SEVEN WAYS TO PORTRAY COMPLEXITY

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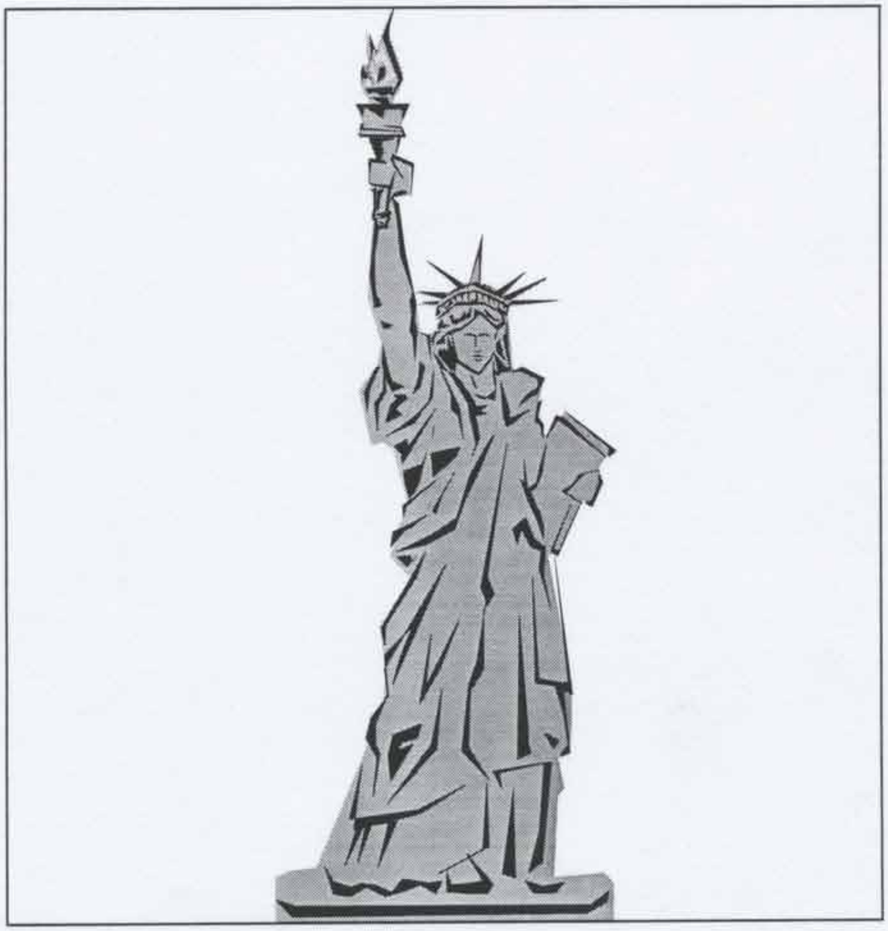

"sum, ergo cogito"

This document was prepared specifically to supplement and support a presentation at the George Washington University Notational Engineering Laboratory, February 28, 1996

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ABSTRACT
SEVEN WAYS TO PORTRAY COMPLEXITY

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Prose alone is inadequate to portray complexity. Mathematics is often unavailable because mathematical language is restricted to a small percent of the population. For this reason, language components comprised of integrated prose-graphics representations enjoy unique potential for representing complexity.

Because of the desirability of taking advantage of computers to facilitate the development and production of such integrated representations, it is best if the prose-graphics representations are readily representable in computer algorithms, even if their utility for general communication is limited. Mappings from mathematical formats to graphical formats can often be readily done, although manual modification of graphics for readibility may be necessary.

The following specific graphical representations have proved useful in representing complexity:

- Arrow-Bullet Diagrams (which are mappable from square binary matrices, and which correspond to digraphs)
- Element-Relation Diagrams (which are mappable from incidence matrices, and which correspond to bipartite relations)
- Fields (which are mappable from multiple, square binary matrices, and which correspond to multiple digraphs)
- Profiles (which correspond to multiple binary vectors, and also correspond to Boolean spaces)
- Total Inclusion Structures (which correspond to distributive lattices and to power sets of a given base set)
- Partition Structures (which correspond to the non-distributive lattices of all partitions of a base set)
- DELTA Charts (which are restricted to use with temporal relationships, and which sacrifice direct mathematical connections to versatility in applications)

Each of these will be described briefly (detailed descriptions are given in the References), and at least one example of the use of each in an application will be given. All structures from applications were developed participatively by persons intimately engaged with the relevant issues.

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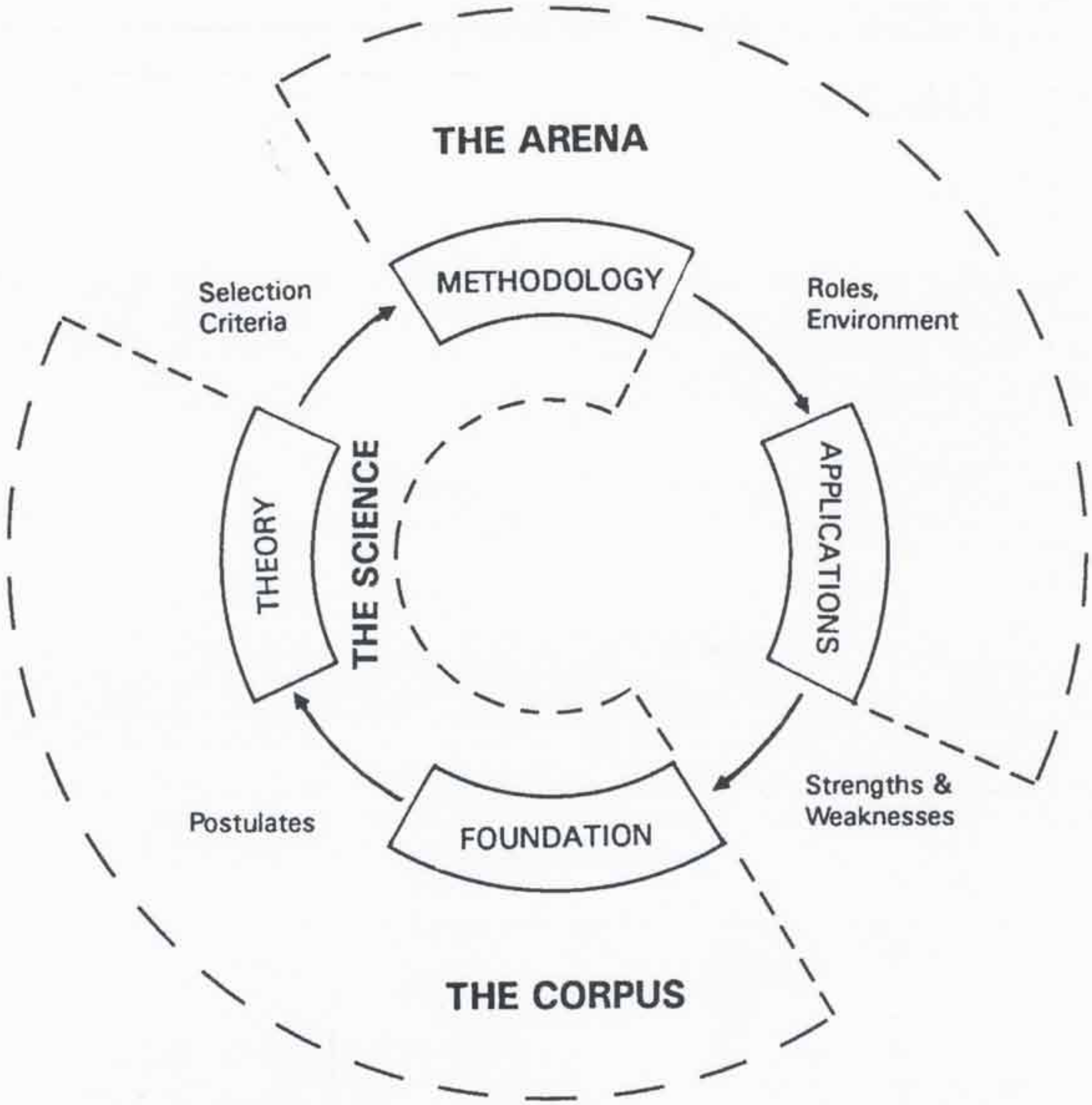
SEVEN WAYS TO PORTRAY

COMPLEXITY

- ARROW-BULLET DIAGRAM
- ELEMENT-RELATION DIAGRAM
- STRUCTURAL FIELD
- STRUCTURAL PROFILE
- TOTAL INCLUSION STRUCTURE
- PARTITION STRUCTURE
- DELTA CHART

THE DOMAIN OF SCIENCE MODEL



SCHOOLS OF THOUGHT ABOUT COMPLEXITY		
NAME OF SCHOOL	**UNDERLYING FORMALISM**	**WHERE COMPLEXITY LIES**
SYSTEMS DYNAMICS	**ORDINARY DIFFERENTIAL EQUATIONS**	**IN THE SYSTEM**
CHAOS THEORY	**ORDINARY NONLINEAR DIFFERENTIAL EQUATIONS**	**IN THE SYSTEM**
ADAPTIVE SYSTEMS THEORY	**PARTIAL DIFFERENTIAL EQUATIONS**	**IN THE SYSTEM**
CEA (COGNITIVE-EMOTIONAL-APPRECIATIVE THEORY)	**FORMAL WESTERN LOGIC, INCLUDING SET THEORY, THEORY OF RELATIONS, DIGRAPH THEORY, LATTICE THEORY, BOOLEAN METHODS, AND THE ALGEBRA OF PARTITIONS**	**IN THE MIND** **[Much of the foundational work is represented by Peirce, Piaget, Polanyi, and Vickers. Substantial empirical validation exists, including determination of the quantitative indexes of complexity. Logic underlies all formalisms, including those of the other schools, hence more clearly deserves to be seen as the foundational underlying formalism of a science of complexity.]**

COMPLEXITY

That sensation experienced in the human mind when, engaged in observing or considering a system, frustration arises from lack of comprehension of what is being explored.

