level of redundance that is to be set in any iteration of the process.

ID-Rule 8*: The elements that are to be changed are rules where higher levels of redundance produce higher levels of awareness in the rule user. For lower levels of the structure property, the elements are chosen in reverse order.

Diffusion and redundance are not strictly independent one of the other. If we increase redundance, we are likely to increase diffusion, but the reverse is not so. We consider them both because of cost issues and the effects that redundance has on other performance properties. To increase awareness, one would choose the design variable that costs less. There is no a priori reason why one would cost more than the other. Each case must be treated in the context of the actual costs. Also, redundance levels are related to the levels of the performance properties of alertness and accuracy. Even if this variable costs more, it may be the one to use to increase the level of awareness too.

## 6. Design Rules for the Reward Substructure Performance

The design rules for the reward substructure will be derived next. The group of rules on fairness are derived last and given their own section of the chapter, because they are complicated by the fact that fairness has many subjects, and because the levels of this property affect those of many other properties of all three substructure. Rules on designing the reward substructure are designated as RD-Rule 1, etc., where D refers to design and R refers to the reward substructure.

RD-Rule 1: The higher the level of the performance property of material richness that is desired, the higher the level of rule receiver orientation that is to be set in any iteration of the process.

RD-Rule 1*: The elements that are to be changed are the rules where higher levels of receiver orientation produce the larger levels of the material richness to the receiver. For lower levels of the structure property , the elements are chosen in reverse order.

Material richness can be increased by increasing the amounts of the material reward components directly. Whatever a person received in money may be doubled, and so the reward is richer. The cost of the increase is the amount of the salary. If this amount had been used to increase the salary by 50%, and the other half had been spent on a combination of benefits, the receiver may well have valued this combination more than he did the former. Rewards have many components. The receiver may well have preferences for combinations of these. Even if the component that is increased is money, it does not follow that the receiver can spend half the increased benefits and get the same value that he would have received had the total money increase been distributed between money and benefits which would be bought for him. The benefits the receiver could get with half the salary might well be less than those the organization could get for him if it had spent that amount. These possibilities should be considered when the reward rule mappings are determined.

Higher levels of this property mean better understanding of what these preferences are and better knowledge of the relative importance of the variables that define the space over which the receiver has his preferences. That is what this design variable we call the goal orientation of the reward receiver does for the design. It is the mechanism by which the designer can consider the efficiency of the reward mappings. Included in the design problem are the choice of the components of the reward and the choice of the combinations of their levels. The consistency rule says to pick those rules where the receiver has strong preferences. More participation by this receiver will make the changes in the material reward. The stronger the preferences of this receiver, the more richness in the reward he gets from the changes his participation produce in his material rewards.

RD-Rule 2: The higher the level of the performance property of emotional richness that is required, the higher the level of rule receiver orientation that is to be set in any iteration of the process.

RD-Rule 2*: The elements that are to be changed are the rules where higher levels of receiver orientation produce the larger levels of the emotional richness of the reward component of the rule to the receiver. For lower levels of the structure property, the elements are chosen in reverse order.

Once it is recognized that some reward components have no economic value to the receiver, the concept of emotional value becomes useful. Army medals have no economic value to most of those who receive them, but they are important components of the reward. Everything argued for the previous vector applies here with even more strength. The reason is that many components of the material reward may at times be traded for one another. Errors in the design of the rewards substructure may be in part corrected by the receivers through trading. The non-economic components have no markets and though the money part of the Nobel prize is tradable, Euros for Dollars or for cars, the prestige of the name is not.

RD-Rule 3: The higher the level of the performance property of material richness that is desired, the higher the level of ownership that is to be set in any iteration of the process.

RD-Rule 3*: The elements that are to be changed are the rules where higher levels of ownership produce the larger levels of the material richness of the reward component of the rule to the receiver.

For lower levels of the structure property, the elements are chosen in reverse order.

RD-Rule 4: The higher the level of the performance property of emotional richness that is desired, the higher the level of ownership that is to be set in any iteration of the process.

RD-Rule 4*: The elements that are to be changed are the rules where higher levels of ownership produce the larger levels of the emotional richness of the reward component of the rule to the receiver. For lower levels of the structure property, the elements are chosen in reverse order.

Ownership is participation by the receiver in the making of the reward rules that apply to her. Participation improves the likelihood of the consideration of hers views in making the rules. This makes using the two previous rules easier. But ownership has a direct effect on both kinds of richness because the value of the components of the rewards and the value of combinations of their levels may themselves be altered by the participation of the receiver. The fact that the reward receiver has a say in what they are may enhance their values to her.

RD-Rule 5: The higher the level of the performance property of interdependence that is desired, the higher the level of the rule domain-domain connectedness or the higher the level of the range-domain connectedness that is to be set in any iteration of the process.

RD-Rule 5*: The elements that are to be changed are the rules where higher levels of domain connectedness or of higher range-domain connectedness produce the larger levels of the interdependence of the reward component of the rule to the receiver. For lower levels of the structure property, the elements are chosen in reverse order.

The two design variables are to some extent substitutes, and may at times reinforce the effects of one another. For this reason they should be chosen in a logically simultaneous manner. The use of the term or in the rule states that the choices are any one of the following: increase the level of the domain-domain connection only; increase the level of the range-domain connection only; increase the levels of both kinds of connections.

The only performance property of the reward substructure that remains to be made the object of the design is that of fairness. The analysis of this property earlier makes it very clear that the level of fairness that an individual assigns to the reward he receives is derived in some manner from some combination of the levels of fairness he assigns to a number of things that define the reward substructure. The receiver assigns levels to the fairness of the reward rule, the set of makers of the rule, the set of users of the rule, the domain of the rule mapping, the range of the rule mapping, and the mapping itself. He does the same for some other people in the organization, and on the basis of all this, he assigns a level of fairness to the reward as a whole. What the person includes in the combination, how he combines these levels, and the other people he considers, are all governed by certain beliefs and values relating to the culture to which he belongs and to idiosyncratic variations on these. Whatever the process, the response of this individual to the level of fairness of the reward that emerges will affect his behavior in the operating, the information, and the reward substructures. How he reacts is itself the result of the culture values and notions of what is very fair or very unfair, and whether there is unfairness for and against one. Culture will also determine the broad characteristics of the response to such things as a low level of fairness against the individual in one the piece of the reward and a high level of fairness for the individual in another piece. Do they cancel out, or does the bad negate any effects of the good? The answers differ for different circumstances.

All these complications mean two important things for the designer of the operating and the reward substructures. The first is something we have mentioned before, that there is no meaning to the concept of designing organization structures in specific cases unless the designer knows the relevant facts of this organization. These include its technologies, its environments, the response of its people to elements of the design, and of course, their response to the reward substructure. Despite all these differences, there are fundamental similarities between all cases. It is possible to arrive at some conclusions on the general issue of design. These involve the logic of the process which people use to determine the level of fairness of a reward.

People use many components as a basis for their judgments. The manner in which the levels of these are translated into a fairness measure may be quite complex. These mappings may allow for compounded effects of the levels of two or more variables, they may allow for some tradeoffs between variable values, they may include some minimal specific ratios between some variable levels, and so on. Whatever the variety, the set of components used to determine the fairness of any rule is always a subset of the set made up of the components of what we defined as a reward rule. These components are the set of rule makers, rule users, etc. In general, all designers should work with this set of components and attempt to identify how its elements are combined by the people in the specific case to come to their conclusions on the fairness of the substructure. A general way of combining these elements is derived from the ones of the individuals and applied to the set and used in the process of designing the reward substructure which has the level of fairness the designers want it to have.

RD-Rule 6: The higher the level of the performance property of fairness that is desired, the higher the level of ownership, the higher the level of involvement, the higher the level of rule mapping consistency, or the higher the level of receiver orientation that are to be set in any iteration of the process.

RD-Rule 6*: The elements that are to be changed are the rules where higher levels of ownership, or higher levels of involvement, or higher levels of rule mapping consistency, or higher levels of receiver orientation produce the larger levels of fairness as viewed by the receivers of the rules. For lower levels of the structure property, the elements are chosen in reverse order.

Again, the term or is used to mean that a number of variables should be considered for increases or decreases in their levels in each step design. The designer should consider the many possible changes in the levels of the variables and make those that get him closer to the level of fairness he wants. The designer should use a rule that produces designs in which the level of each variable is chosen in the context of the levels of all others. Even when this rule is followed, the work of designing for fairness is not over and more work on such things as the identity of the rule users, the makers, and so on, need to be worked on.

## 7. General Design Rules on Substructure Consistency

In developing the design rules for substructure properties, we made connections between a rule used for the design of one substructure with rules used for the design of another. This was the result of our concepts of external consistency between substructures. Some general rules may be specified to satisfy this consistency requirement for substructures of all organization structures. Team Theory (J. Marschak and Radner, 1972), (J. Marschak, 1959), (MacCrimmon, 1974) shows the relations between the information available to the decision maker and the quality of the decisions made. The theory is applicable to all organizations and is useful in explaining what we must do to make the assumption on external consistency a correct one. In terms of our concept of the process of design, the operating substructure gives the decision variables their values, while the information substructure collects parameter values, sends them, stores them, etc. We argued that the performance of the former depends on the latter and made some general connections between the properties of the two. These connections hold only if the two substructures are consistent with one another. When we stated that the level of the performance property of alertness of the former increases the level of the responsiveness, we also stated that we assumed that the two substructures were consistent. We explained that this assumption was about the details of where the information was collected, where was it sent, etc. We assumed that the logic of Team Theory held for the details. Information generated by the alertness of the information substructure, which is designed to be alert, needs to get to those in the operating substructure to whose decision rules the information is relevant and needs to get there very soon after it is collected. We now identify some generals rules of design which we need to use to make certain that this consistency assumption is correct, that is, that it describes the facts as they are. The rules guide the design process at the point where the properties of the substructure components are being set or at the level when the elements of these components are being identified. Consistency rules are rules that produce substructures that fit one another in logic and economics. Their use does for the external consistency, or fit, of the substructures, what the earlier consistency rules do for the internal consistency of a substructure. The first set of rules deals with the consistency between the operating and the information structure. These rules are designated as the IOD rules, where I refers to the information substructure, O to the operating one, and D to design.

IOD-Rule 1: For every decision rule in the operating substructure which has parameter X as a dimension of its domain, there must be at least one decision rule in the information substructure which meets the following conditions:

1. X is the dimension of the range of the rule;
2. the rule instructs the user set U* to read or to receive the value of X;
3. U* and U have one or more elements in common;

4. the level of its range resolution is at least as high as that of the level r*.

IOD-Rule 2: Rule 1 holds for every parameter that is a dimension of a decision rule in the operating substructure.

When an information decision rule meets the above condition for an operating decision rule, we may say that the former empowers the latter. If there is in the information substructure an empowering rule for every dimension of an operating decision rule, then this rule can be used. The existence of such an empowering set is necessary for the use of the decision rule. Team Theory shows that since reading a parameter's values is costly, it should be done only if it is economically superior to the use of a substitute value. There is also the design rule which obviously follows that the value of a parameter is never to be read if there is no decision rule in any of the three substructures where that parameter is a dimension of the rule's mapping. Then, there is the question of the resolution of the decision rule on a parameter. If the decision rule in the information substructure has a range resolution lower than that of a rule in the operating substructure, then the latter cannot always be used with the information that results from the use of the former. The parameter value obtained by the former may to be too coarse to allow its use for the latter. If the latter needs to know the value in inches and the former supplies the value in feet, then the former does not have the information that allows the use of rule.

IOD-Rule 3: No decision rule should be in the information substructure if it does not empower at least one decision rule in the operating the substructure.

IOD-Rule 4: A decision rule with parameter X may be put into the information substructure only if the level of the range resolution of the rule's mapping is no higher than the highest level of domain resolution of the parameter X in the mappings of all the rules with X as a dimension of the domain. This applies to all parameters that are dimensions of the domains of mappings of the decision rules in all three substructures. There is implied in this rule another which would state that the range resolution of an information decision rule should be no lower than the lowest domain resolution level of all the decision rules where the variable is a dimension of the mapping. If the operating decision rule is in terms of feet in the measurement of the value of X, then he can use measurements of the parameter in inches or in feet. If the increase in the level of the range resolution raises the cost of the procedure of measuring the value of the parameter, then it should not be incurred if such levels are not used.

IOD-Rule 5: For every decision rule in the operating substructure and for every parameter that is a dimension of the domain of its mapping, there must be a matching rule in the information substructure which serves it. The servicing rule must have the dimension from the rule it serves as the dimension of its range, the component "read value of" or equivalent, and a set of users that contains at least one element that is in the user set of the rule it serves.

If the value of a parameter is used to make operating decisions, then someone should be reading its value. This value must be read by one of the people in the set that is going to use it. It does not mean that once a decision rule is in the operating substructure, the information rules that are to service it must be put in at once. The process of design is one of many stages, with information being collected at each stage, re-evaluations of parts of the design made, and changes introduced into it. It is only in the finished design that the rule holds, but it is also to be used during the process to obtain estimates of the costs of servicing the operating rules and to use them to decide whether these estimates need to be changed.

Reward substructure and information substructure consistency can be expected to require rules that are analogous to the rules for the operating and the information substructures. Each of the above rules has its analogue rule with reward substructure replacing operating substructure, with the condition that the values of the variables that define the domains of the reward decision rules are known to their users, and are in a form that satisfies their domain resolutions. For each IOD rule, there is an analogous IRD rule.

The next set of rules, the ROD-Rules, which needs to be derived is that which must be followed if the designer is to get consistency and fit between the reward and the operating structures. Making the reward substructure fit the operating substructures or the information substructure is more difficult to achieve than making this last fit the other two. Decision rules of the reward substructure need to fit those of the operating decision rules in terms that involve things not relevant in the other two cases. Fit is now to be discussed in terms of such things as the dimensions of the domain of the reward rule mapping and the nature of the characteristics of the domain and ranges of the operating rule mappings, the connection between the makers and users of these rules, and so on. Rules on fit stem from the notion that rewards are intended to get people to do certain things, and whatever these may be, the reward must be connected to them in a logical manner. If you tell a person exactly what to do and the reward rule you use for this person has the outcome of his decision as the dimension of the domain of its mapping, then that person will do what he's told as long as the outcomes of the rewards are good. But if the outcomes and the rewards are bad, then the logical connection between doing as you are told and getting what you want no longer holds. What you get when you do as you are told is not what you want. There is no reason to do as you are told. The reward no longer does what is was intended by the maker of the reward rule. Though it is not clear what the reward rule should be when the operating rule leaves no discretion to its user, the reward rule should not be based on the outcome of the use of the operating rule. It is true that it is very difficult to make design rules about the best fit in this case, but it is very easy to make rules about a very bad fit. What follows are rules of this latter kind, ones that tell the designer what decision rules to avoid putting into the designs of her substructures.

ROD-Rule 1: If there is in the operating substructure a set of rules each of which has the person X in its user set and the rules have a very high level of comprehensiveness, very high levels of fineness, and very low levels of enfranchisement, then no rules which have person X as their recipient and have a high level of outcome orientation are to be in the reward substructure.

ROD-Rule 2: If there is in the operating substructure a set of rules each of which has the person X in its user set and these rules have very low levels of comprehensiveness, very low levels of fineness, and very high levels of enfranchisement, then no rules which have person X as their recipient and have a high level of decision orientation are to be in the reward substructure.

ROD-Rule 3: If there is in the operating substructure a set of rules each of which has the same person as the user and has a very low level of explicitness, then no rules which have this person as the user and have a high level of decision orientation are to be in the reward substructure.

ROD-Rule 4: Rules which have different persons as their recipients and are interdependent should not be in the reward substructure unless there are rules which have user sets that contain these persons in their intersection, or rules that do not have intersecting user sets but are domain-domain or range-domain connected.

Common sense notions and simple logic would suggest that the weaker the logical or causal connection between the reward that a person receives and what the person does, the less the effect will be the reward on the decisions of the latter. If there is no connection between the decision rules that people use, then making their rewards contingent one upon the other makes no sense either. There are other rules that derive from common sense, but not all apply to all cultures. People in different cultures have differing views about the causal connections that exist between what they do and what they get for it. To the extent that there are elements of fatalism in some people's concept of what happens to them, organization reward rules will have weak effects on their behavior as users of decision rules in organization. If the people of a culture are not fatalists and they believe that what they do does affect what they get, then the effects of reward rules on use of the operating ones will be strong. People's culture will determine the strength of the effects of any reward substructure on their decisions. It will also determine what makes for the good and bad fits between substructures.

## 8. To MBC With More Advice

The MBC for which a structure needs to be designed in a world where it does the following:

Brews beers:
  of different levels of alcohol
  of different tastes
  of different aerations
  in different containers
  of different brands,...and so on
Sells to: different geographic markets
  different customer age groups
  different buyer operations (retail store, bar, wholesale),...and so on
Makes sale transactions:
  of different prices
  of different payment schedules
  of different ordering characteristics
  of different delivery methods,...and so on

Uses inputs:of different forms (degrees of completeness, etc.)
    of different quality,...and so on
Buys inputs from:
    different geographic markets
    different seller operations,...and so on
Makes buy transactions:
    of different prices
    of different payment schedules
    of different ordering characteristics
    of different delivery methods,...and so on
Gets capital from:
    different finance operations,...and so on

The advice to MBC executives is that they use the design rules to design a new structure that fits better the new transformations and environments that describe the worlds in which they operate. The facts necessary for the initial steps need to be collected and the process of design started. Throughout the process, facts on the changes in outcome and costs of combinations of levels of performance properties will need to be estimated and used to derive the substructure properties needed, and so on. When the process should stop, and the design is implemented, depends on the magnitudes of the changes that the design brings to outcome and costs, the opportunity costs of living with the old structure, and the degree to which the designed structure will be realized. People already in the existing structure of MBC will decide on the degree to which they will accept the new structure on the basis of their perceptions of a number of factors. Learning new ways to do things requires time and effort. The larger the differences between the new and the old structures, the more the people things will have to learn. Making the designed structure real will require that people be convinced that this time and effort will have consequences that they value. If they can be made to see that the rewards they receive in the new structure are higher than the ones in the old, they will be more likely to the change. Improvement in rewards may be either explicitly stated in the designed structure itself or implied in the change in outcome that it is to bring about. In either case, the value to the people in the organization that results from a change in structure depends on their evaluations of the change in outcomes it is to bring about and the costs they incur in making the change. These evaluations depend on the difference between the designed structure and the one they are in, and on the frequency with which the structure is changed. The question then is one of determining the amount of change that the new design brings and the frequency with which to make changes. For MBC, the costs of getting the people in the structure to accept changes of different magnitudes, the costs of getting people to accept a series of changes, and the opportunity costs of the delay in making a change should be considered when making the decision on the size of the changes made at any one time, and on the frequency with which they are made. MBC is advised to design the new structure it needs and then decide on how it is to make it a reality.

