A robust approach to military research programme planning

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Introduction

This paper describes a collaborative 'Pathfinder' study by the Centre for Defence Analysis and Smith System Engineering. The aim of the study was to investigate a framework for flexible, responsive operational analysis.

The study concentrated on analytic support at the early stages of procurement, when there are numerous options to consider, none of them defined in any great detail. Assessments then depend on military and technical judgement, so the study reviewed a range of 'alternative' (soft) operational analysis techniques with a view to adapting them and combining them with more traditional, quantitative techniques.

Using robotics as an example, this paper describes how Rosenhead's robustness analysis can be adapted to describe a sequence of research and procurement decisions and the possible products of these. Since the future may render any of these products irrelevant, the technique calculates not some average value in an average scenario, but the proportion of significant products which will be available to later decisions. 'Significance' may initially be a judgement, replaced when appropriate by results of a more detailed, quantitative analysis.

Recently, we have moved on from robotics to consider how the results of the Pathfinder study might apply to the much broader problem of the balance of investment in all land systems research. The paper describes some initial methodological conclusions from this.

Robustness analysis

Traditional operational analysis can be caricatured as aiming to eliminate uncertainty about the future: identify a single, preferred future and plot a course towards this. Robustness analysis[1] on the other hand embraces future uncertainty: decisions made now are robust if they leave your options open. The approach discussed here is robustness analysis adapted to our particular problems and does not necessarily follow Rosenhead's own development of the technique[2].

The components of robustness analysis, as applied to military research, are as follows.

- *Decisions* are made now about the research programme for the next few years. A decision might be to research further into robotic vision, or build a demonstrator of a robot able to move itself across rough ground.

1 in ROSENHEAD J (Ed.), *Rational analysis for a problematic world*, Wiley, Chichester, 1989.
2 in REINHOLD A J (Ed.), *Rational analysis revisited*, OR Society 1995.

- *Products* are the planned, ultimate results of the research, eg new equipment or improvements in current equipment. Given the uncertainty of research, and of later procurement decisions, these products might or might not get implemented. The products might be a robotic sentry or a mine clearance robot.

- *Scenarios* represent circumstances when the products will be of use: they are examples of the *type* of military task that is expected rather than descriptions of particular events which are expected to happen. A single scenario is only one part of a 'possible future', since more than one of them may 'occur' in the timeframe of interest. A scenario might be a Bosnia-type deployment, or some future conflict similar to the Gulf conflict. It is, in theory, possible to put priorities to these scenarios (eg high, medium, low) representing the extent to which they are allowed to drive the research.

- The *value* of a product in a scenario can be expressed in terms of how well the products help the military achieve their objectives. Robustness analysis is a judgemental technique and only a relatively coarse scale is expected to be used: eg high, medium, low, not applicable.

These components fit together in the way shown in figure 1. This is different from the usual robustness analysis picture, but the explicit identification of each of the scenarios suits the problems in hand and is consistent with traditional military operational analysis.

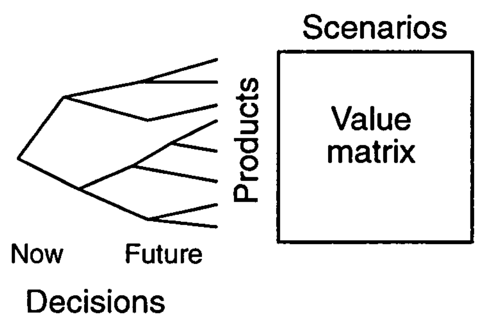

Figure 1
Components of robustness analysis

Once the value matrix has been established it can be used to evaluate research decisions in a number of ways, leading to conclusions such as: 'This research programme puts us in a position to benefit from 9 out of the 11 products assessed as high or medium value in high value scenarios.' Thus robustness analysis is quantitative, but the results are a matter of counting rather than anything more complex.

The study considered a number of ways to put the matrix in a form from which decisions could be made. In particular, the results need to be presented in a way which those not involved in the analysis can understand and which brings out the sensitivity of the results. In practice, the approach to this stage will depend on the values in the matrix.

Figure 2 summarises the stages of robustness analysis.