		OUTCOMES			
		DESCRIPTION	**DIAGNOSIS**	**PRESCRIPTION (DESIGN)**	**IMPLEMEN-TATION**
BEHAVIOR	**INDIVIDUAL**	■ Limits ■ Triadic Compatibility		■ Requisite Parsimony ■ Requisite Saliency	
	GROUP	■ Limits ■ Uncorrelated Extremes	■ Inherent Conflict ■ Structural Under-conceptualization ■ Diverse Beliefs	■ Requisite Variety	
	ORGANIZA-TIONAL	■ Limits ■ Organizational Linguistics	■ Forced Substitution ■ Precluded Resolution		
	PROCESS	■ Limits ■ Triadic Necessity & Sufficiency ■ Universal Priors	■ Success & Failure ■ Universal Priors		■ Gradation ■ Validation

BEHAVIOR--OUTCOMES MATRIX (Understanding The ***Work Program of Complexity***)
showing which Laws of Complexity relate strongly to which combination of behavior and outcome.

SUMMARY DATA FROM APPLICATIONS ON COMPLEXITY MEASURES			
INDEX TYPE	EMPIRICALLY-FOUND VALUES FOR INDEX		
	MINIMUM	MAXIMUM	AVERAGE
MILLER	5	20	10
SPREADTHINK	4	13	7
DEMORGAN	11	51	30
SITUATION	52	2,250	764

Data as of November, 1995

9

IM OPTIONS FIELD (part 1 of 3). CHOOSE OPTIONS TO CREATE OPTIONS PROFILE.

A. PHASE SELECTED	B. OUTCOME SOUGHT	C. SUCCESS LEVEL	D. STEERING FACTOR
■ Planning Phase	■ Isssue or System Definition	■ Level 1	■ Context Statement
■ Workshop Phase	■ Alternative Designs	■ Level 2	■ Triggering Questions
■ Followup Phase	■ A Chosen Alternative	■ Level 3	■ Generic Questions
	■ Workshop Plan	■ Level 4	■ A White Paper
	■ Implementation	■ Level 5	■ A Workshop Plan
			■ A Workshop Report

TIE LINE

IM OPTIONS FIELD (part 2 of 3). CHOOSE OPTIONS TO CREATE OPTIONS PROFILE

E. IM ROLES

- Client
- Sponsor
- Broker
- Participant
- Wkshp Planner
- IM Facilitator
- Pattern Interpreter

E. IM ROLES (cont.)

- Report Manager
- Workshop Observer
- Facility Preparer
- Computer Operator
- Video Operator
- Display Arranger
- Recorder (Scribe)

F. IM PROCESSES

- Ideawriting
- Enhanced NGT
- ISM
- DELPHI
- Field Development
- Profile Development
- Tradeoff Analysis

TIE LINE

IM OPTIONS FIELD (part 3 of 3). CHOOSE OPTIONS TO CREATE OPTIONS PROFILE

G. PRODUCTS SOUGHT

- DELTA Chart
- Problematique
- Enhancement Structure
- Intent Structure
- Priority Structure
- Resolution Structure
- Curriculum Structure
- Newly-Identified Structural Type

G. PRODUCTS SOUGHT (cont.)

- Options Field
- Problems Field
- Options Profile
- Attributes Profile
- Tapestry of Quads
- Comparison Bar Charts
- Unified Program Planning Linked Matrices (QFD-Like)

TIE LINE

A1. Comprehensive Health Care: Policy

- Comprehensive national health policy for infants, children, youth and their families (17)
- A structure that links health care services in a comprehensive and coordinated manner (7)
- Dollars (59)
- Networks of supportive services for child-rearing families (18)
- A system designed to provide easy access to health services for all children (85)
- Sufficient health care resources (120)
- Availability of care providers (11)
- Child and family advocates (50)

A2. Comprehensive Health Care: Goals

- Provision of health care regardless of ability to pay (3)
- Comprehensive and continuous health care from conception to adulthood which will impact positively on healthful living behaviors throughout life (6)
- Health care which supports quality of life (20)
- More realistic and reliable reimbursement for a broad range of nursing practices (58)
- Preventive health care regimes (76)
- Least restrictive environment for children to promote their growth and development (81)
- Non-stigmatizing health care (88)
- A smokeless society for nurses as well as children and their families (93)
- A society which promotes supportive services to the disabled and mentally retarded (respite care) (96)
- Promotion of optimum development (108)
- A healthy psycho-social environment (114)
- Stronger partnership between society and family (117)
- Quality child care for the working parent (70)
- Quality child care for families who elect to use it (119)

A3. Comprehensive Health Care: Programs

- Children with chronic illness will need a spectrum of care (4)
- Family resource centers akin to farm program run by the Department of Agriculture (21)
- Development of variety of pediatric care delivery sites (28)
- Alternative care systems for young children whose parents are unavailable due to work or emotional problems (32)
- Ready availability of intensive nursing interventions (38)
- New models for well-child care which are environmentally and educationally oriented and intended to promote health for all children (45)
- Professional support for families facing exceptional stresses (65)
- Economical and effective technologies to monitor individual patients or groups of patients in other than hospital settings (67)
- Health, social and educational strategies that give children and families with poor starts a second chance (68)
- Techniques and strategies to prevent and treat various types of alcohol and substance use and abuse in families and children (72)
- Continued efforts to reduce adolescent pregnancies and teen suicide (school-based clinics) (78)
- Provision of home health care in a dual-career working society (83)
- Coalition building between the elderly and children for health care resources (101)
- Learning opportunities which utilize peer counseling and role modeling for behavior change (106)
- Research on coping with the aftermath of disasters (124)
- Provide supportive services for homeless and migrant families (127)

Figure 10.12 Anticipated needs field for pediatric health care consumers in the twenty-first century. (Items in grey boxes were judged by participants to be closely coupled.) (Continued on next page)

B1. Dimensions of Care: Consumer Perspective

- Knowledge and skills for greater autonomy within and without the health care system (1)
- Availability of assertive training (27)
- Need to normalize the life of children and families with health problems (30)
- Parent education/knowledgeable parents to guide children to optimal status (31)
- Assistance in developing a sense of integrity (34)
- Greater empowerment of the family or the child, when possible, to be an active participant or member of the health care team (39)
- Family education regarding the risks facing our children (56)
- Early health self-care by the child (60)
- Lifestyle options with dignity for individuals with mental retardation, dependency, or chronic illness (82)
- Knowledge, attitudes, skills, and habits (115)
- Opportunity for children, youth, and their families to learn and exercise their consumer rights: to be informed, to be safe and to choose (122)
- Health information packaging in usable formats (videotapes, audiotapes, CAI) (123)

B2. Dimensions of Care: Practitioner Perspective

- Understanding and acceptance of cultural dimension of clients (2)
- Need to promote wellness (8)
- Provision of atraumatic care (14)
- Need for high tech/high touch (19)
- Knowledge and acceptance of diverse and changing family lifestyles (36)
- Health care strategies which consider future as well as current problems (42)
- Environments that interface human care with machines (43)
- Coordination of care of sick children as they move to the wellness end of the continuum (44)
- Health care strategies addressing population-induced or intensified problems (51)
- Eradication of selected communicable diseases and reduction of unnecessary infectious diseases through good nursing practices (98)
- Prevention of sexually transmitted conditions in youth (107)
- Promoting healthy sexual development (121)
- Care of children whose parents are children (77)
- Care of children who are also parents (126)

C1. Pediatric Nursing Profession: Issues

- Need for appropriately prepared care providers in settings outside of the hospital (33)
- Professionals prepared to deal with new health conditions that evolve as a result of high tech (46)
- Incentives for nurses to practice in underserved areas (49)
- Nurses with advanced preparation in child development and family systems (52)
- Clarification of the role of acute care, long term care, and home health care and services delivered (62)
- More global networking and research by health professionals (63)
- Cadre of nursing leaders able to influence national and institutional health care providers educated to provide family centered care (66)
- Policies related to health care delivery systems (73)
- Prevention of burnout and support for nurses in stressful situations (74)
- Nursing leaders able to administrate complex health care systems (80)
- Validated nursing care which recognizes and takes into account the human responses of children and their families (84)
- Update of nurses' knowledge and skill in health promotion (95)
- A health care environment that supports the recruitment and retention of nurses (97)
- Accountable health care providers (99)
- A need for appropriately credentialed/certified health care providers (100)
- Nursing curricula which prepare nurses to accept role of family in promotion of self-care (shared responsibility) (102)
- The nurse as the evaluator of care (111)
- Professionals prepared to deal with new health conditions that evolve as a result of lifestyles (116)
- Provide an avenue for nursing to have input into the future marketing of pediatric care (126)

