Structuring Complex or Wicked Problems: A Multimethod Approach in Practice

Alejandro S. Hernandez
Naval Postgraduate School, Monterey, USA

ahernand@nps.edu

Abstract: Complex or wicked problems necessarily require multidisciplinary approaches to shape the issue(s) into a structure that can lead to viable solutions. This paper presents a case in which a systematic approach was used to combine structuring methods to support a research design that intended to quantitatively relate variables which have been insufficiently defined. Misconstrued definitions of variables and the dearth or missing data are just some of the characteristics that make this problem "complex." The scientist's primary work in the early stages of this type of research effort is to apply a series of techniques that meaningfully define the variables, specify relevant data to support development of quantitative models, and generate and\or collect that data. The sequence of discussion in this paper is a multimethod outline for addressing complex problems. This paper begins by defining complex or wicked problems. Next, an illustrative military problem that exhibits complex characteristics is presented. Sequentially, various structuring techniques from several fields of study such as systems engineering, operations research, and computer science are discussed and applied to the problem. Activities began with a workshop to learn about the problem and provide context. This venue allowed primary stakeholders to describe the variables from their stance. During the workshop, participants conceptualized relationships among the variables. An in-depth literature review before and after the workshop informed development of theories and hypotheses about the variables and plausible connections among them. Using functional decomposition, the team broke down the variables into their fundamental components. Relational matrices and causal loop diagrams formed initial ideas for how the components may be linked. Functional decomposition syntax also led to relevant, quantifiable measures that afforded an opportunity to mathematically formulate relationships among components, thereby achieving the primary objective of the problem. Blending techniques from different disciplines and their respective structuring methods is a powerful approach for creating conditions to solve complex or wicked problems. The utility of this study is in identifying the critical properties of a complex or wicked problem and mapping suitable methods to "tame" them. The overall approach is applicable to complex problems found in industry, government, and scientific research.

Keywords: Complex and Wicked Problems, Functional Decomposition, Causal Loop Diagram, Value Modeling, Computer Simulation Experiments

---

1. Introduction to Complex and Wicked Problems

Certain problems exhibit characteristics that deem them complex or wicked. Bentley and Toth (2020) describe a mess as a collection of complex problems. Similarly, Gharajedaghi (2006, 131) calls a complex problem a "system of problems" or simply, a "mess." Both terms are appropriate when describing conditions that include numerous actors with conflicting goals and views, intangible variables that bear on the problem, and a substantial number of unknowns. These characteristics directly map onto earlier descriptions from Rosenhead and Mingers (2001). Rittel and Webber (1973) explain complex problems in the same way but further describe circumstances that pose social obstacles to finding answers. The inability of participants to agree on an acceptable solution or reasonable tradeoffs are in themselves, problematic. Varying perspectives often result in conflicting information. The politics involved with having multiple stakeholders are inherently messy.

Complex or wicked problems are chaotic, filled with uncertainty, poorly structured, and have numerous unknowns, to include unknown unknowns (Bentley and Toth 2020). Rittel and Webber (1973) suggest that problems in the natural sciences are definable with solvable solutions and therefore "tame." However, mathematical optimizers would disagree with this generalization and present non-deterministic polynomial time (NP)-hard problems as an example (Bazaraa, Jarvis, and Sherali 2004). Mitchell and Toroczkai (2009) notably discuss complexity by pointing out the criticality of system size and emergent behavior. Systems engineers explain the difficulties with set-based designs in which the solution space contracts and expands throughout the design process (Whitcomb, Hernandez, and Vizzini 2019; Hernandez and Whitcomb 2018). The Systems Engineering Book of Knowledge (Adcock 2023) describes complex systems in the large number of components involved and the manner that those components are interconnected. In these descriptions, the system is abstracted into physical entities, concepts, and processes. Among these characterizations of complexity, Sheard and Mostashari's (2010) typologies are particularly useful for this paper. Categorizing messy problems in terms of structural (size, connectivity, and architecture), dynamic (short or long term), and socio-political makeup enable analysis.

It is evident that taming wicked and complex problems into a solvable one demands a multifaceted approach (Mingers 1997). The thrust of this paper is to illustrate a multimethod process to analyze complexities of a problem and prescribe suitable structuring techniques to tame those difficult elements. It implements ideas that have been formulated by a host of researchers to deal with increasing complexities in areas that scientists and leaders wish to explore. Therefore, the author offers this application-focused paper using a miliary problem as a vehicle for the discussion.

2. A Study Overview

The backdrop for describing complex or wicked problems in this paper is the presentation of a realistic, military situation that is based on current conflicts. Consequently, the problem is generalized to avoid security classification issues. However, the focal point for the reader is the multimethod approach to a wicked problem.

