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Methodology Catalog

An Aid to Intelligence Analysts and Forecasters (U)

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An Aid to Intelligence Analysts and Forecasters

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✓ Delphi III-9-20

PREFACE

This Methodology Catalog provides a descriptive inventory of selected analytic and predictive techniques. It is designed to help the individual analyst or forecaster make an informed decision as to which method(s) to pursue. Our expectation is that the user will then take the initiative in seeking assistance from available experts in the organization or from appropriate training personnel. For those users interested in pursuing self-instruction, the Methodology Catalog provides a list of creditable texts on the various techniques.

For convenience sake, the techniques have been grouped into five major sections: Structuring Techniques, Qualitative/Judgmental Methods, Trend Analysis, Probabilistic Forecasting, and Automated Simulation Models. Each technique in these five sections is treated in uniform fashion. There is a brief description of the technique, a discussion of underlying assumptions and rationale, and an illustrative problem. This is followed by discussions of resource requirements to apply the technique, typical users of the technique, strengths and weaknesses, and references for further information or self-instruction. The Catalog concludes with a section that makes some representative correlations between specific intelligence forecasting functions and appropriate analytic methods.

The Catalog is published as a loose-leaf, updatable document. We intend to publish and disseminate additional descriptive pieces (e.g., on "payoff-regrets matrices" and "political-risk analysis") as resources permit. Feedback from users would be most helpful in guiding our future efforts. Please address comments, recommendations, or questions to: Defense Intelligence Agency, (b)(3):10 USC 424,(b)(3):50 USC 403-1(i) Washington D.C. 20301. Our telephone numbers are: (b)(3):10 USC 424,(b)(3):50 USC 403-1(i)

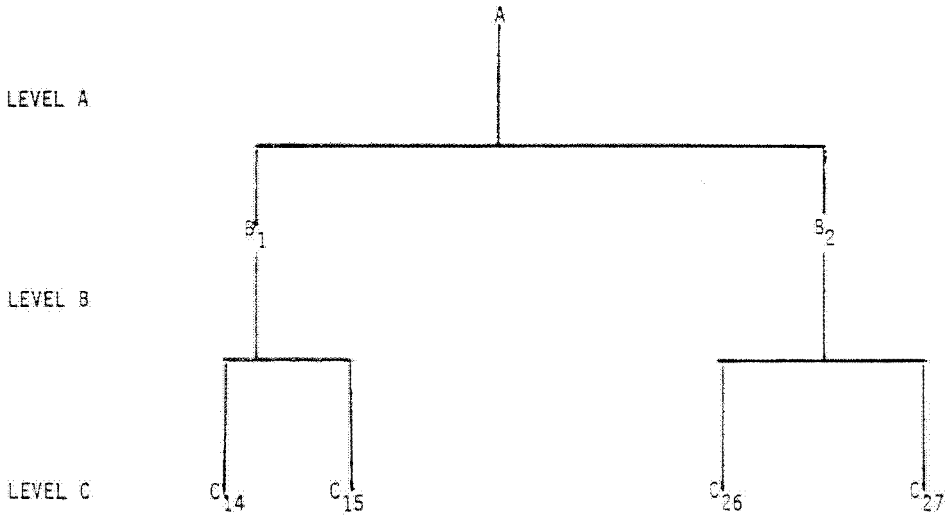
B. RELEVANCE TREES

1. Description

Relevance trees portray complex hierarchical relationships using the vertical tree diagrams, such as in Figure II-1. The tree is divided into branches at various levels, with branches at each lower level containing more detailed and finer subcomponents of the system than the level just above it. The point of the tree at which a branch subdivides into lower branches is a node. Each node has a minimum of at least two branches emerging downward (depending) from it; the maximum is unlimited. The nodes in a specific relevance tree are not required to have the same number of branches. Each lower branch is included in or related to the branch from which it emerges; each upper branch contains all the lower branches emerging from it. Usually some notation identifies the branches of a relevance tree, so that the sequence of subscripts uniquely identifies the path from any given branch to the top of the tree.