It is clear that the transformations that MBC uses are very different from the ones defined for it in Chapter 2. There are more ways for MBC to produce beer than there were. There are more ways to transport and distribute beer than there were. There are ways to produce goods which are similar in some respect to beer, which had not existed till recently. The market transformations contain elements that relate a top product that just came into being, new brands, and new beer makers, with new offerings. Along with these new elements come all kinds of new interactions among elements both new and old. Transformations that MBC now has to work with are made up of more variables than they had had and contain more connections between their variables than did the old ones. In part, as a result of these changes in technology, there have come changes in the environment of MBC. New dimensions have been added to the old environment to create a new one that includes all the decisions made by all the makers of "Malternatives" and of the new mini breweries. These new elements have added the variables that describe the interconnection between them and the dimensions of the old environment. This new environment is bigger than the old one, and also has different characteristics. When the variables of the new environment change, they sometimes change by amounts that are much larger than there were in the old environment. Also, the state of the environment changes slightly more often than it did before. It also makes moves between a number of states that is slightly larger than before. Translating all this into the terms used in our design rules is necessary before MBC can use our design rules. Compared to the old technologies used by MBC, the new ones have a much higher level of the property of variety, and also a higher level of the property we call tightness. There are increases in the environment properties of breadth, depth, and exposure. MBC now has a new environment that is different from the old one. Not only does the environment contain new parameters and new decision variables, it has more states which have some reasonable level of probability of occurring. Its environment is larger in size and has higher levels of variedness. Because it goes from one state to the next more often than the old one, the new environment has a higher level of changeability.

Most striking is the difference between the magnitude and speed of changes that occur in the states of the new environment, as shown by the rapid changes engendered by the new product, the new competitors, and their new assortments. The changes are much greater, and the speed of change is much higher in the new environment than they were in the old one. This difference is the largest and most compelling one. It translates into the statement that the world in which MBC operates, its environment as a whole, has a much higher level of the raggedness property than it had. Finally, there is the new outcome function, or functions, that the brewery has. These have changed for the worse because MBC has to compete with new products, new brands, and new competitors. There may also be changes in the laws that might make it harder for the company to maintain its sales, revenue, and profit levels. In short, its outcome functions have become more sensitive to its decision variables and to its parameters. They also show a lower level of environment generosity. These changes make it worthwhile for MBC to design a new structure, one that is more suited to the circumstances created by the changes in technology and environment. Most critical are the changes in the level of the generosity property of the outcome function, that of the raggedness property of the environment, and that of the tightness property of the technology. We advise the executives of MBC to use the rules of design developed in the previous chapter and to start designing for these properties. First, the facts that are needed, those about the property levels of the technologies and environments, are to be collected.

Design rules to be used first are those that tell us what levels of structure performance properties we need, given the levels of the critical properties we identified. Relevant rules are those in Chapter 11 that mention tightness and raggedness. They are rules number 1, 3, 4, and those on consistency. We have already used rule 1 by embarking on the work of designing a structure. Rule 3 is the rule on tightness. It states among other things that the higher the level of the tightness of the technology, the higher the level at which the structure performance property of coordinatedness is to be set. Next, rule 4 states, among other things, that the higher the level of the environment property of raggedness, the higher the level at which the structure performance property of responsiveness that is to be set. Substructure consistency rule 14 tells us that the higher the level at which the level of this responsiveness is set and the higher the level of the structure property of coordinatedness that is set, the higher the level at which the information substructure property of alertness is to be set. Rule 18 says that the higher the level at which this coordinatedness is set, the higher the level at which the information substructure property of accuracy is to be set. Rule 21 is the same as this last rule, but awareness replaces accuracy. Rule 23 says that the higher the level at which this coordinatedness is set, the higher the level at which the reward substructure property of fairness is to be set.

Next, we search the rules of structure design for those that tell us how to design a structure that is responsive, coordinated, alert, aware, and fair in the way it treats its members. First, there are the rules that tell us that the higher the level at which we set such and such a performance property of the structure, the higher at which the levels of the this and that properties of the structure are to be set. The definitions of these properties will tell how the components of the design are to be changed to get these higher structure property levels. In the first step of the design process we use these rules as if they were in terms of relation between absolute values of property levels and not comparative ones. We do this only in the first step of the process of design. The reasons we do so are given in the next chapter where the process of design is laid out. We start with rules 15 to 21 and work through the process of design, making estimates of both the outcome cost effects of changes made and might be made. Then we identify the next set of changes to make. At various points we must pay attention to rules of consistency and balance and make the needed adjustments. The prediction is that the final design of the structure MBC we get will be one that has decision rules that are fairly comprehensive and fine and also strongly connected. It will have many decision rules given to many people about information collecting and disseminating, and about rewards given. All three sets of rules will be consistent with one another.

Note: Charts that contain the rules of this chapter are in Appendix II.

# CHAPTER 14

# A USEFUL PROCESS OF DESIGN

## 1. The Designer and the Designs

There is nothing in the analysis or the rules of design derived from them that implies that they can be or ought to be used in designing only a whole organization. It has been stated that it might be more efficient to design the substructures separately and then put them together. It is also possible to segment the environment, whenever the separation does not disconnect real and important connections, and to design for each of these segments a structure made up of an operating, an information, and a reward substructure. The process for the design of each segment is also that which designs each substructure separately, and then puts them together. The result may be a called a segment structure, which is then put together with other segment structures to get a whole structure. In fact, it is suggested that when faced with the task of designing a large and complex structure, the designer should follow this process. First, the environment is segmented, and for each segment an operating, information, and reward substructure is designed separately, and then all modified and put together into a consistent whole. When such a complete structure is designed for each segment, we have what we might call a set of segment structures which are then adjusted and put together into a whole structure for the whole environment. The rules of design which are derived in the previous chapters are applicable to any organization, with any number of people, decision variables, parameters, and so on. They are applicable to a substructure of a structure, they are applicable to a segment structure, and they are applicable to a whole structure made up of segments.

We may also use the design rules to design any structure, or any substructure, or segment of one for which the levels of only a subset of properties are identified as those that it is to have. That the partial design may not produce a very good design does not mean that it cannot produce a fairly good one. A designer may work only on the operating decision rules and not on anything else. The rest of the structure may then be created by people in the organization, each working on some small piece. The result may well be a better structure than that which would have emerged without the design of the operating decision rules. It is also clear that the process of design may be partial not only with respect to the structure, but partial also with respect to the performance. All the analysis and all derived rules are clearly defined and separated, and so may be used singly or in varying combinations. If you want to design only for high levels of responsiveness, you will find all the rules you need to do so. This property may have an effect on outcomes that is much larger than that of any other. Designing for it alone gives us a structure that costs less to design than would one with required levels of many properties and produces an outcome level that is higher than we now have, though lower than it would have produced if the other properties had not been ignored.

Not much has been said so far about who the designer might be. It was explicitly stated that unless the designer knew well the technology and the environment of the structure to be designed, the quality of the design is likely to be very low. Besides this requirement, any number of people may be engaged in the design of a structure. Their design work may be done with the conscious recognition that it is design work or is not. Designing an organization structure is nothing more than connecting people by decision rules that govern their behavior so that some change is made in the world they inhabit.

## 2. A Metaphor for the Process

The last step in the process of design is to choose the elements of the components of the structure. The movement of the process of design is from the required set of levels that a set of performance properties is to have to the set of levels which a set of structure properties is to have. From these, a set of components of a structure is derived and this defines the design of the structure. An original set of required levels of the performance properties of the designed structure is obtained from a process that derives its elements from the environment, technologies, and goals the structures is to seek. For each property of the structure, the level chosen for the structure is that which leads to levels of the properties of the performances that are what the designer wants them to be. These are the levels which, in the context of the technology which the structure uses and the environment in which it performs, bring about the levels of expected outcomes which the designer wants. Going from the desired outcomes to the organization structure by way of the performance structure that is to get them is the decision problem for the designer. The route followed is that which is laid down by the logical connections which have been shown to exist between the structure property levels and the property levels of its performance, and between these and the outcomes given the context of the transformations and the environment.

To capture the essence of this whole process, it is useful to use the metaphor of the designer's box. The designer is given a box with a panel which he or she faces. On this panel there are dials and levers and knobs, each of which is labeled. A dial may be in the form of a clock face or something like a screen on which there appear some symbols. Knobs and levers are like oven controls, TV remote controls, etc. Every one has associated with it a dial so that both the knob and the dial have the same label. Inside, the box is full of wires which run from levers to dials, and from dials to other dials. The designer sits facing this panel, reads dials or displays, and manipulates knobs and levers, which cause changes in some of the readouts. She does this only after examining and understanding the complicated wiring connections. Having done this, the operator's task is to choose the settings for the levels of the structure's performance properties. After the operator reads what is on some of the dials which give readings on the states of the environment and technology, she enters her choices into the box by manipulating some of the levers. These are the levers which set the levels of performance properties which the designer considers appropriate. Through the complex wiring inside the box, these lever settings for the levels of the performance properties, along with the readings on the dials for technology and environment, give readings on dials relating to expected returns. Next, the operator manipulates the performance property levels and checks their effects on the outcome readings. After settling on a set of values, the designer turns her attention to the levers that allow her to set the levels of structure properties. These levers are set at certain values which are entered into the box. They are the choices of the operator, given the performance properties she settled on. These are the structure properties which the operator believes will give the values she settled on for the performance property levels and which are registered on the dials. Once the structure property levels are set, they determine the resulting performance property levels. Through the wiring in the box, setting the former produces the readings for the latter, which in turn produces readings for the outcomes that result from them. Also, the box is wired to show the costs of these levels of structure properties, and the cost readings now appear on dials. The output and the cost are now compared, and the structure property levels and the performance property levels are reset as needed. After each iteration the comparison of outcome and costs may be used to guide the next move, or no move, which stops the design process.

This box is what we have built so far in this work. It's the wiring in the box that describes all the analytic connections and mappings derived earlier. Understanding all these wiring connections and the design rules derived, and knowing all the mappings that state them, allows the designer to determine the first settings of performance properties and those of the levels of the structure properties. The adjustments made in the iterative design process are made in an efficient manner by the operator who does understand the wiring. In the preceding chapters we defined all the properties of technology, environment, performance, and structure. We theorized about connections that exist and showed causal connections between performance property levels and outcomes when the levels of technology and environment properties are given. The connections between structure properties and the resulting environment property levels were also explored. These connections are those represented by the wiring inside the box. By analyzing them we were able to derive a list of design rules which the designer may use to design the structure that gives whatever outcomes are desired. But to operate the box and design a structure that does what is needed, the operator needs his dials and knobs. All these are on the box and represent our definitions of the properties of technology, environment, performance, and structure. The definitions and the analysis make clear which properties are represented by dials, levers, or knobs, and what the read outs on the dials refer to. The operator is to use the design rules developed earlier to guide him to the dials he is to read and the settings for the levers which he is to manipulate

## 3. Details of the Designer's Box

One may think of the designer's box as one of those electrical boxes which sound engineers use at music concerts. These tremendous boxes are full of dials, knobs, levers. They allow the engineer to determine the output, which is the music that the designer and the people in the audience hear. The organization design box has the following:

1. A set of dials or digital displays, or descriptor displays, each of which gives a measure of a property of the firm's technology. Each is labeled by the name of a property of the technology, such as tightness. For every property listed earlier, there is one such display. What is on there may be numbers, the words very high, or blue, and so on. What is on the displays is determined from outside the big box. All the box operator can do is to activate the displays to get the facts about the technology.
2. A set of read outs similar to the ones above, except that each is labeled by the name of a property of the environment, such as changeability. There is one for every environment property listed earlier, what is on display is determined from outside the box, and the operator can only activate the displays to get the facts on the environment.
3. A set of read outs identical to the ones above, each of which gives a measure of the level of an outcome the firm considers relevant. Each is labeled with the name of an outcome and shows the level of this outcome which the firm would expect to attain. What appears on the display is a result of the readings on the two sets of displays for technology and environment and on the levels of the two described next.
4. A set of readouts, each of which is marked "desired", and is labeled by the name of a property of the performance of the structure, such as coordinatedness. There is one such readout for every performance property listed earlier, and each display gives a measure of the level of the labeled property of the structure in appropriate terms. What is on display in the unit that is marked "desired" is determined only by the box operator's manipulation of the lever for that property. The readout on every one of these displays is chosen by the box operator and is a level which he wants a performance property of the structure to have.
5. A set of displays that match one for one those described in the previous set, but each is marked "actual", and is labeled by the name of a performance property. There is thus a pair of displays for every performance property, one marked "desired" and one marked "actual". The read outs on the "actual" displays is determined by all the levers, both those for performance and those for structure properties. The connections inside the box are complex. What appears on the dial may be the result of the interactions between the settings on many levers.
6. A set of levers (or buttons or any mechanism that allows someone to determine its state), each of which is labeled by the name of a performance property of the structure. There is one lever for every

display described in the previous set. The operator manipulates the lever for any property, and by doing so, he sets directly the level which appears in the display for this property. What is displayed here is the level of this property which the operator chooses for his structure. There is a direct connection between each lever and each display for every performance property level.

7. A set of displays similar to those defined in the previous two sets listed before in 4. and 5. Here, each is labeled as "desired" and "actual". Each display is labeled by the name of a structure design property such as decision rule fineness. The read out on every display is determined by the box operator, and represents the level of its structure design property which the operator chooses and gets.
8. A set of levers similar to those in 5. Each lever is labeled by the name of a structure design property and is connected directly to its identically labeled dial as described in 7. When the operator manipulates these levers, he is choosing the level for the properties of the structure, and the choices appear on the dials. These settings determine the actual levels of the performance properties, and these levels appear on the appropriately labeled dials. The connections from structure design levers to performance properties is represented by the wiring in the box, which describes the analyses made earlier.
9. A set of dials, each labeled with the name of a structure property. Each dial is labeled by the term cost and the name of a structure design property. The read out on each dial is a measure of the cost of the level of the property set and is shown on the dial giving the read out for this property's level.
10. One dial that registers actual output and one dial that registers the total cost of operating a structure. These dials register the results of the settings, given the levers that are used to specify the property levels of the designed structure.

## 4. Operating the Box

To operate the box, the operator needs rules that are derived from the analysis and are in a form that tells him what to do and when to do it. First, he needs the rules that tell him how to set the levels of performance properties which are desirable. Second, he needs the rules that tell him how to set the levels of structure design properties to get the performance property levels he chose. He also needs the rules that describe the iterations of the process that he may need to make when what he thinks is going to happen when he sets the levels of structure design does not in fact happen. All these rules of design have been stated earlier.

If one were to use the box to design a structure, one's first step would be to locate all the dials readouts, levers, and knobs, and to make sure that one knows what the labels and markings identifying them mean. It is also necessary that one understand what the read out on each dial and the setting for each lever means, i.e., what it measures. It is to be expected that each property be measured in operational terms, and that the scale of measurement be operational and fit the level of finesse of the definitions used in this work. The scale used to get a measure must also fit that of the definition and be in appropriate units. All levers must also meet these requirements. Dials, knobs, and levers must be correct representations of the variables of the definitions and analyses developed in this work. All logical and causal relations of the analyses are expected to be correctly represented by the wiring in the box. This done, one is ready to start the iterative process of design described earlier.

Step 1. Activate dials for technology and environment properties. The readouts supply the parameters which are the 'if' part of the design rules for performance properties.

Step 2. Choose one performance property and use its rules to derive the initial level for it and for all the properties coupled with it in a rule. Set the levers labeled for all these performance properties at these initial levels. Observe readouts on outcome dials and make small changes in level of properties which are coupled in rules. Make sure that the sequence of rule use does not cancel dominance relations. Given the changes in these, set levers at levels that obey the dominance relations and show superior or good outcomes.

Step 3. Check the substructure consistency rules and apply them, making called for changes in property levels.

Step 4. Repeat step 2 for the next performance property. There may now be new pairs to be adjusted. New dominance relations may show up. All must be considered along with all past pairs.

Step 5. Repeat step three for all properties for which levels have been set.

Step 6. Continue as in the two previous steps until all performances have levels set for them.

On the basis of the facts of the technology and the environment and the outcomes hoped for, the performance property levels have now been set. The levers for these properties are set and the readouts for these settings are on the dials. Next comes the process of choosing the levels of structure properties that are best in terms of both outcome and cost. Since cost depends on the structure, and since no structure property levers have been touched, there is nothing showing on the cost dials. The operator starts the next phase by using the design rules to get a set of levels for the structure properties which will give these performance property levels. There will now be cost figures on the dials for these property levels. Both the readings on outcome and cost must now be monitored by the operator as he manipulates the structure design levers in search for levels that are better in terms of both outcomes and costs than those of the starting set. The process continues to iterate until it arrives at a good, superior, or best combination of levels for all performance levels and all structure levels. The detailed operations on the box that describe these iterations are given below. To avoid confusion, we will use the term operation, or Op for short, to designate a step which the operator takes in the process of setting levels for the structure properties.

Op 1: Select a performance property and use the structure design rules for it to set values for all the structure properties in the rules. Whatever levels are selected for these structure properties will appear on the dials for them. The lever settings for these structure variables will produce through the connections in the box a reading for this performance property on the dial for it that is marked as the actual. Adjust the values of the structure properties in the rules for this performance property so that the reading for its actual level is the same as that of its desired level. Read the cost dials for the levels of structure properties obtained in this step.

Op 2: Manipulate the levers set in Op 1 to get a set of performance property values that is close to the starting one. Read the cost dial for this set and the set of actual performance property values it produced. Using the cost figures and the gross outcome measure for the set, choose the set that gives a better combination of costs and outcomes. Use this set as the starting one for a repeat of the process. Continue to do so until the changes that occur produce differences in costs and outcomes that are too small to be relevant.

Op 3: Repeat Op 1 and Op 2 for the second performance property.

Op 4: Repeat Op 2 for the settings for both performance properties simultaneously. Apply the dominance rules for all structure property levels in the two settings.

Op 5: Repeat Op 1 and Op 2 for the third property.

Op 6: Repeat Op 4 for the settings for all three performance properties simultaneously.

Op 7 & 8: Repeat the iterations for the next performance property and the settings for the structure properties that go with it. Do the same for the next and the next to the last performance property, the nth.

Op n: Repeat Op 7 for the nth and last performance property.

What we have now is a well designed structure given the technology, the environment, and the connections inside the box. No one has made and wired such a box to help design organization structures. When someone does create the box, it would be like this imaginary one. It would be logically similar to the boxes which are used in recording the sounds made by people playing musical instruments, or in broadcasting through loudspeakers. The next step is for the designer to use the substructure consistency rules and make whatever changes have to be made in the settings of the levels of the structure properties on which we have just settled. An example of an inconsistency between the operating and the information substructures is that where there is an operating decision rule with a domain defined over a number of variables, and there are no information rules that specify that the user of the operating rules has the values of one or more of the variables in the domain of his rule. All consistency rules should be used. The end design should be free of any inconsistencies. If the removal of some inconsistencies turns out to be very costly, we may have to return to our design machine and make changes that produce a structure free of such inconsistencies. This structure is then compared to the first one to determine whether the cost of removing the inconsistencies from it is worth our while, or not. If it is worth our while, we do it, and if not, we choose the second design.

