

Dynamics of Operational Procurement: Systems Modelling for Performance Tracking and Auditing¹

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Abstract—The current method for auditing and tracking the performance of projects, programmes and enterprises is becoming increasingly unsuitable. Traditional independent project performance evaluations take time and disrupt business-as-usual. They are often executed when performance has taken a noticeable dip and are therefore used to identify causes of failure. They deliver a one-off report of performance based on the best data available at the time. The alternative to a one-off report is performance tracking. Tracking performance as a project matures runs the risk of moving focus from the technical end goal to the satisfaction of performance measures. Additionally, as projects, programmes and enterprises increase in complexity, traditional performance tracking does not necessarily identify the full scope of organisational performance.

We see considerable gains from the synergy of both approaches; combining performance evaluation and continual tracking into one performance auditing method. We believe that qualitative system dynamics models could provide this synergy, allowing a model of a system to be continually updated and internally and independently analysed as required. This provides the advantage that as both tracking and auditing activities contribute to the accuracy of the model, the time and cost of the effort required for each activity reinforces the quality of the outcomes of the other.

This research presents the first steps on the journey to creating a framework that, with the aid of qualitative system dynamics, can be used to both track and audit any project, programme or enterprise performance within the engineering or technology domains. As such, it tests the initial hypothesis that it is possible to create a system dynamics model of an existing performance audit that can be used to provide adequate recommendations for performance improvement. Using the Bernard Gray report of defence procurement as a test case, it creates a qualitative system dynamics models, examines the causal loops found within, and uses these to create recommendations for improvement. These recommendations from the models are then compared with those that the Gray report initially devised.

From this it can be seen that the use of qualitative system dynamics has utility in creating an enterprise performance audit. It is the intention of the authors to develop the framework further in three directions: to be initiated as part of an internal performance tracking process (where no current audit exists); to be validated as an independent project, programme, or enterprise audit; and to be used in the wider engineering and technology domains.

Keywords—Performance evaluation, performance tracking, document analysis, defence, strategy.

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1 INTRODUCTION

The main measures of performance for a project, programme or enterprise (henceforth referred to as organisation systems) are time and cost; these are the means by which we know whether a business undertaking is being successful. Yet most large complex development projects experience substantial cost and schedule overruns as identified through performance evaluation (Lyneis, Cooper et al. 2001).

Performance evaluation is not an unusual method of measuring success; there has, in recent years, been a noticeable increase in performance auditing of organisation systems. Where once audits were confined to financial scrutiny, they are now prevalent in such areas as environmental, security, management, and information performance (Power 1994), due to a significant shift in “*demands for managerial accountability in public and private sector administration*” (Power 2003).

There are a number of issues with performance evaluation, however. It puts various demands on the system being audited – mainly cost and time – and produces a one-off analysis of performance at a single moment in time. Moreover, however objective the auditor’s intentions, to summarise an audit and produce recommendations, the auditor is required to use their judgement and understanding of the organisation system. They are required to take a stand, to take the evidence gained from the company, assess outcomes and meaning, and make a decision about what they think about that system at that moment in time with that information available.

The alternative to this single snapshot of performance is performance tracking. It too has seen a dramatic increase in public and private sectors in recent years. In its current guise, performance tracking is rooted in the mental model that whatever is measured is controlled. However, with regards to project, programme and enterprise performance management and auditing, this is not necessarily the case (Loveday 2008; Seddon and O’Donovan 2011). Indeed, when faced with systems of increased complexity, Seddon and O’Donovan’s analysis of performance measurement in essence agrees with Loveday’s: performance management has a detrimental effect on groups of people where the system-of-interest is not understood by those in control.

Not only is the way we traditionally measure performance being proved increasingly inappropriate, but organisation systems are also becoming more complex. More complex technology – often borne out of integrating existing and/or new technologies – requires more complex projects to ensure success (Williams 1997). Complex projects have more specialists working across a larger number of technical and organisational boundaries (Barber, Graves et al. 2000). Integration does not happen just at the technical level, however. Integrated projects produce programmes; integrated programmes produce organisations; integrated organisations produce enterprises. As governance around these organisation systems grows, so does the complexity of the situation.

It seems then that significant advantages could be made from having a single way of both tracking and auditing complex organisation system performance. We believe this could be realised by using a framework whereby a system’s structure and behaviour can be characterised, updated when things change and used to understand how things may fail or succeed. Auditors could then use the same framework to check inputs and understanding, and investigate whether the system-of-interest has been fully covered. This would mean that instead of systems being scrutinised only when things have gone wrong, when morale is low and uncertainty high, they could be tracked when things are going well too. It would also mean that the effort auditors put into collecting and interpreting data could be useful to the company being audited.

Our challenge then is fourfold:

1. To create an framework for a project, programme or enterprise;
2. That we can use to initially audit the system;
3. That can be continually updated to reflect changes in the system or in the data available;
4. That is performed purely from outside the system-of-interest.

