“First find out what the question is – then find out what the real question is.” – Vince Roske

3.1 DEFINITION OF PROBLEM FORMULATION

Effective problem formulation is fundamental to the success of all analysis, but particularly in Command and Control (C2) assessment because the problems are often ill-defined and complex, involving many dimensions and a rich context. Problem formulation involves decomposition of the analytic problem into appropriate dimensions such as structures, functions, mission areas, command echelons, and C2 systems. Problem formulation is an iterative process that evolves over the course of the study. It is essential even for small studies or where time is short – it will save time later and help ensure quality.

The problem formulation phase should identify the context of the study and aspects of the problem-related issues.

The context of the study includes:

- Geopolitical context that bounds the problem space;
- Political, social, historical, economic, geographic, technological environments;
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- Actors;
- Threats;
- Aim and objectives of the analysis, including the decisions to be supported;
- Generic C2 issues¹;
- Relevant previous studies; and
- Stakeholders and their organisational affiliation (including both stakeholders of the problem and stakeholders of the study).

The aspects of the problem include:

- Issues to be addressed;
- Assumptions;
- High-level Measures of Merit (MoM);
- Independent variables (controllable and uncontrollable);
- Constraints on the values of the variables (domain and range);
- Time constraints on delivery of advice to the decisionmaker; and
- Whether this is a single decision or (possibly one of) a chain of decisions to be made over time.

*The problem is not formulated until the assessment team has addressed each aspect of the problem.*

In simple terms, problem formulation can be seen as an iterative process. First, the team must identify the variables that bound the problem space. Then they must determine which of these are outputs (dependent variables) and which of these are inputs (independent variables). The team proceeds by iterating to build an understanding of how these relate to each other. It should be viewed as a voyage of discovery. In most, if not all, cases of C2 assessment, the knowledge domain under study is in fact a system characterised by rich interaction and feedback among all the factors or variables of interest. The choice of dependent variables results from a clear specification of the issues and products needed to satisfy the terms of reference. Independent and intervening variables are also chosen based on the purpose of the analysis.

In the initial problem formulation iteration, it is critical to begin with an understanding of the REAL problem rather than a determination to apply readily available tools, scenarios, and data.

Within the NATO context, a number of documents are available or under development that may assist in understanding the study context. They are listed at the end of this chapter.

### 3.2 PRINCIPLES OF PROBLEM FORMULATION

There is no universally acceptable approach to problem formulation. However, best practices exist that can be applied. The principles associated with problem formulation are addressed in two categories: those that are appropriate for all C2 assessments and those that are appropriate for assessments of C2 for Operations Other Than War (OOTW).

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¹ Broad C2 issues include key systems, doctrine, Tactics, Techniques, and Procedures (TTP), organisational structures, and key assumptions (e.g. system performance parameters).
3.2.1 Principles Appropriate for C2 Assessments

Explicit problem formulation must precede construction of concepts for analysis or method selection. This is not a trivial exercise, especially in C2 assessments. Proper resourcing of problem formulation activities will improve the overall efficiency and quality of the study.

An understanding of the decisions to be supported by the analysis and the viewpoints of the various stakeholders (e.g. customers, users, and suppliers) is essential to clarifying the study issues. This understanding should be fed back to the stakeholders. A careful review of previous and current work must be carried out as a valuable source of ideas, information, and insight. This review should also serve to identify pitfalls and analytic challenges.

Problem formulation must not only provide problem segments amenable to analysis, but also a clear and valid mechanism for meaningful synthesis to provide coherent knowledge about the original, larger problem. The formulated problem is thus an abstraction of the real problem that can be defined in terms of dependent variables that relate to this real problem and coherent settings for the independent variables that can be interpreted in terms of decisions and actions by the customer.