The study of a military problem in this paper has many applications, including business practices. Relating military problems to challenges in business is not new. The business community began adopting wargaming practices since the late 1950's (Hershkovitz 2019). In business, there are situations that are so complex that traditional, linear analysis is insufficient. However, wargaming, a military technique, can help investigate such problems. (Oriesek and Schwarz 2008). As Gilad (2009) explains, business strategies are complex problems where outcomes are determined by third parties and uncontrollable factors. The marketplace is more akin to combat than some may admit. However, once competing vendors are seen as opposing forces and maneuvering people and products are equated to military operations, the similarities are quite clear. Consequently, the military problem in this paper is just a means to introduce important ideas that are applicable to business and other areas that consist of complex problems. The author leaves it to the audience to apply the concepts to other areas.

Sheard and Mostashari (2010) analyzed complex problems based on the typology that they developed. Along with this typology, the work in this paper referenced the library of problem structuring methods and OR techniques to resolve difficulties of the military problem (Mingers and Rosenhead 2004). Additionally, Sigahi and Sznelwar (2023) provided a framework for choosing methods to address complexities of the problem.

Once the complexities of the military problem were identified, specific techniques were mapped in accordance with the characteristics of the problem (Sigahi and Sznelwar 2023; Yearworth and White 2014; Sheard and Mostashari 2010). This paper further describes a step-by-step application of different techniques that results in a structured problem that is the basis for finding solutions to the research problem.

3. Relevant Studies of Existing Problem Structuring Methods

Since the 1960's, volumes of methods have been accumulated to address extremely difficult problems in a manner that enabled the interested parties to formulate assessable alternative solutions. Collectively, strategies to shape a solution space for ill-defined, multilayered problems are called problem structuring methods (PSM). Numerous disciplines have contributed to the PSM portfolio, including operations research, physics, engineering, and the social sciences. Accordingly, many researchers have documented and catalogued different PSM types and OR techniques. The following studies were particularly useful for developing the ideas in this paper.

Mingers and Rosenhead (2004) provide a comprehensive overview of PSM, including an assessment of appropriate PSM to apply for different research conditions. Their study begins with a comprehensive discussion of proven PSM and the category in which the PSM belonged, i.e., SODA (strategic options development and analysis), decision conferencing or decision analysis, and others. Their work included specific cases for which one or more types of PSM are used. However, the research problems described in the paper did not necessarily exhibit complex or wicked characteristics.

A systems point of view is important to discussing complex problems. Systems engineering is only applied for complex engineering problems. Sheard and Mostashari (2010) relate complexity science in systems engineering terms. Their work discusses complexities of a problem in parallel with typologies that are presented in this paper. Examples of each complex system showed existing design challenges. A discussion of the engineer's thoughts and activities to resolve the issue illustrated a useful sequence of systems thinking, discovery of relevant tasks, and applicable structuring technique(s). Engineers accept this evolutionary approach to complex system or system of systems development but would not typically consider the approach to be problem structuring. Unique to Sheard and Mostahari's (2010) work is a set of measures for identifying different typologies.

Case studies are valuable documentation of specific instances of successful application of PSM. The unasked and unanswered question in these cases is determining how else specific PSM could be applied to future research problems, whether or not the future problem is similar to the problem in the study. Yearworth and White (2014) attempted to address this question in their paper. Arguing that a codified process for PSM use does not exist, Yearworth and White (2014) offered a list of nine propositions or axioms to define PSM, thereby the types of problems for which it could be applied. Numerous case studies were used to test the axioms. A summary of how the PSM fits the axiom showed the axioms' utility for selecting an appropriate PSM.

Sigahi and Sznelwar (2023) recognized the rise of complexity sciences and the need to systematically examine complexity-based approaches to resolve complex problems. In their paper, Sigahi and Sznelwar (2023) first categorized the types of complex problems, followed by a framework to characterize various structuring strategies. While not a primary objective, their work linked different complexity-based approaches to specific complexity types. The result is a systematic process to shape complex or wicked problems.

These previous efforts to determine appropriate PSM application are the basis for tackling complex problems. This paper does not intend to develop new definitions of PSM or even their categories. The work in this paper focuses on implementing previous studies on multimethod approaches to develop a practical way to deconstruct a complex situation and apply a combined set of PSM, as well as OR techniques to produce a solvable problem.

4. An Example of a Complex Problem: Deter an Enemy from Attacking

Military campaigns are among the most chaotic environments in which to resolve issues. Although the technological enablers for organized violence have changed, the nature of war has not. The characteristics of war remain the same because *friction* in military conflicts persists as they have before and after Clausewitz coined the phrase. Watts (1996) summarizes Clausewitz's ideas about friction: missing information, myriad of uncertainties, differences between expectations and reality, intangibles that affect resources, and unpredictable behavior of leaders and subordinates when executing a plan. These messy elements of forces in combat are remarkably reminiscent of the typology of complex and wicked problems from Sheard and Mostashari (2010).

