STRUCTURAL THINKING: PRODUCING EFFECTIVE ORGANIZATIONAL CHANGE

for

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Presented by:

Dr. John N. Warfield
George Mason University
and
Ing. Roxana Cárdenas
Instituto Tecnológico y de
Estudios Superiores
de Monterrey

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John N. Warfield
George Mason University
Institute for Advanced Study in the Integrative Sciences (IASIS)[1]
Fairfax, Virginia 22030-4444

A Silver Anniversary Paper
Commemorating 25 Years of Research on Complexity
by the Author

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[1] IASIS is part of The Institute of Public Policy (TIPP)

ABSTRACT

STRUCTURAL THINKING:
PRODUCING EFFECTIVE ORGANIZATONAL CHANGE

For the large organization faced with complexity, only the incorporation of structural thinking into the conceptual work and management of the organization can offer a way to produce effective organizational change.

Structural thinking emphasizes the use of computer-assisted relational thinking to construct relationships among factors involved in complex issues. The relationships may be any of the following types: definitive, comparative, influence, temporal, spatial, or mathematical.

Seventeen Laws of Complexity furnish the necessary information to enable quality control to be applied to structural thinking. These laws provide **focus** on the individual, the group, the organization, and the processes to be applied within the organization. The **functions** emphasized by the Laws are description, diagnosis, prescription and implementation.

Interactions among the Laws of Complexity are described. These interactions help to indicate criteria for structural thinking that are applied to its quality control.

Each of the seventeen Laws of Complexity is described individually in a brief, which provides:

- Name of the Law
- Origins of the Law
- References, if any, which elaborate upon the Law
- Statement of the Law
- Interpretation of the Law

The briefs provide essential background for understanding the significance of quality control of structural thinking, as embodied in the criteria.

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John N. Warfield
George Mason University
Institute for Advanced Study in the Integrative Sciences (IASIS)[2]
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For the large organization faced with complexity, only the incorporation of structural thinking into the management of the organization can offer a way to produce effective organizational change.

Four categories of factors are primarily responsible for bad organizational performance and bad organizational environments. These are: individual attributes, individual attitudes, organizational ambience, and the defective knowledge base that has reached the performers from the educational system.

The undesirable Individual attributes include individual incompetence and ignorance. The undesirable Individual attitudes include hubris, indifference, and intransigence.

Undesirable Individual attributes and attitudes can be corrected with relatively straightforward action in one way or another in and by the organization (although they will not necessarily be corrected on any reasonable time scale).

Organizational ambience includes complexity of issues and organization alike, inadequate linguistic domains in the organization, groupthink, clanthink, and "structural incompetence" (i.e., individual inability to be effective due to overly restrictive and oppressive organizational processes and strictures, rather than personal attributes of the affected individuals).

It is typical that the conditions associated with organizational ambience have been created over long time periods by faulty education and bad practice. Correcting these conditions will require significant time and effort. But they can be corrected by appropriately conceived and implemented structural thinking in the organization.

The Linguistics of Organizational Change. Part of the problem associated with organizational change is bad linguistics in the organization. In working to correct this problem, it is helpful to recognize certain distinctions, shown in Table 1.

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[2] IASIS is part of The Institute of Public Policy (TIPP).

TABLE 1 LINGUISTIC DISTINCTIONS		
ITEM	**SYMBOL**	**DESIGNATION**
Normal Organization	O	Organization
Organization to Change the Organization	O^2	Meta-Organization
Object Language	L	Designed Language
Natural Language, Language to Describe Language	L^2	Meta-language
Normal Thinking	T	Thinking
Thinking About Thinking	T^2	Meta-Thinking
Object Linguistic Domain	D	Linguistic Domain
Linguistic Domain of Meta-Language	D^2	Linguistic Meta-Domain

Table 1 introduces the use of the superscript 2 to designate a "second-order" use of a term from the normal language, and indicates the occasional use of a special symbol to ensure that the necessary distinction is made between the "first-order" usage and the second-order or "meta" usage. With this designation, the task of this paper can be described as operating in the T^2 domain (the traditional domain of philosophers) with the L^2 language, drawing on domain D^2, proposing D and an associated object language L that supports the development of O^2 in O for the purposes of developing structural thinking in O.

The concept of a linguistic domain, introduced by the Chilean cyberneticist Maturana, refers to the aggregate of the components of language that are held in common by any particular group; hence any particular linguistic domain is inevitably tied to a specific group. Moreover the linguistic domain associated with a specific group will change if the membership of the group is changed in any way, and it will change over time provided the group engages in activity that is conducive to expanding its linguistic domain.

Undesigned linguistic domains tend to be most useful when their content is oriented correctly toward the past; and reflects established knowledge and relevant experience.

Undesigned linguistic domains tend to be least useful when their content is mis-oriented by bad education and irrelevant experience, and when the content is oriented toward innovation. Significant innovation inherently involves a related requirement for linguistic innovation,

which means that any group engaged in collaboration toward innovation will have to upgrade its linguistic domain to enable the necessary communication involving novel terminology to take place.

Principal Requirements for Effective Organizational Change. Figure 1 shows the principal requirements for effective organizational change. Effective organizational change requires cultural change. Cultural change requires the construction of a new linguistic domain for the organization. This domain may have various component linguistic domains in various parts of the organization, which need to be linked in order to support effective communication and decision-making in the organization. The explanation of this requirement will be discussed subsequently.

Construction of a new linguistic domain requires the acceptance of the science of semiosis as a basis, because the widely-accepted intuitive bases for upgrading communication involve so many defects that there is no hope of correcting them. The terms of acceptance have been laid out by J. Deely[3]. His arguments reveal not only that semiosis is the proper intellectual basis for communication, but also what is wrong with many components of the prevailing bases. Deely recognizes and sets forth the intellectual debt to J. Poinsot and C. S. Peirce.

Acceptance of semiosis can take place indirectly. There exists a system of management called "Interactive Management"[4] which is based in the acceptance of semiosis. So the organization can choose to accept semiosis indirectly through its acceptance of the practice of Interactive Management. What it cannot afford to do is to continue to accept directly or indirectly whatever other basis it has been operating under, and still expect to change to an effective organization.

All of the changes mentioned require structural thinking. Structural thinking then becomes the key aspect to be illuminated as the way to produce effective organi- zational change. This task will occupy the rest of the paper.

Structural thinking, in its most elaborately researched form, is responsive to the requirement that contextual implication of linguistic components be elaborated in detail, in order to uncover defective suppositions (consciously held and stipulable) and presuppositions (unconsciously held and not articulated); and to the requirements that

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[3] John Deely, Basics of Semiotics, Bloomington, IN: Indiana University Press, 1990.

[4] J. N. Warfield and Roxana Cárdenas, A Handbook of Interactive Management, Fairfax, Virginia: IASIS, 1993.

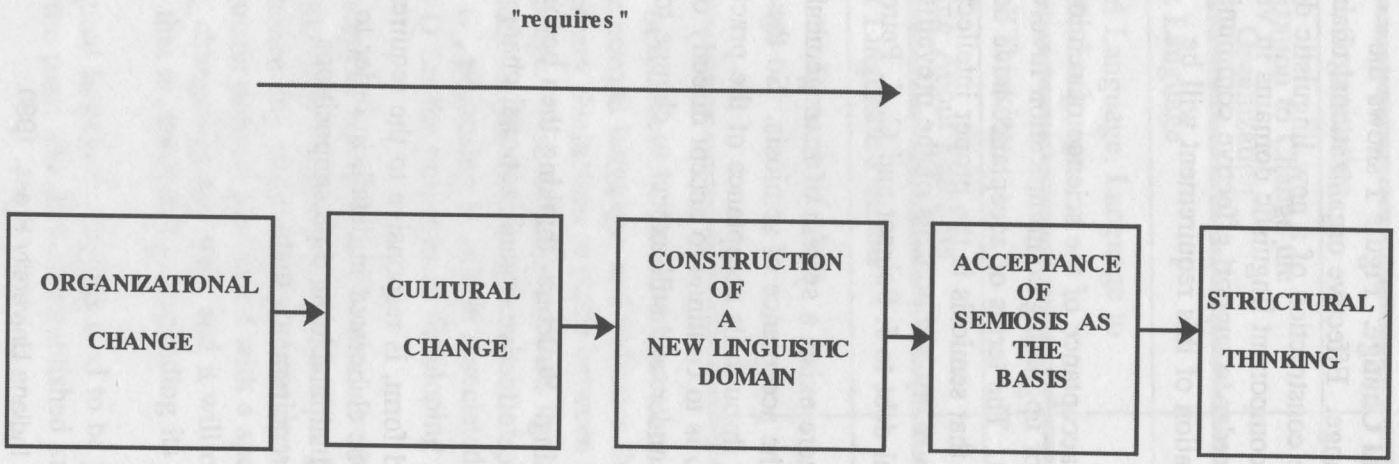

FIGURE 1. Chain of requirements for effective organizational change Warfield, 1994.

displayed products of structural thinking lend themselves to referential transparency; that the structural thinking be marked by thinking in articulated sets and articulated relationships, patterns, and systems; and that the processes applied in structural thinking shall be open at scale (i.e., not limited to some predetermined scope or dimensionality.) **These and other evaluation criteria relate to the Laws of Complexity, discovered during a twenty-five year period of research on complexity.**

Structural thinking, **by definition,** integrates the following attributes:

- It generates sets by generating and clarifying members of the sets
- It focuses upon selected, particular relationships as the basis for organizing information concerning the generated sets
- It explores the relationships among the members of the generated sets in great detail
- It produces logically consistent relationships among the members of the generated sets
- It specifies the structural features of the relationships in generic terms that enable effective interpretations to be developed
- It allows comparisons of relative complexity to be made among relationships
- It foregoes exclusive use of prose as the means of representing structural features of the relationships, instead producing designed types of visual patterns for interpretation
- It uses computer assistance in developing, organizing, and representing the relationships
- It is indifferent to the scale of the topic being considered, because the methods used in structural thinking are open at scale
- It is a self-documenting process
- It incorporates what is known about formal logic

Structural Thinking Stresses Relational Thinking. The term "structure" in the phrase "structural thinking" refers to the relational patterns that are involved among members of a set or system. Structural thinking stresses relational thinking as its primary distinguishing attribute.