Figure II-1

Simple Relevance Tree

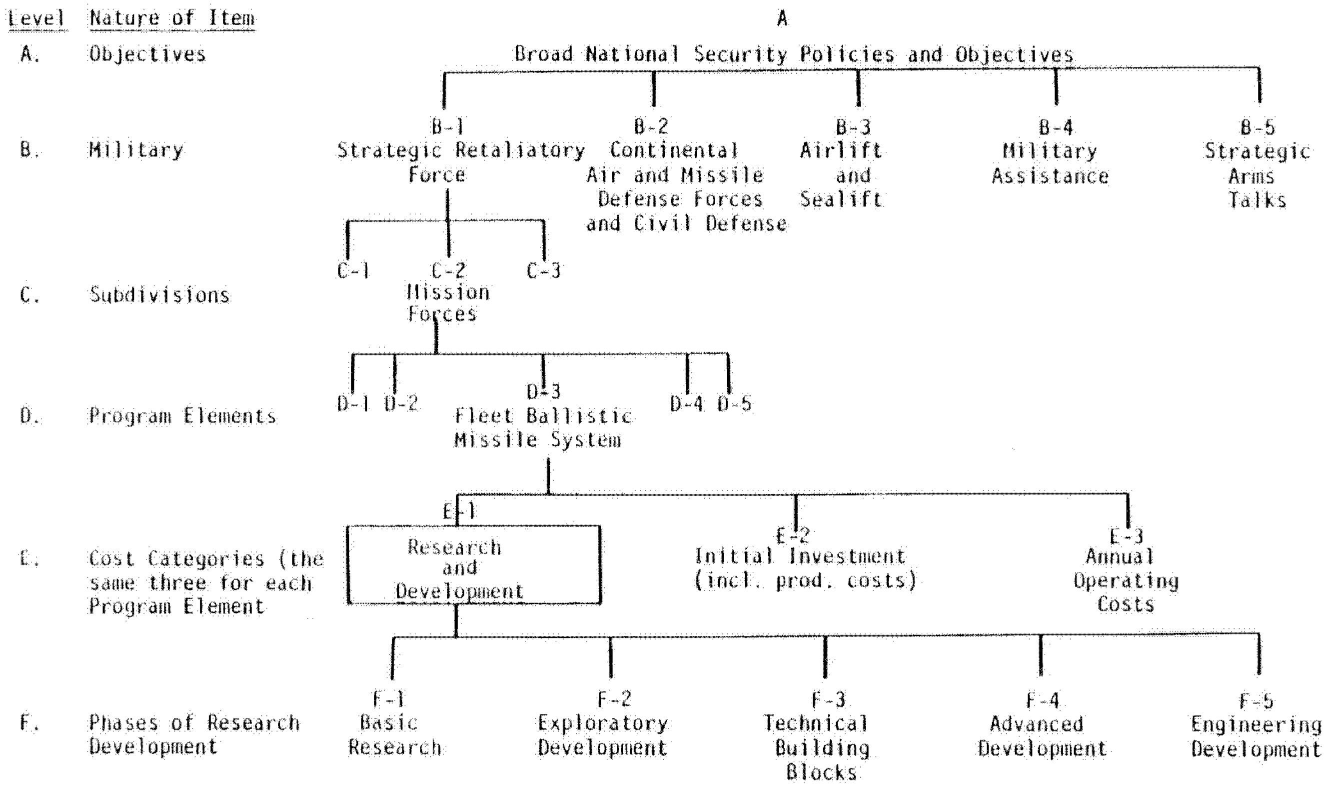


Relevance trees are frequently used to describe a system in ever-increasing detail or to examine a broad objective or complex issue by decomposing it into smaller elements. The tree can be used as a tool in analyzing the performance of system, or conversely, may show alternative solutions to various aspects of a problem. They can be used in normative (top-down) forecasting by associating goals with each node. For a problem tree, all the problems branching from a node must be resolved before the goal for that node can be met; for a solution tree, the goal can be met if at least one of the solutions branching from the node is viable.

Numerical weights (relevance numbers) can be assigned to the branches of each node of a relevance tree. These weights can then be used to derive quantitative estimates of the relative value of elements on the lower level of the tree. The meaning attached to the relevance varies according to the purpose of the tree. Examples include the relative importance of an item in terms of its contribution to achieving the overall objective or mission, the probability of accomplishing an item within a given time frame, or the relative costs of the items. Relevance numbers are always normalized so that the sum of the relevance numbers of the branches depending on a given node is equal to one. The relative weight attached to the lowest level elements is then calculated by multiplying the relevance numbers along each path from the highest level objective to the lowest element.

Relevance trees are not used to predict or forecast a future event. Rather, they are an analytic tool that provides a framework for identifying the components of a system and the interdependencies among the components and for evaluating the relative importance of the components within the system. The tool can provide the structure that is often required with a variety of other techniques (such as pattern identification, precursor analysis; social trend analysis; KSIM, and cross-impact analysis).

Figure II-2 RELEVANCE TREE IDENTIFYING PROGRAM REQUIREMENTS FOR A NATIONAL SECURITY PROGRAM



Source: Adapted from Erich Jantsch, Technological Forecasting in Perspective. (Paris: OECD, 1967.) p. 306.

2. Underlying Assumptions and Rationale

Relevance trees are based on the following underlying rationales:

- The understanding of a complex system is facilitated by the identification of the component and the relations of the component to one another.
- The system can be decomposed into successive levels of complexity with a branch at a given level relating to only one node on the above level.

The technique incorporates concepts from systems analysis theories, opinion polling theories, and network theories. All relevance trees possess several important characteristics:*

- The branches depending from a node must be an exhaustive list of all the possibilities for that node. Closure of the list may come from simply listing all the elements of a finite set, or the list must be closed artificially, by a consensus of agreement.
- The branches depending from a node must be mutually exclusive from each other. Sometimes the items will naturally be mutually exclusive, other times the items will need to be carefully defined so as not to overlap onto each other.
- A relevance tree used for a normative purpose must be viewed as a set of goals and subgoals. Each node will be a goal for all those branches depending from it. Thus each node (goal) will be satisfied by the accomplishment of the branches below it.

3. Illustrative Problem

Since one purpose of this structuring technique is to identify levels of hierarchy, it could be useful in developing order of battle formations. For example, the Group of Soviet Forces Germany (GSFG) includes five