Figure 10.12 Anticipated needs field for pediatric health care consumers in the twenty-first century. (Items in grey boxes were judged by participants to be closely coupled.) (Continued on next page)

C2. Pediatric Nursing Profession: Environments

- Local area health care systems that are nurse-based (5)
- Severity of illness and care-setting placement (22)
- Planned health care consultation in child care settings (24)
- Least restrictive environment for nursing practice (87)
- An environment for effective information processing by consumers and providers (103)
- Working with other health care professionals to come up with creative ways to provide health care in a complex environment (110)
- Provide an environment for nurses to practice and make decisions based on sound nursing practices rather than legal and institutional constraints (125)

D1. Research: Demonstration and Evaluation

- Child health status indicators that reflect function as well as dysfunction (12)
- Interdisciplinary research to determine the predictors of positive family and child health (48)
- Administration research to examine resource allocation of health professions (57)
- Better methodologies for recognizing early mental health problems in children (79)
- Research to measure outcomes of nursing intervention (86)
- Application of research to nursing care (91)
- Research to measure the true cost of health care for children and families (92)

Grey box:

- Knowledge of the long-term effects of illness and loss on families (16)
- Knowledge about health conditions and health care practices that take into account an appropriate time continuum in measuring outcomes (112)

D2. Research: Program Initiatives

- Immune banks (10)
- Single parents' family resource facility (35)
- Child care for sick children (53)
- Adapted well-child services which take into account advances in genetic research (54)
- Alternative health care systems for children with progressive and terminal health care problems such as AIDS (61)
- Traveling tutus (69)
- Community nursing organizations for children (schools, juvenile correctional facilities) (71)

Grey box:

- Research to help understand the effect of giving or receiving care in ambulatory settings versus the hospital (64)
- Research to clarify when services are/should be delivered (118)

Grey box:

- Use of information and computer technology for effective case management (89)
- Use of new information in clinical decision-making from multiple alternatives (90)

E. Ethics/Decision Making

- Support for decision-making in a complex environment (15)
- Assistance with ethical decisions (25)
- Ethical technology management (40)
- Health care decisions which do not place children and their families in ethical dilemmas (94)
- Appropriate decision making by health care providers regarding use/non-use of technology (104)
- Incorporate the right-to-know concept as it relates to patient, family, care providers, and others (113)

F. Pediatric Consumer Rights

- Safe physical environment (9)
- A healthy physical environment (health protection) (29)
- Freedom from abuse and neglect (55)
- Injury prevention (105)
- Choices for families for health care delivery systems (37)
- Need to feel good (self concept) (41)
- Early preparation for parenting and family life (47)
- Protection of confidentiality and privacy (26)
- Successful academic achievement (23)
- To die with dignity (75)

Figure 10.12 Anticipated needs field for pediatric health care consumers in the twenty-first century. (Items in grey boxes were judged by participants to be closely coupled.) (Concluded)

Figure 1.1: Attributes Field for Analytical Powertrain

A) Database Content

- Unambiguous dictionary/encyclopedia of key words/phrases for manufacturing and product engineering. (1)
- System should contain an audit trail of changes to design showing cause and effect. (66)
- Database capable of handling administrative as well as technical data. (67)
- Contents of database must be current. (83)
- Require standard symbology for representation of the Analytical Powertrain architecture. (108)
- Implement data and object dictionaries. (111)
- AP to include life-cycle plan of the powertrain program to support/drive implementation of manufacturing flexibility. (120)
- System contains historical product design and manufacturing processes (Bookshelf). (125)
- Design and Manufacturing Knowledge (Rules). (127)
- Corporate standards and methods. (128)
- Manufacturing process capabilities and field quality reports. (129)

B) Objectives

- Accessible database or databases that contain all recordable information required to do the job. (2)
- System must be easy enough to use to support part-time use. (4)
- Provide a fearless computer environment. (5)
- Integrates with engineering business needs and practices as represented in EIS (Engineering Information Systems). (8)
- Must be a living, upgradable process which allows for evolutionary changes. (10)
- Has to provide ownership to the people who use it. (16)
- Must include our suppliers as part of the process. (21)
- Capability should be responsive and fast enough to support prototype series in which the design is constantly changing. (28)
- Must be characterized by simply understood goals and less nebulous definitions. (33)
- Provide high-end CAE tools which are usable without detailed analysis knowledge. (36)
- Must be characterized by realistic goals rather than grandiose plans. (44)
- Must assure application development addresses all disciplines equally. (59)
- Must provide for analysis and manufacturing input earlier in the design process. (61)
- System should be migratory with short-term successes and progressive implementation plan. (76)
- The system plan should address simultaneous development of hardware, software, and cultural change needs. (85)
- Must free-up engineer's time for more creative work. (89)
- Provide a structured environment which also encourages user creativity. (94)
- Must be a "want to use" engineering tool. (101)
- Must encompass current CAD/CAM/CAE initiatives (i.e., CAD/CAM the Master). (103)
- Hardware and software must be reliable. (122)
- Design process must be reliable. (123)

Figure 1.1: Attributes Field for Analytical Powertrain (Cont'd)

C) Implementation Guidelines

- Needs an adequate support staff to develop CAD/CAM/CAE methods and to customize computer tools to implement and maintain. (11)
- Characterized by standard professional software development practices for version control and production releases. (19)
- Address or be responsive to the engineers' current needs. (20)
- Needs to have on-site computer systems support of hardware and software rather than the present bureaucracy. (22)
- Proper training and correct mix of engineers during initial implementation. (42)
- No barriers to use as part of overall design philosophy for the environment. (49)
- Computer hardware and software are available for all who function in the process. (57)
- Analytical tools provided must be complete. (70)
- Must allow and take advantage of user input during development. (71)
- Accessibility to the system should be location independent. (74)
- Prevent using jargon. (79)
- Must utilize standards whenever possible. (80)
- Human resource and the work environment need a much higher management priority. (84)
- Implementation must be partial and gradual. (95)
- Divisional and departmental support of the Analytical Powertrain plan. (109)
- Needs an adequate support staff to develop AP methods and to customize computer tools to implement and maintain. (114)

D) Data Access

- An entry system -- the ability to locate any manufacturing process or part design by features or functional characteristics. (23)
- Ability to transfer data without additional translation between different engineering tasks and different PEOs (Project Engineering Offices). (39)
- Must interface with vehicle CAD/CAM/CAE systems as well as corporate administrative systems. (40)
- Allow for concurrent access of data. (48)
- Must allow access to manufacturing process capabilities and field quality reports. (69)
- Allows for secure access privilege to suppliers, both component and facilities suppliers. (78)
- Provides for access to variant design and manufacturing processes from key words or parameters or feature descriptors. (117)

Figure 1.1: Attributes Field for Analytical Powertrain (Cont'd)

E) Acceptance Criteria

- Ability to be very responsive and always available. (26)
- 100 percent buy-in of all powertrain operation employees. (46)
- Need implementation measurables. (54)
- Each user of the system must derive some value to him/her. (91)
- The system will produce a 3-dimensional replica of the design within one hour. (100)
- Must be better than the system today. (107)

F) System Functionality

- Information generated to produce a product will be protected from general access. The results of the effort will be the only data available to other designated users. (13)
- Provide engineers (product and manufacturing) with the ability to view and markup designs. (15)
- Flexibility to allow each person to customize the system for a particular use without altering the core data repository. (34)
- Must support redesigns as well as new designs. (37)
- On-line help: (micro/macro) provide an avenue to acquire assistance all the way down to a self-taught course. (45)
- Ability to trace long-term design failures to design/manufacturing rules, practices, and software in-place at time of design. (52)
- Ability to integrate with the test plan and reporting system design validation/ production verification (DV/PV). (62)
- Support interactive department-level identification/authorization of responsible users. (97)
- 3-dimensional solid model must support the needs of all discipline. (102)
- Needs to handle legacy data. (112)
- Provide a method to utilize corporate standards and methods. (116)
- Data transfer to database must be automatic at completion of task -- not at discretion of user. (119)
- Integration must exist between Ford and suppliers' CAD/CAM/CAE systems. (121)

Figure 1.1: Attributes Field for Analytical Powertrain (Cont'd)

G) Tools

- CAD/CAM/CAE tools based on solid models. (7)
- Provide tools to interpret CAE data according to uniform standards. (68)
- Manufacturing process development and analysis tools. (73)
- Needs a better system of report writing and classification. (99)
- High-end CAE tools. (126)