For this reason it is important to possess a systematic understanding of relationships. Table 2 shows the six main types of relationships and provides examples of each type.

Definitive Relationships. Definitive relationships are those which express arbitrary distinctions that have a linguistic basis in logic. For example, if we say that something "is included in" something else, there is a distinct contextual implication involved. For whatever reason, the "container" that holds the "content item" has been designated as a category that encompasses lesser concepts.

A relationship such as "is included in" illustrates a basic logical attribute known as "transitivity". "Is included in" is a transitive relationship. The property of transitivity, with respect to that relationship means that if (a) A is included in B and (b) B is included in C, then, by virtue of the property of transitivity, (c) A is included in C.

TABLE 2. TYPES OF RELATIONSHIPS AND EXAMPLES OF EACH TYPE

DEFINITIVE	COMPARATIVE	INFLUENCE	TEMPORAL	SPATIAL	MATHEMATICAL
Includes	Is greater than	Causes	Must precede	Lies east of	Is a function of
Is Included in	Is heavier than	Affects	Must follow	Lies west of	Affects the likelihood of
Implies	Is preferred to	Aggravates	Precedes	Lies to the right of	Can be computed from
Is a member of	Is of higher priority than	Enhances	Precedes or coincides with	Lies to the left of	Is computable from
Covers	Is of equal or higher priority than	Supports	Requires more time than	Lies above	Is disjoint with
Is a partition of	Is more useful than	Confirms	Overlaps in time with	Lies below	Has a non-zero intersection with
Is necessary for	Is more important than	Weakens	Is disjoint in time with	Has a component that lies to the left of	Equals
Is sufficient for	Is more critical than	Strengthens		Crosses in a plane	Is greater than
Is in the same category as	Requires more space than	Is dependent on			Is less than
Is assigned to		Modifies			Is greater than or equal to
Is associated with		Is a partial cause of			Is congruent with
Is reachable from					Is a cover of
Is isomorphic with					Is a partition of
					Is a greatest lower bound for

Since transitivity of the inclusion relationship is important to our understanding of the material world, to define a relationship as one exhibiting what we normally observe as inclusion but which does not have the property of transitivity would be to produce a disorientation in the mind. Transitivity is necessary to the choice of terminology to express inclusion. Definition is not, therefore, completely arbitrary. However because the definitive relationships are defining in character, they can be more arbitrary than some of the other types of relationships.

Comparative Relationships. Comparative relationships are those in which one concept is compared to some other concept, based on some expressed attribute. The attribute incorporated in a simple comparative relationship involving two items to be compared need not be numerical or even measurable. The only requirement is that it be acceptable to the individual who will make the comparison, based on whatever reasoning the individual chooses to exercise.

But once again, if there are more than two items, comparisons are constrained. For example, if some concept A is said to be of higher priority than B, and if B is said to be of higher priority than C, the requirements contained in Western logic indicate that necessarily A shall be of higher priority than C; and the individual who furnishes the first two judgments is not permitted to make an arbitrary third judgment.

Comparative relationships are also transitive.

Influence Relationships. The tendency for physical scientists to focus upon causal relationships sometimes obscures the more general type of relationship called an "influence" relationship. If A causes B, then A influences B in some way. However A can influence B without being a cause of B.

Influence relationships are normally transitive relationships as well. If there is some reason to believe that some specific influence relationship is not transitive, careful consideration should be given to whether such a relationship even belongs in the category of influence relationships.

Temporal Relationships. Temporal relationships are those involving time, and may have to do with e. g., whether some event occurs earlier than another one. On the other hand, some objects of study take place throughout a certain time period. If A is an activity that takes place during the period from 8 AM to 11 AM, and if B is an activity that takes place during the period from 10 AM to 12 Noon, then one can assert correctly that A overlaps in time with B. It is possible that a third activity C might take place between 11:30 AM and Noon. With the conditions stated, A overlaps in time with B, and B overlaps in time with C. However A does not overlap in time with C. Thus the relationship "overlaps in time with" lacks the general property of being transitive.

On the other hand, events that take place at particular instants can be envisaged as either coinciding or not coinciding, and the concept "overlap" is not applicable except in a trivial sense. Temporal relationships involving events are inherently transitive, while temporal relationships involving activities are not inherently transitive. This explains why we can maintain time orientation in our daily lives, in terms of time instants, rather than time intervals.

Spatial Relationships. Spatial relationships are those involving positions in space. They are those relationships that enable us to interpret and convey physical orientation. The transitivity of these relationships is the attribute that makes the physical world appear to us to be ordered, enables us to construct and use geographical maps as a basis for travel, and permits us to navigate with confidence in a spatially-transitive universe.

Mathematical Relationships. Mathematical relationships are those relationships that can be expressed in the language of some branch of mathematics, such as algebra or calculus. Some of them are transitive (e.g., "greater than") and some of them are not (e.g., "is twice as large as").

Definition by Relation. Among the means of defining, definition by relation is the most powerful and the most useful. To define by relation requires that whatever is to be defined be described in terms of its distinguishable components, and that the family of relationships involving those components be developed through structural thinking. This family, when developed, then comprises the definition by relation of whatever was to be defined. Other methods of definition constitute special cases in which only a part of the distinguishable components are incorporated or only a part of the family of relationships is developed.

The Laws of Complexity. The Laws of Complexity furnish the necessary information for quality control, i.e., the criteria, for structural thinking. There are seventeen of these Laws presently identified. To understand how to apply these laws in governing structural thinking, it is valuable to understand the following:

- How the Laws are focused with respect to complexity
- What functions the Laws serve with respect to complexity
- How the Laws are interrelated, in the sense of how some Laws help illuminate other Laws

Table 3 presents a matrix showing how the laws are focused, and the functions that they serve. The Laws identified by title in Table 3 are individually discussed in separate "Briefs" in Appendix A.

FOCUS →→→→→ FUNCTION ↓↓↓↓↓	INDIVIDUAL	GROUP	ORGANIZATION	PROCESS
DESCRIPTION	■ Limits ■ Triadic Compatibility	■ Limits ■ Uncorrelated Extremes	■ Limits ■ Organizational Linguistics	■ Limits ■ Triadic Necessity and Sufficiency ■ Universal Priors
DIAGNOSIS		■ Inherent Conflict ■ Structural Under-Conceptualization ■ Diverse Beliefs	■ Forced Substitution ■ Precluded Resolution	■ Success & Failure ■ Universal Priors
PRESCRIPTION	■ Requisite Parsimony ■ Requisite Saliency	■ Requisite Variety		
IMPLEMENTATION				■ Gradation ■ Validation

TABLE 3. LAWS OF COMPLEXITY, STRUCTURED VERTICALLY BY FUNCTION AND HORIZONTALLY BY FOCUS

Focus for the Laws of Complexity. As Table 3 indicates, the Laws of Complexity are organized by four focal topics: the individual, the group, the organization, and process. Functions are organized by four areas of activity: description, diagnosis, prescription, and implementation.

Focus on the Individual. The individual is the unit of membership for groups and organizations. Ultimately all group and organizational behavior rests with the individual. The individual is not sufficient as a unit of analysis because the individual is constrained in two significant ways: first by constraints inherent in being human, which limit the individual's capability to process information; and second by constraints imposed by organizations which typically manifest themselves as well in behavior in groups. Focus on the individual emphasizes the information constraint inherent in being human, and draws attention to the existence of limits on the individual. This focus on constraints relates to (a) the individual's ability to produce high-quality descriptions of complex issues, where the individual may strive to describe or define existing or contemplated systems; and (b)the individual in a learning mode, where the individual may strive to attain a higher level of insight into complex systems.

In all focal areas, there is sought a balance between Laws that are descriptive of the focal areas and Laws that prescribe ways of overcoming difficulties associated with the focal areas.

For the individual, two Laws give prescriptions for mitigating the effects of human limitations.

Focus on the Group. Whether seen from a historical point of view or in terms of future developments, organizations derive much of their value from work in groups. Focus on the group deals in a descriptive and diagnostic way with the aggregate behavior of individuals when they perform in groups. Five of the Laws of Complexity reflect descriptive and diagnostic aspects of groups.

The single prescriptive Law that focuses on the group is the Law of Requisite Variety. Recognized by systems researchers as possibly the single most significant discovery in the study of complex systems this Law, as applied in the system of Interactive Management, is often sufficient to overcome the impact of the other Laws that reflect problems in working in groups.

Focus on the Organization. Focus on the organization is gained through four Laws of Complexity that are either descriptive or diagnostic of organizations. No Law relates directly to prescription or implementation in the organization. Instead ameliorative measures that can be taken at the organizational level will apply to groups and individuals as the two key sources of high-quality organizational performance.

Focus on Process. Organizational processes are essentially all-determining in terms of their impact on organizational behavior of individuals and groups. The installation of processes in organizations that enable the organization to redesign itself as needed and to design those strategies and actions that resolve organizational difficulties offers the means of making structural thinking possible in organizations.

Five of the Laws of Complexity shed insight into the description and diagnosis of theories and processes in organizations, and two of the Laws relate to implementation within the organization.

Interactions Among the Laws of Complexity. Descriptions of the Laws of Complexity appear in individual Briefs in Appendix A.

While it is possible and desirable to study the Laws through the individual Briefs, an adequate understanding of the Laws requires a study of the interactions among them. The interactions are especially useful in interpreting the Laws of Complexity. Figure 2 shows interactions among the Laws as portrayed through the relationship "helps explain".

To read Figure 2, one notes that for any Law lying to the left of a second Law and connecting to that second Law by means of a directed path, the Law lying to the left is judged to be helpful in explaining the second Law.