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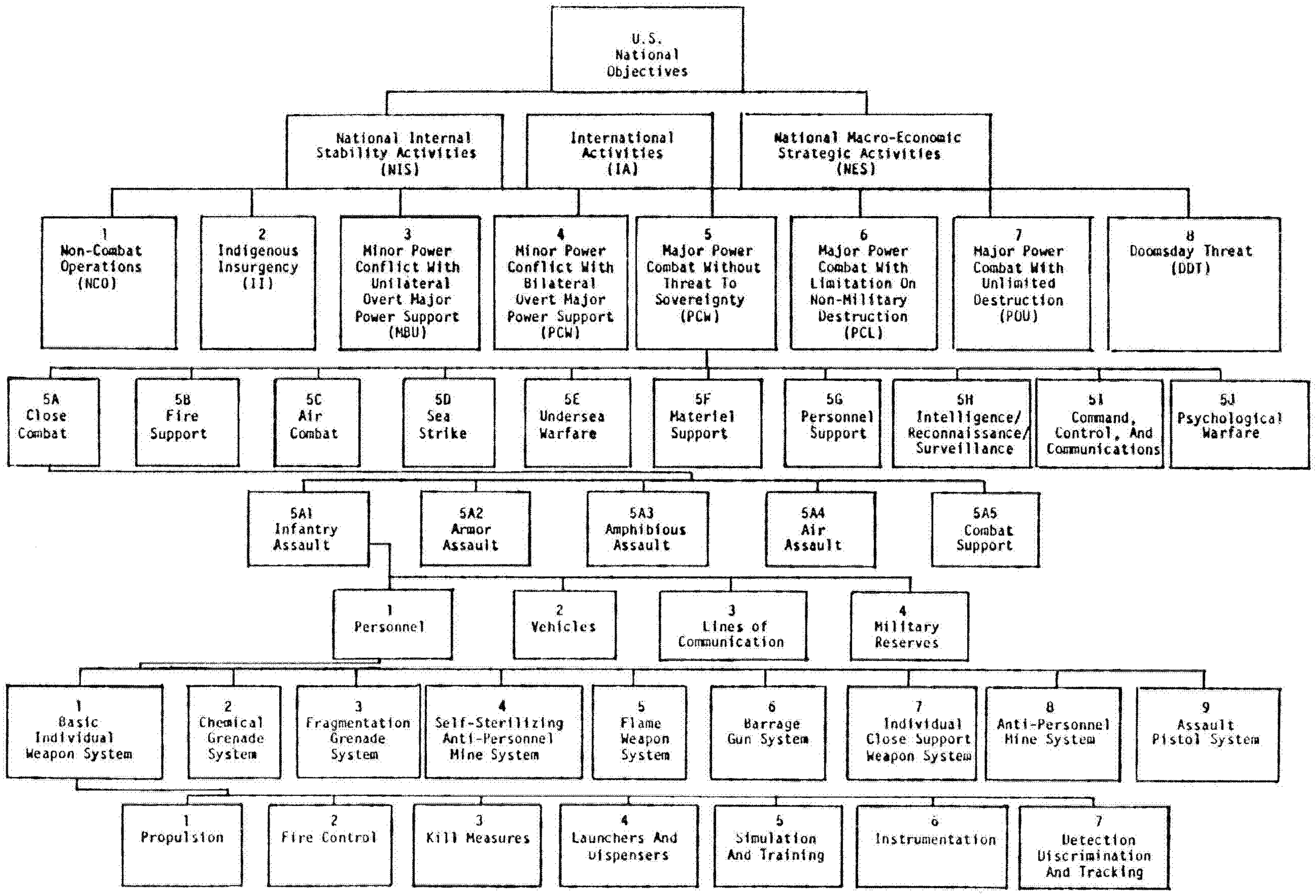
*Joseph P. Marino, Technological Forecasting for Decisionmaking (New York: American Elsevier Co., Inc., 1972), p. 288.

Figure II-3 SAMPLE BRANCH ARMY RELEVANCE TREE



Source: U.S. Army, Army National Development and Readiness Command, Foreign Science and Technology Center combined arms armies--the 2nd Guards Army, 20th Tank Army, 3rd Shock Army, 8th Guards Army, and 1st Guards Army. Individual Soviet and East German Units composing the GSFG could be organized under these levels.

The method lends itself to examining military missions. Figure II-3 traces an army mission through one of three types of national activities through one level of combat, to one mission (close combat) to one operational task (infantry assault) to one target type (personnel), to one weapon system (Basic Individual Weapon System), to one subsystem/technology area (propulsion).

4. Resource Requirements

The logic and credibility of a relevance tree depend on the comprehensiveness and reliability of contributor input. Therefore, it is best to use a team of people who are well informed about the mission or topic to be explored to assure a balanced and complete coverage of possible events.

The required data and their availability will vary depending on the scope and scale of the project. The construction of numerical relevance trees may require the use of a computer to calculate efficiently the relevance numbers. Time and cost will also vary with the scope and scale of the project. Relevance trees are often used for large-scale, complex projects. For such projects the input of several teams of experts, use of a computer, and several man-months are typically required for the preparation and revision of the relevance tree. However, the trees can be effective for smaller scale projects where they may require only a few hours of an analyst's time.

5. Summary of Uses

Honeywell is the acknowledged pioneer in the development and use of both quanitative and qualitative relevance trees. Its PATTERN technique was first used to establish long-range R&D program priorities for its aeronautical and space activities, and later was extended to cover all the military and space activities in which Honeywell was interested. Many variations of the relevance tree technique have been used by government and private industries for a variety of purposes, including product development, program development and evaluation, technological forecasting, and establishing goals and priorities. Some current and potential applications of the technique include:

- Assessing current and future impacts. Batelle Memorial Institute developed a "perspective tree" that provides a framework for structuring miniscenarios for evaluating future technical alternatives against potential political, social, and economic changes in the environment.

- Upgrading and structuring research and development programs. For example, North American Aviation uses SCORE to relate objectives 5 to 15 years in the future to strategy and operational tactics. The Planning Program-Budgeting System (PPBS) used by the U.S. Department of Defense used relevance trees as a basis for resource allocation and program ranking.

- Providing structure and input for long-range social and political forecasts. The technique is useful for providing a basis of information for developing global or regional scenarios, identifying the relevant factors to be considered in a threat parameter or threat system analysis, identifying the program elements for completing various missions, and so on.

- Planning and organizing complex situations, such as identifying the functional parameters and capabilities for completing a specified mission, the required manpower, targeted weak points, and so forth.

- Identifying technology deficiencies in relation to systems, concepts, and broad requirements. For example, variations of PATTERN were used for NASA's Payload Evaluation Tree, the U.S. Air Force for a study entitled "The Role of Air Power in Limited War and Counter-Insurgency," and the U.S. Air Force for a tactical fire power study.

- Evaluating alternatives, in accordance with main objectives.

- Identifying the relative value of selected technology improvements in a given area, such as greater accuracy, lower cost, lower weight, and so on.

6. Strengths and Weaknesses

Relevance trees are flexible techniques that can be easily adapted to meet different needs, whether establishing goals and priorities or describing and analyzing very complex systems. The basic method is easy to learn and to use, although relevance trees for very complex systms do tend to become very detailed and usually require the input of several people to be comprehensive. Numerical relevance trees are a bit more complicated to use and require knowledge of some probability and weighting schemes.