The goal of the research presented in this paper is to create and test a method that satisfies all four of these points.

2 RESEARCH METHOD

According to Jackson, research methodology is:

“a higher order term that refers to the logical principles that must govern the use of methods in order that the philosophy/theory embraced by the approach is properly respected and appropriately put into practice.” (Jackson 2003)

The understanding of research methodology is important for understanding the limitations and acceptable uses of methods, tools and techniques (Kothari 2008). To choose these, we must first understand their purpose. We therefore require a way of:

1. Understanding what is happening within the organisation system we are auditing from a position outside the system-of-interest; and
2. Using this analysis to pinpoint where interventions within this system could be made that would measurably improve it.

To do this, our framework is based on a comparison between a traditional published audit report of a complex system and our method for continual audit. Therefore, we must first select a test case we can use to trial our method on and measure how well it works. From the research challenge presented in Section 1, we therefore require a documented audit of a project, programme or enterprise system that is open-source (freely available), and of a complex and complicated system that includes multiple stakeholders.

2.1 Data Source

The document we have chosen for this is a study of the defence procurement process, performed by Bernard Gray and published in 2009, entitled “Review of Acquisition for the Secretary of State for Defence” (henceforth referred to as the Gray report).

The Gray report provides an independent analysis of procurement within defence, readily available from the MOD². Not uncontroversial when published (Oliver 2009; Sturcke 2009), the report addressed the fundamental issues with the MOD’s acquisition process (Kinkaid 2010). The overall assessment of the report within the MOD was of *“the willingness of DE&S openly to consider the qualitative recommendations of the Gray report”* (HC Report 2010).

The resulting analysis from the Gray report is of the overall behaviour exhibited by the defence acquisition enterprise system as a whole. It presents an aggregate of departmental behaviour through a narrative of its effect on one or more of capability, duration and cost across equipment procurement project systems.

² At www.mod.uk

In this case, the system-of-interest would be defined as defence procurement bounded by the Ministry of Defence (MOD). Thus, the system does not include other members of the defence supply chain, nor involves activities not directly associated with procurement. The system is a complex mix of hard and soft systems. Indeed, the MOD themselves characterise this complexity using Defence Lines of Development (DLoDs), which are composed of eight discrete areas: training, equipment, personnel, information, concepts and doctrine, organisation, infrastructure, and logistics (often formed into the mnemonic TEPID-OIL) (Ministry of Defence 2011).

The responsibility for delivering equipment falls to an area of the MOD called Defence Equipment and Support (DE&S). The responsibility for defining the capability this equipment ultimately satisfies lies with a number of different stakeholders:

“Defence should, in theory at least, be the servant of foreign policy, which in turn is a reflection of the aspirations of the British government and its people and the level of resources they are prepared to invest in this area” (Dorman 2010).

We therefore feel that the Gray report on defence procurement satisfies our requirements for a test case. Also, in taking a report that is pertinent today, we hope to demonstrate our approach, illustrate its utility over and above the traditional audit process, and spark off debate about its relative merits. We believe the analysis presented in the Gray report provides a firm base for further analysis of the system with a specific focus on the *dynamics* of the system. This confidence allows the formulation of an approach for creating a performance monitoring and auditing framework that we can test against the recommendations of the Gray report.

2.2 Approach

According to Karapetrovic and Willborn (Karapetrovic and Willborn 2000), a generic (i.e. not specific to quality, safety, environment, finance etc.) audit is an:

“Independent and documented system for obtaining and verifying audit evidence, objectively examining the evidence against audit criteria, and reporting the audit findings, while taking into account audit risk and materiality”

In this definition, two notable observations are that any audit: i) relies on the input of evidence to proceed; and ii) produces documentary report of the findings. The reliance on data restricts auditing to mature, manageable projects; outside these, it may not be possible to access data of sufficient fidelity required (Beckmerhagen, Berg et al. 2004) for the audit to be effective. The requirement for findings to be documented is a function of the cross-contract working required to demonstrate audit independence. That it is presented in a final report is only due to tradition (Barzelay 1996).

Both of these issues could be solved using system dynamics modelling. However, part of our argument for developing a new, model-based audit is that confidence in, access to, or sufficient understanding of information on the organisation system’s performance is low. This means that there is little utility in developing quantitative system dynamics analysis (Sterman 2000). This research, therefore, produces a qualitative causal loop analysis only. In this way, we will stop short of the accepted ‘conceptualisation’ modelling process of creating, through interaction with the system and data collection, a system dynamics model; simulating this model; and analysing the output of the simulation to create possible interventions (Lane 2008). However, we believe the qualitative approach to modelling to be the most suitable for achieving our purpose and utilising the data available.

A subject of interest for a number of authors (Ackermann, Eden et al. 1997; Wolstenholme 1999; Homer and Oliva 2001), we fully acknowledge the merits of quantitative modelling.

