Developing a Risk Method for the Analysis of UK Network Enabled Capability

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ABSTRACT

“No plan ever survives first contact with the enemy” is an old adage that still remains true. This might be regarded as surprising considering that in the information age, planning is more inclusive and better supported. This paper describes a capability risk method that provides a view of capability considering a complex adaptive enemy that is characteristic of modern warfare. Drawing upon extensions of Benefits Analysis, this paper defines the method used and by means of an example case study views the resultant risk portfolio. As part of the reflective process, this paper contributes towards the NEC/NCW literature by presenting “points of principle” that can be applied to C2 (Command and Control) metrics, modelling and analysis. This paper concludes by discussing the utility and potential future applications of the method.

1.0 INTRODUCTION

“No plan ever survives first contact with the enemy” is an old adage that still remains true. This might be regarded as surprising considering that in the information age, planning is more inclusive and better supported. Through reviewing the challenges faced by the UK MoD (United Kingdom Ministry of Defence) in delivering coherent capability and the desirable characteristics of analysis in support of through life capability management, this paper discusses the practical aspects of applying a risk method that provides:

- A view of equipment programmes mapped to capability;
- Direct identification of potential problems;
- Improved equipment coherence through alignment of programmes, and
- An assessment of the impact of programme changes.

This paper extends standard risk practice by drawing on work by Mathieson[1] to offer insights into the benefits and axioms of applying risk method. As part of the reflective process, the paper reviews the utility of some of the work conducted within the UK MoD Network Enabled Capability (NEC) delivery programme. It is hoped that the insights offered will benefit the NEC and capability based planning communities.

The paper is structured as follows. It begins by reviewing the themes of warfare and capability management within the NEC era. It goes on to introduce the risk method theory and establishes points of principle in its application, including a sample case study and results from the work. Finally, this paper draws conclusions about the limitations of the work and points to areas of future potential development.
2.0 CAPABILITY CONTEXT

Effects Based Operations

Effects based operations are not new in concept; throughout history a good military commander has always focused on “planning and delivering the end-state rather than organising military activities. Effects Based Operations considers the whole environment, recognising that it is complex, unpredictable and adaptive, requiring constant iterative Assessment and Analysis to maintain and develop understanding before and during its Planning and Execution.”[2]

The emphasis on effects based operations within doctrine is relatively new, and with it a new language for policy makers and strategic planners is being established. This doctrine recognises that the military contribution to effects based operations cannot be considered in isolation of Other Government Departments and Non-Government Organisations such as the Red Cross. If effects based operations are to be successful, then stakeholders in the Diplomatic, Economic, and Military instruments of power will all adopt this way of thinking and embrace this as a common language.

The emphasis on effects places a new challenge on the decision support community conducting analysis, research and experimentation. They must now not only embrace the language of the wider community, but also support both analysis and assessment of the contribution of these different actors, while appreciating the physical, information and cognitive nature of effects.

Maintaining Political Choice

The desire to maintain political choice and be able to respond positively to political directives is also established. However, there is an increasing need to respond rapidly and appropriately to the prevailing Military, Physical, Political, Scientific and Technical, Social and Cultural, Ethical and Moral, Legal and Economic situation. This has resulted in the desire for military capability to become increasingly agile, defined within UK doctrine as responsive, robust, flexible and adaptable. It should be noted at this point that in due course they may be similar demands placed upon the non-military stakeholders.

The desire to maintain political choice requires the decision support community to be able to assess the utility of military and other contributions in all dimensions of the strategic environment. This not only requires methods that can account for the many and varied factors, but also ways of rapidly eliciting and structuring information that has traditionally been restricted to assumptions lists or regarded as out of scope.

Future Threats

The defence and security challenges of the future are likely to be driven by the strategic trends and developments in key areas of resource, social, political, military and science and technology. This will provide a rich framework for a complex adaptive and evermore ‘invisible’ enemy who will be able to achieve near instantaneous global reach through the rapid expansion of the information communication technologies.

Strategically the enemy will be able to coral the masses through unofficial and unregulated web-based media. They will be able to further incite agression by an increased awareness of the divide between the rich and poor, whether perceived or real, and consequently sponsor greater inter-racial/ethnic/religious divide; ironically it may be the very technology that is hailed for creating a global network community, that is the cause for greater localised divides and evermore irrational friction.

Commercial based science and technology is likely to continue to extend its lead over military developed science and technology in all but the very niche defence areas, and potential agressors will be able to increase
their own levels of technical sophistication by taking advantage of the proliferation of cheaper and more effective commercial technology in the areas of communications, surveillance, and weapons, whilst the Armed forces struggle to analyse and prioritise their threats and risks against ever-decreasing budgets. Furthermore, we will probably see yet more unanticipated shocks as the enemy seeks to counter high-technology based defence and security systems with extremely simple terrorist actions. Greater urbanisation will serve to increase the likely impacts whilst the instantaneous media reporting will aid the spread of confusion and fear more effectively. Whilst the regular armed forces struggle to introduce and absorb NEC, the new enemy will use the commercially created NEC to exploit weaknesses at the strategic, operational and tactical levels.