A major strength of relevance trees is that they can provide a graphic display of a complex system from which a person can easily grasp the complicated interrelationships and interdependencies among the variables and easily identify the steps necessary to achieve some goal or mission. However, the structure of a relevance tree can also be a hazard in that events (branches) not identified will not be considered and evaluated for their impact. Thus the potential exists that a branch excluded through insufficient care or consideration may be more important than those included, and elements essential to the successful accomplishment of a mission could be misssed. Therefore, care should be taken to use a team of expert people to gain a comprehensive and balanced spectrum of input.

Another caveat to remember when using numerical relevance trees is that relevance numbers obtained by the consensus of expert judgment are only as valid as the credibility of the experts.

7. References

A number of references and applications of the relevance tree technique exist in the files and libraries of defense agencies and private industries. Some representative examples of relevance tree discussions in the scientific literature follow:

Bright, James R. Practical Technology Forecasting Concepts and Exercises. Austin, Texas: The Industrial Management Center, Inc., 1978. Chapter 8 provides some very useful exercises for grasping the reasoning used when constructing relevance trees.

Esch, Maurice E. "Honeywell's PATTERN: Planning Assistance through Technical Evaluation of Relevance Numbers." A Guide to Practical Technological Forecasting. Eds. James R. Bright and Milton E. F. Shoeman. Englewood Cliffs, N.J.: Prentice-Hall Inc., 1973. This chapter provides a description of the PATTERN methodology in a military application.

Jantsch, Erich. Technological Forecasting in Perspective. Paris: OECD, 1967. Pages 219-33 discuss the PATTERN relevance tree methodology.

Martino, Joseph P. Technological Forecasting for Decisionmaking. New York: American Elsevier Co., Inc. 1972. Chapter 9 has an excellent, simple, clear-cut discussion on the basic principles, method, and use of relevance trees.

C. CONTEXTUAL MAPPING

1. Description

Contextual mapping graphically depicts plausible sequences of development in a given topic area (such as the development of jet engines). The maps may also indicate future possible and plausible development outcomes for the designated sequence of events. The technique assumes that a given sequence of technological development will make possible certain further developments. An analyst using this technique could specify any development sequence desired and from it try to discover what further developments could be encouraged and made feasible. Conversely, the analyst could specify some future technological development of interest and working backward try to discover how many different sequences of preceding development could lead up to the development of interest. For example, the analyst could specify some generally desirable features for a new missile system in Southeast Asia. Then working backward, the analyst could try to estimate how many different sequences of R&D could enable the development of the system.

Contextual mapping has a variety of versions. Two versions described by Cetron et al.* will provide a basic understanding of the approach.

- Figure II-4 is a contextual map that views a trend of development as a process in the acquisition and application of knowledge. In the example, high vacuum technology" is shown as a series of inventions and concepts that led to further advancements. This approach is based on the fact that inventions often occur in functually equivalent groups.

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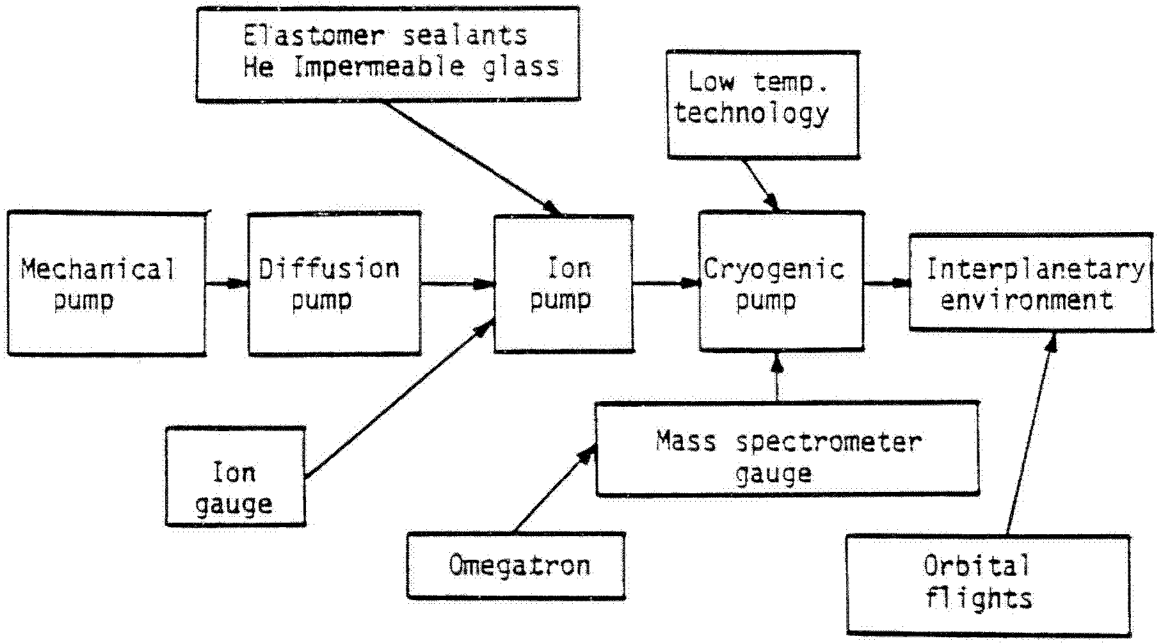
*Erich Jantsch, Technological Forecasting in Perspective. (Paris: OECD, 1967), p. 172.