However, it is unsuitable in this situation. Firstly, confidence in the fidelity of the information on the organisation system’s performance is low, rendering any simulation results meaningless (Coyle 2000); indeed, they may produce the opposite result required by being easy to refute, or by undermining the credibility of the auditors (Coyle and Exelby 2000). Secondly, customers are not looking for the ability to predict the future from the current model, but to understand where and how issues arise. The value in system dynamics over conventional report-based audit for them is that system dynamics does not just deliver a snapshot in time, but can track the progress of a project programme or enterprise as it evolves. Thus, the time-consuming and costly analysis that goes into project audits is only required for the initial model-building exercise; maintenance and update of the model requires considerably less resources. Lastly, the value in the process to an organisation conducting an audit is that those who experience the process can come to a common understanding of the system, a known outcome of qualitative model building (Chapman, 2010). Importantly for an audit, this common understanding leads the auditors to draw common conclusions and create a coherent set of recommendations, drawing from the diverse set of skills from the auditing group. This, however, requires the model to be built by a group of people together.

The process we used to realise the aim of the research – to create a method of continual audit of an organisation system from outside the system-of-interest – draws on three main concepts: document-based initial model building, group model building, and document-based outcomes comparison.

Document-based initial model building takes heuristic programming of documentary evidence to create a starting point for a system dynamics model (Vennix 1996). Instead of attempting to formulate a single dynamic hypothesis, this approach programs the initial model using existing non-model-based analysis. Following the schema for the design of the modelling process proposed by Vennix, our process introduced an initial model based on the Gray report before using group model building to create a model from which interventions could be designed (Figure 1).

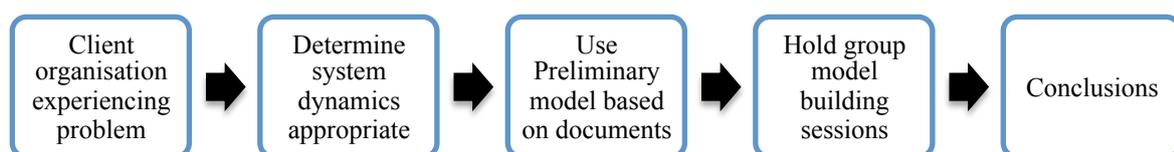


Figure 1: Group Model Building Process Employed, After (Vennix 1996)

The group model building in our process aimed to ensure a competent understanding of the data. It was limited to building the model, and was not used to design recommendations. The group model building process took the form of three workshops (Figure 2). Each involved five participants, all of whom have had prior but differing experience with the system of interest. Two were consultants who perform the majority of their work in the defence sector; two had previously held a managerial post within DE&S before retiring from the civil service; two had previously served in the Armed Forces.

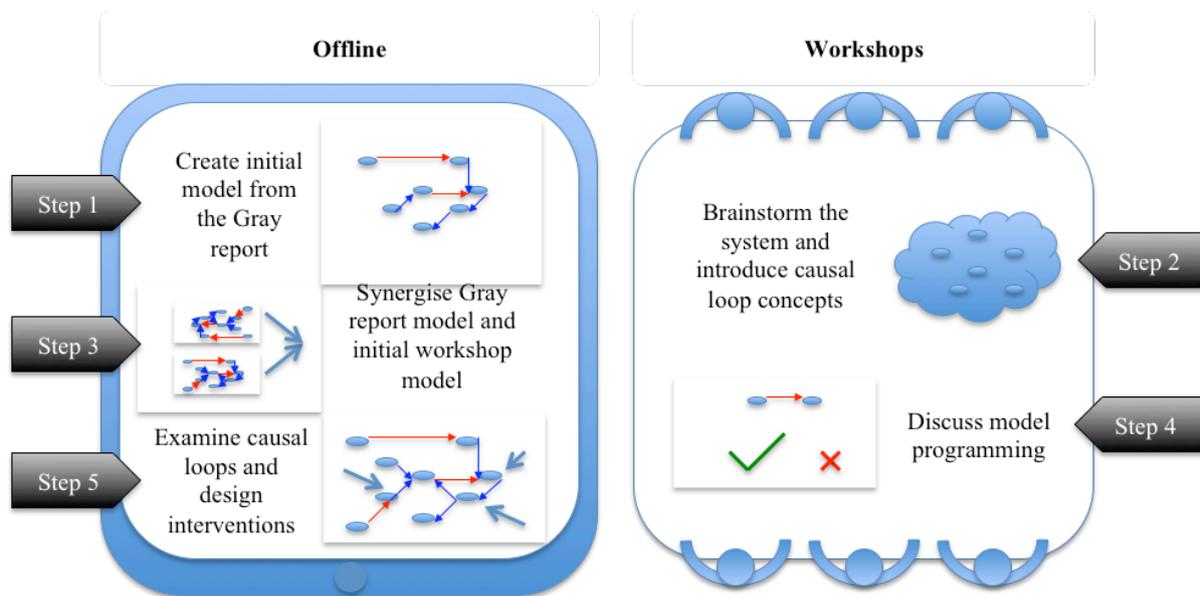


Figure 2: Group model-building process

Once agreement was gained about the meaning of the text and how this should be modelled, we analysed the models to construct a number of possible recommendations from them. This was done by identifying and examining the causal loops within the models. These recommendations were then compared to those given in the Gray report. This was to test both the efficacy of the recommendations identified by the modelling process, and to understand where further consideration is necessary. An overview of the interaction between the model and the Gray report is shown in Figure 3.