A common military scenario is the need to deter one military force (Side B) from acting contrary to the wishes of another military force (Side A). In this case, Side A wishes to deter Side B from attacking. (For a non-military context, one may imagine a company that wishes to deter another company from initiating a hostile takeover.) From Side A's viewpoint, the current situation is in terms of its operational variables (OV): 1) the legal basis to engage in combat, 2) positioning of military units and systems in time and space of the conflict area, 3) actual system capabilities that are available to the military units, and 4) information and knowledge about Side B. These domains contain near-uncountable components that change with respect to the flow of battle.

In this problem, the researcher was tasked with examining the situation between Sides A and B and quantitatively relating the OV with deterrence. This research design is experimental. The complexities of the problem are apparent when considering the definitions for the OV or in measuring the degree of deterrence, i.e., measuring how much an act does not occur. The problem is characteristically complex (Table 1).

Table 1. Map of Complexity Types to the Attack Deterrence Problem (adapted from Sheard and Mostashari 2010)

Complexity Type: Subtype	Defined Characteristics	Elements of Attack Deterrence Problem
Structural: Size	Numbers of elements, instances, types of elements	Large military forces consist of many types and numbers of organizations and weapon systems.
Structural: Connectivity	Numbers of connections, types, strength of connections	All military units are expected to interact with all other units to achieve a singular mission.
Structural: Architecture	Patterns, clustered connections, inhomogeneity, boundaries	The connections in the hierarchy of military organizations are regimented and have official, as well as non-official communication lines.
Dynamic: Short Term	Sudden rapid and frequent changes in system behavior	All military leaders make decisions necessary for their unit survival and specific mission. Thus, positions and application of weapon systems quickly change. Tactical units are much more affected by situational changes.
Dynamic: Long Term	Changes in number and types of things and relationships	The size of the unit or hierarchy of the force is more persistent in the ascension of command.
Socio-Political	Human cognitive limitations, multiple stakeholders, global context, environmental sustainability, economics	The legal basis for prosecuting a war is inherently messy, filled with human and global context, as well as the opposing force's responses. Positioning military units is based on permissions and

Complexity Type: Subtype	Defined Characteristics	Elements of Attack Deterrence Problem
		negotiations with allies. Factors that deter Side B are only truly known by Side B, thus requiring Side A to speculate.

Categorizing the types of complexity within the Attack Deterrence Problem identified critical challenges that must be overcome to deliver acceptable solutions. The tasks that emerged manifest the difficulties involved with each element of complexity. The compiled task list was the basis for a plan to structure the problem.

1. Clearly define the OV in context of the scenario,
2. Determine initial relationships among OV,
3. Identify tangible, measurable ways to change the nature of the OV,
4. Develop deterrence measures from Side B's perspective,
5. Create a bounded environment to examine OV changes and outcomes,
6. Generate and collect data that relate the OV to deterrence, and
7. Formulate mathematical models.

5. Combining Different Structuring Methods

The implication of the resultant tasks is the need to have a multidisciplinary approach. A collection of studies from scientists such as Sigahi and Sznelwar (2023), Yearworth and White (2014), Sheard and Mostashari (2010), Mingers and Rosenhead (2004), Mingers and Brocklesby (1997), Mingers (1997), Jackson (1993) and many others, provide convincing arguments that there is no generalizable approach to any single problem. Therefore, problems with complex or wicked characteristics require a blend of PSM to define a feasible solution space.

Guidance from Mingers and Rosenhead (2004) was a valuable source for selecting specific structuring techniques to mitigate the complexities in the Attack Deterrence Problem. Additionally, ideas from Sigahi and Sznelwar (2023), Rosenhead (2013), and Mingers (1997) result in Table 2 which tracks the tasks for the military problem to a PSM category. Different techniques are available within PSM and OR types. The specific methods are listed to address the task and thereby resolve the complexity characteristics. The list below was not an attempt to cover all possible PSM or techniques. The researchers selected practical techniques to address the specific task.

Table 2. Tasks to Structuring Techniques for the Attack Deterrence Problem

Task	OR and PSM Types	Technique(s)
1. Clearly define the OV in context of the scenario	SODA, Soft systems methodology (SSM), Strategic choice approach (SCA)	Workshop methodology, Policy studies; Literature reviews, Drama theory
2. Identify tangible, measurable ways to change the nature of the OV	Drama theory, Decision conferencing or analysis (DA), SD	Systems analysis, Functional decomposition, Measures development, CLD
3. Determine initial relationships among OV	SSM, Systems dynamics (SD), Visual systems model (VSM), Critical systems heuristics (CSH)	Conceptual models, Heuristics, Causal loop diagrams (CLD)
4. Develop deterrence measures from Side B's perspective	SSM, SCA, SD, CSH, DA	Policy studies, Scenario methodologies, Systems analysis, Functional decomposition, Measures development, Value modeling
5. Create a bounded environment to examine OV changes and outcomes	SCA, Robust analysis, Drama theory, Operations research (OR), Decisions science (DS)	Scenario methodologies, Wargame, Simulation, General Morphological Analysis (GMA)
6. Generate and collect data that relate the OV to deterrence	SCA, OR, DS, DA	Computer simulation, Experimentation, GMA
7. Formulate mathematical models	OR, DS, DA	Statistical methods