Figure II-4

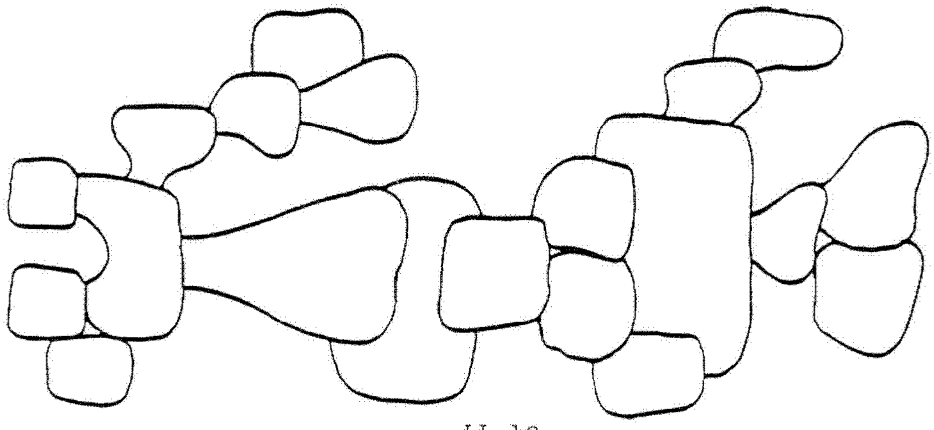
A TREND AS A PROCESS OF THE ACQUISITION AND APPLICATION OF KNOWLEDGE IN THE DEVELOPMENT OF HIGH VACUUM TECHNOLOGY



The contextual map of Figure II-5 views a trend of development as evolution in the configuration of a system. This approach is particularly applicable for large complex systems such as military technical systems that are in continuous evolution and apart and discard a large number of specific technologies (for example: NASA space research or air defense). In this map, directives of systems growth that were abandoned or are expected to flourish only temporarily are depicted as buds that stop reproducing. The size and interfaces of buds can be used to indicate the strength and sources of growth increments.

Figure II-5

TREND AS AN EVOLUTION IN A SYSTEM



The contextual mapping methodology permits us to place observed capabilities into contexts of potential uses and applications, or allows us to search for indicators and signatures for potential developments. To establish the potential context of uses and applications, it is necessary to project observations made of systems development into the realm of a fully developed system. Conversely, if one were to envision a fully developed system, it would be possible to use the context of this system to look for its components and identify indicators and perhaps the necessary signatures to develop notions of the potential direction that a country may take toward the acquisition of such a system's capability.

The technique is most useful for exploring the possibilities, interrelationships, and conditions between different parameters of a system or problem. The greatest value of contextual mapping comes from its use as an exploratory technique supplementing a normative forecast. For example, a relevance tree can be used to identify the normative goals, objectives, and priorities of a project. Then contextual mapping can be used to sort out the criteria for meeting those various goals and objectives.

The challenge in applying contextual mapping is to look for the missing elements. They are the elements in intelligence work that frequently cast doubt on future possibilities. However, identification of the missing elements should be an encouragement for more extensive work on the part of the intelligence observer, and the expectation should be that the developer will expend considerable effort in the area where expertise appears to be lacking. Consequently, contextual mapping, carefully used, can establish areas to be monitored and signatures to be developed. Complex contextual mapping includes simulation of system effects in varying stages of maturity·and deployment.

The logic and credibility of contextual mapping is highly dependent upon the level of confidence placed upon the intelligence, experience, and judgment of the people providing the input. Thus the results from a contextual mapping exercise will generally be accepted as credible when they are presented as a range of possibilities rather than if they are presented as a prediction of a certain event occurring at a certain time.

2. Underlying Rationale and Assumptions

Contextual mapping is built upon the rationale that "future developments that depend on the simultaneous progress of a number of parameters or capabilities or on certain environmental (economic and other) conditions can be explicitly forecast--where it would be difficult to forecast with any reasonable probability time dependent progress or all the parameters involved."*

The technique is based on systems analysis and simulation theory. Basic assumptions include the following:

- Current technological developments will evolve in foreseeable directions.
- Logical, plausible new "clusters" of emerging technological capabilities can be foreseen if enough good historical data are provided.
- Uses to which the technological clusters might be put can be systematically explored.
- Future technology responsive needs can be foreseen, and can be related to emergent sequences of technological developments.
- Preceding capabilities can be seen far enough ahead in sufficient detail to make contextual mapping a profitable investment in support of research and product planning and capital budgeting.

3. Illustrative Problems

Contextual mapping could be used to monitor nuclear weapon proliferation. Careful observation of such factors as scheduled nuclear power plant installation, changes in anticipated reprocessing needs, or the sudden acquisition of potential nuclear delivery systems in a so-called

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[*] Erich Jantsch, Technological Forecasting in Perspective. (Paris: OECD, 1967), p. 173.

"near nuclear" country could significantly alter the probability that its national leadership might exercise the nuclear option. Political-military as well as technical factors can be equally important. The withdrawal of a security guarrantee by a superpower or the sudden emergence of a regional security threat coiuld spur political leaders to seek a nuclear capability.

Contextual mapping could assist analysts considering alternative paths of weapon development (e.g., minimum resource option, hedge option, suprise-free option) to identify probable time frames for weapons development in prominent near nuclear countries. The exercise could be the first step in developing disincentives for nuclear weapon development as part of U.S. strategy to discourage the proliferation of nuclear arms.

4. Resource Requirements

The use of contextual mapping requires a person or people trained and experienced in general systems analysis thinking and the methods of contextual mapping. Such people also need to be experts in the topic to be explored.

The data required, and their availability, depend on the topic area to be forecast. If the topic is narrow and well defined (such as jet engines), then detailed and quantifiable data would be useful. However, if the technique is to be used for systematically conjecturing about future complex and highly uncertain social-political situations, then less-detailed qualitative and quantitative data may be used. The time and cost requirements for a contextual mapping exercise would range from a few workdays and minimal cost for a narrowly defined topic with a short time span to a number of work-months and medium cost ($50,000) for a long-range forecast in a broad and complex subject area (such as the analysis of strategic ground and air weapon systems in emerging conflict areas of various regions of the world until the year 2000).