H) Knowledge Based Engineering Tools

- Ability to capture or document past products and manufacturing knowledge in a database/bookshelf. (9)
- Ability to show interrelationships between parts/designs so that when one is changed, the other will automatically reflect the change. (12)
- Provide knowledge linking the interaction between component specifications and systems functionality. (14)
- Ability to capture "know-why" as well as "know-how." (17)
- Capability to identify design conflicts between different engineering disciplines. (25)
- System needs to provide detailed knowledge to the engineer about disciplines other than his own. (29)
- Characterized by standard consensed design rules and designated design starting point, i.e., comparator model. (41)
- Record the decision-making process involved in the powertrain design. (47)
- Must produce analytical prototypes with complete geometry definitions based on functional performance projection. (50)
- Ability to express design requirements within an acceptable range rather than a single value. (58)
- Ability to identify product definition change descriptions from the comparator at the feature level with the feature catalogue for reference by product engineers. (72)
- Provide generic component and system development plans. (77)
- Future design flexibility requirements based on production assumptions must be integrated. (113)
- System should provide an audit trail of changes to design and manufacturing showing cause and effect in order to build knowledge based reasoning. (124)

Figure 1.1: Attributes Field for Analytical Powertrain (Cont'd)

I) Analytical Powertrain Evolution

- Computer tools always need the same look and feel. (27)
- Characterized by hardware/software infrastructure which is consistent and follows planned and nearly simultaneous upgrade policy. (30)
- Must provide non-redundant processes. (32)
- Must provide computer equipment independence as much as possible (open systems). (43)
- Cannot invent technology but show technical stretch. (51)
- Requires a list of components to be included in the scope of the Analytical Powertrain. (81)
- Must have end-user input throughout the system life. (82)
- Needs not to be in a constant state of flux -- must be standards for computer tools. (92)
- Must remove the need for engineering drawings. (106)
- Must recognize that some engineering technology is still evolving, such as fatigue analysis. (110)
- Must identify evolving role changes and associated training requirements. (115)

J) Cultural

- Must address the cultural, environmental, and technical differences in the powertrain activities (engine, transmission, casting). (18)
- Identification of different customers and their needs. (31)
- AP process which creates little or no disruption to the organization. (35)
- Let data dictate design and process, not management. (53)
- Needs a shift in management thinking away from (the perception) that computer hardware and software can or will substitute for human creativity in the workplace. (55)
- Existence of a product design and manufacturing process improvement cycle independent of an approved program - feed bookshelves. (63)
- Must have the capacity to motivate those who are relied upon to make contributions (such as modelers and analysts) Since push-button engineering may not totally work by itself. (65)
- Needs to hold those managing the process accountable for results. (75)
- System should encourage harmony between disciplines. (87)
- All engineers will do their own CAD designs at full implementation level. (93)
- Software solutions should not be substituted for process and human or cultural solutions. (104)
- Modeling must be understood in a much broader context than CAD geometries and material databases alone. (105)
- Must address cultural issues for interfacing with non-powertrain activities, e.g., vehicle office, purchasing, and B&A. (118)

Figure 1.1: Attributes Field for Analytical Powertrain (Cont'd)

K) Concurrent Engineering Tools

- Ability to communicate design ideas and concepts between engineering activities. (3)
- A computer environment where concept design, design analysis for functional and manufacturing concerns, and detailed design can take place concurrently. (6)
- Direct correlation between literal information, CAD and manufacturing data. (56)
- CAE tools which accomodate specification ranges. (86)
- Need to prevent the feeling that this new design process is directed and controlled by the "computer people." (60)
- Capacity to support multiple users doing same task on different but similar products at same process level. (90)
- Automatic notification of those affected by design/process changes. (98)

Figure 1.2: Problem Field for Analytical Powertrain

A) Cultural Barriers

- Resistance in manufacturing and material handling engineering to learn and use 3D CAD/CAE tools. (34)
- Unwillingness of some users to share data. (39)
- Hostility toward databases. (45)
- Loss of Ford expertise due to fear of transition to AP . (67)
- Unwillingness to give up current tools and practices. (73)
- Fear of black boxes. (76)
- Resistance to concurrent engineering. (78)
- ***Resistance of Ford's culture to change to AP methodology. (88)***
- ***Inability to resist temptation to roll it out too early. (92)***
- Unwillingness to use AP products because "not invented here." (99)
- Resistance to redefinition of jobs or roles by designers, design engineers and analysts. (118)
- Failure to accept computer simulation (CAE) in place of hardware tests for certification due to legal barriers. (124)
- Resistance to give up a known solution for a new or different one. (128)

B) Lack of Readiness of Technology

- ***Shortfall of 3-D solid modeling systems that can meet the needs of all the different engineering environments. (1)***
- ***Lack of a complete set of analysis methods. (3)***
- ***Lack of readiness of some core technologies for implementation. (4)***
- ***Inability of some technologies selected and initially implemented to survive as viable products. (15)***
- Shortage of proven knowledge-based engineering techniques. (18)
- Shortage of manufacturing process development and analysis tools. (20)
- Lack of standards/methods to interface different databases together. (23)
- Lack of clear definitions of design and manufacturing features. (55)
- Inability to create an always accurate analysis system. (57)
- Potential failure of automeshing to be ready on time. (65)
- Lack of strategic control of third party software vendors product or product direction. (70)
- Lack of stable industry standards. (72)
- Inadequate capacity to contain database content. (105)
- Lack of technology to reduce CAD solid to CAE model. (115)
- Lack of technology to supplement CAD model for CAE analysis. (116)
- Inability of technology to handle the volume of data required. (120)
- Immature Object Oriented Database (OODB) Technology. (122)
- Lack of computer models capable of correlating to physical testing. (123)

Items that are highlighted in *italics* were selected by participants as being of "higher relative importance" and appear on the Problematique displayed in Figures 3 & 4.

Figure 1.2: Problem Field for Analytical Powertrain (Cont'd)

C) Misperceptions About Technology

- ***Overanticipation by management that AP will solve more problems than it really will. (22)***
- ***Failure to recognize that solid modeling and materials data represent only a small fraction of CAE needs. (33)***
- ***Misperception by management that CAD solid provides adequate model for CAE. (43)***
- Inability of analysis of results to always converge to an answer. (87)
- Conflict between vision and reality. (109)
- Unreasonable expectation of management that AP be usable by totally CAE unskilled workforce. (111)
- Misperception that technology will last forever. (117)
- Misperceptions about CAE technology - Engineers will not accept computer simulation, even when past results have been well correlated. (125)

D) Incomplete Scoping/Planning

- ***Scope of Analytical Powertrain undefined (2)***
- ***Lack of clearly defined vision process for end user (6)***
- Analytical Powertrain too ambitious-doubt a sufficient technically skilled workforce will be put in place to implement and support. (11)
- Lack of accurate assessment of technologies defined for AP. (17)
- Lack of a complete definition of analysis tools required. (25)
- Unclear definition of AP scope related to manufacturing. (28)
- ***Lack of clear role definitions among design engineer, designers and analysts. (38)***
- Conflict between priority of future AP implementation vs. solving engineers current problems/wants. (63)
- ***Failure of AP team to include in its design the needs of all users. (64)***
- Failure to include suppliers as AP participants. (75)
- ***Lack of definition of domain and scope of database contents. (82)***
- Unclear where AP fits with other corporate CAD/CAM/CAE strategies. (83)
- Inappropriate bench marking criteria for selecting technologies due to undefined scope of AP. (91)
- Failure to acknowledge or support existing minor CAE tools used by engineers. (101)
- Lack of a guiding corporate CAD/CAM/CAE strategy. (112)
- ***Difficult to limit the domain and scope of AP application into S/T & L/T plans. (114)***
- Inability to plan effectively due to lack of technical dictionary. (127)

Figure 1.2: Problem Field for Analytical Powertrain (Cont'd)

E) Implementation Risks

- Lack of time required for training of users may jeopardize implementation plan. (24)
- Loss of momentum due to slow start. (58)
- Unwillingness to admit some decisions were wrong and restart. (86)
- Unacceptable responsiveness caused by system complexity. (90)
- Lost of product advantage through data theft. (108)
- Inability of some technology suppliers to survive. (119)

F) Lack of Implementation Tool Standards

- Inability to coordinate software development across activities. (47)
- ***Failure to communicate precisely due to lack of technical dictionary (49).***
- Dilemma of having to deal with multiple solid modelers. (60)
- Lack of component and equipment supplier compatibility with Ford computer systems and software. (74)
- Lack of PTO standard tools/methods for developing system user's interfaces. (77)
- Difficulty in defining Ford standards for GUI (graphics user interface) ("What is easy to use?") (100)
- Difficulty in integrating applications from vendors with proprietary information. (106)
- Lack of corporate guidelines for solid modeling. (113)

G) Ineffective Management Participation

- ***Resistance to change by management. (7)***
- ***Lack of "effective" consensus among middle management on who does what. (30)***
- Failure of the organization to stick to an established plan. (32)
- Resistance of engineering managers to allow their engineers to design on CAD. (35)
- Resistance to remove organizational barriers. (69)
- Failure to maintain AP vision if top management changes. (96)
- Failure of management to commit to fully implement/utilize AP. (97)
- Interference from management during development process and component design. (102)
- Failure of management to allow AP to evolve beyond initial implementation. (103)