## 5. Other Processes of Design

Designing an organization structure is no easy matter. First, one has to know the way in which the values of the design variables affect the values of the performance variables, and through them the outcome values. Next, one has to know how the costs of operating the structure are affected by the values one chooses for the structure design variables. Since all these are complex connections with multiple interactions, finding the design variable values that give an effective and efficient structure is no easy matter. An iterative process of design seems a reasonable way to work through the complex connections. Choices are made for only a few variables at a time, then remade in the context of the choices made after that for some other small set of variables, and so on. The iterative process must also be efficient in the sense that it must be made in real time. The sooner it is over, the sooner its advantages may be enjoyed. What is needed is a process that is an iterative one as described, which one may use continuously while implementing its partial design outputs at various stages. Once the basics givens are found to have changed, the whole process must restart with changes incorporated. These givens are the technology, the environment of the organization, the people in the organization, the cost relation of the structure, and the specifics of the outcomes that the design is to achieve. It may be a process that is always a little behind what gives the best design for every instant. But, it is a process which can be very valuable nonetheless. The faster it is the better, the less changes that have to be made in the implemented partial designs the better, and the sooner that changes in the givens are incorporated, the better.

The alternatives to using the iterative process we created above are dismal. If one were to simplify the problem by working with a few vague and non-operational variables, the structures that actually emerge may be very different from those intended, because the meaning of a design is vague. It may be interpreted to give any one of a large variety of structures. Without the use of properties, the notion of variables that allow for some comparative description of the forms they may take is impossible., A logical basis for identifying search procedures to guide the design process cannot be specified. Process efficiency in these circumstances is not a subject that is within one's power to affect. Without properly defined properties of structures, there are no bases for defining the efficiency of the process and no bases on which to make informed changes in a design to another that is better. Finally, without the specifications of the iterations in the design process, there is no way for one to develop the concept of the efficiency of what the designer is doing. And so, there is no basis for learning from experience, let alone learning from someone else. It is these considerations that governed what went into this work on designing efficient organization structures, and doing so in an efficient manner. The process of design that is best is not independent of the nature of the conditions that determine the costs of the process and those that determine the cost of the structure designed. We need to consider some other design processes and their levels of efficiency.

## 6. Comparing the Efficiencies of Design Processes

Efficiency is an important criterion for choosing the process of design to use. If we start with the effort or cost of the process we just described, we find that it calls for many iterations. For each of these it calls for the generation of a number of choices and their comparison on the bases of their estimated returns and costs before a choice is made. This information is to be carried forward to the next step and be used as the starting form of the estimates for the choices to be made in that next step. At times, the designer has to revisit decisions made at earlier steps to determine their consistency with other existing decisions and with the one being made now. All this might suggest that the process was inefficient, especially when it is compared to others available in the literature that are easy to use and cost little. But this one sided comparison is dangerous because efficiency is a two dimension criterion. What may appear to be a superior process because it is very simple, easy, etc., turns out to be inferior when the nature of its output is also considered.

A process has been created by Burton and Obel (1998, 2004) which makes use of what computers do better than humans and of what the humans do better than computers. The process is built on a theory that combines the best works in the literature. It is a process that rests on design rules that are integrated into an artificial intelligence program which allows the computer to use them to make a design that is efficient given the facts on the environment, etc., which the person seeking a design gives the computer. The process of design is made so simple that it is not an issue for the designer. The theory they develop supplies the computer with all the design rules and the instructions for using them. All that is left for any designer is to give the computer some facts. This is obviously far better than having the designer use all the design rules developed in previous chapters. But before one holds it to be superior to the complex iterative one we created, one needs to compare the designs that emerge from the two processes. First, one compares the efficiencies of the two designs in terms of what they do, and what they cost. Second, one compares the clarity and precision of the designs to determine whether the set of structures that is compatible with the design obtained from the computer process is smaller or larger than the set that is compatible with the design we get from our process. The efficiency of the designs that result from the theory we use and the process we create are fully discussed earlier. When we are finished doing the same for the designs that result from the theory used by Burton and Obel (1998, 2004), and the process they created, we will be in a better position to identify the circumstances under which this theory and process are superior to the ones we developed in the previous chapters.

Burton and Obel (1998, 2004) have a theory of design that synthesizes the works of many authors, such as Galbraith (1973), Burns and Stalker (1961), Baligh and Burton (1981, 1984), Baligh, Burton and Obel (1987, 1990 ), Daft (1992), Duncan (1972, 1979), Lawrence and Lorsch (1967), March and Simon (1958), Simon (1976, 1981), Mintzberg (1980), Ouchi (1980), Perrow (1967), Robbins (1990), and others. Using pieces of theory in these works and adding new pieces of their own, Burton and Obel (1998, 2004) create a theory that is much more comprehensive than any one found in these works. Their variables of design and the relations of these to performance and to outcome are the very best which can be obtained from all these works. They create a cohesive theory of design which they use to derive a process of design which is in a form that a computer can use to create actual designs. They develop an artificial intelligence program that uses facts about the environment, the outcomes, the technologies, etc., given it by the person seeking a design to create the one that is best. The computer is given a set of interconnected design rules which it uses in an iterative process which concludes with a structure design. They have a process that is easy to use and has a low cost of use because the computer is the one that goes through it and produces designs that are in terms of the best concepts to be found in the literature. The work sets the standards for organization structure design.

It is to this work then that we must compare to ours. In what follows, we compare the logical characteristics of the two theories. We compare the efficiencies of the computer process they derive from their theory to the process we derive from our theory. We compare the usefulness to a person who wants a design for a real world situation of the structure designs generated by their process which the computer uses to produce designs to those generated by our iterative process which uses brain work. We will look at the costs of each, the nature of the designs they produce, and the value of these designs in the context of someone who is searching for an organization structure that performs in the best or in a very good way in the circumstances of this person's goals, the technology the organization uses, and the environment in which its performances are turned into outcomes.

That our process is more costly than available ones and certainly more than the one that uses the computer goes without saying. But cost is only the beginning. There are many more dimensions we want to use for comparison, starting with the richness of the theory. On this basis our theory and its process of design are more complex and realistic than those of Burton and Obel (1998, 2004). We have two sets of mappings, one from structure to performance and one from performance to outcome. They have only one in all but one case from structure to outcome. We treat outcome and cost separately and have a mapping for each and every structure design variable, while they have only one mapping containing both outcome and cost for each design variable. Our theory has many more design variables than their theory does. Whether our process may be programmed into a computer is an issue we discuss later. For now, we concede that our process of design is more costly that of Burton and Obel (1998, 2004). The denominator in the efficiency ratio of our process is larger than theirs, but so is the numerator. The payout here comes from the higher level of richness of our theory and its process, and the effects this has on the usefulness, quality, and value of the design it gives a person who is putting together a real organization.

Three criteria for comparing the designs our work produces to those produced by the Burton and Obel's (1998, 2004) work may be used. First, there is the theory that is the base of the process. Here we need to examine the analytic mappings and the design rules derived from them. Second, there is the operationality of the design the process gives. Third, there is the detail of the design the process gives. In applying the first criterion, we note that our theories are more rigorous in the arguments that support the theorized connections, and that there are two connections from structure to outcome instead of one. Whereas ours has a clear set of relations between structure properties and performance properties, theirs does not. Whereas we go from the structure to the performance to the outcome, theirs ignores the performance with but one exception, the property they term coordination and control. These are distinguished one from the other in our theory and considered as two independent properties of performance among many others. For the one set of mappings, from structure to outcome, we have two, one from structure to performance and one from these to output. From these two sets we generate many more combinations of connections between structure and output that they do, and our theory captures many more of the ones that exist in the real world. Richness of the theory is enhanced if it is more realistic, or in terms of our design box, the box contains many wiring routes from each structure design variable to outcome. Furthermore, in our theory the cost of operating an organization structure is explicitly analyzed and fully integrated into the theory and the process based on it. That is not so in their theory, where costs are directly included in a single relation between structure and value of outcome, and there is no way for one to distinguish between the structure to cost relation and the structure to outcome one. Because they use one relation that incorporates both outcome and costs, they do not allow structure costs to vary from one structure to another. They make the restrictive assumption that all structures have the same costs of collecting information, of rewards, and so on.

The design we get from our process should be a design that better fits the circumstances of the organization because the theory that underlies it is more explicit and more discriminating in its analytic relations. In these many respects, our theory is more realistic than theirs. The structure designs it produces will be of a better fit for the organization. The reasoning behind the design we get is much more clearly laid out, and we can connect any feature of our design to performance. We cannot do that with theirs in the same detail, because the analytic relations we have, they do not have. We conclude therefore, that on the basis of a number of characteristics, our theory and process of design should give designs that are better fitted to the organization than those of Burton and Obel (1998, 2004). To summarize, we have two mappings, one from structure to performance and one from performance to outcome, while they have only one, in all but one case, from structure to outcome. We treat outcome and cost separately and have a mapping for every structure design variable. They have only one mapping containing both outcome and cost without any distinction that allows one to unravel the effects of cost and outcome on the reason why the variable is what it is made to be in the design.

## 7. More on Process Efficiency

Two other criteria to be applied to the design process to measure its efficiency are those of the operationality of the design each produces and the specificity of that design. One may want to know how many actual structures defined in complete detail meet the specifications of the structure designed by the process. Imagine a process that designs a house and concludes that it should be a Spanish California house. The number of actual houses that could be built to meet this design for a house is enormous. True, the number that does not is even larger. But if one were to accept this design statement as complete and the one to be used to build a real house, then what one actually gets may be a Spanish California house that is totally unacceptable. If one were to turn this design over to a contractor and have him build a house, one might get a house that was exactly what one wanted, or one totally unacceptable. Whether the real house's inside walls are one or six inches thick, whether it has one or fifty rooms, whether its roof is red tile or red plastic, is not included in the design, and the owner may get anything at all. In organization structures, the design that tells one to pick a divisionalized structure leaves a large variety of structures possible for each division. The efficiencies of these differ greatly one from the other. The more detail there is in the design, the closer will the real structure be to the one that is best for the organization. There are no theories and no processes in the literature that give a design that is more detailed than that obtained from our theory and our process. More detail in the design gives us a better basis for determining with greater accuracy what its costs are likely to be, and what its performance and the outcome of this performance will be like. More detail lets one judge with greater accuracy the output and cost of the structure we get when we implement the design and the costs and outcome we can realistically expect. The level of detail in the definition of a structure design is what determines the level of realism which we can give our conclusions about its quality, value, and fitness for a given organization.

Designs produced by the use of the Burton and Obel (1998, 2004) theory and process contain much less detail than those produced from our theory and process. The variable they use for the number of "levels" to be put into the design relates to a relation of authority which takes on only one of two possible values. One person has authority over another or not. No gradations of authority are considered. No authority for A over B for some things, and for B over A for others, is possible. Our design in terms of decision rules identifies many more different authority relations that could exist, and does so by specifying details of the decision rule that its maker gives to its user, or in their terminology that a superior in the hierarchy gives to a subordinate. We allow A to be the superior of B for some decision variables and the reverse in some other decision variables. Their design never contemplates such detail, since their variable of design is the number of levels in the hierarchy where no can be above another in it and have the other be above him. There are many other details in the design our process gives that are not in theirs, such as details on the connections to be imposed on decision rules, the detail of distinguishing between the ways values for decision variables are to be specified in decision rules, i.e., in units of ones, fives etc., and the detail of membership in the set of rule makers. In the matter of information, our designs are also much more detailed than theirs. Properties of decision rules on information are variables of design for our process because they are defined in terms of the designed structure's components. Information rules deal with who is to collect what information, to whom it will be sent, who is to get it, etc. All these details mean that information is represented by many design variables in our theory and process, whereas information is represented by one design variable called media in their theory and process. A comparison of the treatments of rewards in our and their processes shows a result similar to the case of information. They have only one reward design variable. It is defined in terms of the parameters on which the reward is to be determined. The variable may be one of two forms: the set of things the person does, and the set of results of what the person does. We have this decision variable. We allow it to be of many forms of combinations of the two sets. In addition, we have several design variables on the properties of the reward decision rules, such as rewards fairness and the fit of rewards to decision rules on variables of the operating substructure.

When our object is to use the design to create a real organization structure, then the detail of the design becomes an important determinant of its value to us. Because of the greater detail, we should have much more confidence that the structure we create using the design will do what the design says it will do. The more we know about what the design is, the more we know about what we actually get as its output when we use it as the real structure. In short, if we and they were designing houses, then the designs we get from our process would give much more of the description of the house than would theirs. Ours would contain the specification of where studs go, where bedrooms are, where the bathrooms are, the slope of the roof, the places for cabinets, and so on, while theirs would not mention many of these aspects of the house. When shown our design, the owner would be more confident that this design would give her a house that does for her what she wanted done than would be the case if the design was a picture of the outside of the house showing it to be a California Spanish Style, something she wanted but hardly all that she wanted.

Another criterion we use to compare the processes is of the operationality of the designs which the processes produce. A design is more operational than another if its elements are more closely matched with elements in the world than those of the other. A design that is more operational than another is easier to use, because it tells the designer to do things that are more directly within his control than those told him by the other. Elements of the first design are closer in definition to real world design variables. One design specifies that the house walls which have one side exposed to the direct sunlight, rain, etc., is to be built with studs that are 3” x 6”, be made of half inch plywood, and the open spaces enclosed by the studs and boards to be filled with 3 inch thick fiber slabs. Another design specifies that the outside walls of the house are to be such that they keep the house warm in winter and cool in summer. Clearly the first design talks about things that are in the real world. Lumber stores sell 3” x 6” studs and the named insulation. There is nothing in the world that is directly identifiable as “walls that keeps the house warm”, etc. The latter element of the design must be translated into real variables before it can be used and is subject to many possible translations. It could mean thicker walls of solid material such as stone. It could mean stud and plywood walls of any thickness from 3 to 5 inches. Or it could mean exactly what the first design specified.

When we compare the designs we get from using our theory and process of design with those we get from the Burton and Obel (1998, 2004), we conclude that ours are more like the first kind and theirs more like the second kind. Our designs are in terms of choice variables that are more operational. There is greater correspondence between these variables and observable and controllable aspects of the world. The variables are identifiable in the real world. There are ways in which the values they take can be made the ones we want them to be. Designs, after all, are described in terms of values that are to be given to elements. The operationality of an element in a design depends on our ability to identify the element and give it a value. This is what is exemplified by the presence of a knob or lever in our metaphorical panel of design that is labeled with the name of this element. If there is such a lever, and if it is labeled in terms of values that this element is to take, then that element or variable of design is fully operational, if the designer knows how to read, and what a lever is. The statement to the driver of the car, "Push harder on the pedal that is labeled accelerator", is fully operational. What happens to the car depends on many other things. It depends on whether the transmission is engaged or not, on whether the motor is running or not, on whether the pedal is connected to the mechanism that determines gas and air intakes, and so on. But the statement refers to actions that in the given language have direct meaning and can be taken. The statement to the same driver, "Go faster", is less operational because before all the issues of transmission, etc. are even relevant, there is the question of what exactly is the driver to do to regulate speed. He must connect this action of going faster to the action of pressing on a pedal. The second variable of design is going faster, that of the first is pushing on a pedal. The second variable is at least once removed from the second, which is the actual action taken, and is less operational than the first.

Formalization is an element or variable of design in Burton and Obel (1998, 2004). It is described in terms that deal with making rules more or less formal by setting of levels of expected compliance, by putting the rules in writing, and so on. It is clear what writing asks the designer to do, but what does the action of formalizing mean in real world actions by the designer? The act of formalizing does not exist in the real world. The act has to be translated into real actions, such as, telling another person what to do in given circumstances of the world and identifying these circumstances in detail. More formalization may or may not include an increase in the number of circumstances that are covered by the rule, although it is more likely to mean such an increase. To formalize is therefore to tell someone what to do in a circumstance. More formalization means to tell that person what to do in a given circumstance and to do so for more circumstances. Which of these and how much of each is not specified. Any two people may translate more formalization into any combination of these things that have to be done to get the right amount of formalization. The relation of formalizing to "giving latitude in compliance" must also be translated. It says something about what it is that the person is told he should do when the circumstances are such and such. But the latitude can come from making a rule tell the person to do one thing and one thing only, rather than telling him to do any one thing from a set of more than one. Or it can come from restricting this set but not making it contain only one choice. Compliance suggests something that is to be done to make the person not do anything that he was not told he may do in any given circumstance in the list of those explicitly stated.

Compare these translations which the user of design rules needs to make when he uses the rules given him by the Burton and Obel (1998, 2004) computer with those that have to be made by the user of the design rules derived in the previous 13 chapters. No translations need to be made in the latter case, because the design is in terms of rules which are clearly defined. The issue of what circumstances to list is covered by the our design variable of comprehensiveness. This refers to the immediately identifiable real world action of describing a circumstance, and telling the person what he may do when that circumstance is the real world. Translating the phrase "giving latitude in compliance" to compelling the person not to do anything not in the set he is to choose from is a design variable that is a number of steps away from the operational definition. In the terms of our theory, this translation does not produce a variable of design of structure, but one of the performance of the structure which is linked to the variables of design in the reward substructure, and the concept of the fit needed between the values given these and those given comprehensiveness and fineness.

In the one case of formalization, it is true to say that our design variables are much closer to real world decision and action variables than theirs are. The same is true of centralization, and most so in the variable they call configuration. The original definitions of the classes of configurations they use are vague, not exclusive, and not strictly logical. The definitions mix performance criteria with structure ones, may explain the relations between the two, or they may not. They often use criteria that refer to variables that are far removed from the real world. Where in the world is there a design variable called ad hoc? What does the designer specify in the design that makes it more or less of an adhocracy? Come to think of it, the question should have been stated as: What does the designer not specify to get a design that is more or less of an adhocracy? With concepts of design variables such as this one, there are so many steps that are needed to make them correspond to real world variables, that even Burton and Obel (1998, 2004) cannot identify the ones that are best to use in any given design one is creating.

We conclude that our designs are more valuable than those of Burton and Obel (1998, 2004), because our designs describe in greater detail and in terms that are more operational than theirs what the real structure is to be, and what it is to do. In addition, we conclude that our theory is superior, because it can explain the designs in a more exposed logical form of two tiers instead of one. Our explanations use two mappings to get from design to outcome, while they use only one. The mappings we use are more complex and allow for the effects of variables to be interconnected, reinforcing or weakening one another. Our theory takes into account the cost of the structure explicitly, and uses two mappings, one from structure to cost and another from structure to outcomes by way of performance. In general, we conclude that our process of design produces better designs, but is also more costly than theirs. Even if we were to create the program that would allow the computer to use our rules and do the work of creating a design, their process would be less costly, because it involves fewer steps. It seems reasonable to argue that if one were interested in obtaining some preliminary concept of what a good structure of an organization should be like, one might very well use the Burton and Obel (1998, 2004) theory and process, study the design one gets, and make some informed decisions on whether a more detailed and operational design should be obtained. If one concludes that it is worth the time and effort to create such a design, then one might well choose the process developed in the preceding chapters to get that design. Refinements in this process and in the theory on which it rests might make it possible to create a computer program that would allow the computer to go through the process and create a design. This brings us to the question of what artificial intelligence can do, and how it might be used to lower the costs of designing effective and efficient organizations structures.