It is also necessary to note that if two or more Laws appear in the same enclosure, those Laws are mutually helpful in interpreting each other.

The following statements are examples of what can be read from Figure 2:

- The Laws of Triadic Compatability and Requisite Parsimony are helpful in understanding (a) each other and (b) 13 of the other 17 Laws
- The Law of Triadic Necessity and Sufficiency is not useful in helping to explain any of the other Laws, nor are any of the other Laws helpful in explaining it. [Nevertheless this Law, when combined with some others, is helpful in explaining other aspects that are important in structural thinking.]
- The Laws of Forced Substitution and Precluded Resolution are helpful in understanding (a) each other and (b) none of the other Laws; but 14 of the other Laws are helpful in understanding this pair
- One of the several cycles contains five Laws [Inherent Conflict, Limits, Requisite Saliency, Success and Failure, and Uncorrelated Extremes], which are mutually helpful in understanding each other

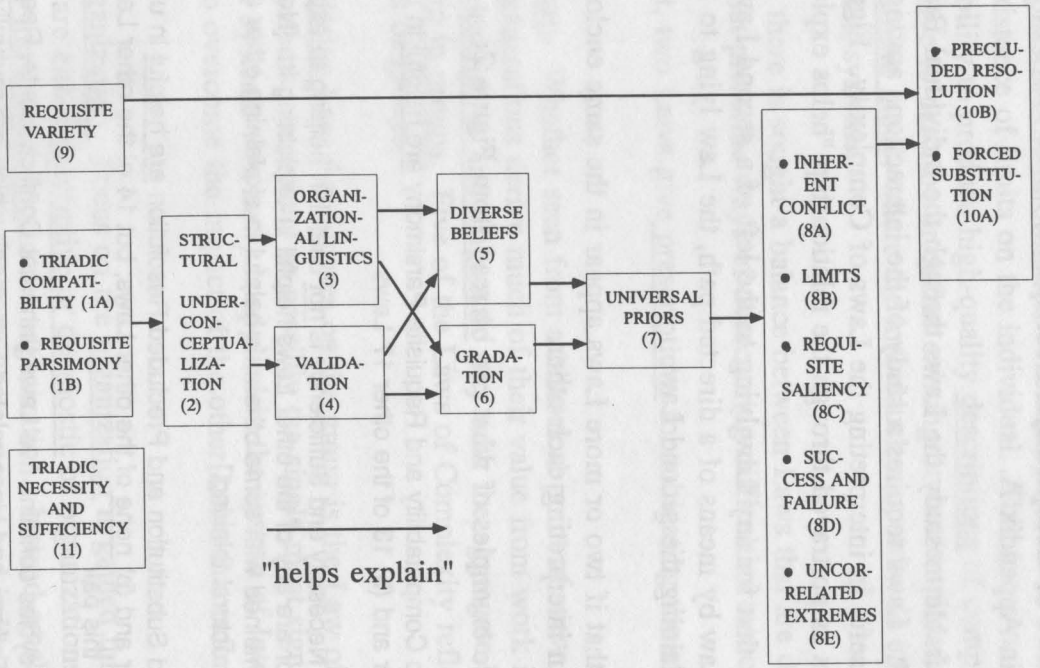

FIGURE 2. Interactions in Interpreting Laws of Complexity. If a Law appears on the left of and connects to a Law to its right, then an understanding of the Law on the left is helpful in developing an understanding of the Law on the right. Laws that appear in the same box (with bullets in front of each Law in the box) are helpful in understanding all of the other Laws in the same box (they are in a "cycle").

An appropriate study sequence is indicated by the index numbers and letters (e.g., begin with 1A, continue with 1B, then 2, etc.)

Laws of Complexity are Origins for Criteria for Structural Thinking.
Most of the criteria for structural thinking originate with the Laws of Complexity described by the Briefs in Appendix A, and their interactions represented in Figure 2. A few of the criteria reflect the necessities emphasized in Figure 1 (which are either addressed directly by the Laws of Complexity or which were taken into account in the development of those Laws.)

The reader who has come to this point will benefit by studying carefully the Briefs in Appendix A and the interactions represented in Figure 2 before proceeding.

The fourteen criteria that are presented are broken into several Parts for ease of presentation.

Part I. Table 4A shows three criteria for structural thinking. The primary factors that are controlled by these criteria are the quality of individual thought processes and the need for documentation to reflect overt development of the appropriate organizational linguistic domains.

Part II. Table 4B shows three more criteria for structural thinking. The primary factors that are controlled by these criteria are the immediate working environment where structural thinking is best carried out, the types of structural patterns produced by structural thinking, and process management to enhance the quality of the products of structural thought.

Part III. Table 4C shows two more criteria for structural thinking. These factors are intended to eliminate the organizational strictures that handicap effective behavior and to promote the development, the quality and the utility of organizational linguistics.

Part IV. Table 4D shows four more criteria. The factors involved here are the frame of mind and insights with which the criteria are applied, and the way in which the computer is used.

Part V. Finally, a single multi-dimensional criterion is set forth in Table 4E. The factors involved here can be used as a check list to help detect oversights or misuse of the criteria.

TABLE 4A
CRITERIA FOR STRUCTURAL THINKING
(CONTEXT: IN AN ORGANIZATION)
PART I

(1) Individual thought processes consciously reflect the message contained in the *Law of Triadic Compatibility*.

(2) The thought production process reflects the messages contained in the Laws of *Requisite Saliency* and *Requisite Parsimony*.

(3) The requirement for a pervasive, integrated, linguistic domain, organized to correlate with organizational structure is reflected in organizational production and documentation processes.

TABLE 4B
CRITERIA FOR STRUCTURAL THINKING
(CONTEXT: IN AN ORGANIZATION)

PART II

(4) The thought production working environment reflects the messages contained in the Laws of (a) *Diverse Belief* and (b) *Inherent Conflict* (4).

(5) All new thought production including creative production is disciplined by the message contained in the Law of *Requisite Variety* (5).

(6) All thought production formats reflect the message contained in the Law of *Structural Underconceptualization* (6).

TABLE 4C
CRITERIA FOR STRUCTURAL THINKING
(CONTEXT: IN AN ORGANIZATION)

PART III

(7) The organizational distribution of authority reflects an organizational intent to avoid the imposition of *structural incompetence* upon individuals, in order to enable the use of the products of structural thinking, and to enhance organizational morale and effectiveness.

(8) The linguistic domain produced by collective structural thinking is organized to reflect insights of the Law of *Gradation* and the Law of *Organizational Linguistics* for the purpose of maximizing linguistic coherence and effectiveness.

TABLE 4D
CRITERIA FOR STRUCTURAL THINKING
(CONTEXT: IN AN ORGANIZATION)

PART IV

(10) When making decisions concerning the applicability of these Criteria, the interactions among the *Laws of Complexity* are taken into account explicitly, and the means for honoring them are documented as part of the organization's decision-making process.

(11) Actors who apply these criteria have "semiotic consciousness", i.e., they are explicitly aware of the role of the sign as that role is played in a given respect [Deely].

(12) Actors who apply these criteria shall be aware of the Peircean Reduction Thesis [Burch].

(13) The necessary role of computer assistance in enhancing the efficiency, effectiveness, and accuracy in producing structural thinking; and in the portrayal and readability of representations of structural thinking is understood.

TABLE 4E
CRITERIA FOR STRUCTURAL THINKING
(CONTEXT: IN AN ORGANIZATION)

PART V

(14) The applier of these criteria to discipline structural thinking is aware of negative consequences of <u>not</u> applying or <u>misapplying</u> structural thinking:

- Structural Underconceptualization
- Diverse Belief and Inherent Conflict in the Organization
- Structural Incompetence in the Organization
- False Expectations of Success
- Ad hoc, Uncommunicable Utterances
- Ineffectiveness
- Unnecessary Stress
- Prevalence of Clanthink and Groupthink in the Organization
- Forced Substitution in Design and Decision-making
- Precluded Resolution of Situations
- Use of Computers in Ways that Violate Laws of Complexity

---and uses this awareness to sustain structural thinking.

Briefs of Seventeen Laws of Complexity. Appendix A to this paper presents Briefs of seventeen Laws of Complexity. Each of the briefs has the same format. Each of them deals with a single Law. Each gives the name of the Law and its origins. If references are available that provide significant additional detail, those references are listed. A statement of the Law is given. Then an interpretation of the law is provided.

The Briefs are assigned numbers according to the pattern of interaction given in Figure 2, so the reader can correlate the Briefs with the pattern shown there, as a way to help assimilate the interactions among the Laws and thereby to gain a better interpretation of them than can be given by simply viewing each Law separately.

Summary. In summary, only by incorporating structural thinking into large organizations faced with complexity can effective organizational change be produced on any significant scale.

The uniqueness of structural thinking in this context lies in the fact that it is **the** means of identifying and interpreting the patterns of interdependence among aspects of the organizational situation that must be understood in order to institute effective remedies.

Beyond that attribute, structural thinking embodies the best of philosophical development extending over more than 25 centuries; and it can be carried out in an organization using Interactive Management, a well-documented and carefully tested system of management invented specifically to deal with complexity in organizations.

The study of complexity has produced 17 Laws of Complexity which focus on organizational components and processes for producing high-quality descriptions, diagnoses, prescriptions, and implementation. Each Law is described in a Brief, and interactions among the Laws are clarified.

In order to help assure that structural thinking is not misinterpreted or misapplied, fourteen criteria have been developed to use as a way to assess and control the quality of its application. These criteria reflect the Laws of Complexity, as well as the science underlying the Laws.

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APPENDIX A

BRIEFS

LAWS OF COMPLEXITY

August, 1993

CONTENTS

LAWS OF COMPLEXITY

BRIEF 1A

NAME OF LAW:

Triadic Compatibility

ORIGIN(S) OF LAW:

Empirical, (Miller, Simon); Mathematical [Lattice Theory], (Warfield)

REFERENCES:

G. A. Miller (1956), "The Magical Number Seven, Plus or Minus Two: Some Limitations on Our Capacity for Processing Information", Psychology Review 63(2), 81-97.