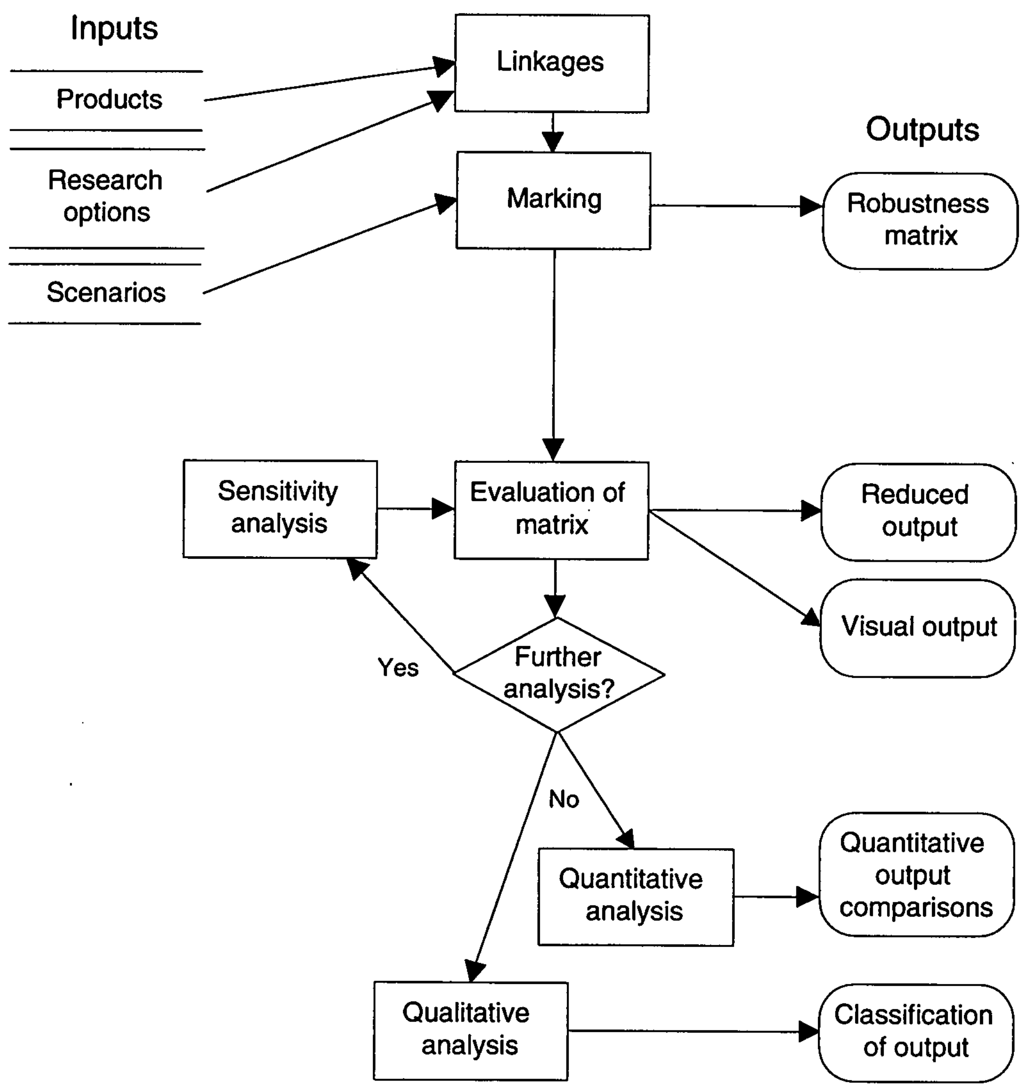

Figure 2
Robustness analysis method

Figure 3 gives one example of ways to look at the robustness matrix, in this case showing how robust a variety of decision sets are to the two high value scenarios used in our example (showing both scenarios together and the worst case). In this figure, a decision set is a pair of research activities.

The study concentrated on effectiveness measures ('how well can the objectives in a scenario be met?'). Technical risk, time slippage and variations in cost were considered. It is possible to describe how to fit them in to the method, but data are unlikely to be available in sufficient detail to draw any quantitative conclusions.