## 8. A Computer to Go through the Process

Artificial intelligence is used by Baligh, Burton and Obel (1987, 1990) to show how a computer may be given a set of rules, and programmed to go through a process that produces a design of an organization structure. It is actually used to do just that by Burton and Obel (1998). It is the potential of the computer to be a designer that this work establishes. The rules and process put into the computer are from a rather simple but rigorous theory. This work established the fact that a design process may be done by a computer, and that it would be much more efficient than a human using the same theory. Many case examples of the use of this program to design structures are given, and the program's usefulness is well demonstrated. Should we emulate Burton and Obel (1998, 2004) and develop an artificial intelligence program to go through the process of design created in this our work? Though the properties used in this work are different from those of Burton and Obel(1998, 2004 ), the two theories are logically similar. There is no reason why we should find it very difficult to program a computer to go through the process of design we developed above, the new process. But before we decide to do so, it would be appropriate to identify the details of the program and derive some conclusions on its usefulness and efficiency.

In the new process defined in this work, specific case parameters or facts are obtained from the use of the process itself and used in the next step of the process. Facts are estimated and derived from the design at one step and used in the next one. If a computer is to do the designing, one would have to do one of two things: interrupt the computer after every step to feed it the relevant values of these parameters, or feed it the full functions at the start. In most cases of real world design, the functions are likely to be very costly to identify. Since they are also case specific, each may need its own artificial intelligence program. The advantage of the computer when it is used in this manner over the person is somewhat diminished. An alternative is to make the computer operate in the step by step search process that our designer uses. Here knowledge of only some of the functions need to be known at any step and also only small segments of these are needed at each step. Both the functions and the segments needed at each step are determined by the design produced by the previous step. The design of an artificial intelligence program that would operate in this manner would mean that it would choose the design variables to work on at each step and generate the appropriate segment of the functions involving these. To have the computer do all this would require a much more complex program that does a search procedure that uses the decisions of each step to identify the nature of the problem of the next step, and get the information needed to solve that problem. But these facts cannot be obtained by the computer on its own. They are real facts unique to each problem. They must be obtained for each step from real world connections and real world sources. They must be fed to the computer at each step after it identifies them, and they must first be derived. The computer would have to be stopped at each step and fed these values. Its advantage over the human designer is somewhat lower than it would be in the simpler case. Obtaining these parameter variables is no easy matter, though the simulation work of Levitt, et. al. (1999) may well be one way to reduce sharply the cost and time of getting the parameter values needed for the next step of design. Either way, there are problems.

Operating an organization structure costs money. These costs are an important element in the process of designing structures that are efficient. One way to handle costs is to embed them in the rules of design. That is what is done in Burton and Obel (1998, 2004), where the rules of design given the computer tell it what to do, given facts which it is fed once at the beginning of the process. In this system, there is the rule that states " if the environment has low equivocality, low complexity, and low uncertainty, then the organizational configuration should be simple or functional, media richness should be medium, with a small amount of information, coordination and control should be direct supervision, and planning and incentives should be procedural based." (Burton and Obel, 1998, p. 1920). This rule has already encapsulated both the effects of the choices on outcomes and on the costs of operating the structure, or else it ignores costs altogether. In any case, these functions from the specified decision values in the rule are the best, given the environment parameters. This is true for all organizations. It is based on known functions that connect the decisions to outcomes and costs. There is a great deal of analysis and synthesis that goes into this rule. Before we accept the rule as a general one, it would be wise to see the details of all the work that produced all the functions embedded in the rule, as well as the work that derived the rule from these functions. It is also clear that the rule is in absolute terms of property levels, and therefore comes from theoretic statements that are absolute. They are of the form: when design decision for structure property x is high, for structure property y is medium,..........., and environment property value for w is low............, then the values we have on the outcomes of this structure and its costs are best, or very good. A great amount of work is combined to produce this general rule, Also, when the conclusion is of this form and applies to all organizations, then both the outcome function and the cost function must be known. That is, the whole mapping must be identified, and then fed into the computer at the start. That is no easy matter, since costs may depend on the technology available to the organization, the same cost function cannot be expected to be true for all cases. The simplicity of using only one function, or even a few, embedded in the rules makes them unusable in any situation with a different mapping. A simple program cannot be a general one. If we suppress the issue of generality, then we give the computer the one function and avoid having to interrupt it at each step to identify the function that is to be in its program. Otherwise, much of the basic source of the computer's efficiency is lost if it is constantly interrupted.

Looking into the existing artificial intelligence program developed by Burton and Obel (1998), one finds a number of important assumptions underlying the theory on which it is based. Since all the design rules are absolute and applicable to all organizations, it follows that it is assumed to be true that all functions relating a design decision to outcome are known and are the same for all organizations. It also follows that the same is true for the functions relating decisions to costs of operating the structure. The rules of design come from theoretic statements in which a level chosen for a design variable is mapped into a value of a variable that is a composite of outcome and cost, a net return variable. The rule is considered to hold for all organizations. This means that all the outcome and cost functions are identical for all organizations, and that those who wrote the rules for the computer know what these two functions are.

Our process of design does not derive theoretical statements similar to the one above. In very few cases are the statements made on the combination of outcome and cost simultaneously. Our conclusions are not absolute, but relative. Our theory statements connect changes in design variable levels to outcome alone and to cost alone. By making our arguments in the form of the higher the higher, rather than if high then high, we have assumed that what is general to all organizations is the sign of the slope of an outcome function, and that the same is true of a cost function. This is assumed for all the functions. As such, these assumption are much weaker than the ones Burton and Obel (1998) make. Not only do we not assume the same functions hold for all organizations, we do not even assume that the slopes are the same. We only assume that the signs of the slopes are the same. We also do not assume that the functions are clear and known to the programmer of the computer or even to the designer of a specific structure before the designer starts the process. What we do is derive theoretic statements about the direction of the changes in outcome alone and in costs alone. We also describe a design process in which the designer searches neighborhoods of specific design variable levels. The search is of a small area, and so not onerous or unrealistic. The information it produces is also about a small segment of an outcome function and of a cost function that are those that hold for this organization. We allow the designer to get some knowledge of a function as he goes through the design process one step at a time. He does not have to know these functions in total before he starts. What he finds out may or may not be true for all organizations. The next time he designs one he will have to get the new facts, ones that are real for the organization he is designing. Because we are not tied to absolute functions involving a composite variable of outcome and cost, and because we use relative rules rather than absolute ones, our process allows us to take into consideration the interactive effects of the use of one rule on the specific changes in the outcome or cost functions related to another. Dominance relations are an example of the attention paid to these interactions.

Iterative processes similar to the one we devised allow the decision made at one step to guide the decision made in the next step. A step is to be dependent on what is learned about the changes produced by the previous step taken in all cases except that of the first step. Changes do not have to be actually experienced and measured. They are estimated on the basis of some understanding of the nature of the functions and the use of mind experiments that change decision variable values in small amounts and estimate what the order of magnitude of the changes in the value of the function might be. What is required is knowledge about only small pieces of the functions and the use of previous experience in making these estimates. Designing a structure using our process allows the designer to use the real functions that describe the circumstances for his organization and to find these out in a piecemeal way. He does not have to have complete knowledge of the functions before he starts the process of design. He does not have to use standard functions that apply to his and every other organization. If he uses the Burton and Obel (1998) program and lets the computer do its designing, the design he gets is based on the fact that the creators of that process assume that the functions are standard, and that they knew what they were when they specified the rules for the computer. Finally, our process allows the designer to use whatever combination of cost and outcome he chooses to create the value function for his organization. Our process is better than that of Burton and Obel (1998) because it is more realistic and allows the use of organization specific outcome and cost functions and their composition into a single goal or value variable. This process also specifies a sensible, realistic, and efficient method of collecting information needed. In this new form, the process of design is in a stronger position when it claims generality. It is better because it requires knowledge of changes in the outcome and cost functions that are true for the circumstances as one moves through the process gaining experience. What we gave up for these improvements is the advantage we could get by making a computer go through the process and save us the trouble of doing it ourselves. Our process is not very computer friendly. Ours is a process that requires many more iterations than the other one. It must be fed information at each step, and rules on how to use it in making the next step. This information cannot be fed into the computer before the process starts because it becomes available only at each step. If we have the computer do the designing, we must feed it all the functions. Getting these functions is a major piece of work that will take a lot of time and cost a lot of money.

## 9. Changing Transformations and Designs

An element of the theory that should be now altered is that which makes the structure to be designed work with only a fixed and predetermined set of transformations. To generalize the theories and process of design, we will consider the case where the organization structure to be designed is one that is to work on choosing the transformation it works with, and even on the discovery and creation of such transformations. Once this expansion of the tasks of the structure is introduced, the concept of a fourth substructure analogous to those of the operating, information, and reward structure ones becomes useful. The object of this substructure is to choose the transformations that the organization is to use from an existing set and to create new transformations from which it chooses those the organization is to use. The decision variable in the issue of choice is a transformation, the function itself. The logic of this decision problem is no different from the choice of a value for a variable which is in a transformation. Choosing the transformation may be a more difficult problem and require different intellects from those needed to choose values for the variables in those transformations, but it too is a substructure like the other three, from the point of view of design. Its components are people, decision variables, and so on. It is however the performance of this substructure that determines the decision variable and parameter components of the operating substructure. Only when the transformations are chosen are these components of the operating substructure determined.

In the simplest form of the problem of designing an organization structure, we assumed that the transformations it works with are fixed and given, or already chosen. The structure that is designed is then that which is going to be the mechanism that chooses the values for the variables in these transformations to get the required outcome under various conditions of the environment, and so on. This is what we assumed to be the case when we developed the theory of design in the previous chapters. When the problem is expanded to include the choice of the transformations, the theories of design that are needed are not different in nature from those of the simpler problem, but are expanded in scope. A fourth substructure is added and is to be designed in a manner logically the same as that for the other three. The only difference is that this fourth substructure logically determines the decision variable and parameter component of the operating substructure. Even so, in the process of design that goes through a sequence of designs and redesigns, only the last design of this fourth substructure, if we decide to have one at all, must precede the last design of each of the other three. When the fourth substructure is to create transformations, as well as choose from those it has on hand, then the work it has to do gets more complex still. However, as in the case of choosing, creating does not change the logic that underlies the design of this substructure. When choosing was allowed, we moved from a given set of transformations for the operating substructure to one that has to be chosen from a another given set.

When the creation of transformation is also allowed, this set that was a given is no longer so. The set itself must now be identified and is part of the choice problem for the organization structure. Again, these decisions on transformations are now even more complex than they were when this set was not part of the choice problem for the organization. As in the first complication, the theories of design developed earlier are applicable to this new situation. They will need to be expanded to handle the choice variables that are no longer identified in the transformations. Designing structures with these expanded choices will be more complex than before, but its logic remains the same. What we can expect is that the complications in the choice problem will require that the fourth substructure that will be found to be the best will be one that has very different substructure property levels from those of the other three substructures that go with it. Levels of properties defined in terms of the decision rule components of the substructures are the one where the greatest differences might well be found.

## 10. Self-Designing Structures

One more complication of the design problem involves one step beyond having the structure create its own transformations. It is that of having a structure, or any of its substructures, design and redesign itself. The structure performance property of flexibility discussed earlier dealt with the different things a structure could do, but the structure property of flexibility we now consider deals with what the different structure could be. Is there such a thing as flexibility of the structure itself? If so, is there a way to design structures that can change themselves? If a structure is self-designing, how does the first actual structure get designed? Is it logical to talk of designing structures that are flexible and optimal, ones that take on the specific form that is best given its environment, etc.? If we can think of what it means to talk of structures that are designed to redesign themselves, then we are going one step beyond the concept of structure design. Meta-design might be a term for it. The philosophical difficulties here are profound. Is the design of a structure that redesigns itself the same thing as creating a computer to design structures? Is this latter case the same as designing a computer that redesigns itself? Who designs the first form of this self-designing computer? Getting answers to these questions is very important. Yet, we have not addressed them in this work. Our discussion of these problems is brief, but will explain why the issue of designing a self- redesigning structure is meaningless until we know what a structure is and what designing is. In fact, the issue of designing a self-designing structure is meaningless without the basis of a discussion of designing a structure. The first thing that shows this dependence is that we find answers to the two questions:

1. Who is to design the structure that will redesign itself?
2. Who is to tell the self-designing structure what designs to choose for itself when it redesigns itself?

Because the connections of organization structures are between people and are made by people, the structure of an organization may be changed by any person in it at any time. The whole issue of the realism of a designed structure involves the way in which a design can be made real. Any design or part of one may be made real by actions of any member. The problem is not one of creating structures that change themselves. They will always do that as long as humans think and act. The problem is one of two forms. The first we discussed under the subject of design realism. Here, the problem is to get people to make the real structure what the design says it should be, and to make it stay there. Making designs of operating, information, and reward substructures that are consistent with one another is the how we attain this objective. If however, we want the people in the organization to create the design, then the problem becomes one of organizing a design team. This would be a group of people who design pieces and add or remove them from the structure, and do so in a manner that improves the efficiency of the structure and fits with the changes made by others in the organization. In a real sense this is a problem of organizing designers, or in other terms, a problem of designing structures where the operating decision variables are structure design variables. Everything about design that is in the previous chapters applies here. The one difference is that of the subject matter itself and the expertise that people have in it. To get structures to redesign themselves to become more efficient and to do so efficiently, the people in the structure have to have the knowledge needed to become structure designers. If the steel making structure is to be designed to redo itself, then not only must the people be knowledgeable about making steel, but they must also be knowledgeable about designing structures that make steel. This latter knowledge may be obtained from reading this book.

## APPENDIX I

## CHARTS OF ANALYTIC CONNECTIONS

The charts in this Appendix represent the analytic proposition made in the book. They are statements about connections that exist between the values of variables. The statements are the results of the analysis, or theory, developed in the book. The statements are represented by charts which we call theory charts. These charts are made up of letters connected by arrows that bear a plus or minus mark. The form $X \xrightarrow{\quad + \quad} Z$ means an increase in X produces an increase in Z and the form $X \xrightarrow{\quad - \quad} Z$ means that an increase in X brings about a decrease in Z. Arrows do not always come in simple form, but in any one of the following:

Arrow $X \xrightarrow{\quad + \quad} Z$ means that an increase in X produces and increase in Z.

Arrow
$$\begin{tikzcd} X \arrow[dr, dash] & & \\ & {} \arrow[r, "+"] & Z \\ Y \arrow[ur, dash] & & \end{tikzcd}$$
means that increase in X alone produce an increase in the value of Z, and an increase in the value of Y alone increases the value of Z, and in both cases the increase that occurs depends on the value of the other variable.

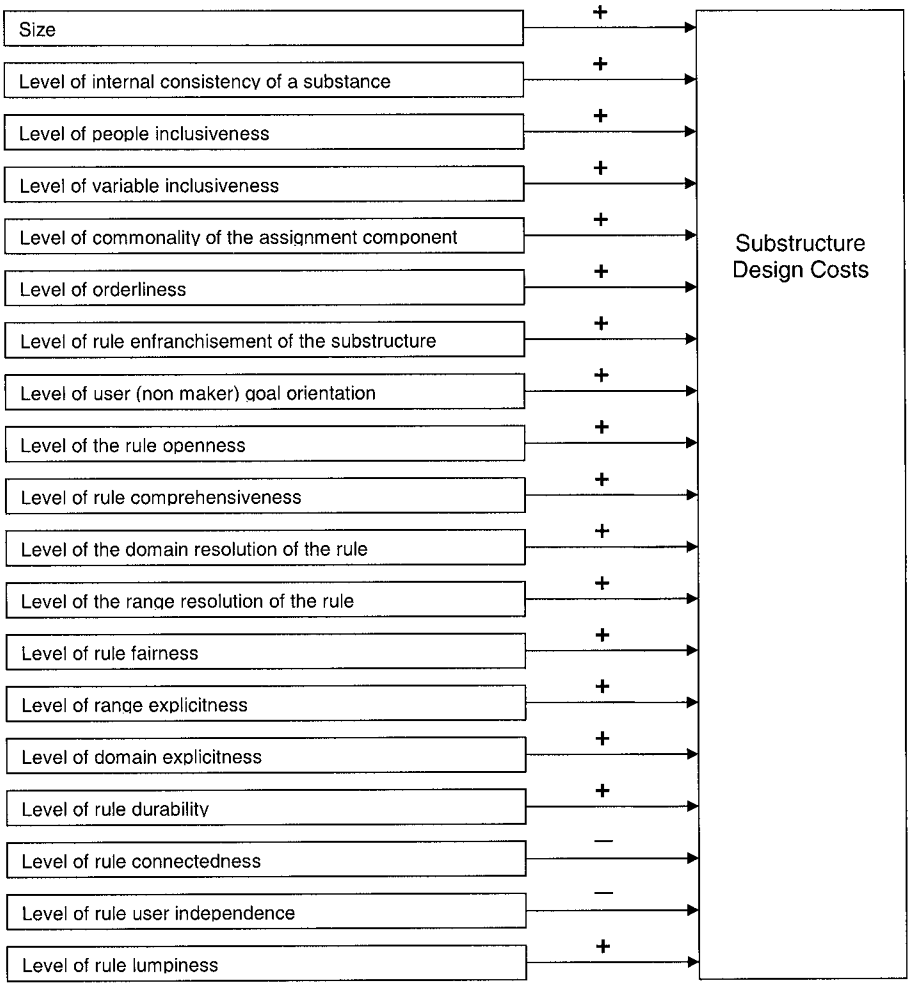
Any arrow that has a minus sign in any of the above cases means that an increase in the value of the variable where the arrow starts produces a decrease in the value of the variable where it ends.