H. A. Simon (1974), "How Big is a Chunk?", Science 183, 482-488.

J. N. Warfield (1988), "The Magical Number Three--Plus or Minus Zero", Cybernetics and Systems 19, 339-358.

STATEMENT OF LAW:

■ **The human mind is compatible with the demand to explore interactions among a set of three elements, because it can recall and operate with seven concepts, these being the three elements and their four combinations; but capacity cannot be presumed for a set that both has four members and for which those members interact.**

INTERPRETATION OF LAW:

This Law expresses both a human limitation and a human capability.

The limitation suggests that human beings cannot process interrelationships among sets of factors, issues, objects, or ideas in general, if more than three components are involved. The reason set forth is that the mind is incapable of recalling into its short-term memory more than about seven items. A way to show respect for this limitation is to determine that whenever decisions are to be made that can benefit from awareness of interactions, it will be advisable to choose and apply a strategy that recognizes the impact of this limitation.

This limitation should also persuade individuals that intuitive decision-making, done without careful analysis, is likely to produce bad decisions and bad outcomes.

The capability that allows us to process interrelationships among three factors, issues, objects, or ideas should encourage us to begin to develop a facility for working with sets of three items. More specifically, it would be advisable to build up a repertoire of sets of three items that are representative of decision-making situations, and develop skill at working with these sets. Simon's "chunking" can consist of integrating patterns.

It might be well to remember that many situations in life have been approached as though there were a dichotomy involved. Instead of allowing our thinking to be limited to dichotomies, we should be encouraged to move to trichotomies as a way of becoming more flexible in thought and action, wherever appropriate.

We may also be persuaded that documentation is much more valuable than might be thought, especially if the documentation takes the form of representing systems of interactions involving more than three interacting members.

When we have developed patterns of interrelationships as documentation, we may work to develop the skill of reviewing and amending such patterns. Moreover, we may begin to see merit in group development of interrelationship patterns, since there is little in the capability to work with three items that suggests an overwhelming power of a single individual to construct patterns of interrelationship that are representative of actual conditions or systems, or of contemplated conditions or systems.

The limitation to interactions among three items suggests a very serious limitation on creative ability as might be reflected in design of complex systems. Ad hoc designs, arrived at in ordinary conversational modes (as, for example, in governmental bodies or committees) might be looked upon as unlikely to be of high quality, and likely to produce bad outcomes.

LAWS OF COMPLEXITY

BRIEF 1B

NAME OF LAW:

Requisite Parsimony

ORIGIN(S) OF LAW:

This law is based on the dynamics of interpreting and learning implied by the Law of Triadic Compatibility. The Law is prescriptive, with the aim of allowing enough time for sequentially-presented information to be interpreted in terms of the interactions, and to allow enough listening time to help ensure that the information is remembered.

REFERENCES:

None

STATEMENT OF LAW:

■ **Every individual's short-term brain activity lends itself to dealing simultaneously with approximately seven items (a number that is reached with three basic items and four of their joint interactions) [see the Law of Triadic Compatibility]. Attempts to go beyond this scope of reasoning are met with physiological and psychological Limits that preclude sound reasoning. For a given designer, there is some number K_d that is characteristic of that designer which typically is chosen from the set {5,6,7,8,9} that represents the Limit of that designer's short-term idea-processing capability. If a design methodology requires a designer to cope intellectually at any one time with some number of concepts K_c, then**

i) If $K_c < K_d$, the designer is <u>underburdened</u>, being uninfluenced by the Law of Requisite Parsimony, since the designer is operating in a Situation that exhibits the Requisite Parsimony, through regulation of the rate of flow of information to the

designer as the designer engages in the design process

ii) If $K_c = K_d$, the designer is <u>operating at the Limit</u> of reasoning capability

iii) If $K_c > K_d$, the designer is <u>overburdened</u> and no reliance can be placed on the designer's decisions.

INTERPRETATION OF LAW:

If the Law is not violated, it has no impact. If it is violated, it can be confidently predicted that the design Target (i.e., whatever description or product the individual or group seeks to achieve) will embody bad outcomes that are beyond the control of the designer, because the design process did not exhibit the Requisite Parsimony, but instead allowed the rate of flow of information to the designer to exceed processing capacity.

It may be questioned why designs have succeeded in the past without overt adherence to this requirement. Design Targets vary significantly in their scope. If the Law of Requisite Parsimony is being unknowingly violated, one would expect that the impact would be revealed in the failure of large system designs. This is precisely what is being observed all around the world.

Those who deny the validity of and those who doubt this Law must accept the burden of providing other explanations for failures. The often-rendered explanation "operator error" may often, itself, reflect the same fundamental cause to which this Law responds in terms of the design process.

LAWS OF COMPLEXITY

BRIEF 2

NAME OF LAW:

Structural Underconceptualization

ORIGIN(S) OF LAW:

Empirical, Mathematical logic

REFERENCES:

J. N. Warfield (1979) "Some Principles of Knowledge Organization", IEEE Transactions on Systems, Man, and Cybernetics, June, 317-325.

J. N. Warfield (1991) "Underconceptualization", in Mutual Uses of Cybernetics and Science, Special issue of Systemica: Journal of the Dutch Systems Group (R. Glanville and G. de Zeeuw, Eds.), Amsterdam: Thesis Publishers, 415-433.

J. N. Warfield (1990) A Science of Generic Design: Managing Complexity Through Systems Design, Salinas, CA: Intersystems, 1990 (two volume set). See pages 427-428, showing structural types, and pages 489-498 showing empirical data.

STATEMENT OF LAW:

■ **No matter what the complex issue, and no matter what the group involved in its study, the outcomes of ordinary group process (i.e., process in which computer support for developing the formal logical structure of the issue is lacking) will be structurally underconceptualized (as evidenced, for example, by the lack of delineation of the cycles and of any structural connections among them).**

INTERPRETATION OF LAW:

A proper interpretation of this Law requires an understanding of the fundamental nature of structure. The term "structure" is widely used by economists in a very loose way, virtually as a semi-metaphor. This widely-practiced usage simply serves to put a veneer on top of what can be very precisely defined. A proper interpretation of structure refers to how individual substantive components of information or knowledge are related.

To understand the foundations of relationships, one needs to know something about the history of the development of what is called "the theory of relations" or "the logic of relatives". The most foundational work done in this area was carried out by a British professor, Augustus DeMorgan, who published his treatise in the year 1847. Listen to how his work was described (sometime around the year 1867) by America's greatest philosopher, Charles Sanders Peirce:

> **"a brilliant and astonishing illumination of every corner and every vista of logic"**

But the direct and clear connection of DeMorgan's work to the structure of information or knowledge did not become precise until the publication of a book by Professor Frank Harary and two junior colleagues at the University of Michigan in 1965 [Frank Harary, R. F. Norman, and D. Cartwright, *Structural Models: An Introduction to the Theory of Directed Graphs*; New York, Wiley].

In this book, Harary showed that any given relation corresponded directly to a particular graphical structure; and that every relation corresponded to some form of directed graph ("digraph").

Taking that information, Warfield showed in his 1976 book [*Societal Systems: Planning, Policy, and Complexity,* New York: Wiley] that the most general form of digraph representing a relation exhibited several attributes:

- A hybrid structure
- Exactly two distinctive prototypical substructural types in a hybrid structure identifiable as either (a) hierarchy or (b) cycle
- A numerical measure of the length of any hierarchical substructure
- A numerical measure of the length of any cycle substructure
- A numerical measure of the "width" of a hierarchy, giving a numerical meaning to "linear structure" as a hierarchy of width 1; and giving a numerical interpretation to the idea "breadth of relationship"

In that same work, Warfield presented a variety of algorithms for developing such structures with computer assistance, providing a methodology that allowed the structures of complex issues to be created by groups of knowledgable people and, thereby, opening the way for the structure of knowledge to take its rightful place among the analytical and synthetic tools available to people to analyze complex issues or systems and to design such complex systems in a way that would make clear how the designs relate to the issues themselves, thereby eliminating the need for vagueness in the design of such systems as health care systems or systems for dealing with other public policy matters; as well as providing a similar benefit in the design of physical systems such as automobiles. Later analysis of software systems produced a numerical measure of the structural complexity of a relationship, based upon the structural features ot the hybrid structure.

But in spite of these developments and the broad-ranging nature of the benefits that could be attained by taking advantage of them, only a relatively small number of people have learned about this area and have begun to take advantage of what is known.

In the laboratory work done by Warfield and his colleagues, a considerable amount of data were taken based on work done by numerous groups with a variety of complex issues. These data showed typical attributes of the structures developed. It was found that over 97% of all structures were hybrid structures (i.e., they contained at least one cycle).

The most evident proof of structural underconceptualization in dealing with complex issues and complex systems is the failure even to identify the cycles that are present in the structures. A lesser evidential point is that frequently the hierarchical substructures are not identified. And finally the set of hybrid structures required to show the underlying structure of information is virtually never constructed.

Hence the wide-ranging scope of the Law of Structural Underconceptualization. But it must be realized that structural underconceptualization always implies underconceptualization. The situation is as though a human body were presented without any skeleton. We would see a limp corpse with no definition of human shape. It is only the structural feature of the body that allows it to be erect or elongated, and provides the basis for its overall appearance.

How frightening can it be that in virtually every major public issue or virtually every large system design seen in our society, the structural descriptions are not even comprehended, and not made available for view and interpretation!

How disappointing and how demoralizing can it be that the latter is not being done, even though it is perfectly feasible to do it, to do it efficiently, and to do it in a responsible, high-quality way!