Problem formulation must be broad and iterative in nature, accepting the minimum of a priori constraints and using methods to encourage creative and multi-disciplinary thinking, such as proposing a number of hypotheses for the expression of the problem. It must be recognised that change is inevitable in many dimensions (e.g. understanding of the problem, requirements, technologies, co-evolution of concepts of operation, command concepts, organisation, doctrine, systems). Thus the assessment process must anticipate and accommodate this change.

Practical constraints such as data availability, study resources (including time), and limitations of tools should be treated as modifiers of the problem formulation rather than initial drivers. Such constraint may, in the end, drive the feasible solutions, but it is important to recognise this as a compromise rather than an ideal. **Proper problem formulation takes substantial time and effort!**

It is important that problem formulation address risk from multiple perspectives. In addition to sensitivity analysis of the dependent variables, risk analysis techniques should be used to directly explore options to mitigate risk (Chapter 10).

C2 assessment often involves impacts on defence business outside the context of a particular campaign or operation. The study must address these impacts.

3.2.2 Principles Appropriate for OOTW C2 Assessments

Problem formulation must address the geopolitical context of the problem and seek to identify the “broad” C2 issues contained within the terms of reference for the study. There are no universal societal “norms”. Therefore, care must be taken in attempting to transfer the experience in one OOTW to another.

OOTW C2 assessments often involve policy-related impacts outside the context of a particular military operation. Therefore, MoM hierarchies must contain measures of policy effectiveness.

An historical perspective is critical to understanding OOTW because social conflict and structures often have roots far back in history. However, it must be remembered that present-day social behaviour is not driven by historical events themselves, but by present-day perceptions, processes, and prejudices which have evolved from the past.

A key risk in complex OOTW studies is allowing the problem formulation process to focus prematurely on subsets of the problem because they are: a) interesting; b) familiar; c) pre-judged to be critical;
or d) explicitly called out by the customer. This requires great discipline by the study team, especially where the team’s previous experience is biased in favour of particular parts of the problem space. The assessment team needs access to subject matter experts from a broad range of disciplines (e.g. social scientists, historians, and regional experts in OOTW assessment).

3.3 PROBLEM FORMULATION PROCESS

During the early stages of problem formulation it is important to quickly cover the whole problem and produce an initial formulation (i.e. an explicit expression of the problem). See Figure 3.1. This prevents premature narrowing of the assessment and serves as an aid to shared situation awareness within the study team.

The process begins with the sponsor presenting the assessment team with a problem to assess and an articulation of broad constraints (e.g. schedule, resources). Based on a preliminary assessment of the problem, the team identifies the key issues to address. This identification of key issues leads to a characterisation of the context for the study (e.g. relevant geopolitical factors, identification of the key actors and threats, identification of generic C2 issues, review of prior studies). Based on the results of this characterisation, the analysis team identifies what it perceives as the real issues to address. It is vital for the team to engage in a dialogue with the key sponsor and stakeholders to get “buy in” for these issues. Once that is achieved, the team must identify and characterise the remaining elements of the problem formulation phase. To facilitate that activity, the analysis team should identify/create and apply selected problem formulation tools and techniques (e.g. brainstorming, Delphi analyses, directed graphics, influence diagrams). The results of that activity will include a summary of the assumptions, high-level MoM, independent variables (both controllable and uncontrollable), and constraints on the variables. Once it is co-ordinated with the sponsor and stakeholders, the end product documents what is to be done in the analysis. The next key activity will be to develop a solution strategy that describes how the study is to be done.
3.3.1 Bounding the Problem/Issues and Assumptions

In dealing with fuzzy or uncertain boundaries, the problem formulation process needs to explore and understand the significance of each boundary before making (or seeking from customers) assumptions about it. This involves keeping an open mind, during the early stages of problem formulation, about where the boundaries lie and their dimensional nature. This is difficult because it makes the problem modelling process more complicated. A call for hard specification too early in the problem formulation process must be avoided. In the end, of course, the problem must be formulated in order to solve it, but formulation should be an output from the first full iteration, not an early input to it.