6. Overview of Implementing a Multimethod Approach to the Attack Deterrence Problem

Table 2 summarizes the flow of activities that the researcher followed to set conditions for the Attack Deterrence Problem. The subsequent discussions highlight the category of PSM and the specific technique(s) that the researcher applied to tame the wicked elements of the problem.

6.1 Clearly Define the OV in Context of the Scenario

Task 1 involved hosting a workshop to kick off the entire project. Participants included the research team, subject matter experts (SME), and primary stakeholders\customers. The workshop was a venue to establish clear and mutual understanding of the problem. Discussions included detailed information for the context in which the problem existed. Known facts bearing on the problem and necessary assumptions were shared with the entire group. The primary stakeholder included constraints such as the time frame, as well as military units and weapon systems that would compose Sides A and B. Prior to the workshop, researchers performed policy studies and literature reviews of the operational environment, the theory of the fight, and the baseline scenario in which Sides A and B confront each other. These outcomes are reasons for using SODA, SSM, and SCA.

6.2 Identify Tangible, Measurable Ways to Change the Nature of the OV

The researchers earlier determined that the OV were not true variables but were actually multidimensional domains. The researchers redesignated the variables as operational vectors (OV) because of their dimensionality versus the singularity that variables would suggest. Changing the nature of a domain required changing its components. The team refined descriptions of each OV: 1) Law – the legal basis to engage in combat, 2) Position – placing military units and systems in time and space throughout the conflict area, 3) Lethality – actual system capabilities that are available to the military units, and 4) Intelligence – information and knowledge about Side B. However, the researcher is still without tangible ways to control the nature of the OV. The team drew techniques from Drama theory, DA, and SD. In particular, the team used systems analysis from the OR and systems engineering catalogs. One useful approach was functional decomposition to break down the fundamental change components of the OV. OR practitioners recognize these components as essential elements of analysis.

Functional decomposition consists of asking a simple a question, “What must the system do, to accomplish its ultimate purpose?” In studying the Attack Deterrence Problem, the team independently identified four primary functions that Side A must show that it can perform, which would deter Side B: 1) Establish a legal basis to act against another force – Law, 2) Place units and weapons at advantageous locations – Positioning, 3) Defeat an aggressor – Lethality, and 4) Produce timely information for decision making – intelligence. These top-level functions overlap the descriptions of the original OV. To further breakdown each top-level function, the team again asked the simple question about each function. For instance, decomposing the functions of Intelligence resulted in the hierarchy of functions in Figure 1.

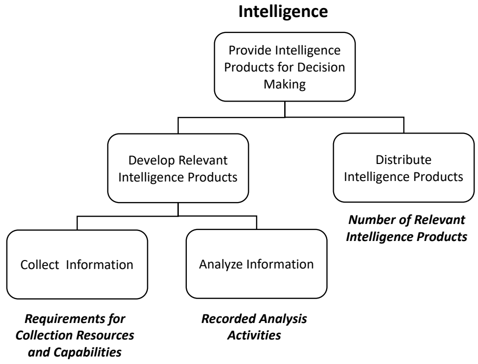

Figure 1. Functional Decomposition of Intelligence

The overarching purpose of the Intelligence OV is to “Provide Intelligence Products for Decision Making.” The functions to achieve the top purpose is to Develop and Distribute Intelligence Products. The decomposition process is iterative. At the lowest node on each branch are the elemental functions that must be conducted. Techniques from OR, DS and DA develop measures that assess achievement of the functions. These measures serve as the fundamental change components for Intelligence and are listed below the lowest node in the tree. As an example, the “Number of Relevant Intelligence Products” that Side A distributes to its forces, has a significant impact on the nature of its intelligence and decision making. The same process was used for the other OV. In total, the team identified eleven change components to represent the set of OV. From these components, the team created relational or 0/1 matrices, initial causal loop diagrams, and heuristics for potential equations.

6.3 Determine Initial Relationships among OV

The research goal for the Attack Deterrence Problem was to develop mathematical expressions among and between the OV and deterrence. The workshop was an opportunity to brainstorm these relationships. SSM, SD, VSM, and CSH consist of techniques that visually and conceptually map the connections in a system. Through systems thinking, the breakout teams created conceptual models for each OV. Heuristics for how the OV would behave explored possible interfaces that would require mathematical terms. These exercises generated initial models to answer Task 3.