LAWS OF COMPLEXITY

BRIEF 3

NAME OF LAW:

Organizational Linguistics

ORIGIN(S) OF LAW:

Empirical

REFERENCES:

None

STATEMENT OF LAW:

■ **As an organization grows, linguistic separation grows both laterally and vertically in the organization. At the higher vertical levels, metaphors and categories become progressively disconnected from the relevant components at lower levels, leading to decisions based on perceived relations between categories that are not borne out by relations between category members.**

INTERPRETATION OF LAW:

Imagine that a group of people is formed by selecting several individuals from the human race at random. Then suppose that exhaustive information is obtained that will reveal what language components are shared by every single member of that group. It may be that one of the members came from a remote tribe in Australia, and another came from a similarly remote trip in the mountains of Peru. It may be that there is virtually no language component that is shared by the group.

The term "linguistic domain" was applied by the Chilean scientist Maturana to describe the language commonality among a group of people.

It is easy to see that if a certain group effectively defines their linguistic domain, the extent of that domain can only shrink as new members become attached to the group, unless some specific actions are taken to enlarge the linguistic domain. Enlargement would require that every single member of the group take on the addition, whatever it might be, in order that an enlarged linguistic domain could be said to exist.

Now imagine a large organization which is hierarchically organized so that conversations mostly occur within rather than across organizational layers. Now each one of these layers corresponds to a certain linguistic domain that holds within that layer. Yet as human turnover occurs in a layer the linguistic domain of that layer changes.

The maintenance of a linguistic domain relies on (a) usage of the existing domain to keep it at the forefront of each individual's usable language; and (b) upgrading of the domain every time a new member enters to prevent its deterioration.

Since big organizations do virtually nothing to maintain even a single linguistic domain, it is inevitable that over time people will only be able to talk to one another knowingly in a given layer and then, only in the fractional terms that remain after the natural progressive deterioration that goes on in these domains.

But deterioration of linguistic domains is often less affected by change in the human makeup of the relevant groups than it is by changing technology. In many industries, technological change causes significant demands to be made to incorporate new terminology in a linguistic domain, and yet the technological terminology is often so poorly defined or so foreign that assimilation of it into a given domain can only be done if the organization pays the price. The price that has to be paid is that time of the affected individuals must be dedicated to human interaction aimed at renewing and strengthening the linguistic domain.

But even if linguistic domains are strengthened in a few layers of a large organization, still another phenomenon becomes critical. What is being talked about in the lower levels of the organization are often highly detailed subjects, these subjects never being discussed at that level of detail in the higher levels of the organization. If there is going to be a linguistic connection between levels, one must recognize that the metaphors and categories (the high-level organizational language) have to have a strong correlation to the detailed information (the low-level organizational language), and that this correlation has to be sustained and renewed constantly in order to preserve meaningful communication across organizational boundaries.

Empirical observation of groups who work at different levels in organizations has shown that the relationships that high-level people construct and apply among metaphors and categories simply do not correlate with the lower-level ideas that high-

level people take for granted are included within those metaphors and categories.

The result is that the decisions and actions taken at high levels in organizations often amaze the operating levels because they make so little sense and vice versa. The reason for the lack of sensibility is that both levels are operating in what might be called incongruous linguistic domains.

Until organizations understand the necessity for maintenance, renewal and cross-organizational development of linguistic domains, those ever-present trends that work against effective communication will continue to bear the responsibility for what appears to the external observer as organizational incompetence.

LAWS OF COMPLEXITY

BRIEF 4

NAME OF LAW:

Validation

ORIGIN(S) OF LAW:

Philosophy of science, as originated by Charles Sanders Peirce.

REFERENCES:

Thomas A. Goudge (1969) The Thought of C. S. Peirce, New York: Dover.

Patricia S. Churchland (1986) Neurophilosophy: Toward a Unified Science of the Mind-Brain, Cambridge: MIT Press.

J. N. Warfield (1990) A Science of Generic Design: Managing Complexity Through Systems Design, Salinas, CA: Intersystems, (two volume set). See page 58.

John Deely (1991) Basics of Semiotics, Bloomington: Indiana University Press.

STATEMENT OF LAW:

■ **The validity of a science depends upon substantial agreement within the scientific community of meaning at its highest grade, i.e., meaning attained through Definition by Relationship.**

INTERPRETATION OF LAW:

Many philosophers believe that they understand the concept of valid knowledge. The people that they like to refer to include Auguste Comte, Thomas Kuhn and Karl Popper. Others, who hear these people being named as the origins of the appropriate views about what constitutes valid knowledge are likely to accept their views without question, based on the assumption that the philosophers have adequately explored the presuppositions underlying the views of people such as Comte, Kuhn, and Popper.

In contrast, the mature philosophy of Charles Sanders Peirce presents a philosophy of science that is not consistent with any of the foregoing. Moreover, John Deely has clarified what is wrong with the popular view of scientific validity, and has made clear why the popular view that there exists "objective knowledge" which is observer-independent and which, therefore, automatically has a higher quality than ordinary knowledge, is misbegotten.

To get a hearing, one must proceed as follows:

- Explain why the prevailing views are wrong (that takes quite a bit of time and argument)
- Explain what the appropriate views are (that requires quite a bit of background from the listener, which most of them who are "college-educated" lack)
- Explain why these views are appropriate

Since that can't be done in a short space, we have to appeal to the reader and make a promise to the reader. The appeal is to suspend belief in the commonly-accepted ideas and take an interest in exploring another point of view. The promise is that the reader who will spend enough time studying the matter can get virtually all of the important ideas from the references given above.

LAWS OF COMPLEXITY

BRIEF 5

NAME OF LAW:

Diverse Beliefs

ORIGIN(S) OF LAW:

Empirical

REFERENCES:

J. N. Warfield (1990) A Science of Generic Design: Managing Complexity Through Systems Design, Salinas, CA: Intersystems, (two volume set). See empirical data in Appendix 5.

J. N. Warfield (1991) "Complexity and Cognitive Equilibrium: Experimental Results and Their Implications", Human Systems Management 10 (3), 195-202. Reprinted as Chapter 5 in Conflict Resolution Theory and Practice: Integration and Application, Dennis J. Sandole and Hugo van der Merwe (Editors), Manchester, U. K.: Manchester University Press, 1993, 65-77.

J. N. Warfield (Editor) (1993) An Interactive Management Workshop on the Variant Design Process: RRM Joint Application Development (JAD) Dearborn, MI: Ford Motor Company Research Laboratory, June 18. (Distributed by Dr. Scott M. Staley, P. E.).

STATEMENT OF LAW:

■ **Whatever the group, whatever the complex issue being considered by the group, at the outset of group consideration of the issue, the individual members of the group will have quite diverse beliefs about the issue; and the probability is high that this situation will remain undiscovered and uncorrected, in the absence of a group learning experience using a methodology whose power to produce the necessary learning has been scientifically validated.**

INTERPRETATION OF LAW:

In order for people to share a common point of view about a complex issue, several conditions must be met. The Doctrine of Necessity underpins the idea that one is:

- The people must all share the same linguistic domain, in order that they can even conceive, express, or share the same point of view

But in complex areas, empirical evidence shows that people do not share an adequate linguistic domain, and frequently cannot even understand the initially-expressed points of view of others because they lack the substantive background knowledge or experience to do so. If they do not even share a common meaning of a critical word or phrase, they will not be able to express any shared point of view that they might hold, or even test whether they hold a shared point of view.

Even in the instances where they do share the same linguistic domain (which our research shows to be a rare situation, much rarer than almost anyone would likely believe until an opportunity is made available to observe appropriate human interactions), some believe that dramatic differences of opinion are a consequence of very different value orientations of individual people. But consider this. If people do not share a linguistic domain that is broad enough to enable them to express and share a common point of view, it will never be possible even to determine the existence or relevance of the influence of presupposed different value orientations. Therefore, even if the proponents of the differing values theory are correct, there is no way for them to establish their correctness in the absence of prior conditions.

Since the evidence of lack of sharing an adequate linguistic domain is compelling, one must give credence to the former. But even if this lack is discounted, the empirical evidence shows very clearly the absence of shared belief among groups of people who are supposedly knowledgeable in areas. So whatever the reason for this absence, the Law stands as an empirical fact.

This Law should compel a certain kind of behavior on the part of leaders who see value in developing a shared point of view. The kind of behavior that is required is to create conditions whereby the linguistic domain of that group of individuals whose diversity of views creates unmanageable or ineffective organizational conditions is enlarged to the point where it becomes feasible to enunciate and share a point of view.

If the leadership is unable or unwilling to do this, at least the leadership should recognize the value in knowing that virtually all individuals in the pertinent group have quite diverse beliefs about any complex issue. The potential benefit that may be seen by a leader is to enter the policy or action vacuum and promote one's own point of view based on the held authority. The potential dysbenefit that might be seen by a leader is that the leader is usually no different from any other of the relevant individuals. The leader's views are just as likely to be unsatisfactory as those of any of the others.

LAWS OF COMPLEXITY

BRIEF 6

NAME OF LAW:

Gradation

ORIGIN(S) OF LAW:

Theory of Relations: Inclusion Relation.