In Appendix I:

Charts 1 to 6 relate to Chapter 4; Charts 7 to 10 relate to Chapter 6;
Charts 11 to 20 relate to chapter 7; Charts 21 to 29 relate to Chapter 29

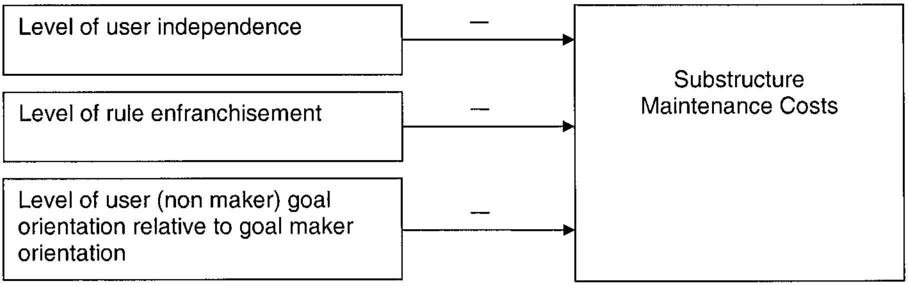
## THEORY CHART I

## Structure Properties and Structure Costs



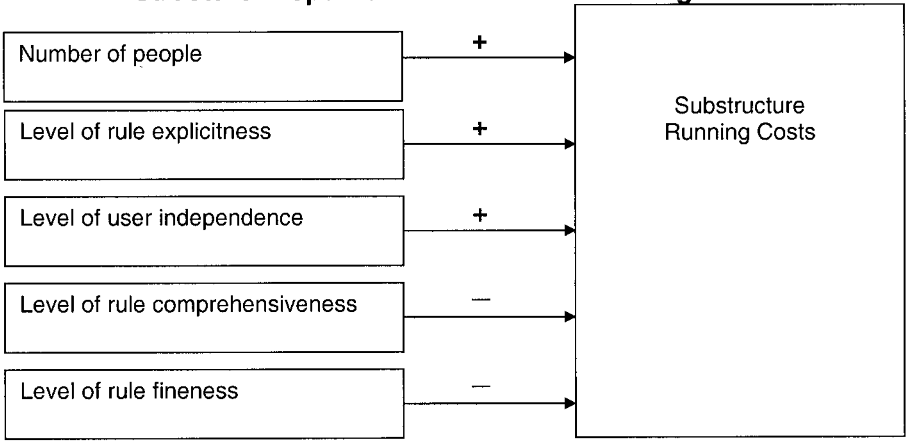
## THEORY CHART 2

### Structure Properties and Structure Maintenance Costs



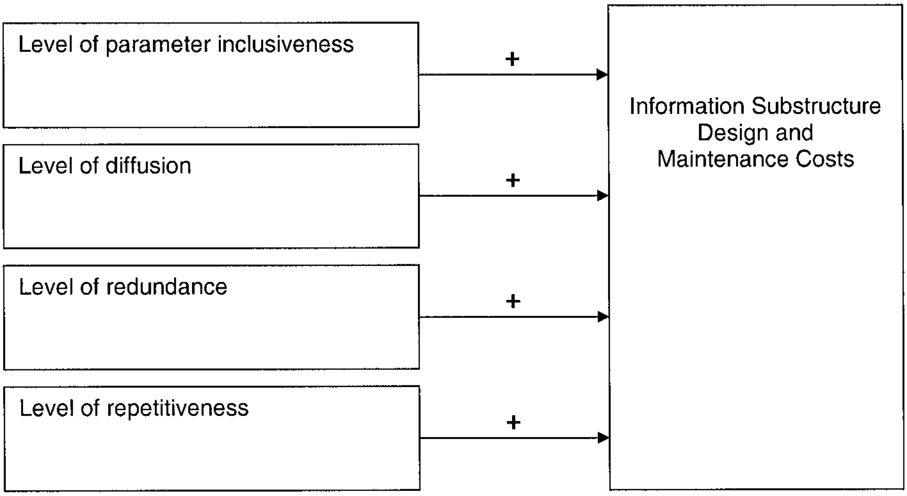
## THEORY CHART 3

### Structure Properties and Structure Running Costs



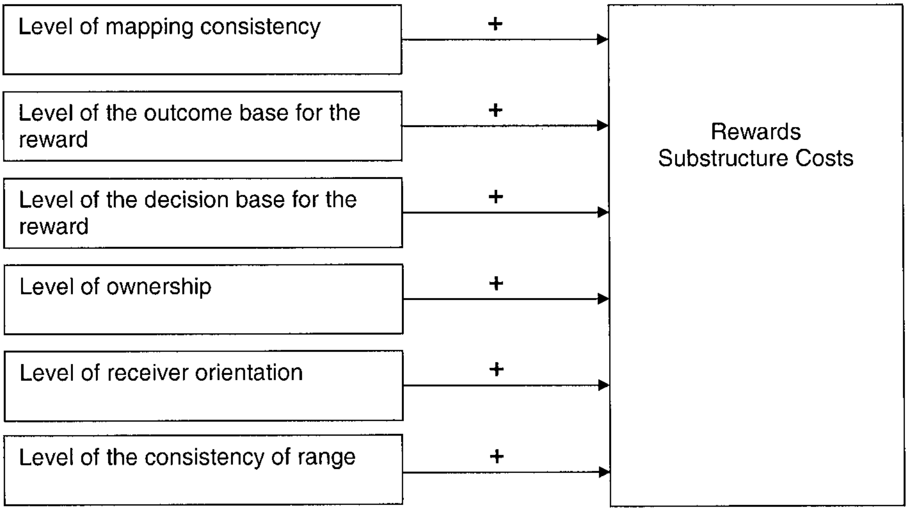
## THEORY CHART 4

## Information Substructure Properties and Substructure Design and Maintenance Costs



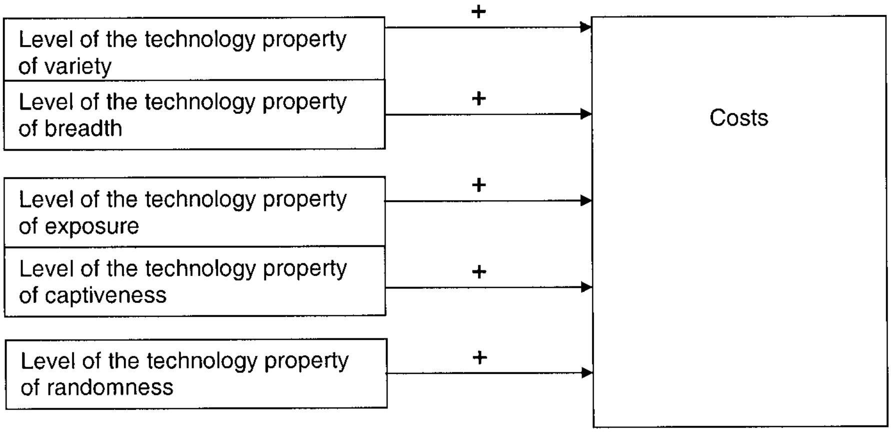
## THEORY CHART 5

## Reward Substructure Properties and Substructure Costs



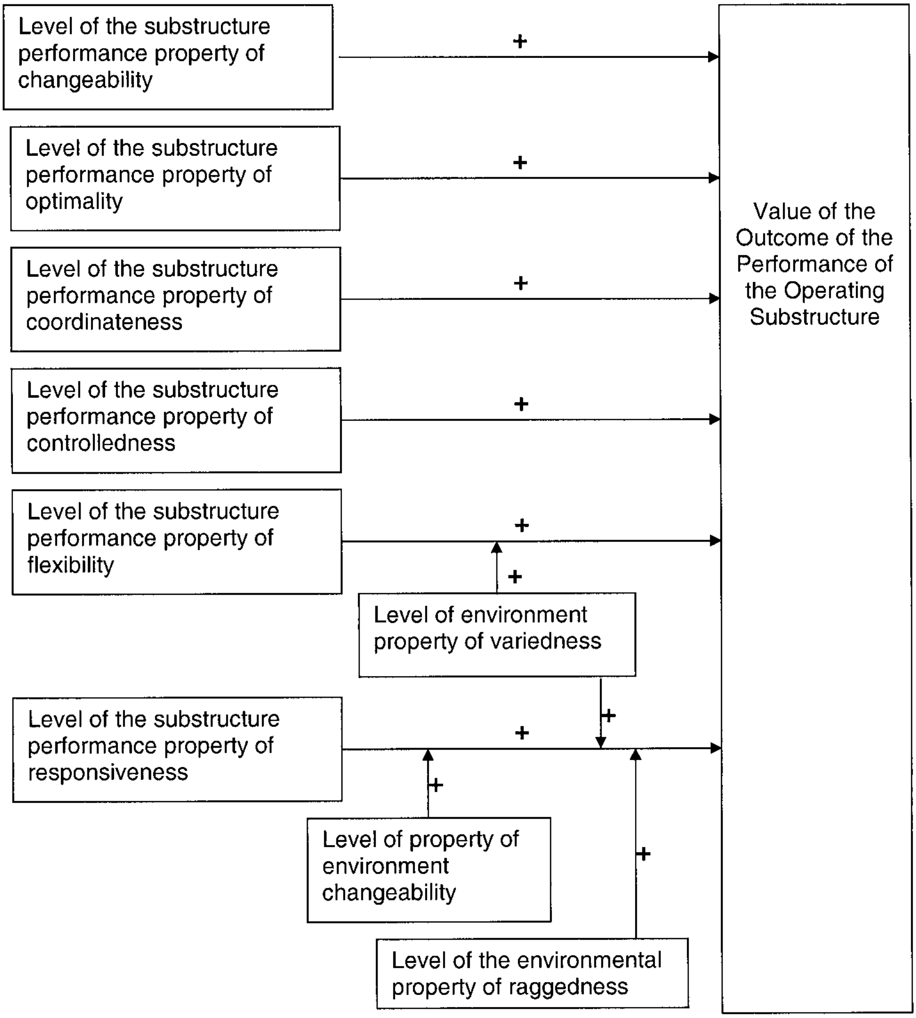
## THEORY CHART 6

## Technology Properties and Structure Costs



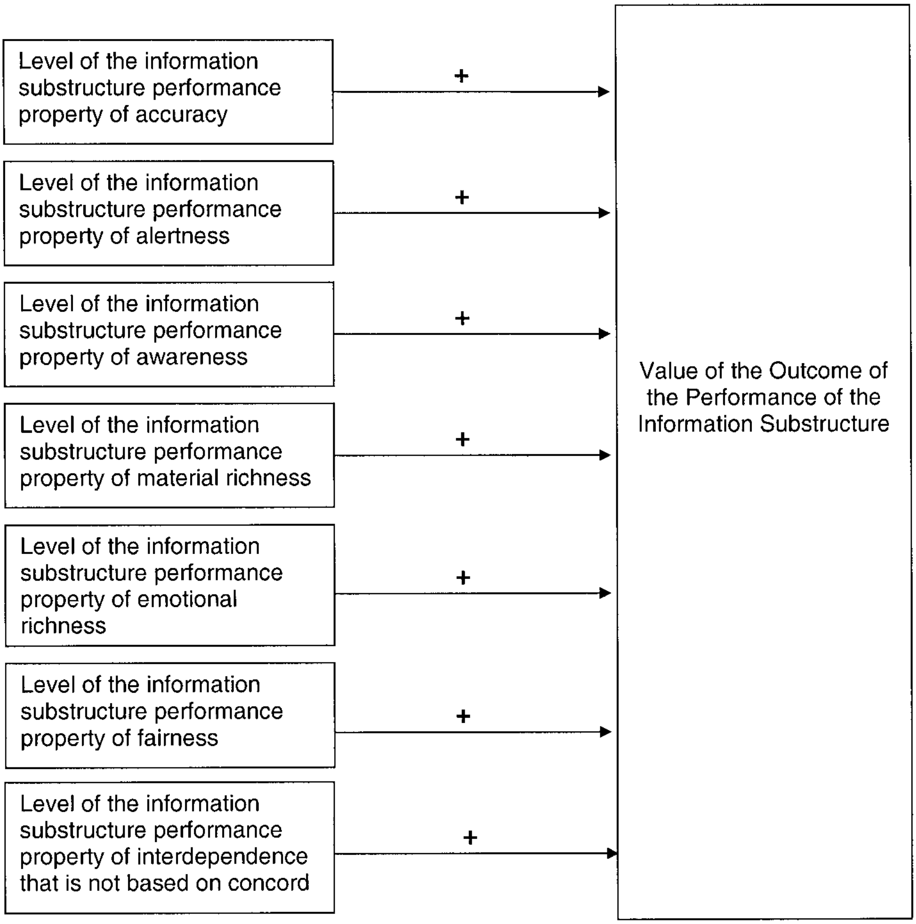
## THEORY CHART 7

### Operating Substructure Performance Properties and Outcome Value



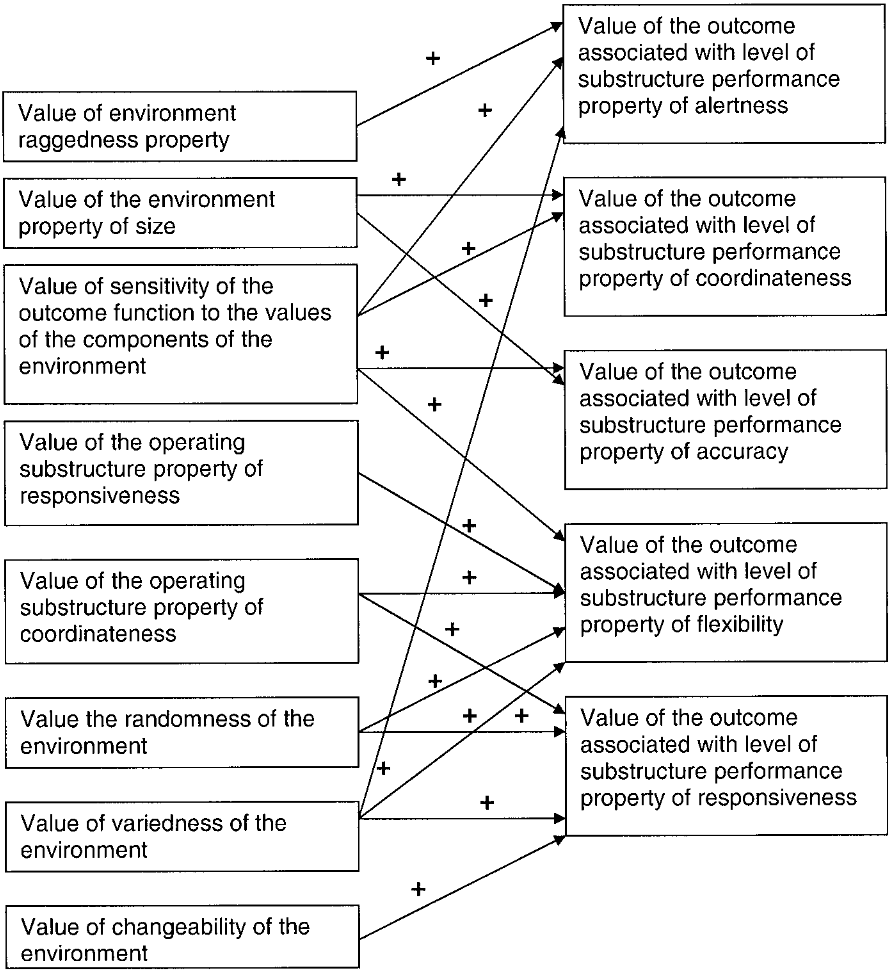
## THEORY CHART 8

### Reward and Information Substructure Performance Properties and Outcome Value



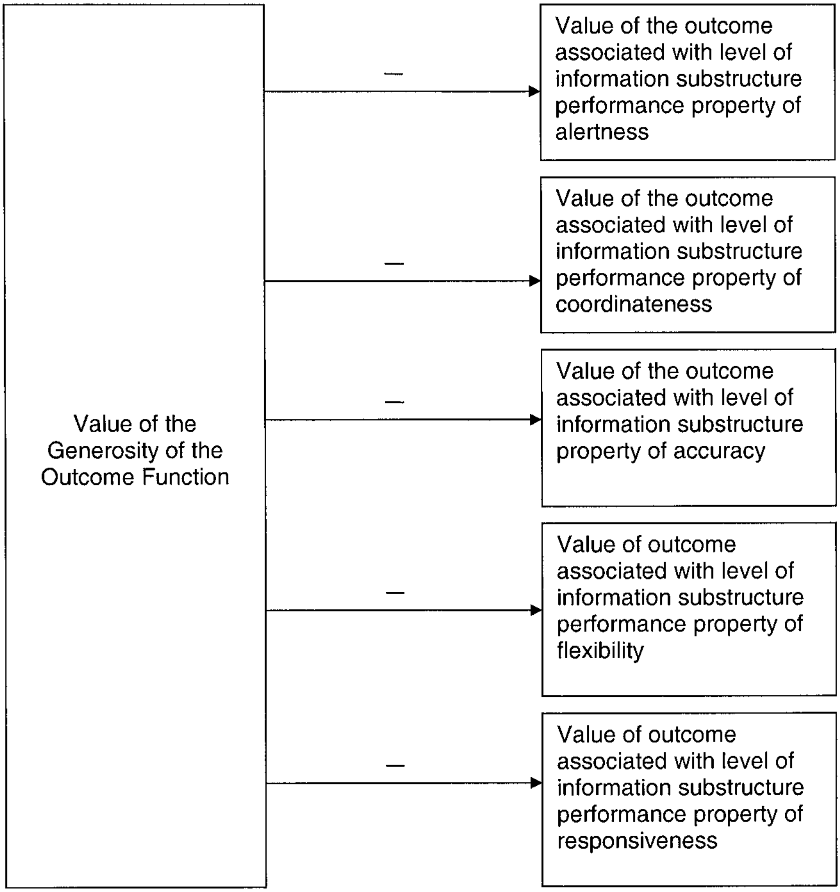
## THEORY CHART 9

### Environment Properties, Structure Performance Properties and Outcome Value Associated with Structure Performance Properties

