Criticality Analysis Technique for Development of Concept Guidance

Dr Nitin Thakur, Dr Thitima Pitinanondha and LTCOL Alistair Dickie

Abstract

A military concept can be described as an elaboration of an idea or the operational approach for employing military capabilities to successfully achieve a strategic, operational or tactical objective, and can exist at various levels of fidelity and application. Military concepts form a crucial part of Defence planning, and a necessary part of the link between Defence strategic objectives and the development of capabilities. Strategic concepts, that provide the broad method of how military operations should be conducted, link to operational and tactical concepts, which provide detailed guidance to operational commanders and the developers of Defence capability.

One of the key challenges in translating and logically linking strategic concepts to lower level concepts is their subjective content, thus making it difficult to provide the necessary analytical transparency and traceability. To minimise subjectivity and ensure the development of robust and logical concepts, a technique for providing detailed guidance for concept development has been developed and tested.

This paper describes the work that has been conducted towards the development of practical guidelines to assist concept developers overcome the challenges in developing concepts at lower levels. This development process has been carried out through several workshops with Subject Matter Experts using a modified Criticality Analysis technique. This paper describes the challenges faced during the workshops and analysis, and showcases the use of the technique for development of this guidance.

Introduction

Concepts form an integral part of Defence planning, by helping develop and experiment with ideas of how strategic objectives might be met, before and during acquisition of capabilities to conduct tasks that meet objectives. This could be deemed necessary when a new problem arises, or when a new solution to an old problem is required; by developing concepts and conceptual plans, and validating concepts before heading down the path of change or procurement. Concepts, therefore, form the link between tasks that achieve objectives, to needs and requirements for acquisition programs[1]. With a sense of affordability built into them, they can provide an early indication of dollar-bound strategy.

There is a hierarchy of concepts in Defence, with each layer possessing differing functions and associated applications. The capstone concept articulates how the organisation operates; the future operational concepts below this would conceptualise how major systems work with each other to meet strategic objectives; and underlying concepts at the operational and tactical layers define how individual systems operate and set requirements for future capabilities. In order for concepts at each layer to be logical and analytically rigorous, they need to be transparent and traceable, and hence be clearly structured and have clear linkages between different layers, and to extant organisational artefacts. The future operational concepts could initiate forerunners of capability

[1] A Framework for Defense Planning, Glen A. Kent, R-3721-AF/OSD, August 1989.

goals, risks and integration issues that could be tested and validated to assess the solution space. Although moves are afoot to generate the layer of future operational concepts, this missing layer implies that there is nothing that currently conceptualises how capabilities in Defence come together as a whole-of-force to meet strategic objectives, and there is no clear guidance for developers of capability acquisition in terms of goals that need to be achieved.

The focus of this paper is on the capstone organisational operating concept, and the, yet to be developed, supporting future operational concepts. To ensure the capstone document delivers the relevant guidance for development of the underlying concepts, and that required associations exist between the two layers, the use of a criticality analysis technique has been described in this paper. The technique is an adaption of the Failure Mode Effects and Criticality Analysis (FMECA) method, which is primarily a method for the study of causes and effects of failure and criticality, which goes a step further than risk management. A case study is presented to showcase that a project and risk management technique can be applied to the subjective and qualitative domain of strategic concepts.

Concepts for Defence Planning

Strategic planning is an organization's process of defining its strategy, or direction, and making decisions on allocating its resources to pursue this strategy. In order to determine the direction of the organization, it is necessary to understand its current position and the possible avenues through which it can pursue a particular idea or course of action. These avenues seed the concepts of operation of the organisation, and need to be developed, experimented and validated such that they can be formalised to indicate the way the organisation achieves its objectives.

Military strategy consists of the establishment of military objectives, the formulation of military strategic concepts to accomplish the objectives, and the use of military resources to implement the concepts. Clearly stated ideas about the challenges we face in the future and potential ways for dealing with those challenges are essential for future force and capability development. A concept-based approach starts with an idea of how the force could successfully achieve future operational missions, and then to develop the capabilities needed to implement that idea. The basic purpose of concepts is to, iteratively, guide change by motivating experimentation in and exploration of new operating methods, which, if validated, drives the development of military capabilities, doctrine, organisational design and policy[2].