**Network Enabled Capability**

The aspiration of NEC is to not only introduce new ways of operating, but also introduce new capabilities to defend against the security challenges of the future. Realising this aspiration is dependent upon changes across the UK MoD Defence Lines of Development (Training, Equipment, Personnel, Infrastructure, Doctrine & Concepts, Organisations, Information and Logistics) to achieve interconnectivity, integration and ultimately synchronised states. There are a series of acknowledged challenges to bringing about these changes. See ref [3] for overview, specifically within the equipment line: “Capability development will often be complex and require the integration of new and legacy systems whilst assuring that the equipment programme provides for future upgrades.”

The implementation of NEC requires that the decision support community be able to assure the internal and external coherence of the plans, through gauging the impact of changes to NEC related investments. The decision support community will require methods that represent the nature of the networked components and account for the interdependency between them while managing the complexity that is inherent within large networks.

**Summary of Challenge to Decision Support**

In summary the challenge that these themes set for the decision support community is to develop methods that:

- Treat uncertainty with sufficient rigour;
- Manage and mitigate the effects of complexity;
- Account for interdependency;
- Maintain transparency; and
- Are sufficiently responsive.

This paper now continues by addressing each of these aspects, relating them to the theoretical basis for the risk method.

### 3.0 TREATMENT OF UNCERTAINTY

**The Utility of Risk**

Risk management is a well established method for appreciating how future external events may impact upon a desired outcome and evaluating the best way to intervene. The following definition of risk has been used within this paper: Risk is the probability of an event happening and the resultant impact of that event.
Accepting that no one can predict the future, but merely define a wide range of plausible futures against which the effectiveness of military intervention should be known; risk is useful, giving a relative measure to compare and contrast different military solutions across a range of futures. There seems to be no lack of information to support risk assessments: there are many trials, experiments, lessons identified and analytical studies that state performance shortfalls, lack of availability, and integration issues.

When assessments are made across a range of futures, there should be a sufficient number of futures considered to avoid specifying a capability that has utility in only one environment and is constrained to one way of operating. In the same manner, weighting of future scenarios also should be avoided as no one plausible future may be judged any more likely than another, and weighting futures will unduly bias the assessment.

Consideration of risk is a useful approach, as it not only allows thought regarding current threat modes of operation, but also prompts contemplation of how threats might evolve to exploit apparent weaknesses. Risk thinking also allows areas where Network Enabled Capability can better exploit environments and opportunities to improve the precision of effects and apply alternative effects.

**Practical Assessment**

Within traditional risk assessments applied to project or programme management, each risk is initially assessed within a risk categorisation table to consider the probability of the event and up to 4 impacts. These impacts are usually Performance/Quality, Time and Cost, and perhaps a softer area such as Reputation or Shareholder Value. The probability and impact of the risk are then convolved through a matrix probability impact grid to produce an overall level of concern for the risk. This determines the importance of the mitigating action to be applied.

Adopting the same approach to consider a network enabled capability would be impossible to implement in a practical way. The sheer number of individual risks each assessed against the number of potential impacts would prevent comprehensive assessment within a sensible timeframe.

The authors advocate that a practical approach is to assess the risk in an alternative way. This alternative considers the impact of risk to be comprised of consequence and severity. The four key stages of the method are shown by the white boxes in *Figure 1*, within this process diagram, PSG is Probability Severity Grid.
Establishing Consequence

Scenario(s) provide context to the deployment and subsequent employment of the capability. This context provides the scope of the benefits framework through articulating the decisive conditions and supporting effects.

Figure 2 depicts a Benefits Analysis framework where the links are causal and the nodes are characteristics of Means, Ways and Ends [4]. The causal framework can be regarded as a description of an effects based plan, working from the decisive condition to appreciate the supporting effects (Ends). From effects the capability (Ways) required can be derived, to ultimately produce the systems (Means) requirement. The description of Ways embodies both concepts and doctrine as a description of the way that the capability is drawn together as discrete but interlocking components.
Figure 2. The Benefits Framework

The node descriptions within the casual framework should not be overloaded with ideas, to prevent the true meaning of a node from becoming ambiguous. The confounding of ideas within a node will make the framework difficult to validate and communicate to stakeholders outside the group that created the framework. As a point of principle each node should be as specific as possible with:

- An Actor specifying the generic red or blue force element that would be measured (for example Own Force Manoeuvre unit); and
- A characteristic specifying the activity and dimension of interest (for example, Timely transit to objective area).

Specifying where and what should be measured allows well defined metrics to be developed thus enabling units or scales of measurement to be standardised. Standardisation of units and scales allows data from external sources to be used to support the creation or validation of the framework with a minimum of conversion and interpretation.