Causal loop diagrams (CLD) display the interrelationship of components of a system. They are often the predecessor for developing systems dynamic models, which require mathematical relationships. Once the elements of an OV were identified, the relationships among the elements could be developed. Figure 2 is an example of a CLD for Intelligence in the military problem. From Figure 1, the components for Intelligence are Requirements for Collection Resources and Capabilities, Recorded Analysis Activities, and Number of Relevant Intelligence Products. The CLD requires a catalyst, a need that compels change in the system (Osgood 2011). In this case, a desired level of intelligence products is the driver. It implies that there is a gap in intelligence products. The relationships are directional. The symbols "S" and "O" mean that the changes between the connected components are in the same (S) or opposite (O) direction. For instance, as the gap in relevant intelligence products increases, the collection and analysis activities also increase (labeled as S). Consequently, as collection and analysis activities increase, the gap in relevant intelligence products decreased (labeled O). Additionally, the Intelligence CLD shows connections to components for the Authorities OV.

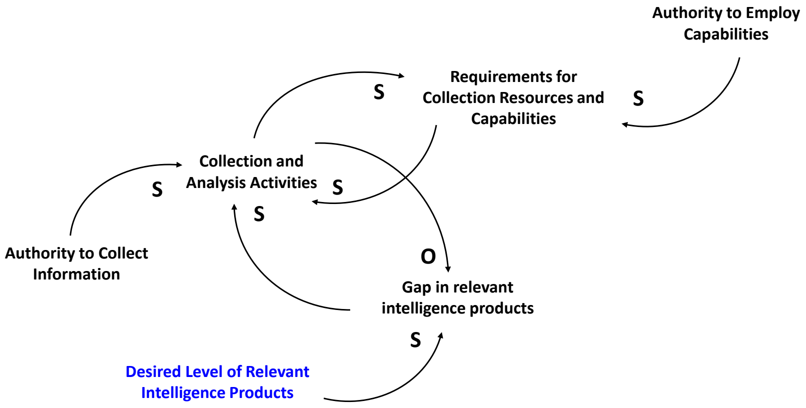

Figure 2. Causal Loop Diagram for Intelligence

The basis for these initial conceptual models was documented in the form of narrative analysis. Additionally, while the linkages between the OV models may at times be self-evident, the theory, doctrine, historical data and\or analysis must be established. Occasionally, the research team determined that operational experience was the most or only available support for the statements about the relational models. The team recorded these instances and the logic behind connecting the OV. In the process of studying the literature, new ideas, questions, hypotheses emerged that could lead to more robust solutions. Heuristics formed via the CLD are useful guides for how the equations among components might be expressed.

6.4 Develop Deterrence Measures from Side B's Perspective

A major challenge in this complex problem is to determine how to define and measure deterrence. The wicked characteristic of the problem is the need to view deterrence from Side B's perspective. A number of PSM types were employed in this task, including SSM, SCA, SD, CSH, and DA. A complete understanding of how Side B may react to Side A actions was filled with uncertainty. Scenario methodologies, policy studies, were just a few techniques to reduce speculation.

The task to develop deterrence measures was especially problematic. The stakeholder wished to understand the degree of deterrence and its relative measure(s). As previously mentioned, there is great difficulty in measuring the extent that an event does NOT occur. Therefore, deterrence must be determined beyond a YES or NO that Side B does not attack. Deep studies in policies and literature provided useful definitions of deterrence. An understanding of the specific scenario for where the conflict would occur also informed the team how to describe deterrence. Further applying the idea of functional decomposition to deterrence, the team defined essential measures for deterrence. However, these measures have different units of measure, thereby convoluting their complete meaning relative to the other measures.

The team used value modeling to aggregate the measures into a total score for the value of attacking (Keeney 1990). The team of subject matter experts in the conflict situation examined each deterrence measure from Side B’s viewpoint and developed a value model or function that converted the deterrence measure into a score from a common scale. The scale, say 0 – 40, represented Side B’s desire to attack based only on the specific deterrence measure. For the purposes of this paper, the score of 40 would mean that it would be to the absolute advantage of Side B to attack. On the other hand, if the deterrence measure indicated that an attack on Side A, would result in devastating damage to Side B, Side B would likely view the value of that measure to be very low. By assigning a weight (or importance) to each deterrence measure, the team could aggregate the scores into one quantum measure for deterrence. The researcher assumed that the change components influence the behavior of the total value score (TVS), as computed from $TVS = \sum_{i=1=}^{k} V(i)$, where *V(i)* is the value score of the i^{th} change component.

6.5 Create a Bounded Environment to Examine OV Changes and Outcomes

This approach required knowledge about the plans of the forces involved in the conflict. The types of PSM in this phase of the work included SCA, Robust analysis, Drama theory, OR, and DS. Scenario methodologies, wargames, and GMA created different operational conditions to examine the change components and deterrence measures.