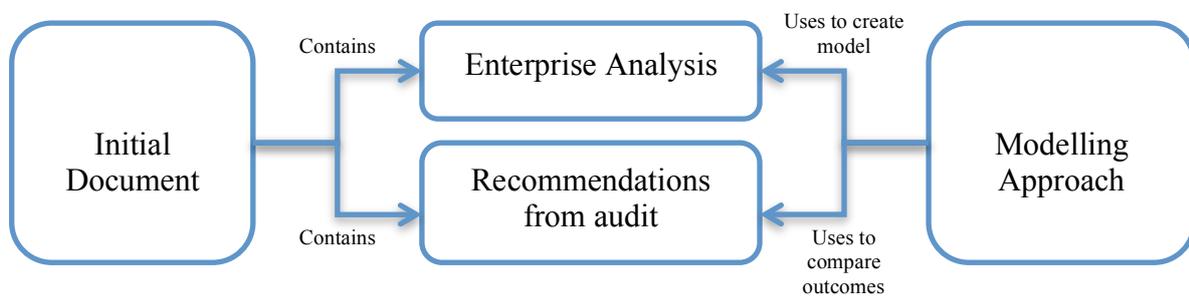


Figure 3: Interaction between the Gray report and the modelling approach taken for this research

The following section details the models created from the second group model building workshop and describes the recommendations for the acquisition enterprise system identified in each model. It is important to stress that these recommendations are not the views of the consultants involved in the group model building exercise. Instead, the recommendations stem from our analysis of the causal loops within the models. The aim of our research here was to test our belief that this type of analysis of causal loop models created from a performance audit of an enterprise system can create adequate performance recommendations. A comparison is therefore presented between the recommendations from the causal loop analysis and those originally presented in the Gray report.

3 SYSTEM DYNAMICS MODELLING OF DEFENCE ACQUISITION

From the modelling process, we were able to create six independent causal loop models (summarised in Table 1).

Number	Name	Category	Comments
1	Over-Specification	Equipment	Over-specification of equipment due to affordability, overspend and requirements changes.
2	Human Resources	Personnel	Drop in quality of expertise due to manpower flexibility.
3	Contracting for Availability and Manpower Flexibility	Personnel	Knowledge management and manpower challenges of introducing Contracting for Availability.
4	Equipment Funding Planning and Performance	Organisation	Cost of contractual changes as a barrier to incremental acquisition.
5	Whole Life Design	Organisation	Challenges of Through Life Capability Management (TLCM) and whole-life design in current cost structure.
6	Technical Risk	Organisation	Divestment of technical risk for complex projects.

Table 1: Characterisation of Models Produced

In any intervention within the defence acquisition process, it is important that capability, rather than just equipment is affected (Neage, Henshaw et al. 2009). To ensure that our models impact capability rather than just equipment, we have categorised each model by the dominant DLoD within the model (Table 1).

Our aim for the remainder of this paper is to present an assessment of the models created from the process shown in Figure 2. This is to communicate an understanding of the system we are presenting, and to show a comparison of the recommendations from the system dynamics model against those of the Gray report. However, as we would like to ensure the method we used is adequately communicated whilst keeping the paper succinct, only one model from each category will be presented. We have chosen the model for each dominant DLoD that has the greatest impact on other DLoDs. Thus, the models we have chosen are: i) the Over-Specification Loop; ii) the Human Resources Loop; and iii) the Equipment Funding Planning and Performance Loop.

3.1 Over-Specification (OS) Loop

3.1.1 Background

The 1998 Strategic Defence Review concluded the need for a radical reappraisal of how the UK conducted defence procurement. Defence Capability³ was to be realised through the development, delivery and in-service support of equipment-based systems. This required the adoption of a through-life systems approach to the procurement, in-service support and management of the acquisition of equipment based systems to deliver enduring capability over time. This approach (termed ‘Smart Acquisition’) placed Systems Engineering at the heart of the procurement, in-service support and through life management of military systems.