Once the framework is complete, the input nodes will provide a comprehensive set of investment characteristics for each Means. These characteristics can then be described more fully as a series of relative risk statements where the characteristics of the system being considered are compared against the target for the effect, the operating environment, the threats to the effect and the political constraints/requirements for the effect. For example “Timely target identification” can be described as “Time taken to identify the target within the proportion of window of opportunity for engagement” and “The range of effector” can be described as “The range of the effector is matched to the relative engagement positions”. The risk statements must be selected so as to be solution independent to allow the comparison of different solutions (Means). This is useful as it gives a structured, atomised, ordered list for consideration within severity and impact assessment.

Prior to assessing the severity and probability of risk, each Actor described in the source risk node description must be related to one or more candidate solution. Each candidate solution will need to be assessed for severity and probability.
Separating the severity and consequence of a risk allows the consequence of risk to be an explicit consideration which is independent of the severity or probability of the solution (Means). Trade-offs are solution (Means) dependent, for example: a tank has mobility and armour which traditionally have an inverse relationship; this is not a causal association because a solution with an enhanced power pack and novel light weight armour would not obey the rule. As such the causal framework is an expression of consequence; it should not be built as representation of trade-offs.

The Assessment of Severity

The scenario context is important for the consideration of the risk severity. Where more than one scenario is being considered, each risk identified from the consequence analysis should be assessed within each scenario. The distribution resulting from the severity assessment is subsequently used to assess probability. Where data from analysis and modelling, experimentation, lessons from operations and trials exists, it should be drawn on to provide an audit trail for the severity assessments. It is important to review not only results from these sources but also the context and assumptions.

The severity of performance risk should be assessed considering the shortfall in each of the scenario contexts. The level of shortfall is evaluated by considering the opportunities for effect, environment and threats, and the military operational situation. The shortfall is the difference between the level of need (determined by the challenging nature of the scenario) and the level of provision. If the solutions (Means) employed are able to operate within political requirements/constraints, matched to the characteristics of the operating environment, robust to the threat and matched to the targets for effect then there will be no shortfall.

The severity of availability risk should be assessed by considering the mission of the solutions (Means) to conduct the mission against the mission priority. The severity of availability tends to be either nil (the mission thread element is required and available), or high (the mission threat element is required and not available).

The severity of interoperability risk should be assessed by considering all the interfaces between solutions (Means) employed. This requirement is driven by the need for interoperability or integration, with the interfaces engineered so that they work sufficiently well together. The interoperability risk may be driven by mis-matching of data, information, physical operation or process.

A RCT (Risk Categorisation Table) supports the translation of severity real world measures of need and provision into severity of shortfall. There should be one RCT for each node, used for assessing the severity of the shortfall in all scenarios.

The Assessment of Probability

The performance probability is the proportion of scenarios for those where a significant level of severity exists. For performance risks, this tends to reflect the number of scenarios that have demanding political requirements or constraints, potent threat capabilities, challenging targets and austere environments.

The availability probability is the proportion of scenarios where there is poor availability to conduct the mission given other operational priorities.

The interoperability probability is the number of scenarios where two or more solutions (Means) will not work together. This probability should reflect the level of confidence within the design. The probability assessment should not be based on the probability that these two solutions (Means) will be used together.

A probability RCT supports the translation of number of scenarios into the probability of shortfall. The same probability RCT should be used for all of the probability assessments.
**Probability Severity Grid**

When considering a specific risk, the assessment of probability and severity will generate a distribution of results (see Figure 3 as an example).

![Figure 3. Probability Severity Distribution](image)

This distribution may be reduced to a single number representing the level of risk through a two stage process. The first stage is to calculate an appropriate risk score for each severity, and the second is then to take the largest of these scores to produce the number representing the level of risk. This avoids having to explicitly test the tails of the distribution for significance.

<table>
<thead>
<tr>
<th>Probability Ranges</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>0.9-1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>0.6-0.9</td>
<td>0.6</td>
</tr>
<tr>
<td>0.3-0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>0.1-0.3</td>
<td>Very Low</td>
</tr>
<tr>
<td>0-0.1</td>
<td>None</td>
</tr>
</tbody>
</table>

**Table 1. The Probability Severity Grid**

To calculate a risk score for each severity, look up the up the risk score based on the cumulative probability of that severity or greater in a Probability Severity Grid such as is shown in Table 1. Thus the probability of medium severity should include the probability of a high severity. For example, using the distribution in Figure 3, working from high severity to none, the cells shaded in amber show the risk scores using the cumulative probability:

- 0.2 (very low) probability of a high severity resulting in a risk score of 0.2;
- 0.5 (low) probability of a medium severity + 0.2 (very low) probability of a high severity = 0.7 probability of a medium or greater severity, resulting in a risk score of 0.4 – the amber shaded cell in the medium severity column.