Scenario methodologies are a collection of techniques to examine future situations (von Reibnitz 1988). The team explored scenarios that established uncertainties as if they were realities, thereby driving participants to address issues that arise (Chermack 2011; Lindgren and Bandhold; 2009, Zwicky 1969). Creating scenarios demanded foundational documents about the situation, and participants with in-depth understanding of the topic being investigated, command of current strategies, the forces and processes, and potential antagonists. Figure 3 highlights required expertise from the scenario designers during each phase of scenario development (Chermack 2011). For instance, the Scenario Exploration phase requires participants to study the strengths, weaknesses, opportunities, and threats that affect organizations, decision makers, and entities in the scenario. The resultant operational environment enabled researchers to use OR techniques such as campaign analysis and wargames, as well as prepare the computer simulation database for experimentation.

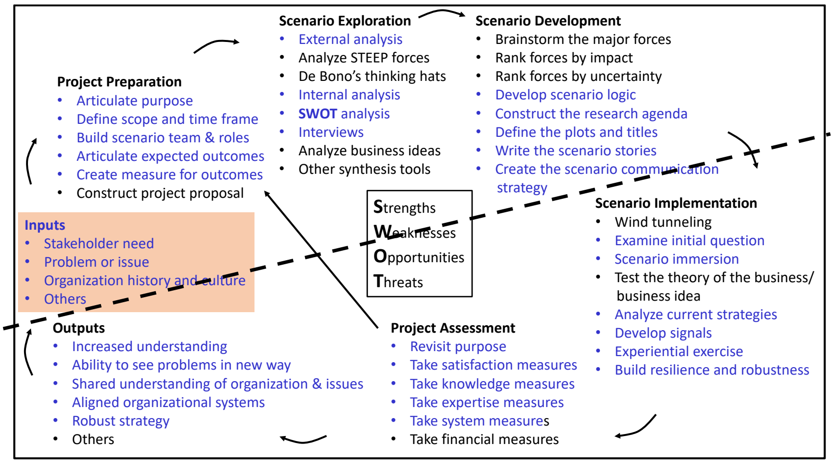

Figure 3: Scenario Planning Process (adapted from Chermack 2011).

6.6 Generate and Collect Data that Relate the OV to Deterrence

The primary objective for the Attack Deterrence Problem is to construct specific quantitative expressions for the hypothesized relational models of OV and Deterrence. To achieve this objective requires a large amount of data that did not exist in any readily available or useful form. Acquiring the data with the appropriate degree to withstand scrutiny involved techniques from SCA, DS, DA, and OR.

The research design centered on experimentation followed by statistical methods to develop the quantitative relationships among the OV and deterrence measures, including the TVS. The analytical backbone for the experiment was computer simulation of the scenario and vignettes developed in the previous task. To ensure that the data generated from the computer simulation met the standards to use traditional statistical methods, the researchers implemented customized designs of experiments. The systematic exploration of the solution space employs the ideas of GMA as first introduced by Zwicky (1969) and expanded upon by Ritchey (2011) and many others. The use of computer modeling and simulations to implement GMA is a focus of many researchers who study structuring methods (Alvarez and Ritchey 2015; Ritchey 2006). The team has identified an appropriate simulation model and are implementing the operational scenario in the computer database.

A major difficulty when using GMA is the large quantity of combinations of scenario factors that could be studied. Even when using lattice sampling (Patterson 1954), a problem with k factors and n values for each factor, results in a total of $(n!)^{k-1}$ possible designs, each being n x k in size. This combinatorial issue is one that experimenters have pondered for many years. In recent decades, there has been tremendous progress in improving the design of experiments to examine complex problems (Lucas, et al. 2015; Kleijnen, et al. 2005). Foremost in these new experimental designs are a family of Latin hypecubes or nearly orthogonal Latin hypercubes (NOLH), which have become some of the most versatile designs for exploring problem spaces with as few experiments as possible (Song-Nan, Min-Qian, and Jin-Yu 2023; Lin, et al. 2018; Hernandez, Lucas, and Carlyle 2012; Cioppa and Lucas 2007). The orthogonality of the designs enabled the scientists to isolate the effects of major factors, as well as two-way, and three-way interactions for more complicated problems. The analysis team for the military problem used a nearly balanced, nearly orthogonal design.

6.7 Formulate Mathematical Models

The final step in addressing the Attack Deterrence Problem is to formulate the mathematical equations when data is available. For this task, the team will apply an array of OR techniques that include but not limited to regression analysis, random forest, and non-parametric trees. However, the utility of the mathematical models is in the ability to interpret the results. For instance, the general equation would be an estimate of TVS as a function of OV components, $i = 1, 2, \dots, 11$. Low TVS (undesirability to attack) corresponds with a combination of settings for each of the change components. It is the use of PSM techniques that develop narratives to explain why a specific combination of change component settings result in the low TVS. The same idea is necessary for high TVS.