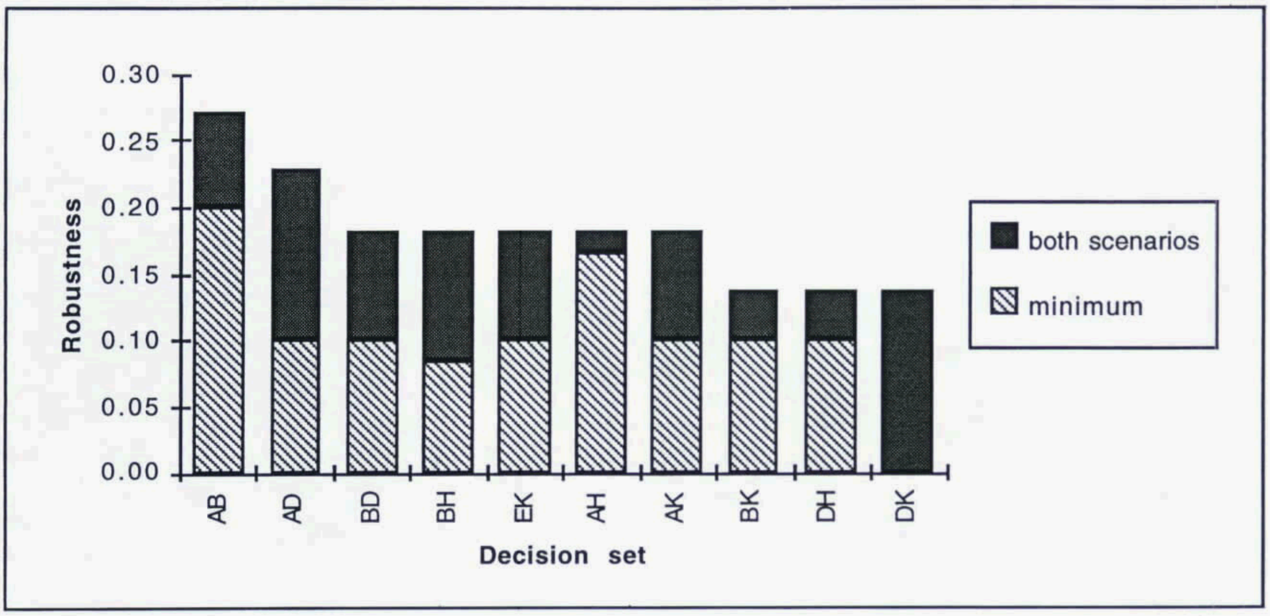

Figure 3
Example of 'visual output'

Discussion

In fact, given the framework in figure 1, traditional military operational analysts could contemplate running simulations to derive the values in the matrix, and producing some weighted average over scenarios. The robustness approach has a number of advantages.

- The size of the value matrix means that populating it using military or technical judgement is more practical than using runs of a simulation.

- Extracting the contribution of individual products to a scenario from the results of a simulation is very difficult.

- Robustness analysis does not try to average over scenarios, in this it is rather like a risk assessment approach.

- Including products in a simulation would involve defining them in more detail than is possible, given that they are many years in the future if they arrive at all.

It is not a trivial activity to define the components of robustness analysis in detail. In particular, the value judgements need to be defined in such a way that the results will stand up to wider scrutiny in the MoD. A full discussion of this is beyond the scope of this brief paper, but the lack of a single 'decision maker' in the MoD makes use of any judgemental technique difficult. The advantage of applying robustness analysis to research decisions, rather than procurement, is that decisions are made by a smaller, more autonomous group. Robustness analysis is a natural extension of assessments they already make.

Land systems research

Robotics was a useful problem to start with because it had already been studied from a number of angles and there was plenty of information available. But the current robotics research programme is well established, so there are no pressing balance of investment questions in robotics suitable for robustness analysis.

The problem we have moved on to for real is a much larger one: the balance of research across all land systems. Although it is relatively easy to phrase robustness questions for this, it was far from obvious that it would be feasible to come up with meaningful answers. So we are approaching the problem in a number of small steps, initially data gathering and now attempting to define a concept of analysis.

Initial, tentative lessons include:

- At this level, budget questions are of much greater importance. One approach to this is to make each 'decision' actually a set of decisions which are of a fixed cost (or a zero cost mix of savings and enhancements).

- The 'products' need to be high-level and, in some sense, independent of each other and (curiously) of the stated aims of the research. Components of capability (command and control, deployment etc) is one possibility.

- There is a difference between near-term judgements (which mostly concern current equipment and its pros and cons) and longer-term judgements (which concern technologies and their viability).

- In order to get a comprehensive assessment, the scenarios need to derive from the defence roles and military tasks, which are the MoD's stated aims[3].

- A detailed, quantitative approach to the balance of investment at this level is likely to founder for lack of data. All the more reason to consider robustness analysis.

- The aims of research include meeting deficiencies, supporting equipment procurements and taking advantage of a possible technological edge. These different aims will result in different value matrices.

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3 *Statement on the Defence Estimates 1995*, Cm 2800, HMSO.

Conclusions

The robustness of a research programme is the degree to which it puts you in a good position to respond to future equipment needs. This is a natural characteristic to try to measure. Robustness analysis is a way to do the measuring without forcing the definition of probabilities and research outcomes in dubious detail. A study to evaluate robustness analysis in this role is in progress and the results look promising.

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