Using similar reasoning:

- 0.2 (very low) probability + 0.5 (low) probability + 0.2 (very low) probability = 0.9 probability of a low or greater severity resulting in a risk score of 0.2;
- 0.1 (very low) probability + 0.2 (very low) probability + 0.5 (low) probability + 0.2 (very low)
probability = 1.0 probability of a very low or greater severity resulting in a risk score of 0.2, and a

- 0 (none) probability + 0.1 (very low) probability + 0.2 (very low) probability + 0.5 (low) probability + 0.2 (very low) probability = 1.0 probability of a none or greater severity resulting in a risk score of 0.

Then taking a “worst case approach”, reduce the set of cumulative probability risk scores (shown in yellow) to a single number by taking the highest of the severity risk score. In the example above this results in a score of 0.4.

When assessing a set of risks, it is important to use a common probability severity grid to assess the risk. Should different grids be used, undue weight could be applied to certain risks, resulting in bias within the results.

The two stage risk scoring approach using a probability severity grid where a low probability high severity scores higher than a low severity high probability, weights the results such that a more robust portfolio of investment is generated. Calculating the total probability of a severity greater or equal to the level of severity results in a risk score that includes the high severity tail of the probability severity distribution as it becomes significant. Ignoring this tail would produce a balance of risk mitigation actions where a risk with a broad range of impact would not be mitigated effectively.

When eliciting the probability and severity scores, it is helpful to be able to reference a graph plot that automatically translates the probability and severity distribution into a risk score.
Figure 4 shows the ‘worst case’ risk score that can be ascertained from the distribution is 0.4, this can be made by adding the probability from the high severity to the scores from medium severity and low severity, producing a high probability of a low (or worse) severity.

To this stage the method advocated provides an appreciation of individual issues with a qualitative view of impact, however without being able to quantify the difference that the risks make in effects terms, only crude prioritisation can be achieved. This may be sufficient for some simple balance of investment problems however does not account for the complex interaction between the investment set.
4.0 COMPLEXITY

This paper continues to describe how individual risks can be aggregated for reporting in capability and effects terms. This is of interest to desk officers and capability area managers as it provides a coherent reporting of risk aligned to the area of interest of individuals within the capability based planning community. Reporting the risk portfolio at different levels is achieved through promoting the probability severity assessments through the causal framework, as shown in Figure 5.

**Complexity of Interaction**

The nature of consequence is causal; therefore it is appropriate to use the framework as a basis for evaluation. The links within the benefits framework represent functional interactions between any set of causes and effects represented in the framework. Within the method these are classified into three types of risk interaction. These are defined as:

- **Compounding Interaction** – All elements of the capability are required to deliver the effect and must be matched to each other;
- **Contingent Interaction** – All of the elements of the capability are required to deliver the effect but not necessarily matched (some compensation); and
- **Mitigating Interaction** – Only one element of the capability is required to deliver the effect.

As these interactions simply describe the interactions between a number of causes and an effect, all the links entering a node must be of the same type. This may in some cases drive the structure of the framework.

**Figure 5. Risk promotion in action**
Compounding Risks
A compounding risk arises when there is a group of dependent risks and the resultant risk depends on the whole group. Compounding risks are applied where a given capability can only be achieved if all the individual capability elements are achieved. The requirement for the whole group will serve to increase the overall programme risk, hence the term ‘compounding’ as the effect of the first risk is compounded by the effect of the second and subsequent risks.

Alternatively, a compounding risk can be considered to be an ‘AND capability’, i.e. the capability can be achieved only if the first capability element has sufficient performance AND the second element has sufficient performance. For example, the availability of the aircraft sortie requires an available aircraft AND an available trained pilot.

Contingent Risks
A contingent risk arises when there is a group of dependent risks, but the result does not depend on the whole group, there is some compensation between them. Contingent risks are applied where a capability can only be achieved if all the capability elements are on average achieved. The existence of contingent risks will serve to moderate the overall level of risk. Hence the description ‘contingent’ as the risk is conditional on all elements, but moderated overall.

Alternatively, a contingent risk can be considered as a ‘soft AND capability’, where the capability can only be achieved if collectively the set of capability elements have sufficient performance. For example, the time to effect is contingent on the planning time AND the time to execute the mission.

Mitigating Risks
A mitigating risk arises when there is a group of independent risks and the resultant risk does not depend on the whole group but only on one of the risks. Mitigating links are applied where a given capability can be achieved from the use of one of several options or where one or more risk mitigation actions have been identified. The existence of independent, alternative actions will serve to reduce the overall programme risk. Hence the term ‘mitigating’, since the effect of the first risk is not compounded by the second and subsequent risks.

Alternatively, a mitigating risk can be considered to be an ‘OR capability’, i.e. the capability can be achieved if the first capability element is achieved OR if the second element is achieved. For example, the survivability or the platform can be delivered through appreciation of the threats and using appropriate counter-measures OR appreciating threat locations and avoiding them.