Concept Primer

A concept is an idea, or in military strategy planning language, the way or how the elements of the Defence Force intend to conduct operations to succeed. Concepts at the strategic and operational levels should inherently be joint in nature, and they have the dual purpose of describing how to use current and approved capabilities (force-in-being), and inform capability development decisions for future capabilities that are not yet approved (future force structure). Concepts based on existing military capabilities are operational concepts and are used as a foundation for the formulation of specific plans for action in the short-range time period. Longer-range concepts may be based on

[2] Memorandum for US Joint Forces Command, Joint Concept Development Vision, GEN J.N.Mattis, 28 May 2009.

estimates of future threats, objectives, and requirements, and are therefore not as constrained by current force posture. Generally the hierarchy of concepts consists of four layers:

- The Capstone Operating Concept: This is the highest level concept which proposes how the organisation could operate in the 15+ year timeframe, by putting forward ideas and rules for the organisation to focus on whilst conducting future planning. Using a framework of generic enduring tasks, in the context of strategic risks and the future operating environment, it suggests how these ideas would support strategic roles in performing the tasks, hence highlighting uncertainties and providing guidance for the sorts of force structures that the organisation needs to aim for. The capstone document for the Australian Defence Organisation (ADO) is the Future Joint Operating Concept (FJOC).
- Future Operational Concepts: These are a suite of concepts that have the aim of distilling strategic guidance provided by the capstone concept, to provide more detailed guidance for capability development. Hence these concepts apply around the 15 year timeframe. They address specific systems of the organisation, by either using an effects-based or a functional-based taxonomy for development and assessment, and which tackle known capability gaps or ways deemed necessary to operate in the future context. The aim of these concepts is to come up with a set of generic capability statements which state how each system or effect or function will achieve success for task objectives. These capability statements have associated attributes which are a measurable characteristic that describes aspects of the system. These attributes form the beginning of the definition and evolution of capability goals. These concepts are akin to roadmaps wherein sub-systems are brought together to describe a capability area or function with the focus on implementation. The intent for ADO is to develop them as a suite of concepts in a Joint Concept Framework (JCF).
- Concepts of Operation (CONOPS): These are concepts that define how the force might achieve a particular operational task. They are the product of planning for operations using capabilities or sub-systems that are extant or future capabilities that have been endorsed. This layer of concepts does not specifically support capability development.
- Concepts of Employment and Operational Concept Documents: Concepts of Employment (CONEMPs) are concepts of how current or currently endorsed equipment or platforms are to be used to generate capability. Operational Concept Documents (OCDs) translate CONOPS for future endorsed capabilities into requirements for specific capability acquisition. This layer of concepts describes the characteristics of a proposed system from the viewpoint of its users, and communicates the quantitative and qualitative system characteristics. Each Defence project is supported with these concepts.

However, the guidance currently provided by the capstone operating concept is too diffuse and strategic for use in specific operational contexts or for force structure and capability needs analysis. Hence, there is a requirement to provide additional detail to assist with the development of future operational concepts. Further, the future operational concepts need to have a direction provided, in terms of where systematic failures could occur and knowledge of critical sub-systems, so that the organisation is aware and prepared (with concepts) to address these criticalities.

Some of the authors have had exposure to a technique called Failure Mode, Effects and Criticality Analysis (FMECA), which is mainly used in reliability and safety domains, and provides estimates of system critical failure modes relative to mission importance. It was judged that this technique, with

its risk-based focus and its ability to deal with the knowable unknowns, could be adapted to provide the required emphasis of relevant critical systems for concept development.

Criticality Analysis (Methodology)

The FMECA method was originally developed by the U.S. military[3] and employed as an analytical technique for evaluating failures to determine the reliability of equipment and system. The failures were classified according to their impact on personnel and the success of missions for the security of equipment. FMECA[4] is the identification of the ways in which a system can fail and the consequences thereof. It assists in the implementation of design and management of corrective actions to minimize the occurrence and severity of failure, and maximize its detection.

FMECA is composed of two separate analyses, the Failure Mode and Effects Analysis (FMEA) and the Criticality Analysis (CA). The FMEA analyses different failure modes and their effects on the system while the CA classifies or prioritizes their level of importance based on failure rate and severity of the effect of failure. The CA provides relative measures of significance of the effects of a failure mode, as well as the significance of an entire piece of equipment or system, on safe, successful operation and mission requirements. In essence, it is a tool that ranks the significance of each potential failure for each component in the system's design, based on a failure rate and a severity ranking. This tool can be used to prioritize and minimize the effects of critical failures and can be performed using either a quantitative or a qualitative approach. Trends are difficult to ascertain when causative events may be random but the detection and severity of outcomes may be controlled. Therefore, FMECA is a useful risk management tool that considers what happens when events do not follow measures of central tendency such as means, but rather are the 'outliers of distributions'.

In the engineering world, an example would be to use FMECA to assess safety equipment on an oil rig, whose components could be a motor (with failure modes as bearing failure or coils shorted) and a power supply (with failure modes as incorrect voltage or unregulated output). There are three basic steps in conducting a FMECA:

- Determining the Probability of Occurrence (O) for each failure mode of the product or system using a scale such as frequent, occasional, or extremely unlikely.
- Determining the Severity (S) of the failure mode of the product or system in terms of potential consequences, using a scale such as catastrophic, critical, or marginal.
- This provides the Criticality assessment of that failure mode which is the mathematical evaluation of the occurrence and severity: Criticality = (O) × (S).