Figure 1.2: Problem Field for Analytical Powertrain (Cont'd)

H) Current Operational Constraints

- ***Demands by Ford culture for product hardware. (16)***
- Work load priorities may not support concurrent engineering. (26)
- Ford has budgeting barriers for procurement of software. (48)
- Demand for too many changes/scheduled inventions on new powertrain programs. (52)
- Work environment at Ford - too many meetings, too much mail, too little workspace, too much task interference and others. (54)
- Resistance to paying a supplier prior to issuing a PO hinders a supplier from being part of concurrent engineering. (56)
- Reluctance of Software vendors to accept Ford's standard terms and conditions. (68)
- Inadequate manpower resource allocation-priority given to current program versus future need, e.g., AP. (85)
- Resistance of management to allow sufficient time for their people to be trained. (121)

I) Lack of Skills/Training

- ***Inadequate skill level for using the specialized CAD/CAM/CAE techniques. (5)***
- ***Inadequate knowledge of Object Oriented Databases (OODB). (12)***
- Lack of skilled CAE computer system support personnel. (37)
- Shortage of skilled software development/management employees to achieve implementation. (40)
- Insufficient training/experience with CAE tools to allow acceptance of simulation results in place of physical testing. (126)
- Lack of user training to benefits and needs of database. (130)

J) Missing Application Knowledge

- Lack of a bookshelf methodology for manufacturing processes and product design. (9)
- Lack of definition criteria to enter bookshelf such as BIC (Best in Class). (31)
- Lack of a record of basic engineering elements/processes that are executed to manufacture a product. (44)
- Lack of agreed upon bookshelf content and DB structure. (89)
- Lack of complete documentation of current design and development knowledge. (98)
- Lack of bookshelf of product designs and manufacturing processes. (129)

Figure 1.2: Problem Field for Analytical Powertrain (Cont'd)

K) Maintenance Concerns

- Conflicts between versions of third party codes and operating system release versions. (27)
- Lack of adherence to standards caused by local support staffs. (62)
- Lack of computer systems are not 100% reliable. (81)
- Lack of reliability of local area network.(LAN) (93)
- Lack of resources to support software as it is introduced. (94)
- Lack of responsive computer system support. (104)
- Lack of resource allocation for proper maintenance of AP application. (110)

L) Development Resource Concerns

- Inadequate development resources. (10)
- ***Limited financial resources. (14)***
- Conflict between development or purchase of software. (29)
- Inadequate present computer hardware to implement AP (workstations, data storage, graphics, speed) (36)
- Demand for a stable resource level for life of AP development. (61)
- Lack of resources to start prototyping of implementation options and ideas. (84)
- Reluctance to commit adequate dedicated resources to the task. (107)

M) User Participation Concerns

- ***Failure to get buy in from all powertrain offices. (21)***
- Inability to obtain complete buy-in by AP users prior to implementation. (50)
- Unwillingness of users to invest in understanding implementation details as stakeholders. (51)
- Conflict between user wants and AP wants. (53)
- Loss of a continuing focus on the user during the development period. (80)

Figure 1.2: Problem Field for Analytical Powertrain (Cont'd)

N) Software Development Concerns

- ***Difficulty in developing software to encapsulate AP tools to control information flow. (8)***
- Evolution of the AP may not keep pace with engineering needs. (13)
- ***Difficulty of dispersing CAE functions to multi-user environment. (19)***
- Failure to integrate existing/new systems to AP. (42)
- ***Inability to acquire the volume of data required. (46)***
- Conflict between a need for commonality and users desire for personalization. (59)
- Lack of knowledge of technical issues for integration. (71)

Figure 13.2 Options Profile--**Workshop Phase** for a **Definition Outcome at Success Level 1**

A. PHASE SELECTED

- Planning Phase
- Workshop Phase
- Followup Phase

TIE LINE

B. OUTCOME SOUGHT

- Issue or System Definition
- Alternative Designs
- Choice of an Alternative Workshop Plan
- Implementation

C. SUCCESS LEVEL

- Level 1
- Level 2
- Level 3
- Level 4
- Level 5

D. STEERING FACTORS

- Context Statement
- Triggering Questions
- Generic Questions
- White Paper
- Workshop Plan
- Workshop Reports

E. ROLES

- Client
- Sponsor
- Broker
- Participant
- Workshop Planner
- IM Facilitator
- Pattern Interpreter
- Report Manager
- Observer
- Facility Preparer
- Computer Operator
- Video Operator
- Display Arranger
- Scribe

F. PROCESSES

- Ideawriting
- Enhanced NGT
- ISM
- DELPHI
- Field Development
- Profile Development
- Tradeoff Analysis

G. PRODUCTS

- DELTA Chart
- Problematique
- Enhancement Structure
- Intent Structure
- Resolution Structure
- Priority Structure
- Curriculum Structure
- Options Field
- Problems Field
- Attributes Field
- Options Profile
- Attributes Profile
- Tapestry
- Comparison Bar Charts
- Unified Program Planning Linked Matrices

TIE LINE (CONTINUED)

$$M: \begin{cases} \alpha: & a + b = 5 \\ \beta: & bc = 10 \\ \gamma: & d = bc^3 \\ \delta: & d + e = \sin e + b^2 \end{cases}$$

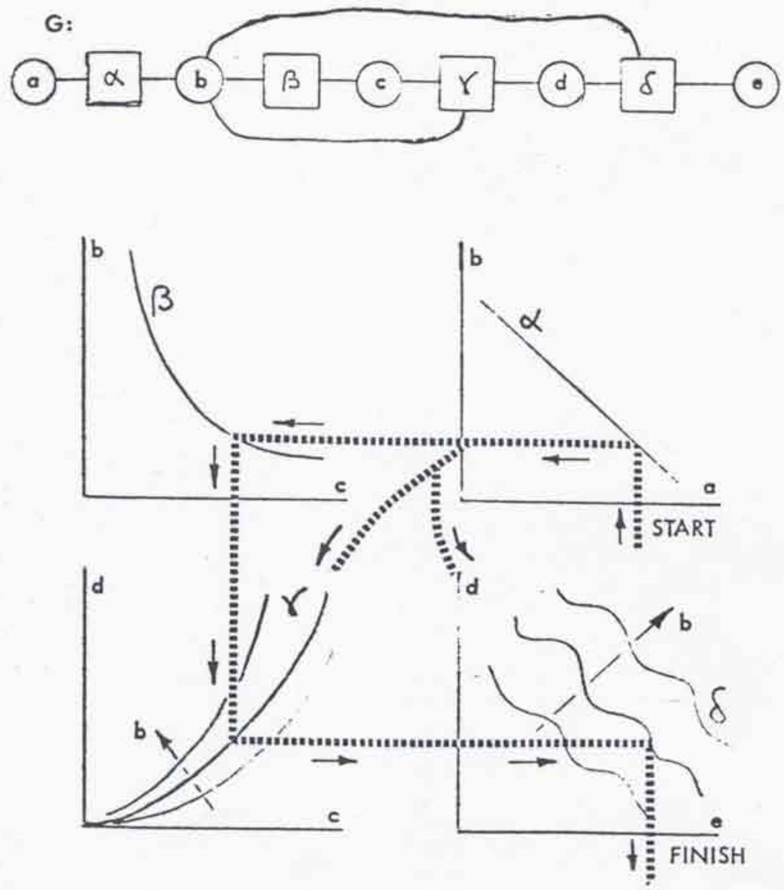


FIGURE 4-1. FLOW OF CONSTRAINT FROM RELATION TO RELATION.

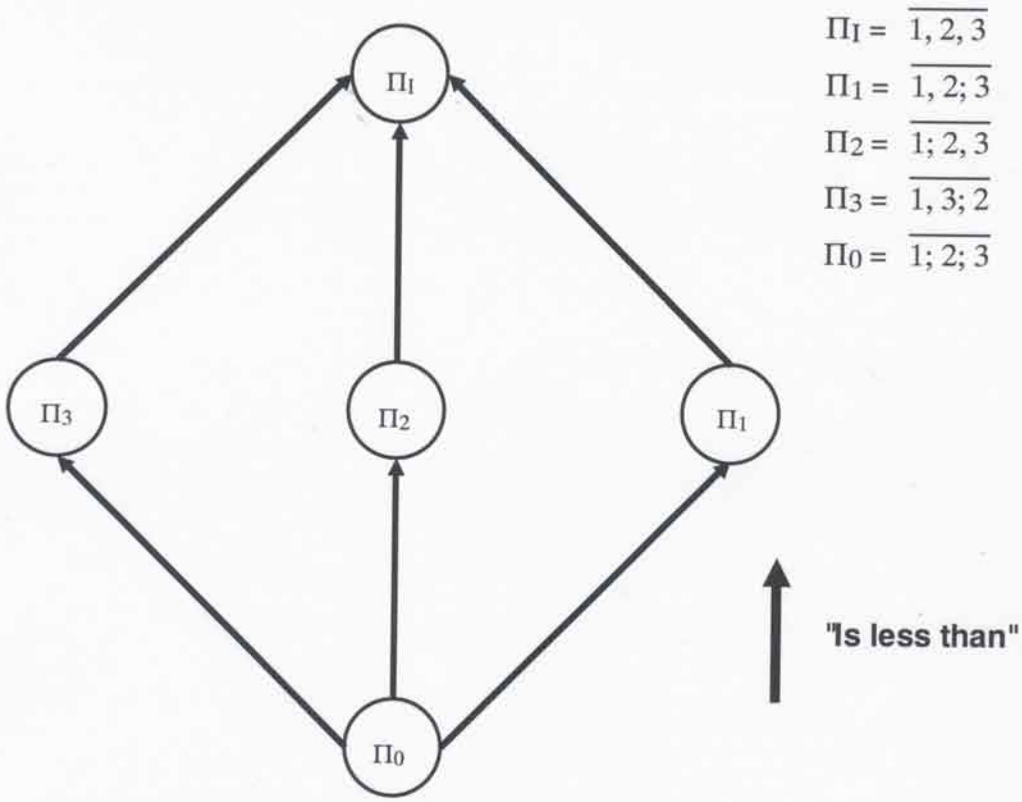


Figure 2.9 Lattice of partitions of a three-element set.