Building a Causal Framework Appropriate for Risk Promotion
If there is a possibility that the causal framework may be used for Risk Promotion, then it is worthwhile adopting the nomenclature of link classification at the time of construct, rather than trying to subsequently convert the framework.

When constructing the causal framework, it is recommended that positive effects be considered first, questioning along the lines of, ‘What is the contribution to the desired supporting effect?’ Then subsequently consider potential negative impact on that positive effect, questioning, ‘Why might this desired effect not be achieved?’ These chains should be integrated with the positive chains as part of the argument using the compounding link. Further questioning along the lines of, ‘How also might this effect be achieved?’ will provide viable alternative positive chains which should be modelled using mitigating links.

When all the lines of argument for positive effect have been articulated, the questioning should proceed by
identifying potential negative effects to be avoided such as fratricide and collateral damage. These could be elicited by asking, ‘What adverse consequences could occur?’ These chains will often be separate to the positive chains and the associated nodes will be described with a double negative. The final round of questions should identify alternative ways to avoid negative effects; again these alternatives should again be integrated using the mitigating connectors.

Within the framework, it is recommended that all the node descriptions be either double negatives or positive such as responsiveness of desired effect, or avoidance of collateral damage. Making this change simplifies the subsequent risk assessments to elicit the severity and probability of an adverse event.

As part of the risk process, it is possible that mitigation options in Ways will be elicited after the initial risk assessment. These mitigation lines should be subsequently incorporated within the causal framework allowing the post mitigation state to be assessed.

Weighting

Within the method a secondary consideration is weighting the interactions according to their contribution to capability. Weighting the input nodes adds additional fidelity to the risk promotion and allows instances where the contribution of the capability elements is not equal to be modelled.

Managing Very Large Frameworks

Four main problems have been found to date when building and maintaining very large frameworks:

- Maintaining consistency of terms and language across the framework is difficult;
- Stakeholders cannot verify very large frameworks effectively without investing considerable time and effort in review;
- Only one analyst can maintain or develop the framework at a time; and
- It is difficult to maintain a satisfactory level of validation status configuration control.

In summary a disproportionate amount of time must be spent effectively coordinating and maintaining very large frameworks. To overcome these difficulties, it is useful to have a modular causal framework system, where each module is limited to a size where they could be independently maintained and reviewed with ease. The modular framework requires a meta-map to be built to describe how each of the elements of the framework should be brought together. This is analogous to the picture on a Jigsaw box, where the framework is carved into a series of interlocking jigsaw pieces as shown in Figure 6. The meta-map provides the following further benefits:

a. Allowing modules to be exchanged rapidly;
b. The reuse of modules when considering similar capability; and
c. Providing an overview of the framework structure for reviewers.
Re-combining elements of a modular framework by visual inspection is a very time-consuming process, and one which can be error prone. Automating this repetitive task using a series of simple algorithms to display the optimum arrangement of nodes in the framework was found to be a quick and reliable way of reconstructing the framework from the modules.

Providing a toolset to support the concept of a modular framework requires that additional constraints are placed on the modules. Specifically every intermediate or output node in a module must be rigorously linked to a source of risk. This may be either from an input node supported by data or from another module using a common node to allow the input to be uniquely related to the output of another module. This constraint allows any unlinked intermediate or output nodes within the module framework to be spotted using quick visual inspection and corrected before the combined framework is processed. Nodes that are not associated with a source of risk should either be removed or linked as appropriate.

To minimise the number of modules created, it is also helpful to have the facility to copy modules, essentially creating a series of instances from the generic framework elements. This allows dependencies within activities such as command planning at each headquarters level to be articulated within one generic module, while still allowing the total activity such as iterative planning across headquarters to be fully represented by a series of connected instances.

To support maximum re-use of a module, it is useful to be able to connect only those nodes that are appropriate to the focus of the investigation being conducted and to allow unconnected nodes to be removed from the framework. This process, known as pruning, allows key benefits strands from a module to be used within the framework without introducing unnecessary complexity and superfluous calculations.
Complexity Summary

Using the risk assessment method to evaluate the risk for all combinations of Actors generates a portfolio of promoted risk. This portfolio presents a relative view of risk for each set of solutions (Means), accounting for the complexity of interactions within the Network Enabled Capability.

5.0 INTERDEPENDENCY

The causal framework relates the dependency of the effect to investments, however there are other forms of dependency that exist between programmes:

- Competition for common resources, such as manpower;
- Requirement for complementary resources, such as research outputs, and
- The sharing of information during concept and development stages, such as requirements and scope.

These forms of dependency relate to either mission availability or interoperability risks considered within the assessment process, or constrain the in-service, out-of-service dates for the project or programme.