Obviously if no quantitative data is available, then a qualitative assessment can be used and the scales can be translated from a lookup table. This is dependent on the Subject Matter Experts (SMEs), and FMECA does require a thorough knowledge of the subject matter.

[3] Military MIL-P-1629, "Procedures for the Analysis of Failure Modes, Effects and Criticality", dated 09 November 1949.

[4] FMECA presentation last updated November 2012, Aerospace Systems Division, Defence Materiel Organisation, Department of Defence.

Criticality Analysis for Concepts (Guidance Development)

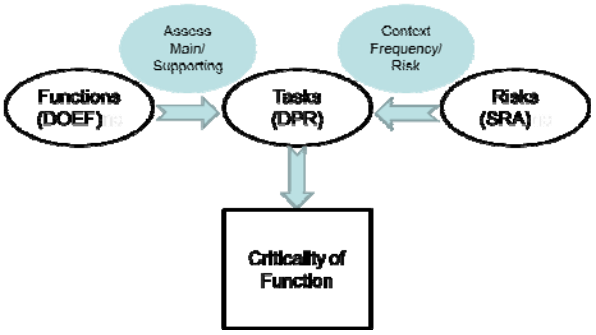
Whereas FMECA is used in reliability domains to detect failure modes, the intent in concept development is to provide relevant focus of critical sub-systems for the Defence organisation. Hence, 'failure mode' is adapted in this context as a Defence-relevant risk event that might eventuate, with a probability of occurrence (O). It is assumed, in this context, that the frequency of response from Defence to this risk event, achieved by using specific functions or tasks, indicates the severity (S) of this risk event. The criticality of that Defence function or task is then a product of likelihood-impact of the risk and the frequency of occurrence of the function or task.

To conduct this exercise, it is then essential to have extant artefacts in the organisation that can be utilised to provide the ingredients for criticality analysis. Three such artefacts are:

- Defence Preparedness Requirements: The Government expects Defence to be able to achieve a number of tasks, potentially at the same time, or in a carefully managed sequence over periods of time, expressed as Defence Preparedness Requirements (DPR). Each DPR is informed by one of four Principal Tasks articulated in the Defence White Paper. The Principal Tasks are those strategic 'end states' that guide internal Defence policy. They are Government's unambiguous direction to Defence in terms of what the Government requires Defence to be able to do to meet the intent of each Principal Task. The DPR represent the military strategic ways to generate the functional outcomes which aim to meet Government's policy guidance and expectations of Defence, now and into the future.
- Defence Operations and Enabling Functions: These functions, or DOEFs, establish a Whole-of-Defence preparedness management architecture to describe, manage and report activities and capability areas that contribute to Defence's Joint Force-In-Being. The DOEF[5] are appropriate as potential future lines of operation as they encompass the range of functions that Defence would use to achieve campaign goals.
- Strategic Risk Assessment: This risk assessment, or SRA, is a tool for decision makers to inform choices about strategic policy, planning and prioritisation in a budget-constrained environment. It identifies the key strategic and enterprise risks in the strategic environment and the organisation out to 2035. Each risk event is assessed for likelihood and consequence, the product of which is the risk associated with each event.

The bringing together of these artefacts for criticality assessment is indicated in the figure below.

[5] The list of eighteen (18) functions are: Information Operations, Cyber Operations, Special Operations, Strategic Strike, Air Control, Population Centric Operations, Sea Control, Sea Denial, Land Combat, Command and Control, Combat Support, Communications, Battlespace Awareness, Joint Fires and Effects, Force Projection, Lift, Logistics, and National Support.



Application or Exemplar

A workshop was held late 2012 in which a group of subject matter experts was brought together to go through this exercise and actually derive the function or task criticalities. The first question that they had to assess was:

- How often would each DOEF-based function be used as a main or supporting line of operation for each DPR-based task? In order to avoid a tendency to go for middle ground, a four point scale was chosen, viz., never, sometimes, often, and always. An example of the type of data is shown below[6]:

Future Approach 2035	DPR1 Understand and Shape Environment		DPR2 Conduct Joint Combat Operations		DPR3 Conduct Peace and Stability Ops	
	Main	Supporting	Main	Supporting	Main	Supporting
Information Operations	Often	Always	Often	Always	Often	Always
Cyber Operations	Often	Always	Often	Always	Often	Often
Special Operations	Sometimes	Sometimes	Often	Always	Sometimes	Often
Strategic Strike	Never	Never	Often	Always	Sometimes	Sometimes

This provided an indication for each task a focus on functions that were always required in a main and/or supporting role. The next question for assessment was:

- How often would each Task be used if a Strategic Risk event were to develop?