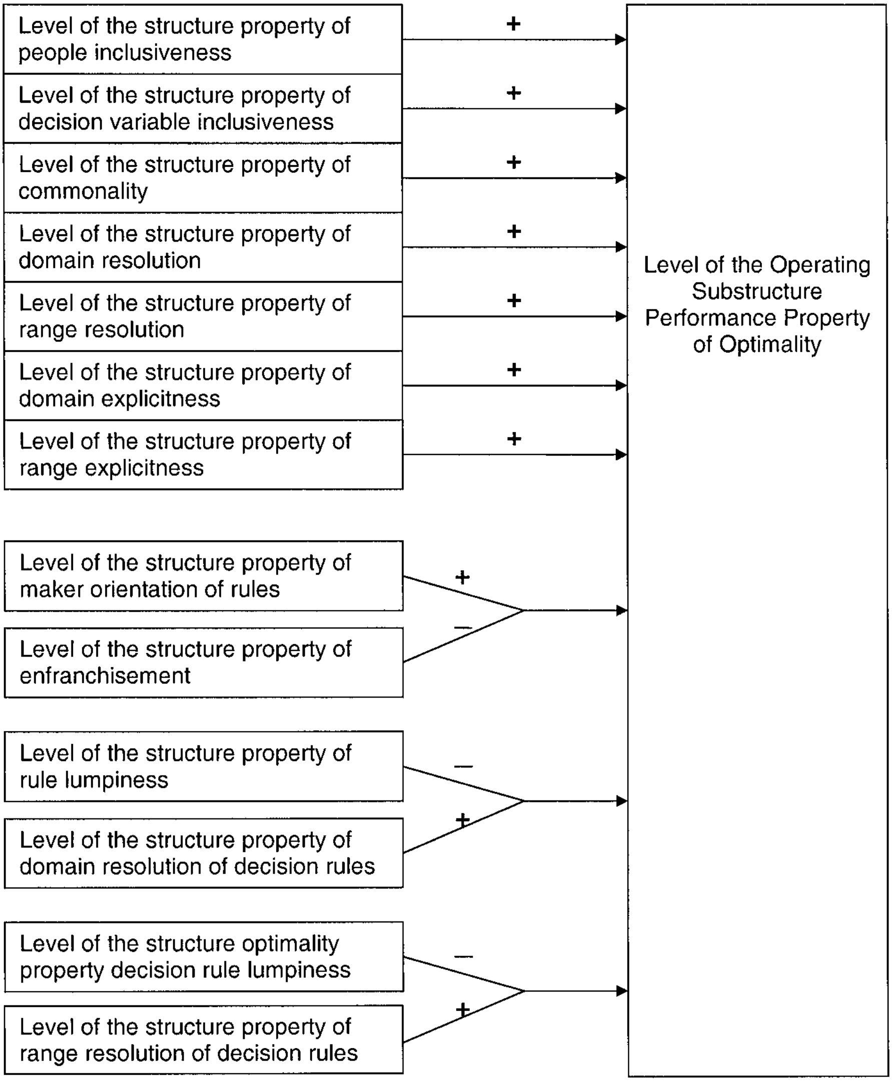


# THEORY CHART 10

## Environment Generosity and Outcome Value of Structure Performance Properties

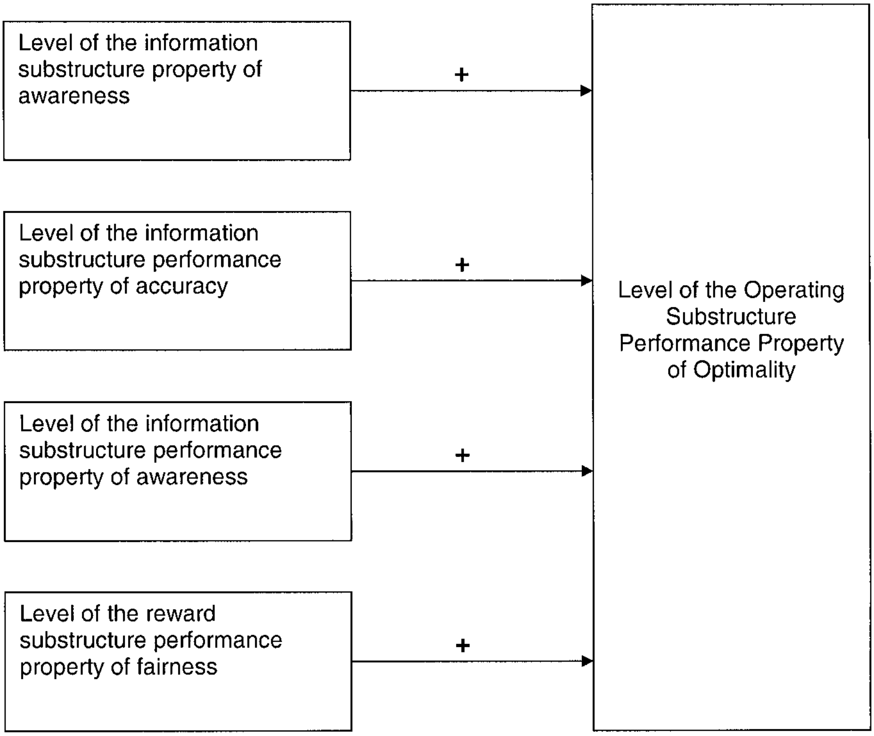


## THEORY CHART 11
## Structure Properties and Structure Performance Property of Optimality



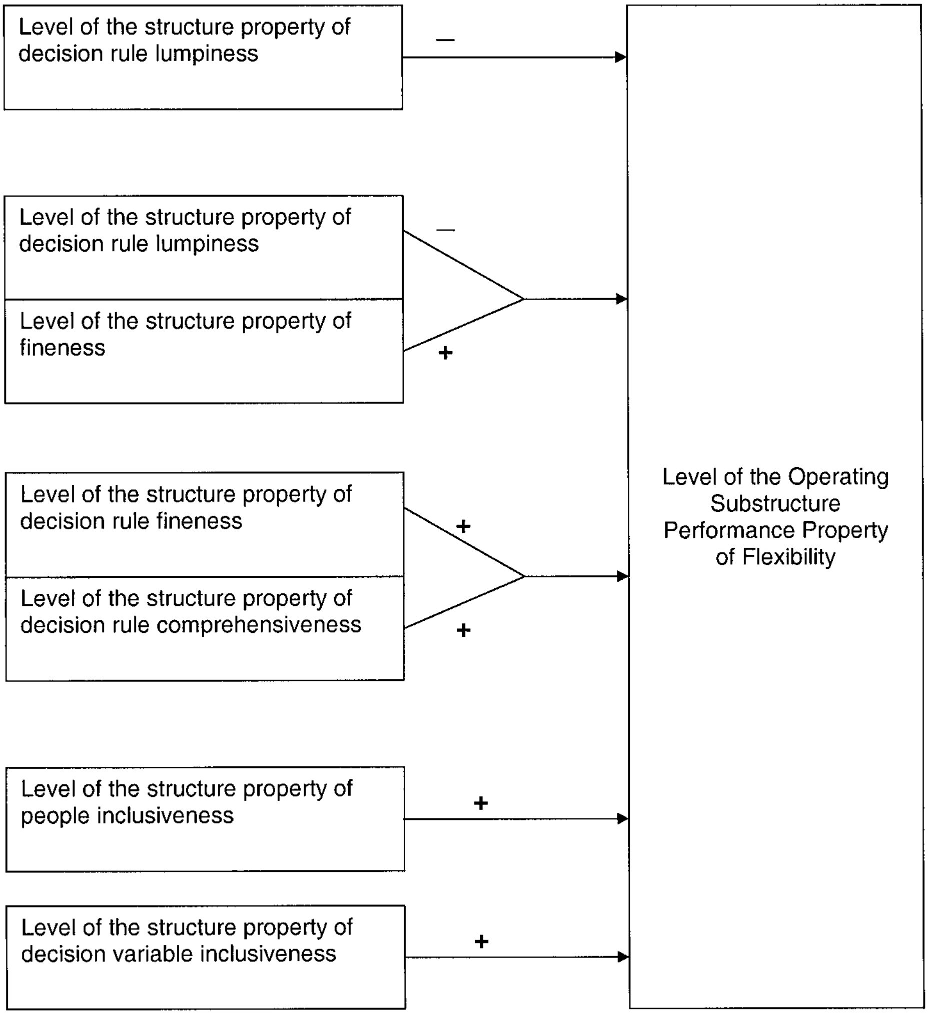
## THEORY CHART 12

## Substructure Performance Properties and Structure Performance Property of Optimality



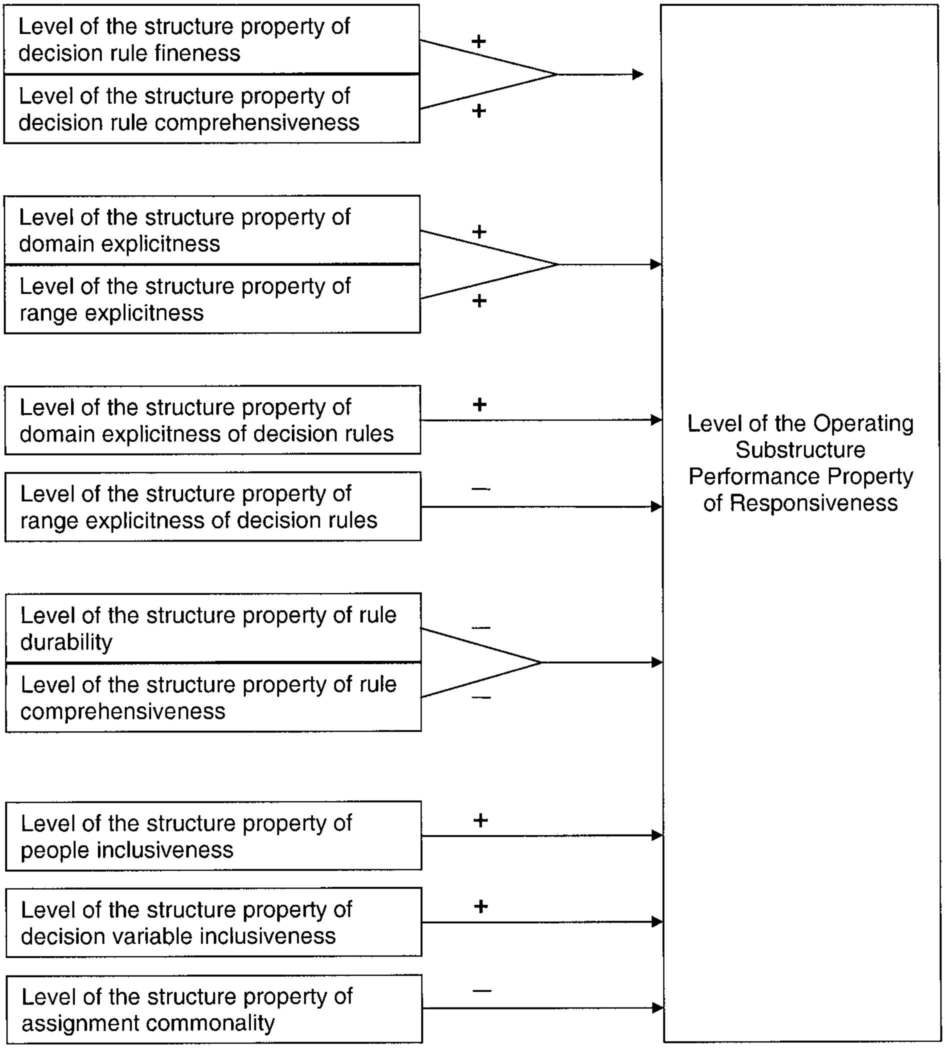
# THEORY CHART 13

## Structure Properties and Structure Performance Property of Flexibility



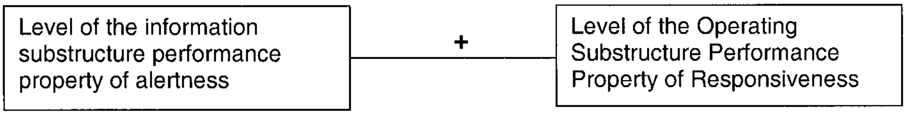
## THEORY CHART 14

## Structure Properties and Structure Performance Property of Responsiveness



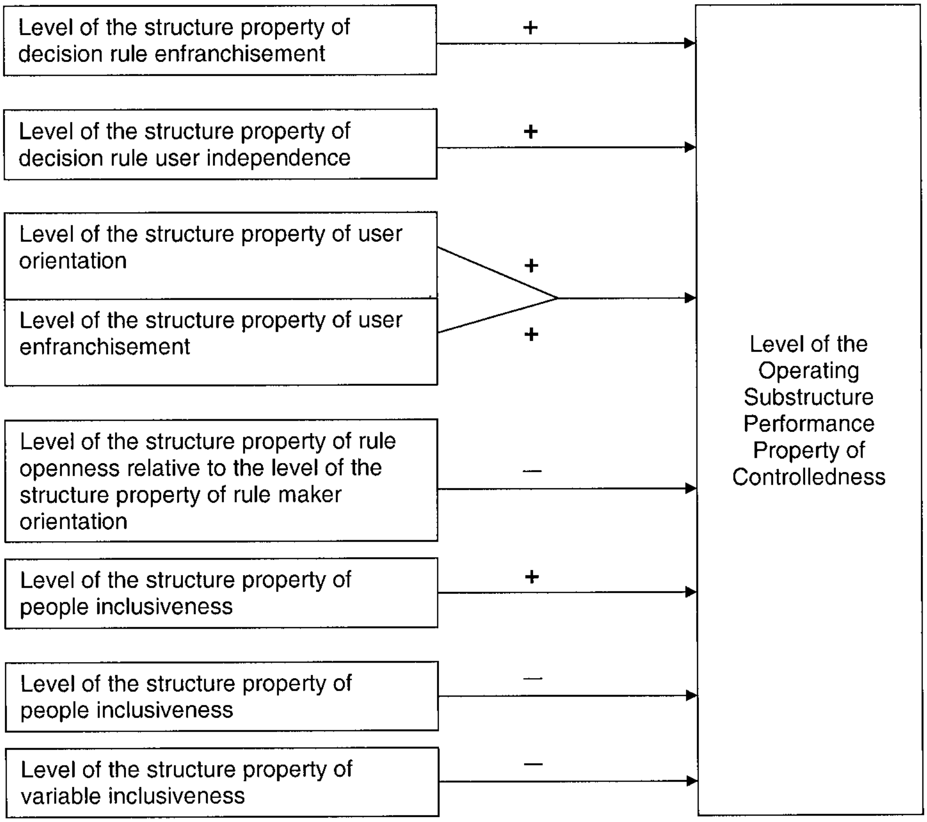
## THEORY CHART 15

## Substructure Performance Properties and Structure Performance Property of Responsiveness



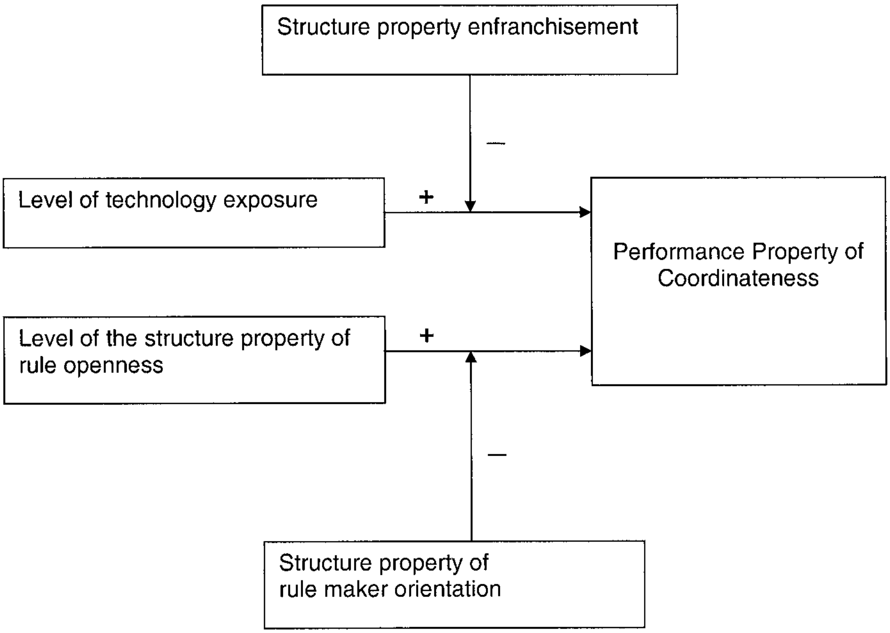
## THEORY CHART 16

## Structure Properties and Structure Performance Property of Controlledness



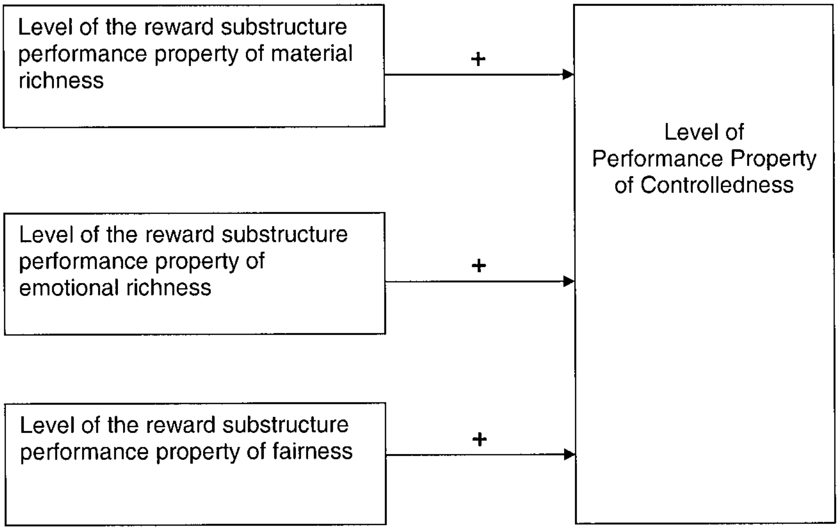
## THEORY CHART 17

## Structure and Technology Properties and Structure Performance Property of Coordinateness



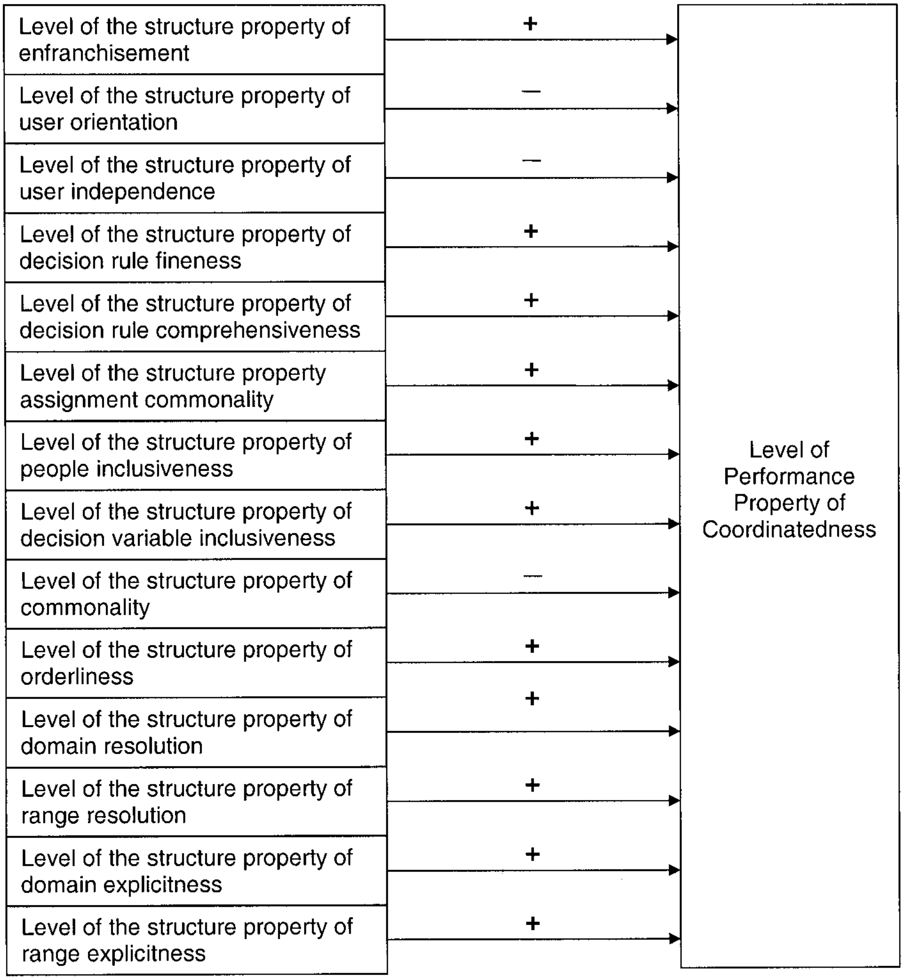
## THEORY CHART 18

## Substructure Performance Property and Structure Performance Property of Contolledness



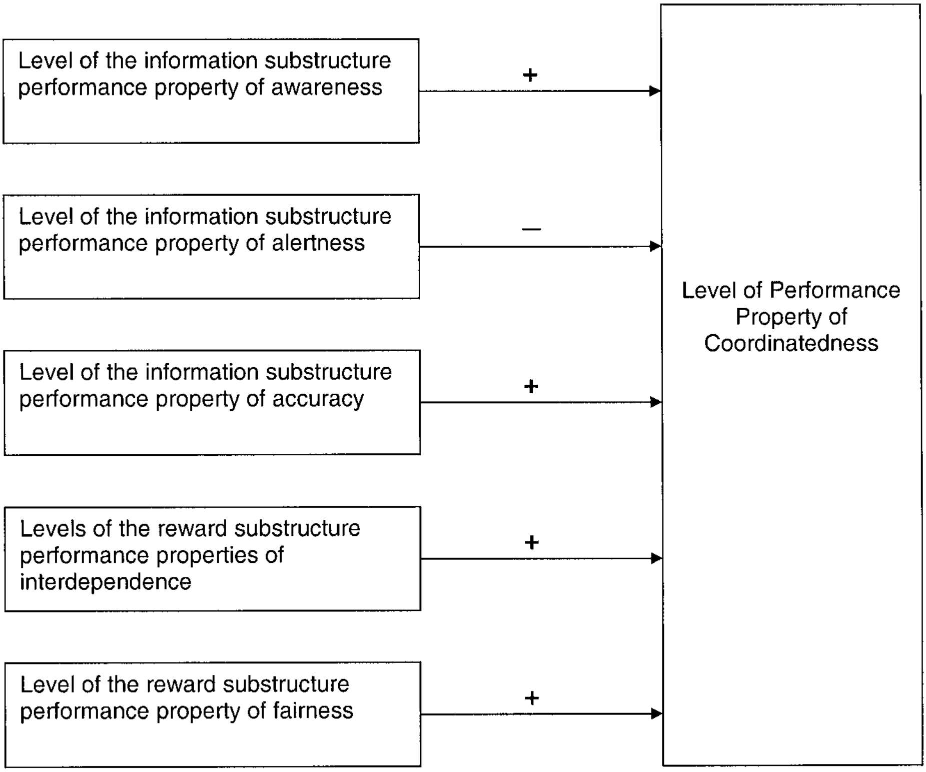
## THEORY CHART 19

### Substructure Performance Properties and Structure Performance Property of Coordinatedness



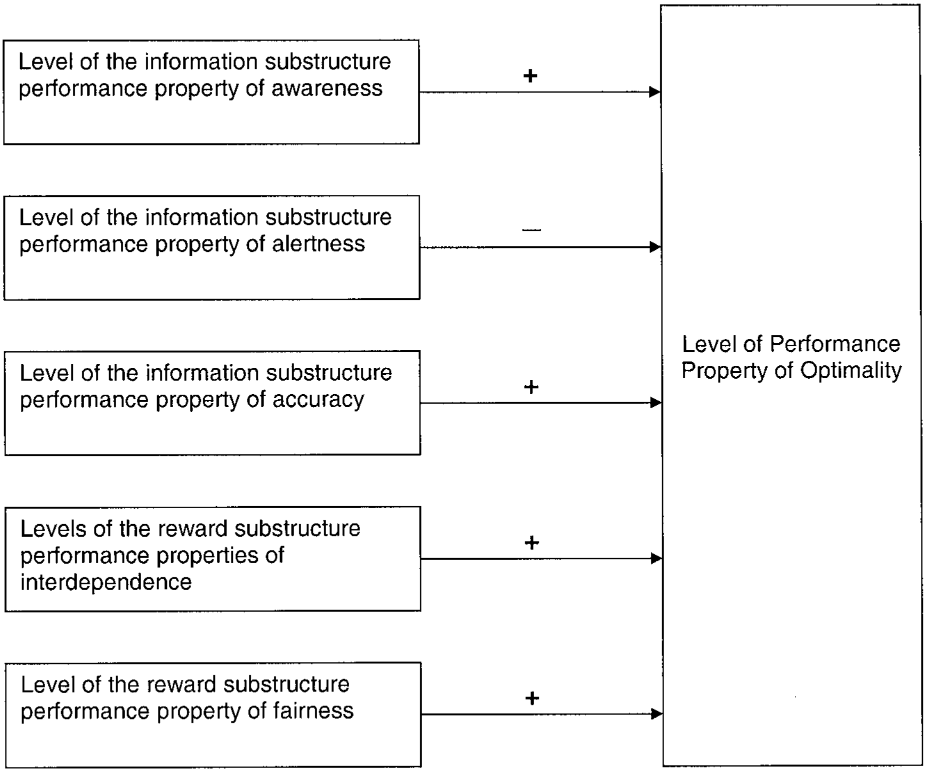
## THEORY CHART 20

### Substructure Performance Properties and Structure Performance Property of Coordinatedness



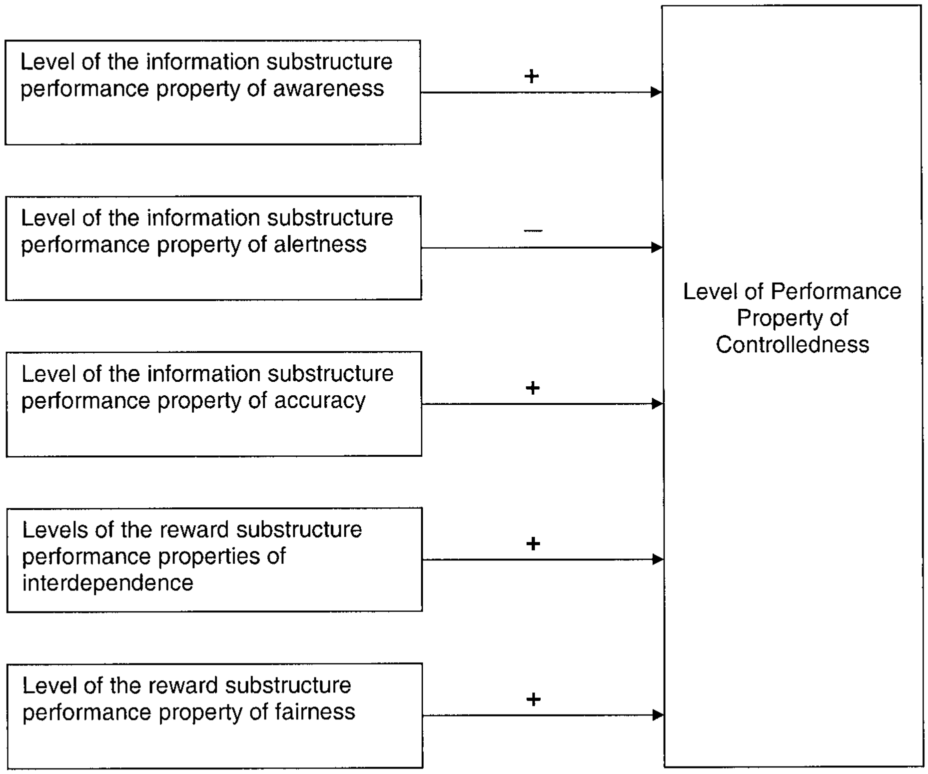
## THEORY CHART 21

### Information Substructure Performance Properties and Structure Performance Property of Optimality



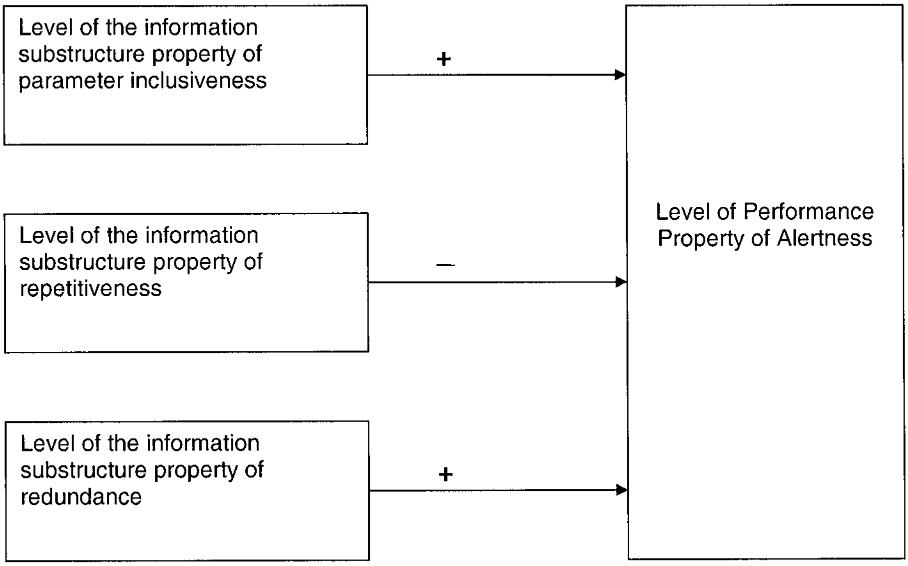
## THEORY CHART 22

### Information Substructure Performance Properties and Structure Performance Property of Controlledness



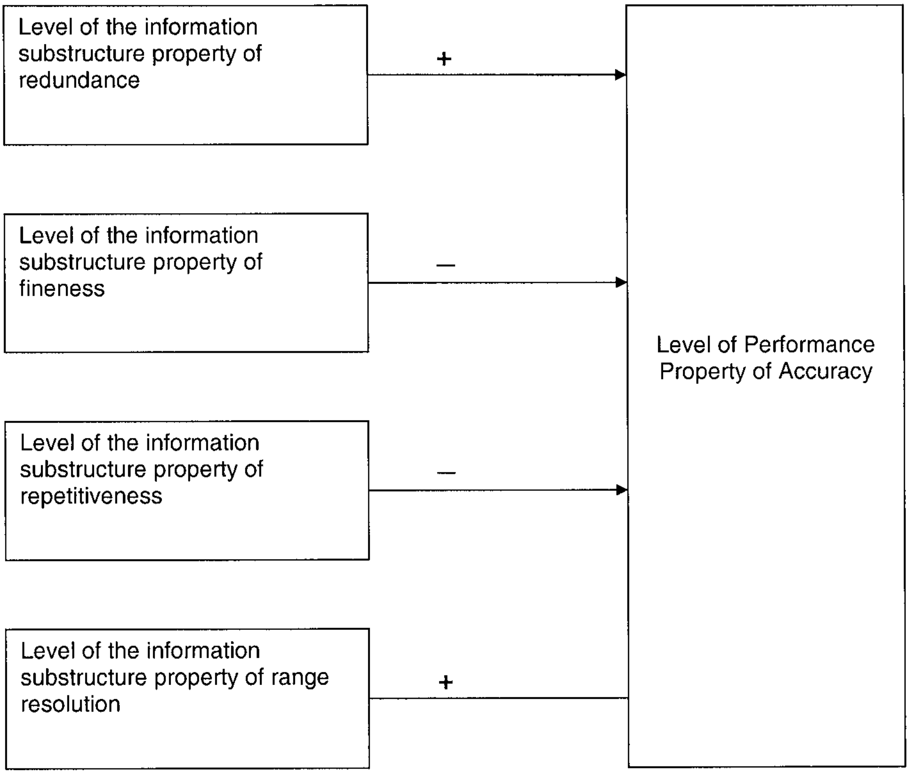