An important aspect to assuring coherence of disparate investment plans is verifying that the mix of solutions (Means) have a common in-service life. This simple timeline comparison technique can often demonstrate that the in-service for the mix of solutions can be surprisingly short. This may potentially cause problems for providers of future collective training.

Collecting the data for a simple timeline analysis is not necessarily straightforward. The scope of some projects and programmes will be far broader than others. Alternatively, where a large programme has been established, it may be necessary to focus on a specific tranche of delivery, to improve the fidelity of the analysis. Where projects are interdependent, all parts will need to be considered, for example Information Applications and Communications systems projects.

Bounding the portfolio scores by the common in-service dates allows the alternative solutions to be compared and contrasted over time. This view informs investment decisions to be made about accelerating or delaying the in-service date of a project or programme, considering the risk incurred by reverting to other alternatives that may exist.

The portfolio is of particular interest where a required capability can only be provided by one solution. Enhancing this solution will potentially result in reduced risk in every solution set, whereas enhancing a solution for a capability where many alternatives exist will only give benefit to a few sets.

6.0 TRANSPARENCY OF THE METHOD

To support investment decisions, the method must give confidence to the decision maker and maintain an auditable trail of justification. Transparency in the method is required for both building confidence and establishing an audit trail. Transparency cannot however be achieved through simply understanding the method, but also through how the inputs are combined to give the result. Appreciating the level of source risk and the intrinsic tolerance to that risk is important, together with appreciating the difference that changing the source risk scores makes to the results.

The tolerance to risk

When the causal framework has been constructed, it is helpful to conduct some qualitative analysis to consider the mix of compounding, contingent and mitigating links used across the framework. This analysis provides
Developing a Risk Method for the Analysis of UK NEC

insight to how risk within the inputs will manifest itself in the generation of effect, giving an indication of the intrinsic tolerance of the capability to risk.

If the framework has only compounding links then any risk within the investment will result in a disproportionately worse risk to generation of the effect. Thus the capability will be intolerant to risk. In the other extreme, if the framework has mitigating links, then the risk within the investment will result in a disproportionately lower risk to the generation of effect. This capability would be regarded as intrinsically tolerant to risk.

For any particular solution, the risk to generation of an effect is of course highly dependent on the relative number of investment nodes with significant risk. The tolerance indicator does not take account of the risk probability and severity score; it merely gives a feel for the potential impact of the risk if it were present.

The sources of risk

Visualising the risk within the causal framework is helpful as it allows the driving sources of risks to be understood. Through visualisation any risk can be decomposed into its sources, and the significant contributors identified. Repeating this process allows risk to be “chased back” to the source, providing a basis for prioritising mitigation action to address these source risks above others.

Sensitivity analysis

Sensitivity analysis of the risks scores allows the implications of uncertainty within the risk scores to be assessed and gives an indication of the implications of changing the risk. As the majority of mitigation strategies aim to reduce the impact of risk, the sensitivity analysis scores test the change in the severity value.

Two types of sensitivity analysis are required within this method:

- Changing risks scores individually, and
- Changing risk scores as a set.

The results are often robust to changes within the individual risk scores, in instances where three or more significant risks compound, reducing one of those source risks to nil without changing the others will not significantly change the result. Similarly, if three or more low risks mitigate each other, changing one of these source risks to high will not also significantly change the result. If changing an individual score does make a difference and the confidence in the risk score being accurate is low, then it is worthwhile to re-visit the score and re-assessing the risk as appropriate.

Changing individual risk scores can give a good indication as to the dependency on assumptions, either considering the context or the level of planned capability provision.

The results from changing multiple risk scores at one time is perhaps more interesting as they may interact together to produce significant changes in the portfolio of risk. Multiple risk score changes could represent either systemic changes to the range of futures or implementing a risk mitigation strategy.

Using the method to evaluate the effectiveness of mitigation strategies is useful, however becomes very powerful if the results are combined with the technical feasibility and cost of mitigation, this provides a balance of investments profile that can be optimised over time.

7.0 RESPONSIVENESS OF THE METHOD

The method described in this paper is very flexible, it can be applied to compare and contrast investments in services and systems across the Defence Lines of Development. However, for the risk method to be useful, it
must be sufficiently responsive to support questions that emerge during the planning and balance of investment rounds. The method can be embodied in a process that is able to meet this challenge. The responsiveness is related to two key aspects:

- Time taken to develop an assessment
- The time taken to respond to questions

The development of the causal framework is tailored to the suit the problem being considered. Each module within the framework realistically takes a man week or so to codify and document the supporting arguments and definitions. The time taken to assess the risk is more dependent on the level of supporting evidence available and reliance of expert judgements.

Given the creation of the modules and population of the risks the method can be run in a very short time with results produced and analysed within half a day. Ultimately the responsiveness of this method is dependent on the availability and accessibility of data. This author believes that the data required to run this method is the minimum essential data set for through life capability management, and therefore represents the set of data that should be captured in a capability management knowledge base.