5. Summary of Uses

Contextual mapping has been widely used for military and industrial technological forecasting and product research and development in a number of areas including weapons development, aerospace, electronics, and ground transportation. The technique was first used by the RAND Corporation in the 1940s to forecast the best engine-airframe combinations for U.S. strategic bombers. The military has continued to use the technique for advancing its weapons systems and aerospace developments. Fairchild Semiconductor found contextual mapping particularly valuable for timing its highly successful entry into the integrated circuits field.

The technique is also being used for forecasting and planning for social, political, and economic problems. SRI International has found contextual mapping to be an effective technique for systematically exploring complex situations, as well as a particularly efficient tool for graphically communicating alternative plausible long-range implications of a given set of development trends and patterns. The oil companies also use contextual mapping for their long-range forecasts to assess the supply and market position of different types of fuel as well as to explore new developments in nuclear energy, fuel cells, and so forth. TRW has developed a multilevel contextual map for product planning purposes that includes social, political, ethical, cultural, and ecological considerations.

6. Strengths and Weaknesses

Contextual mapping is particularly useful as an exploratory forecasting tool to map a range of possibilities, relationships, and conditions as a basis for the development of a normative forecast. The technique is often used to organize a complex problem or project into a visual map of its component parts, and to identify goals, objectives, projected future steps or developments, and actual achievement to date. Project members are able to view the map and quickly grasp a sense of where the project is going, who is doing what, and what changes need to be made.

Another strength of contextual mapping is that it can combine quantitive and qualitative data into a systematic framework for conjecturing about the development and diffusion of future innovations. When the topic is narrow, good historical data are available, and only a few well understood sequences are explored, contextual mapping can be a rigorous forecasting tool for predicting the nature and timing of future developments.

However, practical constraints exist in using contextual mapping. For very complex forecasts, it is often difficult to convey all the intricacies of the interactions among events in a simple enough visual map for an audience to grasp cognitively the holism of the system of events. But this problem can often be overcome by breaking up a very complex contextual mapping into a series of smaller maps. The logic and comprehensiveness of the map is dependent upon the subjective input from the analyst or group of analysts. Therefore, it is important to use a team of people who are recognized as credible and knowledgeable experts in the topic area to be explored.

7. References

The U.S. Department of Defense and NASA have a number of reports on the application of contextual mapping. Research institutes, such as RAND Corporation, and many of the aerospace and electronics industries also have reports. Some representative references from the scientific literature are:

Helmer, Olaf. Social Technology. Santa Monica, CA: RAND Corporation, 1965. Pages 18 and 19 discuss contextual mapping as a device for facilitating communication and coordination among members of large interdisciplinary groups.

Jantsch, Erich. Technology Forecasting in Perspective. Paris: OECD, 1967. See pages 171-73.

Mitchell, Arnold et al. Handbook of Forecasting Techniques, Part II. Menlo Park, CA: SRI International, 1975. See pages 103-07.

D. MORPHOLOGICAL ANALYSIS

1. Description

Morphological analysis was originally intended as a systematic technique for identifying all the possible answers to a problem or all the alternative ways of achieving a given technological development. Today the technique is used more as a heuristic approach for provoking creative solutions to a problem by providing a systematic means for identifying all possible combinations of means to achieve a desired end. Morphological analysis is most useful as a forecasting technique for exploring possible new systems rather than for predicting the quantitative characteristics or timing of future events.

The basic product of morphological analysis is a morphologial box that lists all the possible parameters and capabilities of a system. Figure II-6 is an example of a morphological box. The procedure for constructing a morphological box involves four steps:

- Define the problem or system as clearly as possible. The system may be a complex product such as a jet engine or nuclear power plant or a simple product. Or the system may be a process such as the analysis of a strategic arms objectives program.
- Break the system into parts that can be treated independently. Those parts are then coded A, B, C, D, and so on and listed in the first vertical columns of the matrix. In this example, these include logistics, divisions, and armored weapons.
- Determine the solutions or approaches that could be applied to each part. List these in the horizontal rows for each part. It is not necessary to have the same number of possible approaches in each row.
- Since the overall solution will consist of one approach in each row, enumerate all the possible combinations of approaches to be selected. By juxtaposing and developing new combinations the analyst is stimulated to think of new possible solutions or systems.

In this way, the analyst is given a framework for systematically identifying related sequences of events or for generating new ideas.

- Evaluate the feasibility and practicality of the various combinations of approaches. In this step, the analyst inspects each combination of events to ensure that it is not a meaningless combination or impossible because of a natural or physical constraint. The analyst also inspects the combination of events to decide whether the new system is feasible and operational or if technological, economic, social, or political gaps have to be overcome.

Morphological analysis emphasizes qualitative description of the system. Basically the technique is a cross-impact device since it specifically requires consideration of interactions among parameters and variable events.

The method is especially well adapted to projecting (not forecasting) a generation or more ahead. It is essentially worthless for societal projections of the near-term future, but it is very useful for examining alternatives of complex situations that can change rapidly.

Morphological analysis permits the systematic qualitative exploration of potential force or systems developments. The emphasis should be on the alternative possibilities that may exist in a scenario. Whenever the intelligence analyst is asked to provide a high, best, and low estimate of a threat system or for a threat condition, he or she is likely to begin with a morphological analysis framework. Morphological analysis is particularly useful in special intelligence that deals with certain regional developments and regional threats or to the analysis of new force components that may lead to new capabilities within a geographic area.

2. Underlying Rationale and Assumptions

Morphological analysis was pioneered by the late Fritz Zwicky (then at the California Institute of Technology) when he was engaged in rocket research. The method is based upon the philosophy that if a problem is studied from the widest, most general viewpoint possible, then more assurance exists of exploring all possible solutions. Thus, starting from all the known aspects and solutions of a problem or from the plausible elements, one can hope to discover new unconventional solutions.