REFERENCES:

None

STATEMENT OF LAW:

■ **Any conceptual body of knowledge can be graded in stages, such that there is one simplest stage, one most comprehensive stage (reflecting the total state of relevant knowledge), and intermediate stages whose content lies between the two extremes.**

• **The Corollary of Congruence. The first Corollary to this Law asserts that the class of situations to which a conceptual body of knowledge may apply, in whole or in part, likewise may be graded according to the demands that individual situations can reasonably make upon the body of knowledge. This is called the Corollary of Congruence, because it relates to the congruence between the Design Situation and Target with a restricted grade of the Generic Design Science that is called into play in the specific case. Clearly the designer is not required to uncover every detail of relevance, no matter what the cost. When in doubt, a conservative posture will call for erring on the side of the higher grade.**

• **The Corollary of Diminishing Returns. The second Corollary to this Law is the existing economic Law of Diminishing Returns, which states that the application of a body of knowledge to a Design Situation should be made through that stage at which the point of diminishing returns to the Situation (as opposed to only the user) is reached. This is called the Corollary of Diminishing Returns, and it highlights a major responsibility of the designer to make judgments about when this point is reached. Once again, a conservative posture will call for erring on the side of the higher grade.**

• **The Corollary of Restricted Virtual Worlds. The third Corollary to this Law states that the identification of the stage at which diminishing returns to the situation is reached normally requires the integration of the Virtual Worlds of the affected parties in the situation in relation to the dimensions of the situation. This is called the Corollary of Restricted Virtual Worlds, and it reflects the need for a global point of view in making the kinds of judgments that are required to achieve the appropriate congruence of gradation.**

INTERPRETATION OF LAW:

The importance of this Law to the Science of Generic Design lies in the guidance that it provides to the designer concerning how to perceive any particular Design Situation with respect to the Science.

In this respect, one notes that design Targets may range from very small, limited-scope Targets to very large, broad-scope Targets.

It is not reasonable to take as a criterion for Generic Design Science that all of its Theory and all of its Methodology should be demonstrably required for all design activity. On the contrary, such a Science would be too brittle for use. The Law of Gradation overtly recognizes that Design Situations and Design Targets are themselves graded according to a variety of descriptions, not all of which can be foreseen. Accordingly, the Science of Generic Design should be applied judiciously, extracting from it one of its stages that is most appropriate for the particular Design Situations and Design Target.

The word "generic" does not mean "always required". What it does mean is "covering the set of gradations of Design Situations and Targets as a whole, without overlapping the applicable Specific Design Science; but subject to judicious restriction commensurate with the grade of the Design Situation or Design Target in any particular instance."

It is not the function of a Science of Generic Design to provide a recipe appropriate to every Design Situation. It is the function of such a Science to actuate the designer's professional responsibility to assess and correlate the gradation in the Situation and Target against the total sweep of the Generic Design Science; and to choose that restricted version of the Science which will be used openly, rather than to accept subliminally a restricted version that leads to underconceptualization of the Design Situation and the Design Target. It is the further function of the Generic Design Science to provide the means of documentation consistent with what the Design Situation requires.

LAWS OF COMPLEXITY

BRIEF 7

NAME OF LAW:

Universal Priors

ORIGIN(S) OF LAW:

Empirical

REFERENCES:

J. N. Warfield (1990) A Science of Generic Design: Managing Complexity Through Systems Design, Salinas, CA: Intersystems, 1990 (two volume set). See pages 16-18 and Chapter 2 in Vol. I.

STATEMENT OF LAW:

■ **The human being, language, reasoning through relationships, and archival representations are universal priors to science. (I.e., there can be no science without each of them.)**

INTERPRETATION OF LAW:

• **The Doctrine of Necessity.** The validity of this Law can be established using what is called the Doctrine of Necessity. This Doctrine holds that, independent of the particular attributes of B, if A is necessary in order for B to exist, then A is a prior of B. (The word "prior", used as a noun, fills a need that no other word quite satisfies.) The test of the necessity of each of the four factors mentioned is to imagine that they are withdrawn, and then inquire as to whether in their absence a science is possible.

• **The Human Being.** Imagine first,that there were no human beings. Accepting the common evidence that human beings are the producers and the only producers of science, then it must be that the human being is a Universal Prior to Science.

• **Language.** Imagine next that no language were available. Since all of science consists of language, and nothing else, there can be no science without language.

• **Reasoning Through Relationships.** Suppose now that there is no reasoning through relationships. Since all organization of information is through relationships arrived at by reasoning, there can be no organization of knowledge without it. But science is organized knowledge, hence both language and reasoning through relationships are Universal Priors to Science.

• **Archival Representation.** The human being, language, and reasoning through relationships all can exist and persist without any archival representation, the organization being in the mind. It might, therefore, be argued that these three are sufficient, and that archival representation is not required in order for organized knowledge and, therefore, science to exist. But science depends upon widespread consensus, and library after library attests to the critical importance of archival representation in gaining the necessary widespread understanding and consensus upon which acceptance as science depends.

• **Absence of Foundations.** Overt recognition of the status of the Universal Priors to Science should bury the modest movement to assert that there are no foundations to (at least some) sciences. On the contrary, what is seen here not only states that there are some, but there are some that are foundations to all science. If one is to distinguish one science from another, it may be through finding unique foundations for a particular science that can and must be integrated with the Universal Priors to establish the decision-making basis for the particular science.

• **Diminution of Universal Priors.** One obvious, but misguided, way to try to provide distinctiveness to the foundations of a science is to lay the Universal Priors on the operating table, and to diminish them to shadows of their identity, while retaining slices of them. Thus the human being may be fractionated into an economic entity, a social entity, or other one-dimensional entity such as political, athletic, biological, etc., or through a role such as observer of nature. Language may be diluted by failure to establish and enforce the definitions of its components; and reasoning through relationships may be diluted both by blurring the definitions of the relationship terms and by disguising patterns of relationship. The latter can occur naturally because of the linear sequential nature of prose, which does not lend itself to portraying patterns. Archival representations may themselves be so diluted by the emaciation of the other three Universal Priors as to be helpless to offer any assistance in searching for Referential Transparency.

LAWS OF COMPLEXITY

BRIEF 8A

NAME OF LAW:

Inherent Conflict

ORIGIN(S) OF LAW:

Empirical

REFERENCES:

J. N. Warfield (1990) A Science of Generic Design: Managing Complexity Through Systems Design, Salinas, CA: Intersystems, (two volume set). See empirical data in Appendix 5.

J. N. Warfield (1991) "Complexity and Cognitive Equilibrium: Experimental Results and Their Implications", Human Systems Management 10 (3), 195-202. Reprinted as Chapter 5 in Conflict Resolution Theory and Practice: Integration and Application, Dennis J. Sandole and Hugo van der Merwe (Editors), Manchester, U. K.: Manchester University Press, 1993, 65-77.

J. N. Warfield (Editor) (1993) An Interactive Management Workshop on the Variant Design Process: RRM Joint Application Development (JAD) Dearborn, MI: Ford Motor Company Research Laboratory, June 18. (Distributed by Dr. Scott M. Staley, P. E.).

STATEMENT OF LAW:

■ **No matter what the complex issue, and no matter what the group involved in its study, there will be significant inherent conflict within the group stemming from different perceptions of the relative significance of the factors involved in the complex issue.**

INTERPRETATION OF LAW:

The interpretation of this Law is essentially the same as that for the Law of Diverse Beliefs. The latter offers an explanation for the Law of Inherent Conflict. Because the beliefs are diverse, there is inherent conflict within the group. The two Laws mentioned here are complementary and can often be seen as a composite that could be called the Law of Diverse Beliefs and Inherent Conflict. Nevertheless it is believed that the modest redundancy involved is not adequate justification to repeal the decision to present the two Laws separately. Each Law offers its own unique point of view.

In order for people to share a common point of view about a complex issue, and thereby avoid conflict on that issue, several conditions must be met. The Doctrine of Necessity underpins the idea that one of these conditions is:

- The people must all share the same linguistic domain, in order that they can even conceive, express, or share the same point of view

But in complex areas, empirical evidence shows that people do not share an adequate linguistic domain, and frequently cannot even understand the initially-expressed points of view of others because they lack the substantive background knowledge or experience to do so. If they do not even share a common meaning of a critical word or phrase, they will not be able to express any shared point of view that they might hold, or even test whether they hold a shared point of view.

Even in the instances where they do share the same linguistic domain (which our research shows to be a rare situation, much rarer than almost anyone would likely believe until an opportunity is made available to observe appropriate human interactions), some believe that dramatic differences of opinion are a consequence of very different value orientations of individual people. But consider this. If people do not share a linguistic domain that is broad enough to enable them to express and share a common point of view, it will never be possible even to determine the existence or relevance of the influence of presupposed different value orientations. Therefore, even if the proponents of the differing values theory are correct, there is no

way for them to establish their correctness in the absence of prior conditions.

Since the evidence of lack of sharing an adequate linguistic domain is compelling, one must give credence to the former. But even if this lack is discounted, the empirical evidence shows very clearly the absence of shared belief among groups of people who are supposedly knowledgeable in areas. So whatever the reason for this absence, the Law stands as an empirical fact.

This Law should compel a certain kind of behavior on the part of leaders who see value in developing a shared point of view. The kind of behavior that is required is to create conditions whereby the linguistic domain of that group of individuals whose diversity of views creates unmanageable or ineffective organizational conditions is enlarged to the point where it becomes feasible to enunciate and share a point of view.

If the leadership is unable or unwilling to do this, at least the leadership should recognize the value in knowing that virtually all individuals in the pertinent group have quite diverse beliefs about any complex issue. The potential benefit that may be seen by a leader is to enter the policy or action vacuum and promote one's own point of view based on the held authority. The potential dysbenefit that might be seen by a leader is that the leader is usually no different from any other of the relevant individuals. The leader's views are just as likely to be unsatisfactory as those of any of the others.

LAWS OF COMPLEXITY

BRIEF 8B

NAME OF LAW:

Limits

ORIGIN(S) OF LAW:

Empirical

REFERENCES:

None

STATEMENT OF LAW:

■ **To any activity in the universe there exists a corresponding set of Limits upon that activity, which determines the feasible extent of the activity.**

• **The Corollary of Active Limits. The first Corollary to this Law asserts that for any particular situation, the set of Limits can be partitioned into two blocks: an active block and an inactive block. This Corollary is called the Corollary of Active Limits. The active block is the subset of the set of Limits that is determining at a given time, while the inactive block is not determining at that time. The active block may often consist of a single, dominating member of the set of Limits. Such a member may be so strong in its power to limit that, in effect, all other Limits are forced into hiding by the dominant one. When this occurs, it has both advantages and disadvantages. An advantage is that the designer who recognizes this situation can focus attention upon the dominant Limit and look for ways to modify its impact. A disadvantage is that the non-active Limits may go unrecognized, only to make their impact felt later upon the design activity that has focused overly on overcoming the dominant Limit.**

• **The Corollary of Movable Limits. The second Corollary to this Law asserts that the set of Limits also can be partitioned into these two blocks: movable and fixed. A movable limit is one that can be altered, while a fixed limit is one that is unchanging.**

Clearly if there is a dominant Limit and it is fixed, the potential exists for wasting substantial amounts of time, effort, and resources if one does not understand that it is fixed. On the other hand, if one mistakenly assumes that a Limit is fixed, when it really is movable, the potential exists for missing opportunities for major improvements. This Corollary is called the Corollary of Movable Limits.