## THEORY CHART 23

## Information Substructure Properties and The Substructure Performance Property of Alertness



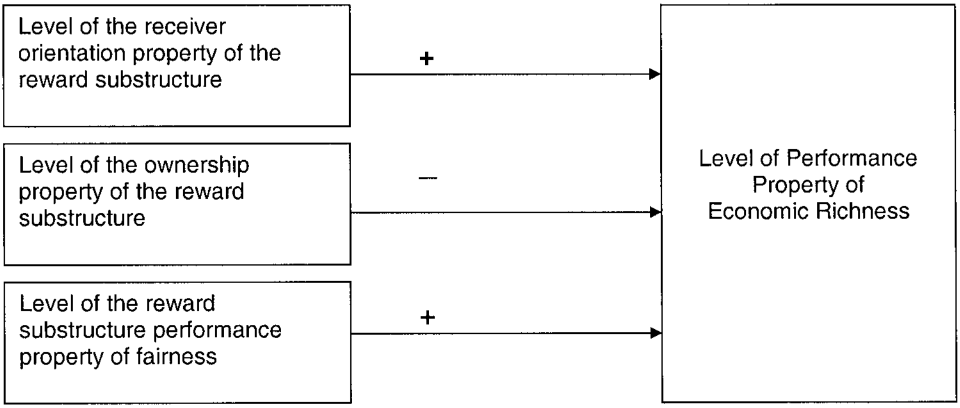
## THEORY CHART 24

## Information Substructure Properties and The Substructure Performance Property of Accuracy



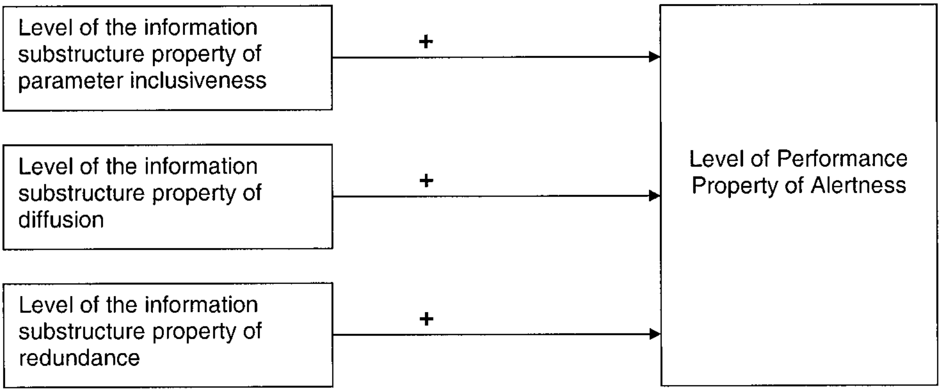
## THEORY CHART 25

### Information Substructure Properties and the Substructure Performance Property of Economic Richness



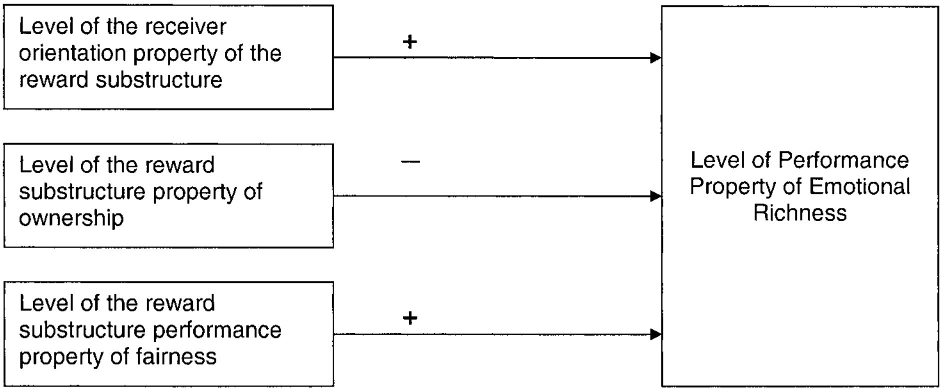
## THEORY CHART 26

### Reward Substructure Properties and the Substructure Performance Property of Alertness



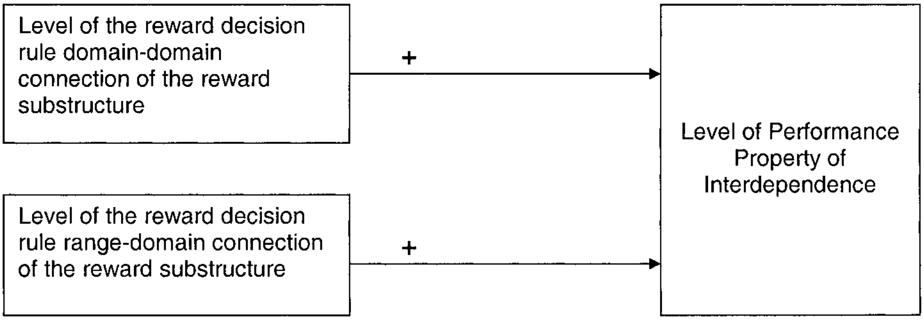
## THEORY CHART 27

### Reward Substructure Properties and the Substructure Performance Property of Emotional Richness



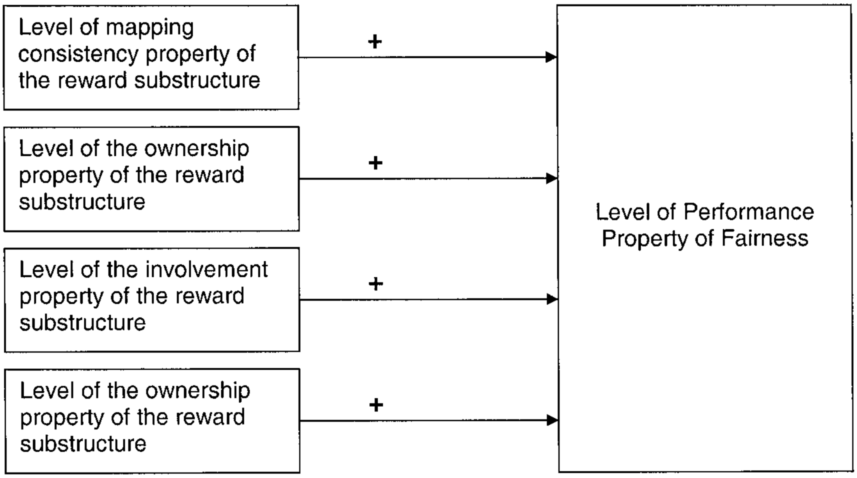
## THEORY CHART 28

### Reward Substructure Properties and the Substructure Property of Interdependence



## THEORY CHART 29

## Reward Substructure Properties and the Substructure Property of Fairness

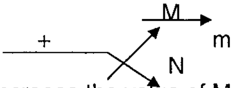


## Appendix II

## Charts of Prescriptive Statements

The set of charts in this Appendix, represent conditional prescriptive statements made in the later chapters of this book. They are Design rules that state that if you want the value of something to be higher than it is, then you should increase the value of something else. If the sign on the arrow is positive, K + M, it means that if you want to increase the value of K, then you should increase the value of M. When the arrow has a negative sign, K - M, it means that if you want to increase the value of K then you should reduce the value of M. The arrows do not always come in the simple form but in any one of the following:

Arrow K $\xrightarrow{+}$ M means that if you want to increase the value of K then you should increase the value of M.