$P_0 = \Phi$
$P_1 = 1$
$P_2 = 2$
$P_3 = 3$
$P_4 = \{1,2\}$
$P_5 = \{1,3\}$
$P_6 = \{2,3\}$
$P_7 = \{1,2,3\} = S$

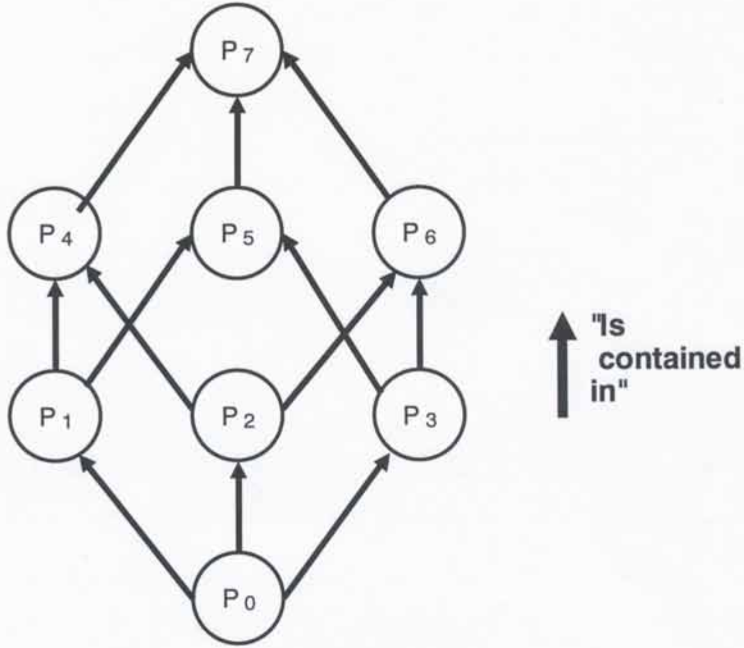


Figure 2.10 Lattice of subsets of a three-element set.

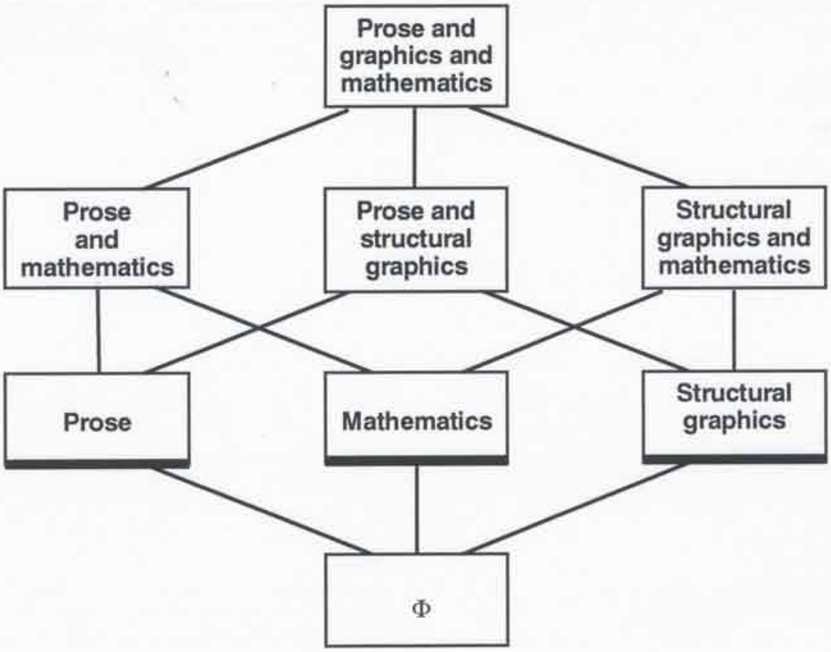


Figure 2.12 Lattice of communication alternatives.

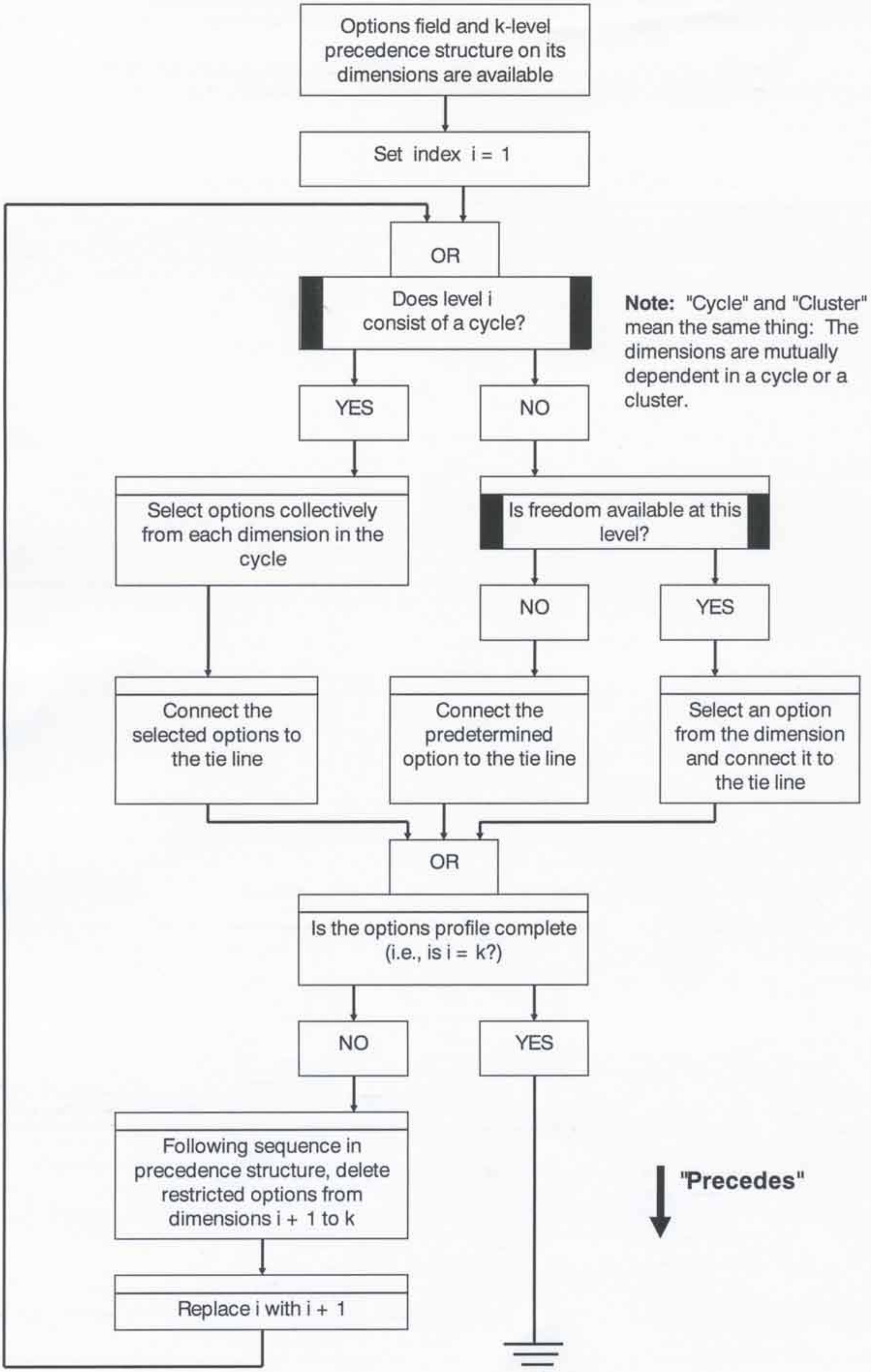
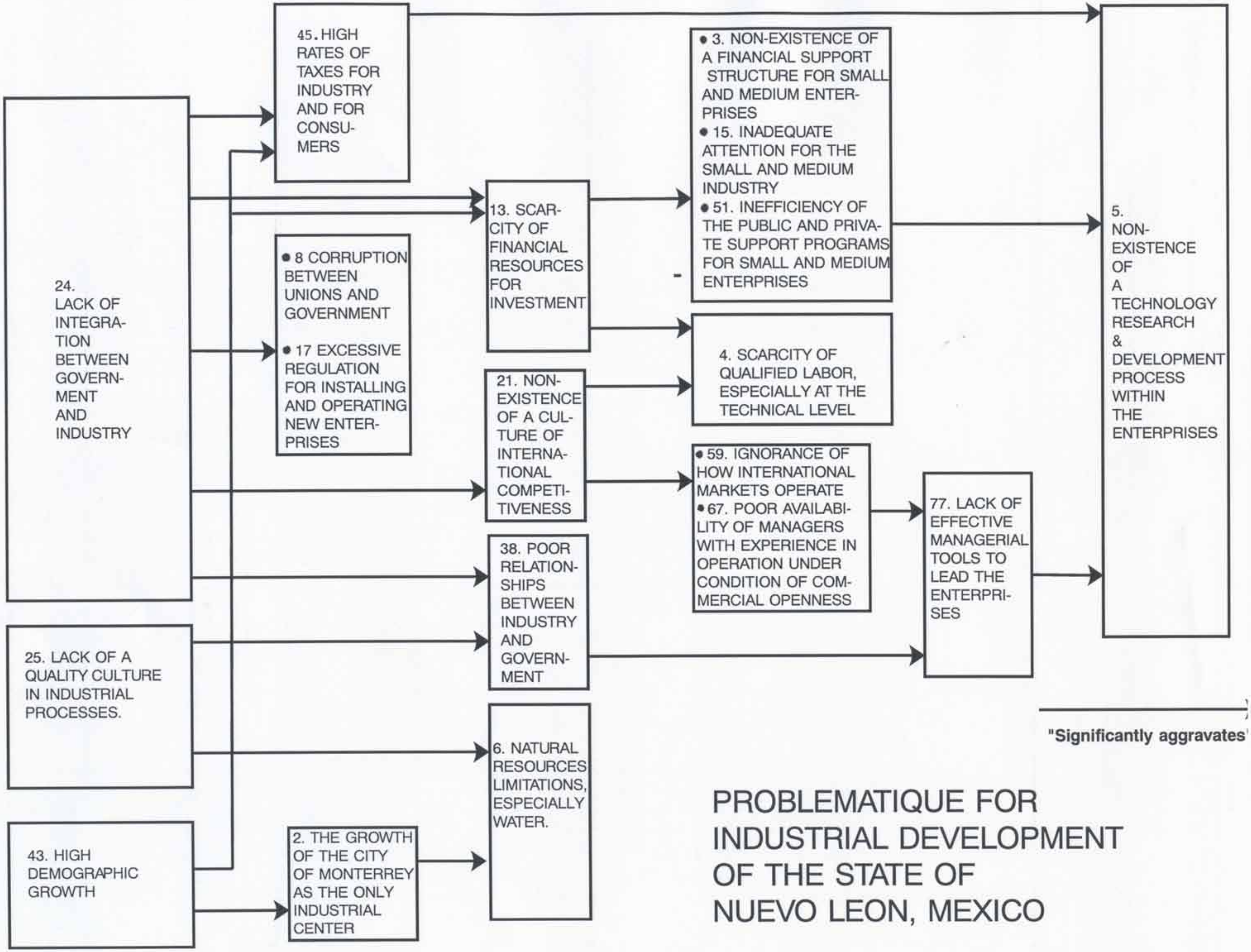