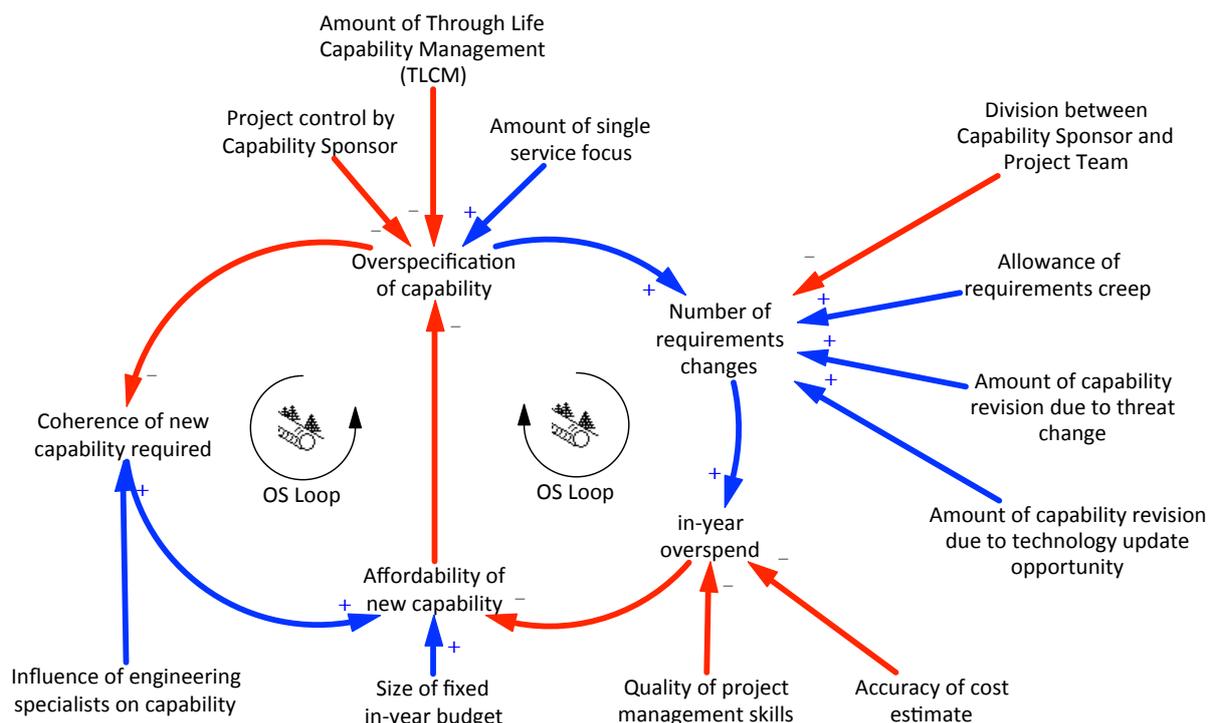
³ The capacity or ability to produce a particular operational effect ADO (2006). Defence Capability Development Manual. Canberra, Defence Publishing Service.

The definition / specification of capability and of the equipment-based system(s) that deliver it is a fundamentally important aspect of the Systems Engineering effort in the early phases of defence acquisition project and the objective is to specify equipment solutions through capability in an attempt to shift the focus on equipment specification from solution to problem. This means that the problem from a user or strategic perspective (or both) is communicated to those having to design the equipment. For example, a solution may be a 4x4 vehicle while the required capability may be the ability to quickly and independently transport personnel short distances across a variety of terrain.

Capability definition sits at the top of a defence requirements hierarchy that breaks down into a series of high-level characteristics, followed by user requirements and then system requirements. The System Requirements Document (SRD) is a comprehensive set of statements that define the functionality and level of performance required, and how that performance can be measured. The SRD is used to invite tenders for candidate solutions from industry. It also informs performance indicators when equipment is in service, judging how well equipment perform against what was initially required.

3.1.2 Model

The OS loop in Model 1 shows a significant feedback loop within the defence acquisition enterprise system showing how it currently leads to over-specification of capability solutions. This is through two reinforcing loops. The first is concerned with the cost of incoherence in capability specification; the second with the cost of requirements changes.



Model 1. The Over-Specification Loop

3.1.3 Description of Behaviour

Capability for standard projects is specified through a strategic, top-down approach (Dorman 2010). This strategic approach is embodied within defence by the Through Life Capability Management (TLCM) process⁴. Defence capability as a whole is considered coherent when

⁴ TLCM is the process within the 'Smart Acquisition' framework that translates defence policy into an approved programme that delivers the required capabilities, through life, across all DLoDs.

each specified capability is understood in its relationship both to all other specified capabilities and to its priority in delivering the overall strategic defence plan. This <coherence of new capability required> is increased by the <influence of engineering specialists on capability>, as these specialists work to ensure systems engineering principles are followed, including capability integration and top-down specification. However, as coherence – equipment synergy (against capabilities required) – decreases, new capability becomes unaffordable.

“By and large, consideration of the affordability of any individual new piece of equipment is taken in isolation ... but the real question is not whether any particular piece of equipment has utility, but rather how it ranks in importance against other possible defence uses of that money.” (Ibid. page 33, section 3.6)

The <affordability of new capability> is massively important for the UK Government for operational, strategic and political reasons. Capability is funded through the Equipment Procurement Plan (EPP). The decision of how to allocate the funding is taken on an annual basis and so capability affordability is curtailed by the <size of fixed in-year budget>.