- **The Corollary of Discretionary Action. The third Corollary to this Law asserts that the movable subset of Limits can be partitioned into these two blocks: movable through discretionary action by people, and autonomously movable. Limits that are autonomously movable change on their own, and thereby drive the system. Clearly the strategic posture for dealing with such Limits is to maintain cognizance of their status and to have some predetermined alternatives in mind for coping with them when they move into prominence. This Corollary is called the Corollary of Discretionary Action. Limits that are movable through discretionary action by people are, of course, those that should be clearly recognized by designers, and to which attention should be given in the event that they are not overshadowed by more prominent Limits that effectively nullify the latent impact of those lying in the background.**

- **The Corollary of Shifting Limits. The fourth Corollary to this Law asserts that the membership of the active blocks and of the inactive blocks of the partitions changes with time. If, for example, discretionary action brings about a change in some moveable Limit that previously was dominant, one or more new Limits will take the place of the previously dominant Limit. This Corollary is called the Corollary of Shifting Limits.**

INTERPRETATION OF LAW:

The significance of this Law to the Science of Generic Design is that it conveys the importance of discovering (a) what the Limits may be upon design in general and how these Limits may relate to any particular Design Situation and (b) those additional Limits that are at work in a particular Design Situation. This Law and its Corollaries have strong implications for the development of Theory because they impose upon Theory the requirement that the Theory contain explicit identification of generic Limits and explicit provision for the incorporation of special Limits.

The Law of Limits itself provides no means of identifying the Limits or of partitioning them after they have been identified. This capability must arise from other sources.

LAWS OF COMPLEXITY

BRIEF 8C

NAME OF LAW:

Requisite Saliency

ORIGIN(S) OF LAW:

Empirical

REFERENCES:

Kenneth Boulding (1966) The Impact of the Social Sciences, New Brunswick: Rutgers University Press.

J. N. Warfield (1990) A Science of Generic Design: Managing Complexity Through Systems Design, Salinas, CA: Intersystems, 1990 (two volume set). See Appendix 5, Volume 2 for empirical data and the interpretation.

STATEMENT OF LAW:

■ **The situational factors that require consideration in developing a design Target and introducing it in a Design Situation are seldom of equal saliency. Instead there is an underlying logic awaiting discovery in each Design Situation that will reveal the relative saliency of these factors.**

INTERPRETATION OF LAW:

Kenneth Boulding identified three major reasons for poor intellectual productivity. These are: ***spurious saliency*** (emphasizing the wrong things, out of proportion to what they deserve); ***unproductive emulation*** (behaving like those who help create rather than resolve problems); and ***cultural lag*** (not using established knowledge with dispatch). Characteristically individuals who become involved in the design process ***exhibit great diversity in their assessment of relative saliency*** (as indicated in the data in Appendix 5 of A Science of Generic Design). This diversity, if uninfluenced by thorough exploration of the Design Situation, will support unfocused dialog, unjustified decisions, and arbitrary design outcomes not likely to be understood or even actionable.

The design process must incorporate specific provision for uncovering the relative saliency of the factors in the Design Situation and the factors that characterize the Target, in order to achieve the kind of understanding that is needed to put the design factors in proper perspective.

LAWS OF COMPLEXITY

BRIEF 8D

NAME OF LAW:

Success and Failure

ORIGIN(S) OF LAW:

Mathematics of discrete probability.

REFERENCES:

J. N. Warfield (1958) "Switching Circuits as Topological Models in the Discrete Probability Theory", Transactions of the IRE PGEC-7(3), September.

J. N. Warfield (1965) "Synthesis of Switching Circuits to Yield Prescribed Probability Relations", 1965 Conference Record on Switching Circuit Theory and Logical Design, Ann Arbor, MI, October, 303-309.

J. N. Warfield (1968) "Switching Networks as Models of Discrete Stochastic Processes", in Applied Automata Theory, J. Tou (Ed.), Chapter 4, New York: Academic Press, 81-123.

STATEMENT OF LAW:

■ **There are seven critical factors in the SUCCESS BUNDLE for the Design Process. Inadequacy in any one of these factors may cause failure. The seven factors are: leadership, financial support, component availability, design environment, designer participation, documentation support, and design processes that converge to informed agreement.**

INTERPRETATION OF LAW:

This Law indicates that a Science of Generic Design must define the critical factors in sufficient depth to enable (a) the assessment of their adequacy and (b) their application in the Design Situation. Success and failure must also be elaborated and, in this context, success in all stages of work, including the implementation and operation, is required in order to proclaim that the design is successful; while failure in any stage is sufficient to constitute failure of the design.

This Law furnishes the impetus for what is called the Sigma-N Concept, discussed in detail in Sec. 6.9 of Volume I of A Science of Generic Design.

LAWS OF COMPLEXITY

BRIEF 8E

NAME OF LAW:

Uncorrelated Extremes

ORIGIN(S) OF LAW:

Empirical, Statistical Analysis

REFERENCES:

I. B. Kapelouzos (1989) "The Impact of Structural Modeling on the Creation of New Perspectives in Problem-Solving Situations", Proceedings of the 1989 European Congress on Systems Science, Lausanne, Switzerland: AFCET, October, 915-932.

J. N. Warfield (1990) A Science of Generic Design: Managing Complexity Through Systems Design, Salinas, CA: Intersystems, 1990 (two volume set). See Appendix 5.

STATEMENT OF LAW:

■ **No matter what the complex issue, and no matter what the group involved in its study, the initial aggregate group opinion concerning the logical pattern of the factors involved in the issue and the final aggregate group-opinion concerning the logical pattern of the factors involved in the issue (i.e., the views at the two extremes of the application of the Generic Design Science, before and after), will be uncorrelated; showing that significant learning takes place through the application of the generic design processes.**

INTERPRETATION OF LAW:

Once it was discovered that there was very great diversity in the views of individual members of groups about the relative importance of elements that were generated and clarified using the Nominal Group Technique (NGT), a research question arose about the persistence of such views after additional work was done. Since such elements were typically the subject of structuring work using Interpretive Structural Modeling (ISM), a natural way to approach this question involved a comparison of the results obtained from using ISM with the products of the voting done as part of the use of NGT.

While NGT is not regarded as a structuring tool, nevertheless a structure can be produced from the results of NGT voting. Here is how such a structure can be produced. For each problem element that gets at least one vote from a participant in group work using NGT, make numerical assignments to those votes as follows:

> The highest rated element coming from some individual's voting gets a score of 5; the second highest rated element from that same individual's voting gets a score of 4; and so on, until the fifth-rated (lowest-rated) element gets a score of 1. Assigning such scores for every individual's votes, one can then compute a cumulative score for each element that received a vote. A structure can then be created using the relationship "has a higher score than", and this relationship can be regarded as equivalent to "is perceived by the group as a more important problem than".

Conducting the ISM session with the same elements, typically a problematique structure is produced using the relationship "aggravates". A method of scoring was developed whereby each problem element in the problematique receives a certain net score. This net score reflects the position of the problem element in the problematique, and takes into account the number of other problems that are aggravated by a given problem, as well as the number of problems that aggravate a given problem. Typically problems lying at the left will get larger scores than those lying at the right of the structure.

It then becomes possible to correlate the scores coming from the NGT-derived structure with the scores coming from the ISM derived structure. While the two structures do not share precisely the same relation, one is justified in presuming that those problems that aggravate many other problems are more important than the ones they aggravate because of their power to sustain those other problems; while those that are, in effect, continued with increased power to do harm by others are regarded as less important. Importance thereby takes on a priority status, and reflects the potential strategy of attack, working first on those that have the greatest power to aggravate other problems. Some data exist to show that this strategy has been very successful.

Judge I. B. Kapelouzos, who was on sabbatical leave from his position on the Council of State of Greece, decided that he would study 31 cases for which data were available to examine the before-and-after correlation for such structures. The "before" structure was the one produced from the NGT work, and reflects composite group results just before the ISM work begins. The "after" structure is the one that is available after the ISM work is finished.

People familiar with these concepts assumed that the work would show some variation from perfect correlation. Everyone was surprised to see the results. The results showed no correlation between the before-and-after structures. The startling nature of this result could only be explained in one way: the individuals in the group, after having gone through a rigorous examination of the relationships among the problems, learned a great deal about how those problems interact (something which they could not readily do otherwise, as indicated by the Law of Triadic Compability); and as a result the type of strategy indicated by their product changed dramatically as a result of this learning.

These research results imply, among other things, that all those methodologies currently in vogue for group work, which do not incorporate in their tool kit the ISM process whereby detailed examination of interactions among elements is carried out by the group, are sorely deficient and are likely to produce very misleading and dysfunctional conclusions.

Much more is learned from the process of detailed study of interactions among elements than intuition had suggested. Even though ISM was specifically designed to be a learning process, it was not envisaged that it would have the power which the Law of Uncorrelated Extremes attaches to it. Further research along these lines should be very valuable in adding to our limited knowledge concerning such matters.

Additional evidence to support the conclusions embodied in this Law are reflected in the Law of Structural Underconceptualization, where the data show unequivocally that individuals and groups do not even produce proper structures without the help of the ISM process, as discussed in the Interpretation of that Law!