The technique has its theoretical foundation in physics, metaphysics, and system analysis. The method assumes that:

- A problem or a system can be divided into a set of parts that, to some extent, can be treated independently.
- Those variables can then be arranged to create new combinations and sequences, and thereby structure ones thinking to be systematically imaginative in the creation of unconventional solutions.
- Development of a technology can be enhanced by the systematic identification and evaluation of the alternative means for achieving the technology.

3. Illustrative Problem

Projecting the U.S. Rapid Deployment Force (RDF) into a region of the globe and estimating the range of possible threats faced by the RDF would constitute an example of morphological analysis. Intelligence would be required to deal with an estimate of the potential hostile and neutral forces and their capabilities. The analyst is likely to begin work by establishing a table of threat elements and their support for the high, best, and low estimates. Figure II-6 is a cursory representation of elements to be considered in an analysis of the threat to the RDF.

The examination of the range of threats confronting the U.S. RDF in a particular region could result from changing political alignments. An increase in hostile force capabilities and threats that affect the ability of U.S. forces to carry out their mission in a particular part of the world would make it possible to establish a range of conflict outcomes that may be quite valuable to the U.S. force planner.

Some aspects of the analyses supporting the National Intelligence Estimates and the Defense Intelligence Projections for Planning can be interpreted to be morphological analysis. Rarely are analysts so confident about estimates that they are willing to project a single future value or a single future--especially, since they cannot be cognizant of all the factors that may lead to a future. Consequently, it is necessary to be speculative and to give the future or scenario in ranges or possibilities.

4. Resource Requirements

Morphological analysis does not require detailed quantitative historical data. The essential data are inherent in the system of the problem or topic. What is required most are creative, imaginative people who are skilled at breaking a system down into its component parts are knowledgeable about the topic. The method works best with a panel of experts whereby the synergy of working on the matrix can be exploited toward an understanding of what at first may not be discernable. The time and money required for a morphological analysis will vary depending on the scope and complexity of the project.

5. Summary of Uses

Morphological analysis is best known for its use in the technological fields. The U.S. Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), and many private industries have used morphological analysis to create innovative solutions to problems in jet engine design, tactical weapons development, ground and air transportation systems development, missle system design, and even planetary engineering.

FIGURE II-6 MORPHOL[illegible]AL ANALYSIS OF HYPOTHETICAL THREAT TO THE U.S. RAPID DEPLOYMENT FORCE IN THE MIDDLE EAST/PERSIAN GULF REGION

THREAT COMPONENTS	ALTERNATIVE THREATS		
	LOW	BEST	HIGH
DIVISIONS	2 Sov AB	2 Sov AB 1 Sov Mech 1 Sov Tank	2 Sov AB 2 Sov Mech 2 Sov Tank
ARMORED WEAPONS	200 T-64/-72	350 T-64/-72	450 T-64/-72 500 T-55/-62
TACTICAL AIRCRAFT	150 Sorties/day	250 Sorties/day	350 Sorties/day
NAVAL COMBATANTS	Major combat vessels	Minor surface combatants Major combat vessles	Minor surface combatants Major combat vessels Attack subarines
INDIGENOUS SUPPORT	1 Syrian div.	2 Syrian div.	2 Syrian div. 2 Iranian div.

In social forecasting, morphological analysis is better used for projecting and exploring possible lines of development than for predicting what will happen. It is a particularly effective technique for structuring a social-political forecast because it facilitates the exploration of societal consequences of specific assumptions (for example, what happens to a region if there is a shift in economic stability, military strength, political power, resources, and so on). The technique is also useful for technology assessment projects to explore systematically a wide range of possible impacts from such programs as providing technical peacetime assistance to an ally, providing military assistance to an ally in war, establishing economic sanctions on an ally who provides important technical assistance to the Soviet Union, and so on.

6. Strengths and Weaknesses

Morphological analysis is an excellent device for organizing the components of a problem or system and for stimulating creative approaches for resolving the problem or completing the system. However, some practical considerations can limit the use of morphological analysis.

- Since the technique is qualitative in nature, results tend not to be believed as easily as quantitative results derived from using more rigorous methods.
- The objective of enumerating all possible combinations of solutions to a problem can be overwhelming. The large matrix used by Zwicky for the jet engine led to the creation of 36,864 possibilities, but by recognizing internal restrictions Zwicky was able to reduce that number to 25,344 combinations. Clearly, such a large number imposes an overwhelming burden for analysis in terms of both cognitive capability, and time and money constraints. However, a matrix can be made more manageable by limiting the number of parameters. Practice has shown that it is most desirable to limit the number of parameters of a system to a number not above seven and preferably to only four or five. Alternative events should also be kept to a manageable level. For even if there are only five parameters with four alternate events, the number of permutations would be 1,024.

- Care should be taken to recognize impossible combinations. This care can quickly reduce the number of possible events that need to receive close review.
- Successful use of morphological analysis requires that its user be able to judge what "new" combination of factors are worth probing more deeply. However, typically most people reject unconventional ideas or combinations quickly on the basis that they won't work. Thus it is important to use a transdiciplinary team for morphological analysis so the panel is not locked into one view of the world and how it works.

7. References

A number of books and articles have been written on the subject of morphological analysis. Some of the better introductory "how to" references include:

Ayres, Robert U. "Morphological Analysis." Technological Forecasting and Long Range Planning. New York: McGraw-Hill, Inc., 1969.

Bridgewater, A. V. "Morphological Methods-Principles and Practice." Technological Forecasting. Ed. by R. V. Arnfield. Edingburgh: University Press, 1969.

Gerardin, Lucien. "Morphological Analysis: A Method for Creativity." A Guide to Practical Technological Forecasting. Eds. James R. Bright and Milton E. F. Shoeman. Englewood Cliffs, N.J.: Prentice Hall Inc., 1973. A good article that clearly describes the procedure for doing a morphological analysis.