In formulating an OOTW problem, we are trying to bound a complex system. This is partly a process of understanding boundaries which exist in reality (e.g. mission statements, geographical areas and the timing of a procurement process) and partly imposing artificial boundaries in order to illuminate the structure of the problem and constrain the scope of the analysis. To avoid the trap of over-specification, boundaries (especially self-imposed ones) should be kept porous, allowing for cause and effect chains to flow through the external environment of the portion of the complex system that the boundaries define. While clear definitions and hard conceptual boundaries are ultimately necessary in order to create a manageable problem space, care must be taken to avoid coming to closure prematurely.

3.3.2 High-Level MoM

Identification of high-level MoM should start with ideal measures of the desired benefits before considering what can be practically generated by analysis (the latter may force the use of surrogate MoM, but these must be clearly related to the desired measures).

A structured analysis of potential benefits should be carried out as a basis for constructing appropriate MoM. Mapping techniques, such as cognitive and causal mapping, are a good way to express the various relationships within the problem space and to identify ‘chains’ of analysis (i.e. links among the independent variables and between the independent and dependent variables). These lead to resultant structure in terms of independent and dependent variables, and hence to high-level MoM.

3.3.3 Problem Formulation Tools

It is useful to identify, develop (if necessary), and apply appropriate tools to support problem formulation. Representative tools and techniques include: techniques for supporting expert elicitation, influence diagrams, causal maps, system dynamic models, and agent-based models.

Problem Formulation is fundamentally a social process of developing a shared understanding. People skills such as the ability to facilitate a ‘brainstorming session’ or to elicit information and context, are thus important. ‘Throwaway models’ (which may be simple simulation models, causal maps, system dynamic models, etc.) may be developed as part of the process, and then discarded as insight is gained.

Tools and approaches used for problem formulation must be consistent with other tools and techniques likely to be considered for the subsequent analysis in order to produce a sensible ‘multi-methodology’ approach to the entire problem and its solution.

3.4 CONSTRAINTS ON THE VARIABLES

The formulation of the problem is completed when the constraints on either the independent or dependent variables have been identified. Constraints on the dependent variables represent “acceptable” thresholds or

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2 The structured analysis of benefits is a logical process that seeks causally to map lower level MoM that can be related to investments or other actions to higher level MoM that can be valued directly by decisionmakers.
limits. For example, one could place a constraint on blue loss, time to accomplish a mission, collateral damage, or some combination of factors. Constraints on the independent variables represent either feasible or acceptable limits on such factors as human performance, C2 system performance, or even supplies. They also could represent doctrinal or legal processes that act as constraints.

3.4.1 The Next Step

The next step in the C2 assessment process is the development of a solution strategy. It should be noted that the team is not finished with problem formulation at this point but is now ready to proceed to build a solution strategy. As work progress on the development of a solution strategy, it will also certainly be necessary to revisit the specification of high-level MoM and the constraints. This chapter concludes with a discussion of the products of problem formulation.

3.5 PRODUCTS OF PROBLEM FORMULATION

Figure 3.2 depicts the essential elements of the formulated problem.

A checklist can be used to ensure that all the aspects described in the definition have been covered. These include:

- Precise statements of the question being researched;
- A list of independent variables;
- A list of high-level MoM; and
- A list of assumptions and constraints.

Figure 3.2: Problem Formulation.
3.5.1 Diagrams
Typically, the problem formulation phase should also produce a number of diagrams such as influence maps which summarise the key issues and interactions.

3.5.2 Data Glossary
The problem formulation phase must begin to create a glossary of key data elements, metadata, information, and terms.

3.6 CHAPTER 3 ACRONYMS
C2 Command and Control
MoM Measures of Merit
OOTW Operations Other Than War
TTP Tactics, Techniques, and Procedures

3.7 CHAPTER 3 REFERENCES


The following additional documents are under development:

- NATO C3 System Baseline Architecture
- NATO C3 System Overarching Architecture