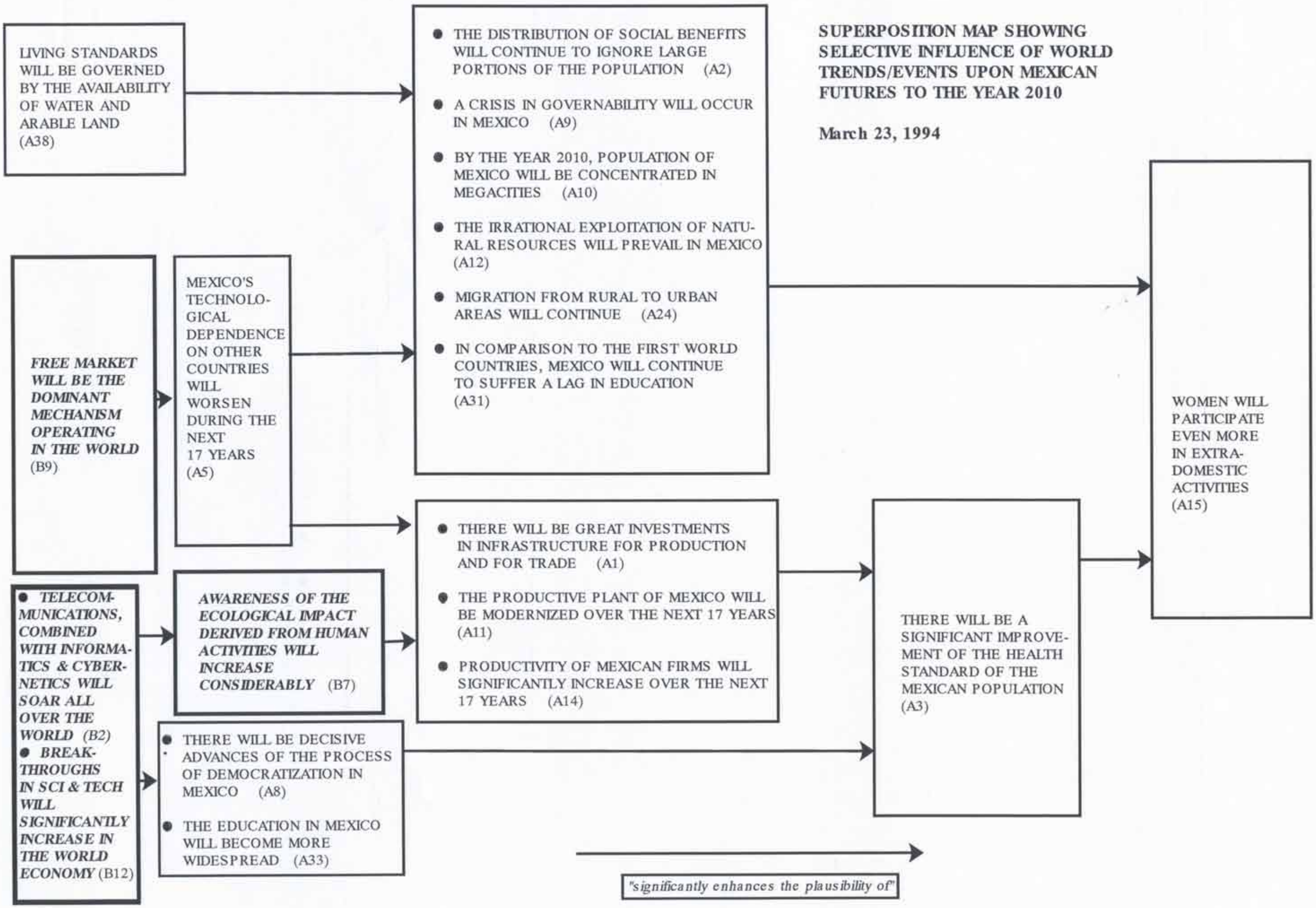
Figure 7.22 DELTA chart of options profile methodology.