8.0 CASE STUDY

The roadmapping origins of the work

The method articulated within this paper was developed by QinetiQ plc as part of a UK MoD research package. The research was a response to the need for a method that could roadmap the progress of NEC, supporting the NEC strategy[5].

Capability roadmapping is now a recognised term within the UK MoD “Capability roadmaps support the processes leading up to development of the User Requirements Document (URD). These roadmaps can be considered ‘capability centric’ in that the primary unit of analysis is a particular capability need, with the owner of the roadmap typically residing within the Equipment Capability Customer (ECC) organisation. This type of roadmap generally contains links to multiple systems, equipment types, technologies and possibly other capability areas.”[6]

Capability roadmapping has been of interest to the Research and MoD communities over a number of years1. As a result of the experience gained through working with the UK MoD, there are generally acknowledged benefits that result from roadmapping activity. These can be classified [7] into two areas:

- Highlighting exploitation or coherence issues across a set of activities, and
- Drawing together disparate communities of interest.

The work conducted not only developed the method for “proof of principle” that could quantify the roadmap but also produced examples to enable the utility of the method to be tested.

INteract

As part of the research outputs a “proof of principle” toolset has been produced known as Interact (Informing NEC through effects risk and capability timelines). The development of the toolset has investigated:

- The utility of different data views;

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1 On 4 April 2001 a community of interest roadmapping workshop was held in Farnborough UK, hosted by Dr Jimmy Cameron
Developing a Risk Method for the Analysis of UK NEC

- The practicality of real time evaluation, and
- Aspects of data interoperability with other related initiatives.

The INteract tool developed a specific nomenclature for the work. The following definitions are used:

Nodes of Interest: Node(s) of Interest are ends that are the final impact of risks. These are selected nodes that have been chosen to represent the operational consequence.

Mission Thread: A specific set of systems (or investments) that work together to conduct the activities described by a capability chain. The mission thread also details the opportunities for effect (targets), and threats to effect (environment and military threat).

The Views

Six views were investigated as part of the INteract software development; these are designed to provide different representations of the risk set to the user, while maintaining a common look and feel.

Table: The Table view presents a summary of the level of risk to nodes of interest, presented for each mission thread over time. The Table view allows relatively high risk areas to be easily identified by the colour of each cell within the table.

Plots: The Plots view presents the level of risk for any two nodes of interest for each mission thread, animated such that the data points move with time. The Plots view allows relatively high risk areas to be easily identified by position of each point relative to others.

Essentially the Plots view and the Table View show the same information. Arguably, one of these views is redundant, however the experience of the development team was that some stakeholders preferred the plots view because it was easier to assimilate the information and some preferred the Table view because it shows a summary across all Nodes of Interest.

Within the INteract the development team experimented with a Data Envelopment Analysis style system to rank Mission Thread over time considering the relative levels of risk across the Nodes of Interest. Although successfully implemented, this functionality was not found to be useful as it did not sufficiently differentiate between Mission Threads when the numbers of threads are of the same order as the number of Nodes of Interest. This ranking is expected only to be worthwhile when the number of mission chains being analysed is greater than 100.

Causal: The causal view presents the cascade of risk between the sources and consequence for one Mission Thread, where the risks within the mission thread change over time the view can be animated. The causal view allows a visual inspection of the factors that have been modelled in promoting the risk and provides an appreciation of the measures of the capability.

The causal view is very complex and large. To make this view worthwhile the nodes and links in framework were filtered such that only the relevant benefits chain would be shown. Although this was successful, the users generally found using this view time consuming and not necessary. The causal view was eventually removed from INteract.

Roadmap: The roadmap view shows how a single Mission Thread is built up from programmes within the Equipment Programme, Short Term Plan, Urgent Operational Requirements and investments in the non equipment Lines of Development.

The roadmap view is powerful as it shows the coincident time frame for each of the investment lines that make up the Mission Thread. This simple view was made to be hierarchical to allow projects to be brigaded
into programmes and further into clusters. Feedback from users has demonstrated that being able to filter timeline information by Mission threads is valuable as it shows the set of programmes for which integration/interoperability is required.

**Picture:** The picture view is a visualisation of the mission threads in a spatial context. The stylised diagram shows the programmes within the Mission Thread as an icon and title. Where a programme is enabled by communications, these are shown as lines connecting the programme icons together.

Military customers for INteract found this view helpful as it shows the elements of the mission thread in context. This view does not show any of the risk information.

**Risks:** The risks view displays the source risks on which the Table and Plots views are based. This view has been designed to answer three main questions:

- Which input risks drive the result?
- Which risks are priorities for mitigation action?
- By how much should a risk be reduced to balance the portfolio?

The Risks view is presented as a table that defines the risk. Each risk within the table is associated with a programme conducting a role. This programme may then contribute towards one or more Mission Threads. For each risk the intrinsic tolerance of the Nodes of Interest to the risk, the risk score and sensitivity of the Nodes of Interest to risk across the Mission Threads is shown.