“In-year financial pressures, resulting from the overheated [Equipment Procurement Plan] EPP and [Equipment Support Plan] ESP, significantly curtail ‘discretionary’ spending” (Ibid. page 149, section 7.9.4)

As affordability decreases, an interesting behaviour can be observed in the system:

“The Department is incentivised to over-specify equipment in order to ensure that sufficient capability is eventually delivered despite funding constraints.” (Ibid. page 140, section 7.8.3)

This means that within the defence acquisition enterprise system, capability is often over-specified. The reason for this (as the Gray report suggests) is that it is an attempt to retain the minimum capability desired, given that projects often experience a drop in funding somewhere along the development process.

The model suggests that <Over-specification of capability> is affected by three separate system behaviours. The <amount of single-service focus> is the amount that personnel within the system understand the implications of projects outside their single service domain.

“The [EPP] is built up from specific programme areas, overseen by Heads of Capability (HoCs) who are generally drawn from the single Service appropriate for that programme ... the single Service HoCs’ future will be determined by their single Service superiors according to single Service criteria.” (Ibid. page 98, section 6.5.2)

An increase in the <amount of through life capability management> decreases capability over-specification as

“TLCM was designed to optimise and synchronise across the 8 Defence Lines of Development (DLoDs)” (Ibid. page 59, section 4.4.2).

TLCM ensures that any capability required is scrutinised against an integrated equipment plan.

The Capability Sponsor is the representative from the strategic side of the MOD with responsibility for a given capability. The capability sponsor assumes the role of customer to DE&S and it is the responsibility of the capability sponsor to provide capability requirements to DE&S from synergising advice from the equipment user and direction from defence strategy (Figure 4).

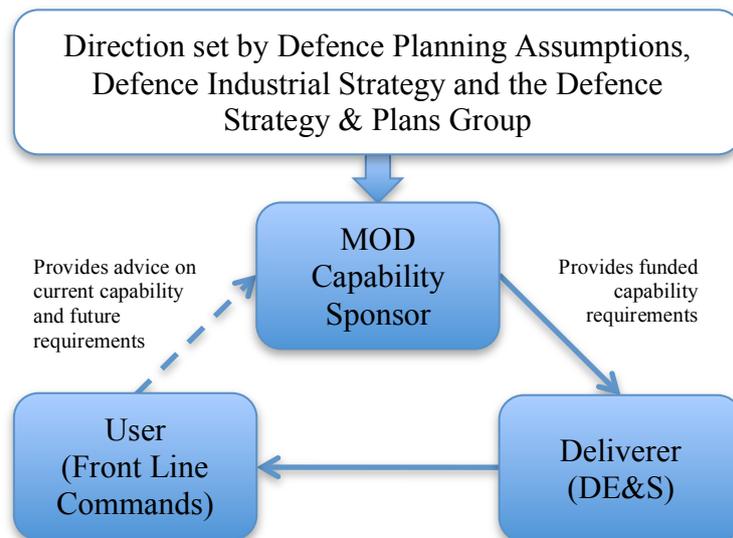


Figure 4: The role of the Capability Sponsor (from (Gray 2009) page 61, section 4.5.2)

In practice, the Capability Sponsor does not control the project sufficiently, to the detriment of capability specification:

“DE&S finds itself in a position where it is able to trade off capability against other factors and where it is therefore partly free to determine the capability that is ultimately delivered (even though this is the explicit role of the Capability Sponsor).” (Ibid. page 138, section 7.8.1)

The three linked behaviours of <over-specification of capability>, <coherence of new capability required> and <affordability of new capability> form into a loop whereby an increase in capability specification causes an even greater increase in itself. This negative behaviour is further reinforced by a second loop where over-specification is increased by changes in requirements.

The over-specification of equipment means that more equipment is specified than is needed. In a system where affordability is an issue, bringing specification in line results in *“capability removed from projects”* (Ibid. page 2.5.4, section E.7.1). If this capability is removed from projects that have already been specified or contracted for, this results in an increase in the <number of requirements changes>.

Three major areas influence requirements changes: i) capability control; ii) requirements creep; and iii) required capability revision. In theory, there is a clear line between the Capability Sponsor and DE&S (Figure 4). In practice, this is often blurred causing an increase in requirements changes.

“Evidence suggests that the close working relationship between DE&S and the Capability Sponsor means that change requests are often accepted by DE&S after internal approvals have been granted against an agreed specification” (Ibid. page 137, section 7.8.1)

Further to this is the allowance of requirements creep without concern for cost:

“Mid-project requirements creep itself derives from a number of factors ... The close linkages between the requirements community, industry and DE&S also “permit” ongoing changes to occur without appropriate consideration being given to cost.” (Ibid. page 142 section 7.8.4)

The third effect on requirements changes is capability revision. Capability is revised for two reasons: i) a change in technologies available whilst the project is in progress; and ii) a change in the threat against which the project was designed to counter.