The concept for using the mathematical models is for informative and possibly prescriptive reasons. The stakeholder may find utility in establishing procedures for future situations. Results could also become guidance for developing plans against similar opponents or environs. The ability to identify scenario conditions that optimize (maximize or minimize) TVS is of great importance to future planners and is one of the primary applications for experimental designs (Koehler and Owen 1996).

7. Results and Conclusions from a Blended Structuring Approach

The PSM library is a growing collection. Coupled with OR, the researcher has an arsenal of techniques to derive approaches to tame complex and wicked problems. To illustrate how a combined approach may emerge, this paper presented the Attack Deterrence Problem which examined a common military situation of one force deterring another force from attacking. The research objective to this problem was to develop quantitative models to express the relationships between operational variables and measures of deterrence. The problem presented the complexities of a wicked problem: “multiple actors, multiple perspectives, incommensurable and/or conflicting interests, important intangibles, and key uncertainties.” (Mingers and Rosenhead 2004, 531) The typologies from Sheard and Mostashari (2010) and other researchers echo these characteristics.

This paper aimed to provide a sketch for dissecting and mitigating the complexities of a research problem. The discussion on managing the Attack Deterrence Problem showcased a step-by-step process and the application of different techniques from PSM and OR catalogs. The approach included a means to deconstruct the problem into complexity characteristics by using different complexity typologies, which identified specific elements of problem to tame. Understanding each element determined the necessary tasks for structuring the problem. Accordingly, the lead researcher must assemble a team familiar with each tasks, including the type of PSM and/or OR techniques to employ. The entire process is a systems thinking exercise as the researcher discovers other issues to resolve which is inherent in wicked problems (Jackson 1993).

There is no attempt in this paper to explore every PSM and OR technique or to examine in any depth how they are categorized or applied for specific problems. A host of researchers have performed much of these studies as researchers such as Jackson (1993) had recognized many years ago. Instead, the author attempts to illustrate the utility for implementing the suggestions of researchers such as Sigahi and Sznelwar (2023), Rosenhead (2013), and others that multimethod approaches are necessary to unravel complex problems. This paper offers a template for researchers who wish to tame wicked problems using a multimethod approach.

References

Adcock, R. (2023) “Complexity.” Systems Engineering Book of Knowledge. Last modified May 17, 2023. https://sebokwiki.org/wiki/Complexity.

Alvarez, A. and Ritchey, T. (2015) “Application of General Morphological Analysis from Engineering Design to Policy Analysis”, *Acta Morphologica Generalis*, Vol. 4, No. 1, pp. 1-40.

Bazaraa, M.S., Jarvis, J.J., and Sherali, H.D. (2004) *Linear Programming and Network Flows 4th Edition*, John Wiley and Sons, NY.

Bentley, J. and Toth, M. (2020) *Exploring Wicked Problems: What They Are and Why They Are Important*, Archway Publishing, Bloomington.

Cioppa, T.M. and Lucas, T.W. (2007) “Efficient Nearly Orthogonal and Space-Filling Latin Hypercubes”, *Technometrics*, Vol. 49, No. 1, 45-55.

Chermak, T. J. (2011) *Scenario Planning in Organizations: How to Create, Use, and Assess Scenarios*, Berrett-Koehler Publishers, Inc., San Francisco.

Gharajedaghi, J. (2006) *Systems Thinking, Managing Chaos and Complexity: A Platform for Designing Business Architecture*, Elsevier, Burlington.

Gilad, B. (2009) *Business War Games*, Career Press, Franklin Lakes, NJ.

Hernandez, A.S., Lucas, T.W., and Carlyle, M. (2012) “Constructing Nearly Orthogonal Latin Hypercubes for any Nonsaturated Run-Variable Combination”, *ACM Transactions on Modeling and Computer Simulation*, Vol. 22, Issue 4, pp. 1–17. https://doi.org/10.1145/2379810.2379813.

Hernandez, A.S. and Whitcomb, C. (2018) "A Set-Based Thinking and Engineering Reasoning Approach to Set-Based Design" Paper presented at the SNAME Maritime Convention, Providence, Rhode Island, USA, October 2018.

Hershkovitz, S. (2019) “Wargame Business”, *Naval War College Review*, Vol. 72, No. 2, pp. 67-82.

Jackson, M.C. (1993) “The System of Systems Methodologies: A Guide to Researchers”, *The Journal of the Operational Research Society*, Vol. 44, No. 2, pp. 208-209.

Keeney, R.L. (1992) *Value-Focused Thinking: A Path to Creative Decision Making*, Harvard University Press, London.