LAWS OF COMPLEXITY

BRIEF 9

NAME OF LAW:

Requisite Variety

ORIGIN(S) OF LAW:

Mathematics, Systems Theory

REFERENCES:

Ross Ashby (1958) "Requisite Variety and its Implications for the Control of Complex Systems," Cybernetica 1(2), 1-17.

J. N. Warfield (1986) "Dimensionality", Proc. 1986 International Conference on Systems, Man, and Cybernetics, 2, New York: IEEE, 1118-1121.

J. N. Warfield and A. N. Christakis (1987) "Dimensionality", Systems Research 4(2), 127-137.

J. N. Warfield (1990) A Science of Generic Design: Managing Complexity Through Systems Design, Salinas, CA: Intersystems, 1990 (two volume set)

STATEMENT OF LAW:

■ **A Design Situation embodies a requirement for Requisite Variety in the design specifications. Every Design Situation S implicitly represents an (initially unknown) integer dimensionality K_s such that if the designer defines an integer K_m number of distinct specifications (whether qualitative or quantitative or a mix of these), then:**

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STATEMENT OF LAW:

■ **A Design Situation embodies a requirement for Requisite Variety in the design specifications. Every Design Situation S implicitly represents an (initially unknown) integer dimensionality K_s such that if the designer defines an integer K_m number of distinct specifications (whether qualitative or quantitative or a mix of these), then:**

i) If $K_m < K_s$, the Target is underspecified and the behavior of the Target is outside the control of the designer

ii) If $K_m > K_s$, the Target is overspecified, and the behavior of the Target cannot be compatible with the designer's wishes

iii) If $K_m = K_s$, the design specification exhibits Requisite Variety, provided the designer has correctly identified and specified the dimensions; and the behavior of the design should be that which the Situation can absorb and which the designer can control, subject to the requirement that the dimensionality of the Situation is not modified by the introduction of the Target into the Situation.

If the dimensionality is changed thereby, the design process can apply the Law of Requisite Variety iteratively, taking into account the dynamics of the Situation.

INTERPRETATION OF LAW:

The Theory of Dimensionality has been introduced, in part, to make possible this formulation of the Law of Requisite Variety, especially to enhance applicability of it to those situations where some dimensions are naturally quantitative and some are naturally qualitative, requiring that both kinds of dimensions be in a common space and subject to comprehensive interpretation in order to achieve a sound design result.

The question might be raised as to how designers have succeeded in the past in the absence of overt response to this Law. Many, if not most, Targets of design are redesigns that benefit from decades of experience which have permitted the development of intuitive knowledge that substitutes for overt application of this Law. Regrettably, it is this same cumulative experience that mistakenly leads designers and their managers to believe that somehow they can intuitively design systems much larger in scale that have never been designed before.

LAWS OF COMPLEXITY

BRIEF 10A

NAME OF LAW:

Forced Substitution

ORIGIN(S) OF LAW:

Empirical

REFERENCES:

None

STATEMENT OF LAW:

■ **Structural underconceptualization and inherent conflict lead to policy vacuums in an organization into which authority injects forced substitution for absent and inadequate conceptualization, in order to avoid institutional paralysis and for self-protection.**

INTERPRETATION OF LAW:

This Law reflects the empirical knowledge that executives in charge of large organizations are essentially forced to take action in regard to problems of the organization. The very large pressures on such executives will be relieved in the short run by taking action. A question of much importance has to do with how effective such action will be.

It has been pointed out by Peter Senge that while executives often have significant amounts of experience on short-term issues of relatively little complexity, such executives often have no reliable experience regarding longer-term issues which are complex. A simple explanation is that by the time the consequences of the decisions

they make are felt, those executives have changed positions, and are not even around to experience directly those consequences. Another explanation has to do with the fact that complex issues are quite small in number compared to the many normal issues facing organizational leadership; so even the statistics work against gaining relevant experience. It is unreasonable to expect that the executive who is making decisions about complex issues is any better equipped to make such decisions than anyone else inside or outside the organization.

The combination of being required to make a decision about a complex issue and the lack of high-quality analysis and experience related to that issue is perfectly calculated to produce action that will not be effective and may make matters worse.

Because it is possible to apply methodology that is compatible with and recognizes the importance of the Laws of Complexity, it is reasonable to postulate that such an analysis or design could have been produced if the leadership were both aware of and willing to sponsor such activity. The choice of the term "Forced Substitution" recognizes that the decision-maker is substituting a "hip-pocket" or "wet-thumb" decision for what could have been a highly-informed decision, informed, among other things, by the structure of the issue; and that the decision-maker is forced by circumstances to make such a decision because to do otherwise would convey an image of ignorance and indecision which (even though it might well be warranted) is not what boards of directors are willing to tolerate.

They will accept bad decisions (unwittingly or otherwise), unsupported by the kind of analysis and design that is now possible to attain taking into account knowledge of the Laws of Complexity, but they will not support inaction.

LAWS OF COMPLEXITY

BRIEF 10B

NAME OF LAW:

Precluded Resolution

ORIGIN(S) OF LAW:

Empirical

REFERENCES:

None

STATEMENT OF LAW:

■ **Forced substitution in organizations is dominated by the combination of:**

- **structural underconceptualization**
- **inherent conflict and diversity of belief**
- **dysfunctional organizational linguistics**

which combine to preclude resolution of complex issues.

INTERPRETATION OF LAW:

This Law is intended to explain the reasons why complex issues are seldom resolved in organizations. The explanation is given in terms of what several other Laws of Complexity have to say.

Recognizing that there is much diversity of belief, and much inherent conflict in the views of individuals concerning the relative importance of various elements germane to a complex situation, at the beginning the organization is in intellectual disarray about the complex issue.

If the organization does not have any effective methodology for learning about the issue, and if it does not use the process of Interpretive Structural Modeling to develop the structural patterns that explain the issue (and very few organizations presently do this), whatever individual's particular uninformed perceptions become the basis for action will necessarily exhibit structural underconceptualization, and will then promulgate an uninformed approach to an implementation scheme already lacking support in the organization.

In the absence of any well-designed means for developing the necessary organizational linguistic domains, people will not even be able to share a mutual understanding of what was wanted and therefore cannot be effective or even mutually reinforcing in implementing bad decisions emanating from a perceived requirement to take some action.

In other words, there is an overwhelming set of institutional conditions that virtually guarantee that complex issues will not be resolved, and the analysis that explains the reason for the persistence cannot help but be supported by the anecdotal evidence being seen in everyday life as to the ineffectiveness and dysfunctionality of systems put in place with improper designs that are unresponsive to the situations they were purportedly to remedy.

LAWS OF COMPLEXITY

BRIEF 11

NAME OF LAW:

Triadic Necessity and Sufficiency

ORIGIN(S) OF LAW:

Mathematical Logic

REFERENCES:

J. Brent (1993) Charles Sanders Peirce: A Life, Bloomington, IN: Indiana University Press.

R. W. Burch (1991) A Peircean Reduction Thesis, Lubbock, TX, Texas Tech University Press.

Walker Percy (1989) "The Fateful Rift: The San Andreas Fault in the Modern Mind", 18th Jefferson Lecture in the Humanities, Washington, D. C.: National Endowment for the Humanities.

STATEMENT OF LAW:

■ **Relations are characterized by the number of distinct relational components, but no matter how many such components a relation may have, the (complex) relation can always be expressed by component relations having no more than three relational components; but triadic relations exist that cannot be expressed in terms solely of dyadic and monadic relations.**

INTERPRETATION OF LAW:

Charles Sanders Peirce studied the logic of relations extensively. In the recent biography of Peirce by Joseph Brent, the following passage appears:

"Abstract forms of relation are objects of a mathematical inquiry called the logic of relations (or relatives), which Peirce began to examine in 1870 with his 'Description of a Notation for the Logic of Relatives'. By 1885 he had proposed in what Hans Herzberger [Professor of Philosophy, University of Toronto] has called 'Peirce's remarkable theorem,' that there are only three fundamental kinds of relations: monadic, dyadic, and triadic; that by combining triads, all relations of a greater number than three can be generated; and that all those of a greater number than three can be reduced to triads. Since, in addition, triads cannot be reduced to dyads, nor dyads to monads; monads, dyads, and triads constitute the fundamental categories of relations. At the same time, triads are made up of dyads and monads, and dyads of monads."

According to Robert W. Burch [Professor of Philosophy at Texas A & M University], others who have examined related issues include Quine, Löwenheim, Schröder, Herzberger, and Ketner. The following passage appears in Burch's 1991 book referenced above:

"By extending both the algebraic ideas of Herzberger and the graph-theoretical ideas of Ketner, this work proposes to develop an algebraic formalism in which a reduction thesis similar to and perhaps identical to the reduction thesis Peirce had in mind can be proved for the general case. This work also proposes to show that the reduction thesis it proves is consistent with the work of Löwenheim and the result of Quine, despite that the fact that these results may appear to conflict with it."

The proof developed by Burch is long and thorny, but it has been examined by other mathematicians who have not detected any flaw.

If we accept the proof at face value, then we are impelled to note the comparison of this Law with the Law of Triadic Compatibility. Seeing them together we conclude that **the number 3 is not only the maximum number of elements whose interactions can reasonably be dealt with in short-term memory because of the limits of recall, but it is also the maximum number of elements that must be dealt with modularly in order to be able to deal with complex relationships of any magnitude.** (Theological implications may surface in this connection.)

The full significance of the foregoing is unclear at the present time, because of the limited amount of investigation into the consequences of accepting all of the foregoing as established scientific fact. But the potential significance is great. The absence of any notable alternative other than to continue the present disjointed incrementalism ("muddling through") advocated by Braybrooke and Lindblom and so commonly practiced in organizations, provides strong motivation to those who are severely concerned with the defects in present organizational practice to move ahead, on the basis of the hypothesis that what is said in the foregoing paragraph is true and provides the appropriate guidance for changing organizational practice and culture.