“a wider change to the requirement for capability at a certain date, either due to a revised view of the threat which the capability is designed to address Mid-project requirements creep itself derives from a number of factors ... better performing technologies become available before entry into service, which specifiers are tempted to try and incorporate in some way.” (Ibid. page 142, section 7.8.4)

Changes in requirements affect the amount of <in-year overspend>: *“A key concern is the cost increase ... resulting from “changed requirements” from the Department” (Ibid. page 126 section 7.4.2)*

This increase in overspend can be controlled by both an accurate cost measurement and quality project management skills. The greater the <accuracy of cost estimate>, the greater the adequacy in the annual budget for programmed equipment; the greater the <quality of project management skills> of the budget holder, the better the project will be at monitoring costs and avoiding overspend.

An increased in-year overspend decreases the <affordability of new capability>. As has already been seen, this decrease in affordability reinforces the behavior of over-specifying equipment.

“When budgetary pressures arise, as they often do, projects are slowed down, and delivered later, with the military customer deciding not to reduce his required specification. What happens to cost in these circumstances is that the short-term cash spend is lowered, while the long-term total cost of delivering the project is increased. All of these effects serve to reduce the resources available for creating new defence equipment.” (Ibid. page 37, section 3.8)

3.1.4 Recommendations from the Model and Comparison with the Gray Report

As with any reinforcing behaviour, there are two options to remedy the situation. The first is to ensure the behaviour reinforces itself positively (for the system-of-interest); the second is to break a connection in the loop. Table 2 summarises the recommendations that can be made from an analysis of this model.

Recommendation	Description from Model
Concentrate effort on increasing TLMC	TLMC is a relatively new concept within DE&S, which requires considerable organisational change, so has not yet reached maturity within the Department. However, concentrating effort on increasing TLMC will bring increased stability to capability specification.
Increase the amount of control the Capability Sponsor has over the project and reinforce their responsibilities	Increased project control by the Capability Sponsor will control the over-specification of capability, as the Capability Sponsor is responsible for ensuring all required capability is fully funded (Figure 4). Making explicit the different responsibilities of the Capability Sponsor and the Project Manager ensures enough division between these posts to deter requirements changes.
Cut the link between in-year overspend and equipment affordability	Protecting the affordability of equipment by ensuring overspend does not affect subsequent funding for equipment will break one part of the loop leading to over-specification.

Recommendation	Description from Model
Increase accuracy of cost estimates through increased project management skills	Increasing the accuracy of cost estimates and quality of project management skills will both decrease the in-year overspend that, in turn, makes new capability more affordable.
Deter capability over-specification due to apparent affordability issues	A feature of both reinforcing loops is the behaviour of capability over-specification due to apparent affordability issues. Deterring this behaviour through training, process or control will help break this link in both reinforcing loops

Table 2: Recommendations from the OS Loop

In comparison, the Gray report produces recommendations on:

- Increasing capability of TLCM, initially through financial modelling of procurement vs support costs (*Ibid.* recommendation 6.d, page 164);
- Clarifying roles between the Capability Sponsor (MOD centre) and project delivery (DE&S) (*Ibid.* recommendation 4, page 160);
- Clarifying ownership of each project/requirement to a single individual (*Ibid.* recommendation 4.b, page 160);
- Bringing the costing of the EP and its affordability against the 10 year defence budget into the responsibility of the MOD, with all known liabilities included within the costed plan, and costings, and the veracity of the estimates, subject to independent audit (*Ibid.* recommendation 3.e-g, page 114);
- Ensuring requirements changes be specifically and realistically costed and included in the next iteration of the equipment plan (*Ibid.* recommendation 4.d, page 160);
- Handle any increases in project costs that threaten affordability by making cuts elsewhere in the department (not on the project itself) (*Ibid.* recommendation 4.d, page 160); and
- Increasing programme and project management skills within DE&S at all levels of the organisation (*Ibid.* recommendation 7.b.i, page).

Comparing the two sets of recommendations draws out two observations. The first is that, through the auditors applying their understanding of the system in the case of the Gray report, more in-depth recommendations could be made. By deliberately not involving the group of consultants in creating recommendations – only agreeing understanding of the model – we can show that although similar areas of recommendations have been arrived at, they differ in the level of detail presented.

The second key observation from this comparison is that the model creates an extra recommendation from an analysis of the causal loop itself. Though the behaviour is noted in the Gray report, it appears too insignificant to become a recommendation in itself.

3.2 Human Resources (HR) Loop

3.2.1 Background

When DE&S contracts work out to private industry, there is often a requirement of each contract to provide MOD personnel. This is to support the contract from the customer-side to ensure that the capability is effectively delivered and supported. This is what is meant by the <demand for MOD resources for project>.