Jones, Harry. "Morphological Analylsis (Chap. 7)." Practical Technology Forecasting, Concepts and Exercises. Ed. James R. Bright. Austin, Texas: The Industrial Management Center, 1978.

Martino, Joseph P. Technology Forecasting for Decisionmaking. New York: American Elsevier Publishing Co., Inc., 1972. Chapter 9 provides a clear explanation of the procedure and includes case study examples on automobile propulsion and automatic instrument landing.

McPherson, J. L. Structured Approaches to Creativity. Menlo Park, CA: LRPS Research Reports (private circulation). Stanford Research Institute, 1969.

Zwicky, Fritz. Morphology of Propulsive Power, Monographs on Morphological Research No. 1. Pasadena, CA: Society for Morphological Research. Provides history in the development of the method and applications of its use. Available from California Institute of Technology bookstore.

Zwicky, Fritz. Discovery, Invention, Research, Through the Morphological Approach. London: The MacMillan Co., 1968.

7. References

Since mission flow diagrams have been used extensively for military purposes, the libraries and files of the armed forces will contain a number of references on the application of this technique. Additional expert-opinion and specialized mission flow projects are available from a number of research institutes in the United States, including Batelle Memorial Institute, RAND Corporation, and SRI International. References from the scientific literature include:

Bright James R., ed. Technological forecasting for Industry and Government. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1968. Harold Linstone's article, "On MIRAGES" on page 223 contains a good description of mission flow diagrams methodology with a focus on a military application.

Bright James R., ed. Practical Technology Forecasting Concepts and Exercises. Austin, Texas: The Industrial Management Center, Inc., 1978. See page 170.

Dridsbury, Howard F., ed. Student Handbook for the Study of the Future. Washington, D.C.: World Future Society, 1979. See page 37.

Martino, Joseph P. Technological Forecasting for Decisionmaking. New York: American Elsevier Publishing Co., Inc., 1972 See chapter 9, page 317.

F. ASSOCIATIONAL ANALYSIS

1. Description

Associational analysis is another structuring technique that assists analysts dealing with complicated problems. Key to the method are matrices (tables of numbers that are somehow related to each other), indices (the descriptors of rows and columns in a matrix), and contextual relations (relationships between horizontal and vertical indices). Contextual relationships can be any associational concept. Possible contextual relationships include the following: is adjacent to, is included in, is caused by, is preceded by, and is necessary for.

The basic steps of associational analysis are:

- The analyst identifies all the major factors in a problem.
- A contextual relationship between the horizontal (rows) and vertical (columns) indices is determined based upon what sort of analysis is desired. It is checked to assure its transitive nature--for example, effects can be passed through one or more intermediate nodes.
- The analyst constructs a rectangular adjacency matrix with identified indices describing rows and columns.
- The analyst shows all the direct linkages between factors that can be determined.
- Manually or by mathematical methods, the adjacency matrix is formulated into a reachability matrix--that is, a square binary matrix whose horizontal and vertical index sets are identical and whose contextual relationship "can be reached from." (Reachability matrices differ from adjacency matrices in that they create lengthy chains necessary to get from one point to another rather than restricting themselves to direct bonds. By analogy, an adjacency matrix would be like a list of all nonstop airplane flights, whereas a reachability matrix would identify which cities could be reached via direct, multiple stop flights and all connections. Thus the adjacency matrix identifies only direct links between elements of analysis whereas the reachability matrix contains all direct and indirect links).
- Finally, diagrams are constructed for analysis.

2. Underlying Assumptions and Rationale

Associational analysis is a necessary first step in cross impact analysis and a useful first step to regression, systems dynamics, and an events sequence network. The rationale for using the technique is that the systematic use of matrices will help analysts understand complex linkages that exist among elements of their problem. It is a means by which analysts can quickly disentangle the complex network of pieces to a problem.

One main use of the method is to provide a systematic means for identifying those variables that are most likely to influence a future event and the ways in which these variables are likely to interact.

3. Illustrative Problem

Threat analysts are attempting to project Soviet reaction to the modernization of the Chinese People's Liberation Army (PLA), and have identified six factors in a causal chain.

- PRC increases military modernization rate.
- Western nations agree to sell equipment and factories to the PRC.
- South Korea, Vietnam, India, and Taiwan all begin to harass China on their respective borders.
- PRC converts domestic production facilities to military facilities.
- United States signs a mutual defense pact with the PRC.
- USSR accelerates arms buildup upon PRC's border.

The analysts prepare a causal adjacency matrix (see Figure II-9a), which shows interrelationships among factors. This matrix, in turn, is converted into a reachability matrix that will identify all possible points that are linked (reachable) from any other points in the system. (See Figure II-9b.) Both matracies portray the relations shown in Figure 9c.

As a final exercise, threat analysts could assign probabilities to various causal chains--that is, the probability that border harassment by PRC's neighbors could trigger a chain of events leading to an accelerated Soviet arms buildup on the Chinese border.

Through the systematic examination of alternative patterns of interaction among the six factors identified, analysts can acquire a more comprehensive understanding of the interaction of political-military developments in the Sino-Soviet context.

The utility of associational analysis increases with the number of factors being considered. In the example cited above, only six factors are involved, so it is not likely that key linkages will be overlooked. When a larger number of factors is under consideration, however, key linkages can be more easily overlooked. Particularly in these cases, the systematic approach to identifying indirect as well as direct links is helpful.

4. Resource Requirements

Resource requirements for associational analysis are relatively modest. There is no need to collect massive amounts of data. Matrices can be prepared by a small team of analysts working perhaps for a few weeks. Computer assistance is seldom required, as the matrices developed are not especially elaborate. As noted above, associational analysis is a first step to other techniques that may require more resources in terms of time, people, and computer assistance. The cost of applying this technique is concentrated in salaries. Graphics can also represent a significant cost.