Risk Event	Likelihood	Consequence	Risk	Context Basis	DPR1		DPR2		DPR3	
					Frequency	Criticality	Frequency	Criticality	Frequency	Criticality
Potential Pandemic			Moderate							
Harassment										
Regional Conflict							Always	Critical		
Conventional Attack					Low		Always	Critical		

The product of the likelihood-consequence of the risk and the frequency of task then yielded the criticality of task. Tasks always required for a function and criticality of tasks in the strategic risk context provide the crucial nexus between that function and tasks in the context of the risk event. The concept for achieving the objective by the joint force is then guided by the functions that are critical to the successful execution of the tasks by the Joint Force.

Additional guidance for concept development can be provided by articulating how the Precepts or ideas contained in the FJOC would work with Strategic Roles, which is yet another artefact that has been extracted by consolidating Operational Preparedness Requirements (OPRs). These roles have

[6] The actual data from the workshop has a security classification that makes it inappropriate to share, but the method presented in this paper is unclassified.

been mapped to DOEFs, which strengthens the logical basis of the concept. As an example, a brief construct of the concept to 'conduct joint combat operations', viz DPR2, could look like:

- Conceptual Basis[7] for DPR2: This high level concept describes how a Joint Force (JF) will conduct DPR2. To meet the challenge of being able to utilise socio-technical factors and understand the centrality of human factors, the JF will have to effectively combine roles such as *pysops* and *public affairs*. In cyberspace the JF shapes the environment assisted with roles of *Cyber Network Exploitation*. To achieve its outcomes for this task, the JF will have to work with composite forces, and hence need to be effective in the roles of *Command and Control in HQs and logistics*.
- Central Idea for Special Operations: The Joint Force will conduct the Function of Special Operations through the collective effect of Task DPR2 which is crucial in the context of Conventional Attack and/or Regional Conflict (viz. Strategic Risks).
- Defining Capability Statements[8]: Special Operations will achieve success by having:
    - The ability to infiltrate and exfiltrate from terrain previously untraversable
- Attributes for Special Operations[9]: Special Operations need to be fully integrated with function Joint Fires and Effects, and the measure[10] is achieving a good degree of precision.

Therefore the criticality assessment provides suitable hooks for underlying concepts in the form of how roles for a joint force function come together whilst it is achieving a strategic objective task; considered in the context of strategic risk; and distinctly linked to the central FJOC precepts.

Discussion and Recommendations

This case study offers a starting point to demonstrate that there are organisational artefacts that can be used to provide robust linkages for logical transparency, and that these linkages can lead to a healthy structured basis for decision audit. It also showcases how concepts can be the forerunners of capability goals by forcing development of capability statements, risks, integration issues for lower layers of capability development and setting of requirements for acquisition.

The limitation of this technique is that the assessments are based on setting the appropriate context and the background of the SMEs who have to envisage the criticalities. Also, changes in external contexts such as budgets and the environment are outside of organisational control, leading to change in priorities, and hence nullifying the assessments.

Other factors that this technique does not take into account are the many-to-many relationships between cause and effect that would influence the interplay between risks, tasks and objectives. The interdependencies and linkages between tasks and functions are also overlooked. So are the temporal, complex and changing nature of decisions that assist in making the assessments.

---

[7] Roles are italicized and precepts are underlined. The roles are considered and assessed for relevance to the precepts in the context of the task.

[8] A definition of the capability required to implement the concept can be made with a capability statement that should start with "the ability to" and include at least one action verb. Example of a capability: The ability to detect and defeat airborne threats.

[9] A testable or measurable characteristic that describes an aspect of a system or capability. For a given capability, attributes should describe the essential characteristics the joint force needs to provide the capability. Attributes are expressed as adjectives that apply to the joint force, such as fully integrated, expeditionary, networked, decentralised, adaptable, decision superior, lethal.

[10] Measures include timeliness of information, degree of operational readiness, degree of protection of comms, degree of precision, probability of kill – and could be qualitative or quantitative.

From the artefacts that are used for assessment, it is to be noted that strategic risks and DPRs are not force structure determinants, and that this analysis is not appropriate for current operations, but only to guide development of future concepts.

Conclusion

Concepts can form an integral part of strategic planning, and it is essential for the different layers of concepts, to be logical and analytically rigorous to ensure they are useful in the planning process. The criticality analysis technique has been modified and applied to provide structural and linkage guidance between different layers, and to extant organisational artefacts, to provide that rigour. It remains to be judged whether this translates and assists with the development of future operational concepts for Defence.