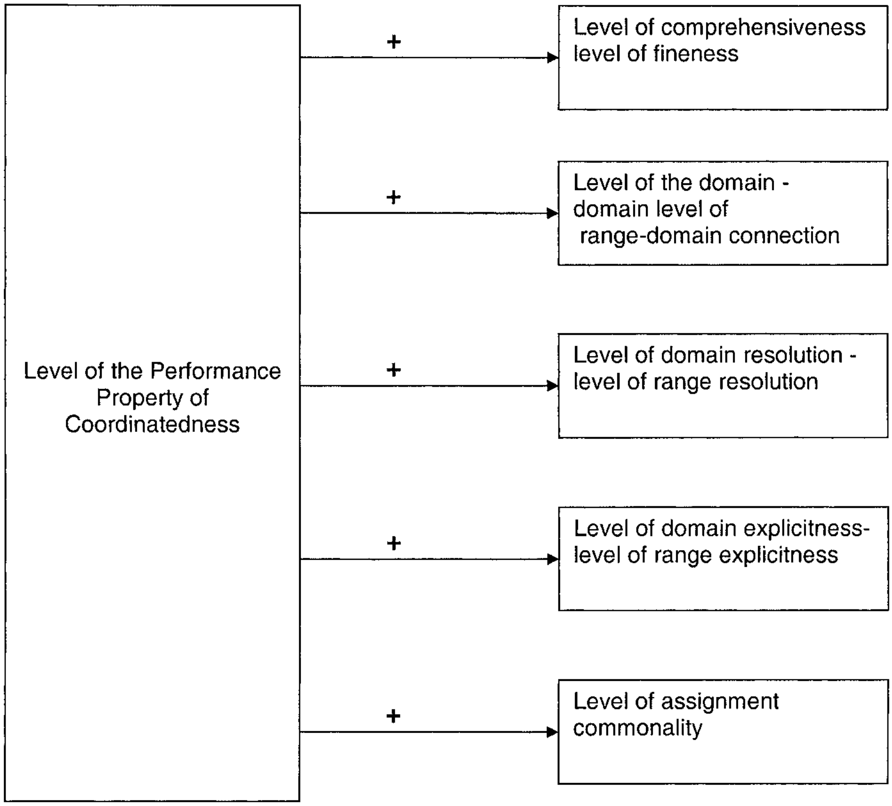
Arrow K means that if you want to increase the value of K, then you should increase the value of M only, the value of N only or the "balance" value of both.

Arrow K means that if you want to increase the value of K, then you should increase the value of a given combination of the values of M, N and P in the manner specified in the full statement of the rule. In all the above, an arrow with a minus sign means that if you want the variable where the arrow starts to increase, then you should decrease the value of the variable where it ends.

In Appendix II:
Charts 1 to 2 relate to Chapter 12; Charts 3 to 12 relate to Chapter 12

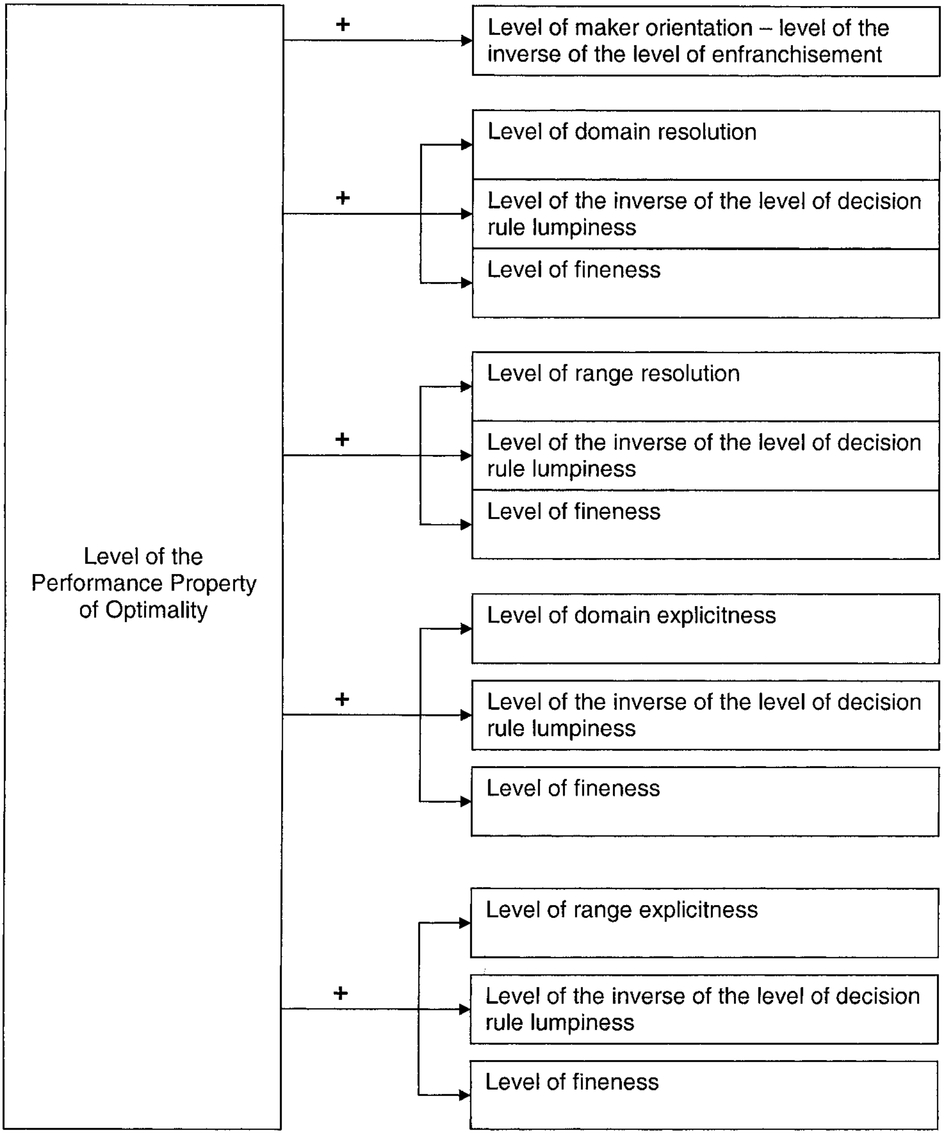
## DESIGN CHART 1

### Structure Performance Property of Coordinatedness and Structure Properties

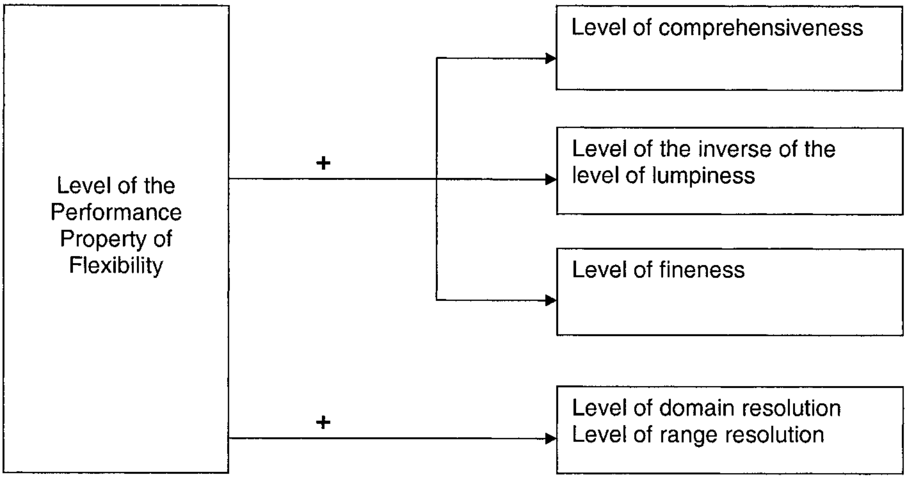


## DESIGN CHART 2

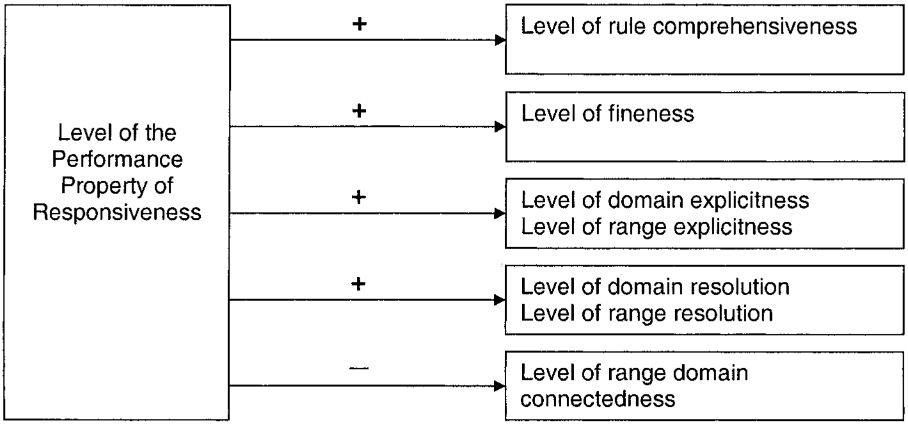
### Structure Performance Property of Optimality and Structure Properties



## DESIGN CHART 3
## Structure Performance Property of Flexibility and Structure Properties

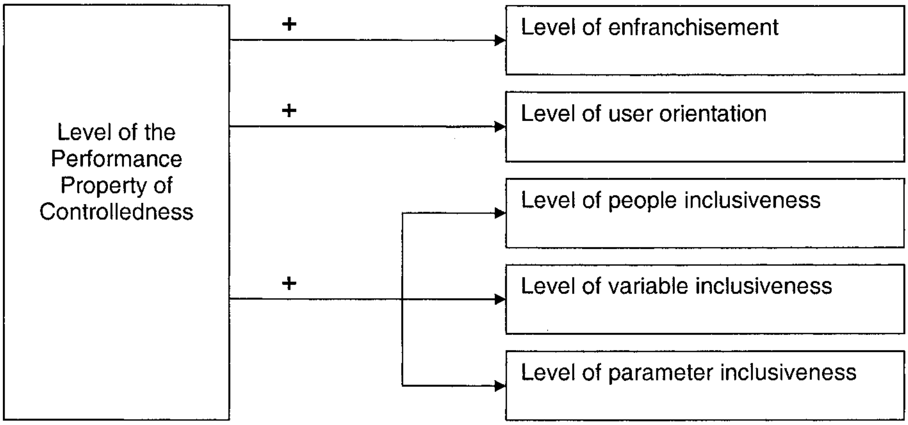


## DESIGN CHART 4
## Structure Performance Property of Responsiveness and Structure Properties



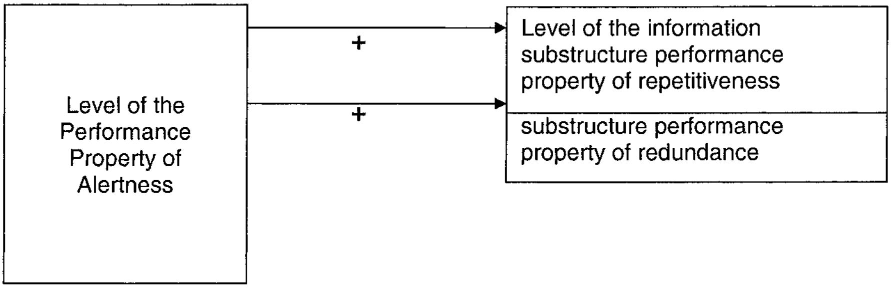
## DESIGN CHART 5

### Structure Performance Property of Controlledness and Structure Properties



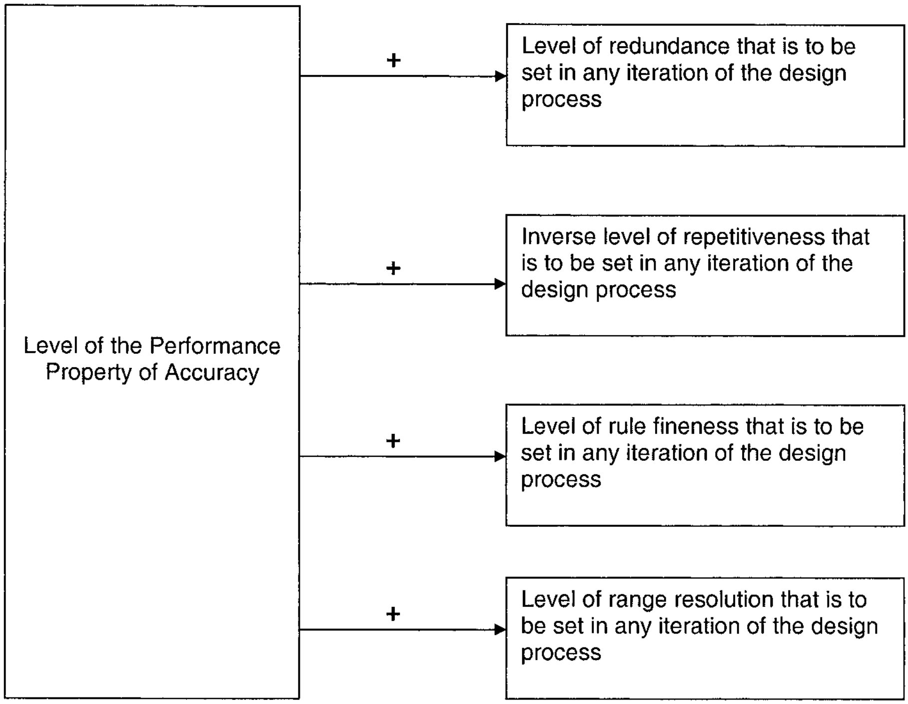
## DESIGN CHART 6

### Information Substructure Alertness Performance Property and the Substructure Properties



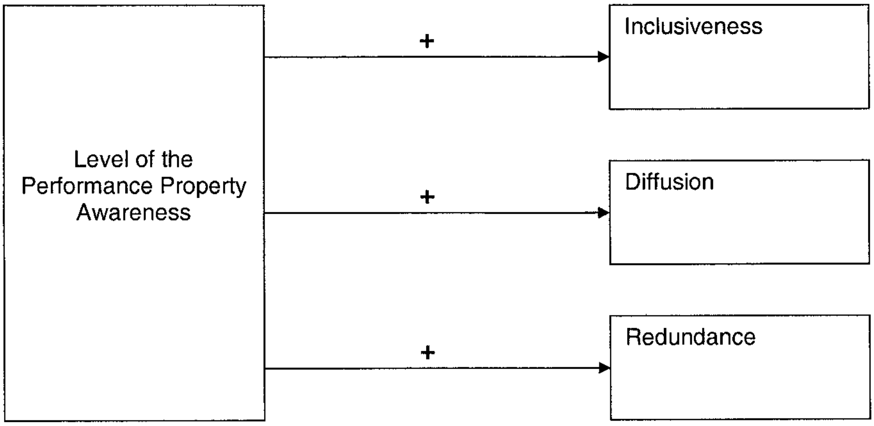
## DESIGN CHART 7

## Information Substructure Accuracy Performance Property and the Substructure Properties



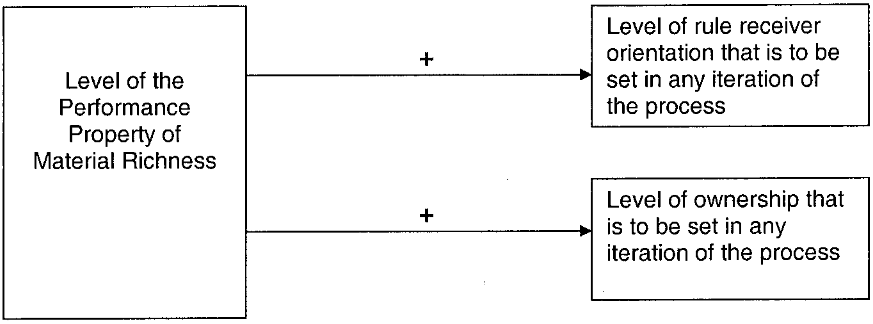
## DESIGN CHART 8

### Information Substructure Awareness Performance Property and the Substructure Properties



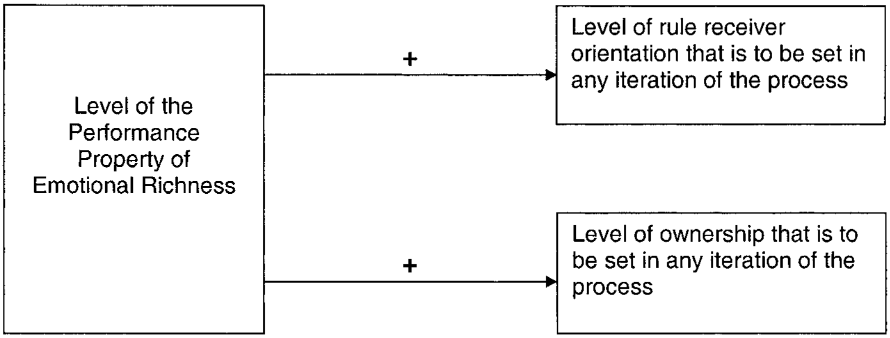
## DESIGN CHART 9

### Reward Substructure Material Richness Performance Property and the Substructure Properties



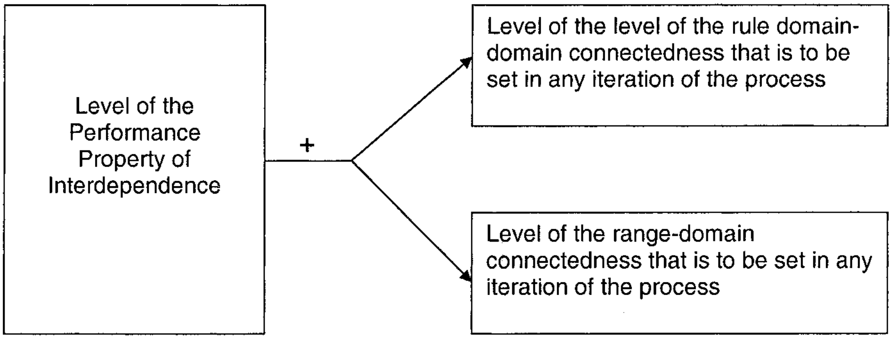
## DESIGN CHART 10

### Reward Substructure Emotional Richness Performance Property and the Substructure Properties



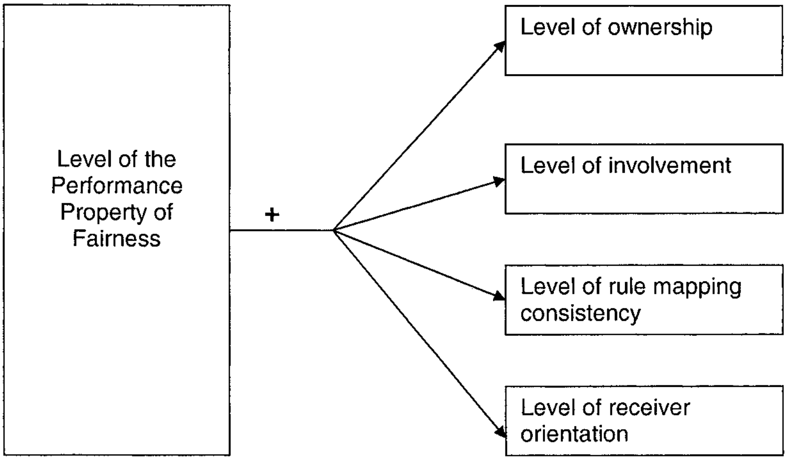
## DESIGN CHART 11

### Reward Substructure Interdependence Performance Property and the Substructure Properties



## DESIGN CHART 12

### Reward Substructure Fairness Performance Property and the Substructure Properties



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