PROBLEMATIQUE FOR INDUSTRIAL DEVELOPMENT OF THE STATE OF NUEVO LEON, MEXICO

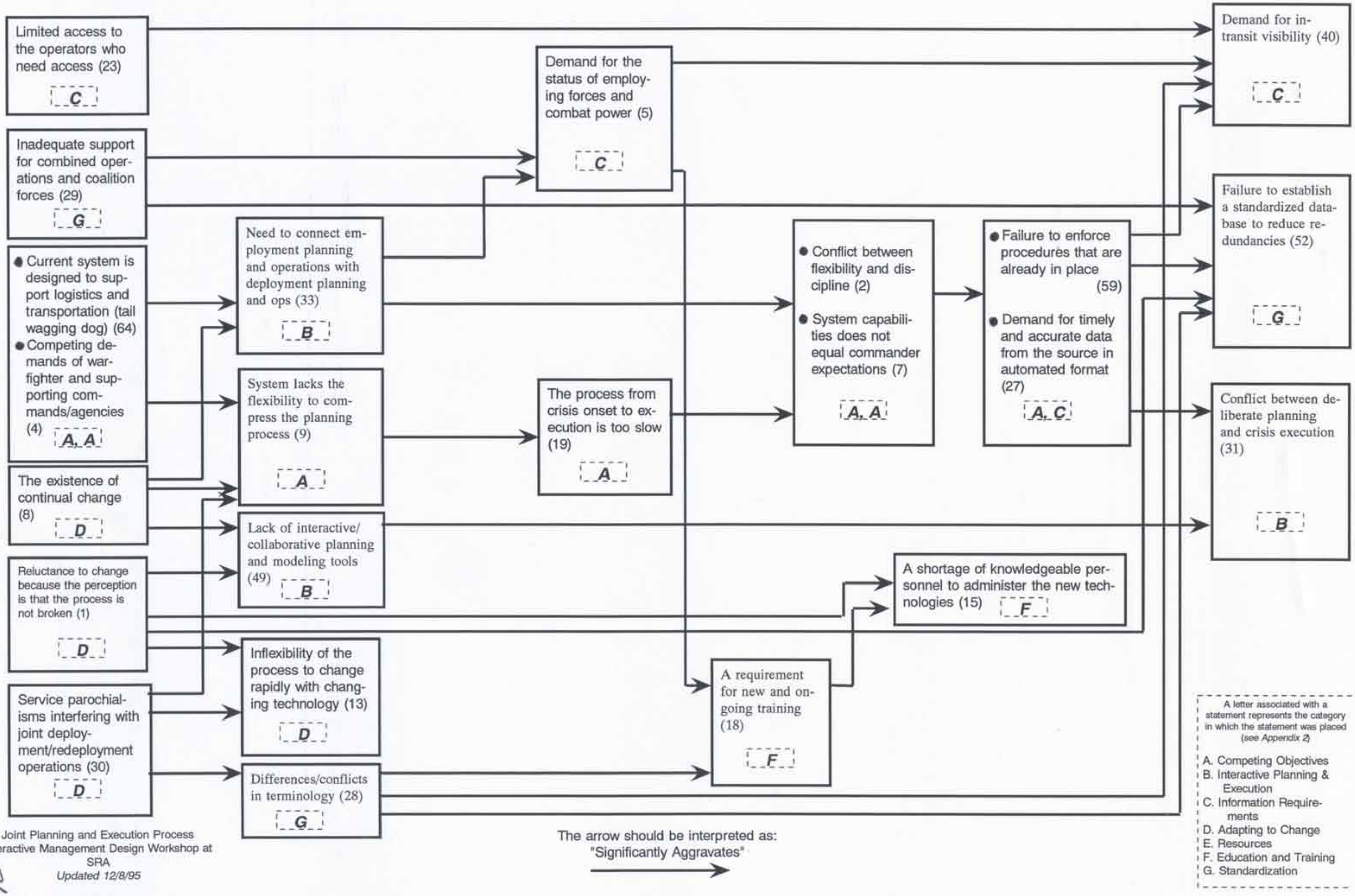
SUPERPOSITION MAP SHOWING SELECTIVE INFLUENCE OF WORLD TRENDS/EVENTS UPON MEXICAN FUTURES TO THE YEAR 2010

March 23, 1994



Problematique

How some problems aggravate others (see Appendix 2)



Joint Planning and Execution Process
Interactive Management Design Workshop at SRA
Updated 12/8/95

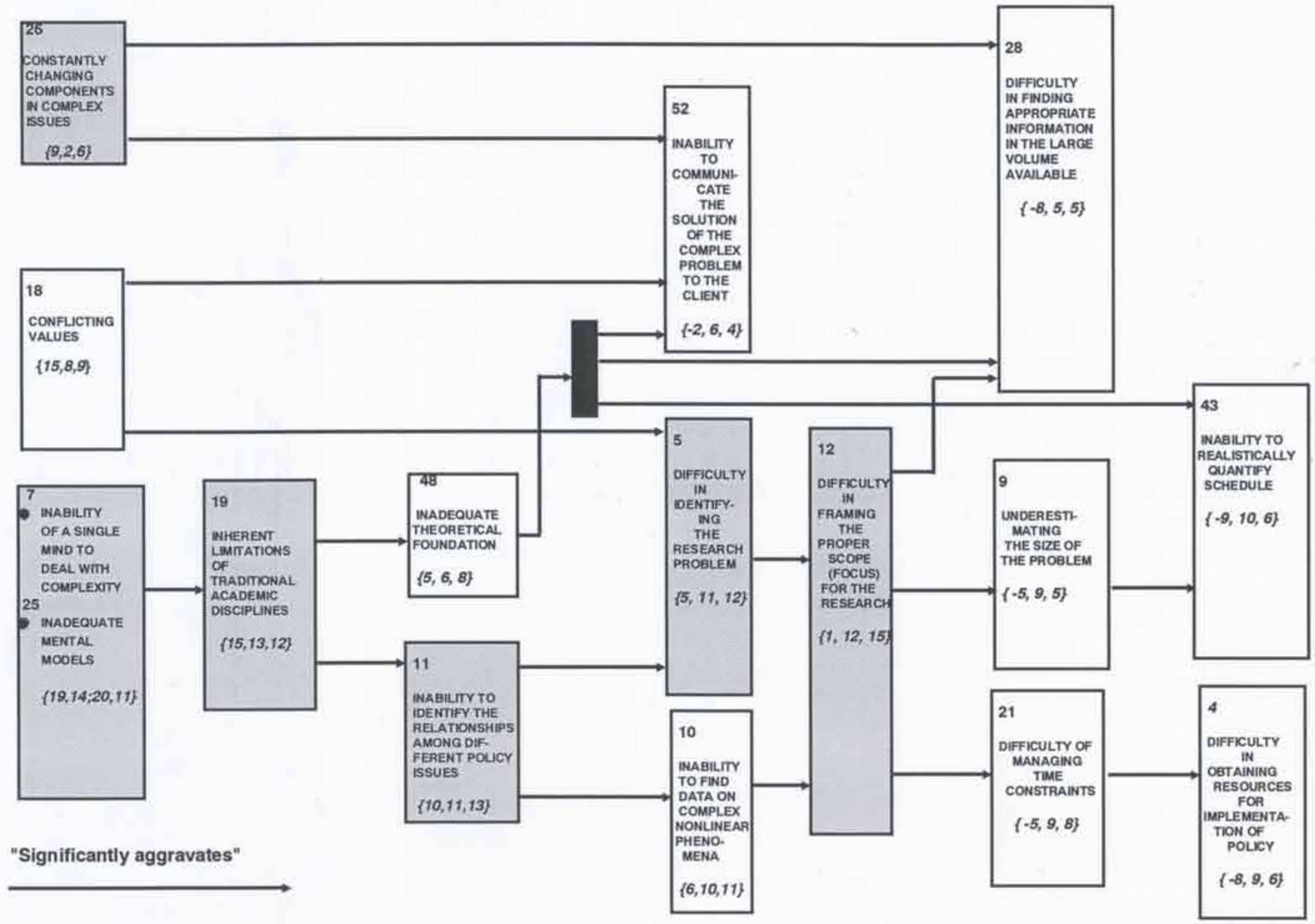


FIGURE 14.5 PROBLEMATIQUE FOR POLICY RESEARCH--DEVELOPED IN JANUARY TIPP SHORT COURSE, 1995

(Scores are in curly brackets in the order: Influence, Activity, Weighted Voting.)

(Prepared by J. N. Warfield, January 14, 1995)

Shaded problems require special attention, as indicated in the accompanying text.

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John N. Warfield is University Professor and Director of the Institute for Advanced Study in the Integrative Sciences (IASIS) at George Mason University (GMU), a state university, in Fairfax, Virginia. IASIS is a component of the Institute of Public Policy (TIPP) at GMU.

He received the A.B. degree, the B. S. in Electrical Engineering, and the M. S. in Electrical Engineering from the University of Missouri (Columbia) in 1948, 1948, and 1949, respectively. He received the Ph. D. degree from Purdue University (West Lafayette) in 1952, majoring in electronic communications.

He has 37 years of university faculty service, of which the past 11 years have been at GMU. He has spent a total of 19 years as a faculty member in Virginia, and during that time has had the designation "eminent scholar" in the Virginia system. He has about 10 years of industrial experience: Director of Research, Wilcox Electric Company (1965-66); Senior Research Leader, Battelle Memorial Institute (1968-74); Senior Manager, Burroughs Corporation, (1983-84). This experience included research of both theoretical and experimental nature, electronic development and reliability testing of navigational equipment for jet aircraft, and management experience in overseeing research projects and industry-university contracts.

He has served as elected President of the Systems, Man, and Cybernetics Society of the Institute of Electrical and Electronics Engineers, and is a Life Fellow of that organization. He has served as elected President of the Society for General Systems Research (later renamed the International Society of Systems Sciences). He served 9 years as founding editor of Systems Research and four years as editor of the IEEE Transactions on Systems, Man, and Cybernetics.

He is the author of two U. S. patents on electronic equipment, and is the inventor of Interpretive Structural Modeling, Interactive Management, and Generic Design Science.

He is sole author of four books, co-author of another book, and co-translator of a classic German work on communication networks. He is author or co-author of over 100 papers. He is in demand as a speaker and collaborator outside the United States where his research contributions are well-known, and has presented this work in ten nations, and has taught one-week short courses in five of them.

His primary activities in the past few years have involved preparing two books for publication in 1994, authoring papers, presenting papers at conferences, teaching short courses, and serving as an information resource or an active participant in working with individuals who are seriously dedicated to improving quality, effectiveness, efficiency, communication, and organizational cultures in their various organizations. He is presently preparing a new book manuscript titled: The Work Program of Complexity: From Origins to Outcomes. Biographical sketches of Warfield can be found in American Men and Women of Science, Who's Who in Engineering, Who's Who in Frontier Science and Technology, and Who's Who in America.