This view allows the severity, urgency and duration to be appreciated; the sources of risk are shown as colours over time, informing the overall priority for mitigation action. For the risks view to be usable, it needs to be filtered and sorted to show the set of risks associated with a specific project, Organisation or related to a Node of Interest.

**Real time evaluation**

The initial version of INteract was implemented as a real time web site where the graphical user interface was Scalable Vector Graphics, supported by a calculation engine written in JavaScript. When initially implemented the volume of data and number of calculations necessary to produce the results set (point and full sensitivity results) for 50 mission threads considering 200 programmes and projects related to 10 Nodes of Interest over 50 timeframes resulted in a different approach being taken.

As a result, the final implementation of INteract has been written in MS Excel with a calculation engine written in Visual basic for Applications. This then produces XML data files that are read in to the web site application to view the results. This approach minimises the time delays for the user switching between different displays, however does limit the real time data changes that can be performed through the client interface.

**Data interoperability**

Using an XML data import and export, INteract is able to become part of a wider federated toolset. During the development data interoperability was tested with an application called “Connect” a research roadmapping tool and EP view an Excel based equipment plan data repository for Equipment Capability Customer community. For tools such as INteract to become widely adopted within the community data interoperability is necessary. This will minimise the data population burden on already busy desk officers and also improve the responsiveness of the method.
Validation of the INteract Method

Approach

Validation is the process of assuring that the INteract method is fit for its intended purpose. Unlike with models that are representations of the real world, the soft approach used by the INteract method can only be validated by demonstrating its utility in supporting decision making. This has been achieved through a mix of black box or open box methods. See reference [8] for an overview for types of validation.

Black box validation

Black box validation is a process of testing the predictive power of the toolset. None of the examples produced in INteract can be tested against real world situations because the evaluation is against a range of futures where, only a few and perhaps none are actual futures. The INteract method has been assessed (in part) against results produced through other analytical and modelling methods. INteract offers the insights into areas of capability where no extant high fidelity models exist to compare results.

To date the predictive power of INteract examples has only been tested through postulating changes in risk and testing to see if the change in result is the one understood from independent analysis or expected based on expert judgement.

Open Box validation

Open box validation is dependent on assessing the appropriateness of the internal workings of the tool. This validation can be achieved through review of the stages in the process of applying the method. This predictive power of INteract is reliant on:

- The causal maps accurately reflecting the consequence of risk; and
- The risk scores representing the need for enhancements in capability.

The extant Interact examples have been developed by using experience analysts to interpret concepts and doctrine, and checked using senior military staff. Ultimately the validation of causal frameworks can only be achieved through agreement by the authors of concepts that the causal representation matches their intended view. Working with the community developing concepts would:

- Assure coherence between concepts, and
- Allow risk and alternative mitigations to be appreciated at the early concept stage.

The Validation of the timeline view can only be assessed through checking with the desk officer responsible for the programme that the dates accurately reflect the plan and that the contribution to capability is appropriate. To date the timeline data used has only been checked against other roadmap repositories.

The greatest issue for the validation of INteract by open box methods is the validation of the risk scoring. This is dependent on maximising the rigour of the assessments. Where possible, data should be drawn from extant validated trials, experiments and analytical modelling where the assumptions and context are known. This has been the method used to date, where risks are not reported, these have been assumed to be nil.

In the cases where risk is unknown or not reported, these areas should be assessed by expert and military judgement. The assessments should be structured and independently facilitated using a workshop Delphi technique allowing live debate about the justification for the scoring and the reasoned arguments to be recorded for audit trail. The assessments should be made by stakeholders who have sufficient experience to make informed judgement with familiarity of the future scenario contexts. In addition to improving the rigour of the assessments, a workshop environment allows the stakeholders to come to a social accommodation about
the pertinent issues and ultimately support the mitigation actions.

9.0 SUMMARY

Through reviewing aspects of modern warfare and the context within which capability based planning now sits, this paper has established the characteristics required of modern capability based planning decision support methods. These are:

- Sufficient treatment of uncertainty;
- Manage complexity;
- Account for interdependency;
- Maintain transparency, and
- Sufficiently responsive.

Structured using these this paper describes the theory and points of principle in application that will allow the method to be partially of holistically implemented. Using the development of “INteract “as a case study, aspects of the relative merits of the user views and requirements for validation have been discussed.

The risk method offered allows desk offices charged with delivery of coherent capability to evaluate the consequences of decisions before acting. Specifically the method provides basis for Delivery of Network Enabled Capability by allowing potential changes to the phasing of equipment programmes to be evaluated and informed decisions can be made regarding areas of apparent risk, resulting in effective targeting and mitigation.

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11.0 REFERENCES


[5] The JCB NEC Delivery Strategy (1* Draft) 1st Feb 05, page 1