Kleijnen, J.P.C., Sanchez, S.M., Lucas, T.W., and Cioppa, T.M. (2005). “A User’s Guide to the Brave New World of Designing Simulation Experiments”, *INFORMS Journal on Computing*, 17(3): 263-289.

Koehler, John R. and Owen, Art B. (1996) “Computer Experiments”, Handbook of Statistics, Vol. 13, 261-308.

Lindren, M. and Bandhold, H. (2009). *Scenario Planning: The Link between Future and Strategy*, Palgrave McMillan, United Kingdom.

Lin W., Fasheng S., Lin, D.K.J. and Liu, M. (2018) “Construction of Orthogonal Symmetric Latin Hypercube Designs”, *Statistica Sinica*, Vol. 28, No. 3, pp. 1503-1520.

Lucas, T.W., Kelton, D.W., Sanchez, P.J., Sanchez, S.M., and Anderson, B.L. (2015) “Changing the Paradigm: Simulation, Now a Method of First Resort”, *Naval Research Logistics*, Vol. 62.

Mingers, J. (1997) “Multi-paradigm Multimethodology”, *Multimethodology: The Theory and Practice of Combining Management Science Methodologies*, Edited by John Mingers and Anthony Gill. John Wiley and Sons Ltd., New York, pp. 1-20.

Mingers, J. and Brocklesby, J. (1997) “Multimethodology: Towards A Framework for Mixing Methodologies”, *Omega*, Vol. 25, No. 5, pages 489 – 509.

Mingers, J and Rosenhead, J. (2004) “Problem Structuring Methods in Action”, *European Journal of Operational Research*, Vol. 152, pages 530 – 554.

Mitchell, M. and Toroczkai Z. (2009) *Complexity: A Guided Tour*, Oxford University Press, Oxford, England.

Oriesek, D.F. and Schwarz, J.O. (2008) *Business Wargaming; Securing Corporate Value*, Gower Publishing Limited, England.

Osgood, N. (2011) “Basics of Causal Loop Diagrams”, Presentation at University of Saskatchewan, Saskatoon, Saskatchewan, Canada, January 25, 2011. https://www.cs.usask.ca/faculty/ndo885/Classes/CMPT858Spring2011/LectureSlides/.

Patterson, H.D. (1954). “The Errors of Lattice Sampling. Journal of the Royal Statistical Society”, *Series B (Methodological)*, Vol. 16, No. 1, 140–149.

Ritchey, T. (2006) “Problem Structuring Using Computer-Aided Morphological Analysis”, *Journal of the Operations Research Society*, 57.

Ritchey, T. (2011) “Modelling Alternative Futures with General Morphological Analysis”, *World Future Review*, Spring 2011.

Rittel, H. and Webber, M. (1973) “Dilemas in a General Theory of Planning”, *Policy Sciences*, Vol 4, pp. 155-169.

Rosenhead, J. (2013) “Problem Structuring Methods”, Advertising Response, *Encyclopedia of Operations Research*, pp. 1162-1172, The London School of Economics and Political Science, London, United Kingdom.

Rosenhead, J. and Mingers, J. (Eds). (2001) *Rational Analysis for a Problematic World Revisited*, Wiley, Chichester.

Sheard, S.A. and Mostashari, A. (2009) “Principles of Complex Systems for Systems Engineering”, *Systems Engineering*, Vol. 2, pp. 295-311. https://doi.org/10.1002/sys.20124

Sheard, S.A. and Mostashari, A. (2010), “A Complexity Typology for Systems Engineering”, *Proceedings of the INCOSE International Symposium*, pp. 933-945.

Sigahi, T.F.A.C. and Sznelwar, L.I. (2023) “Which Complexity? A Review of Typologies and a Framework Proposal for Characterizing Complexity-Based Approaches”, *Kybernetes*, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/K-11-2022-1507.

Liu, S., Liu, M., and Yang, J. (2023) “Construction of Column-Orthogonal Designs with Two-Dimensional Stratifications”, *Mathematics*, Vol. 11, No. 6, 1549; https://doi.org/10.3390/math11061549.

von Reibnitz, U. (1988) *Scenario Techniques,* McGraw-Hill Publishing Co., NY.

Watts, B.D. (1996) *Clausewitzian Friction and Future War*, National Defense University, Washington, DC.

Whitcomb, C., Hernandez, A.S., and Vizzini, M. (2019) “Engineering Reasoning in Set-Based Design”, *Naval Engineers Journal,* Vol 141, No 4, pp. 55-63.

Yearworth, M. and White, L. (2014) “The Non-Codified Use of Problem Structuring Methods and the Need for a Generic Constitutive Definition”, *European Journal of Operational Research*, Vol. 237, No. 3, 932-945.

Zwicky, F. (1969) *Discovery, Invention, Research - Through the Morphological Approach*, The Macmillan Company, Toronto.