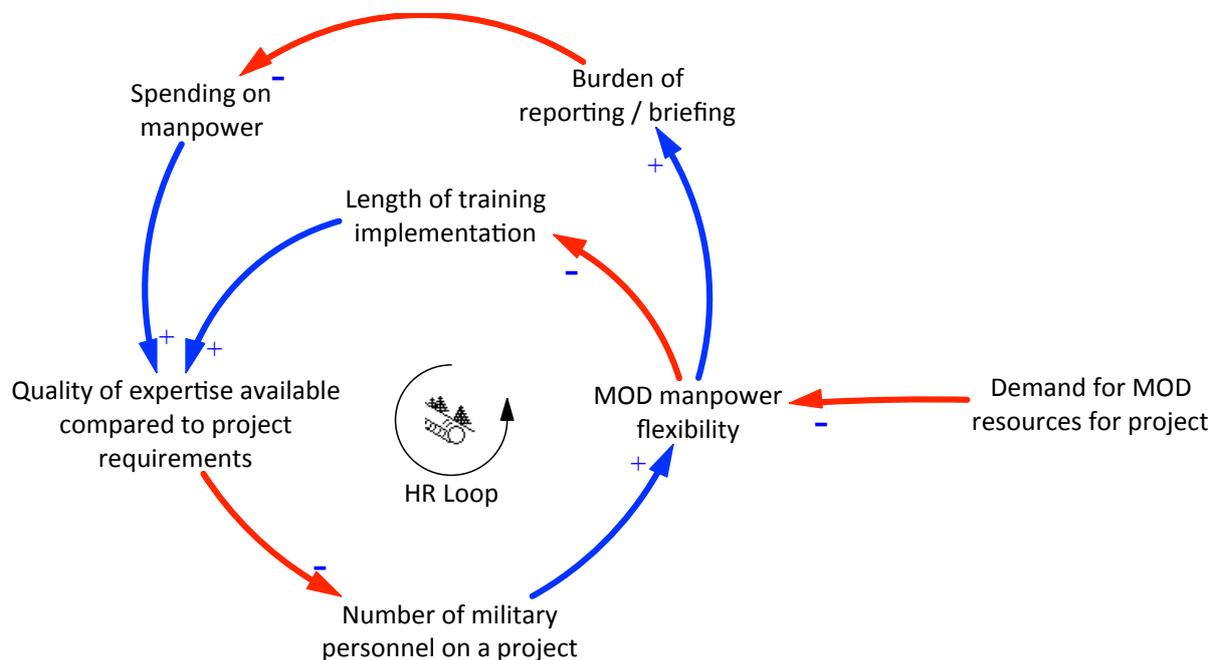
Within a project's or programme's lifecycle, requirements for expertise alter. For example, at the beginning, strategists, requirements engineers, and safety, technical and supportability designers are needed; later on the project requires maintainers, retrofitters and reuse experts.

Each project requires these experts to be available at the right time and in sufficient quantity and of sufficient quality.

Military personnel generally serve three-year terms in DE&S. This term often follows an operational term rather than a similar desk job. This mobility is prized within the MOD as experience within certain posts are required to gain promotion. Thus, this is the definition of flexibility of the military work force.

There is a finite amount of money to spend on the workforce. This is split between salaries, training, or incentives. The efficiency of this spend depends on the utilisation of the workforce; the proportion of their time that each employee spends working on projects or programmes. When new personnel come in to replace an existing post there is a period of time when both personnel are not working on the project. The more handovers happen, the greater is this reporting/ briefing burden.

3.2.2 Model



Model 2. The Human Resources Loop.

The loop in Model 2 illustrates that the more mobile the workforce within DE&S, the less quality expertise is available for projects both because of low utilisation around the handover period and a reduced scope for training. This, in turn causes more mobile, less qualified, personnel to take up posts for short periods of time, resulting in a more mobile workforce.

3.2.3 Description of Behaviour

Manpower within the MOD is very flexible; around 70% of the Department are military personnel (MOD 2009), who predominantly serve three-year terms within any given post. This is an accepted feature of the system:

“The current rotation system for military personnel ... has created a situation where mobility is prized / required” (Ibid. page 184, section 8.5.6)

As military personnel move posts, there is a burden on the system to phase personnel in and out of each post, a <burden of reporting / briefing>. This burden costs money, as during the changeover phase, both the outgoing and incoming personnel are not at 100% project utilisation.

“Whilst the benefits of short tenure accrue mainly to staff (primarily appearance of career mobility, breadth of skill set), the dis-benefits would appear to accrue mainly to DE&S and the MOD, including ... increased reporting / briefing burden (as new senior personnel within and outside the IPT are educated)” (Ibid. page 183, section 8.5.6)

As there is a finite amount of money available for manpower, money that could be spent on attracting greater expertise, or training existing staff is instead spent on administration (Figure 5).

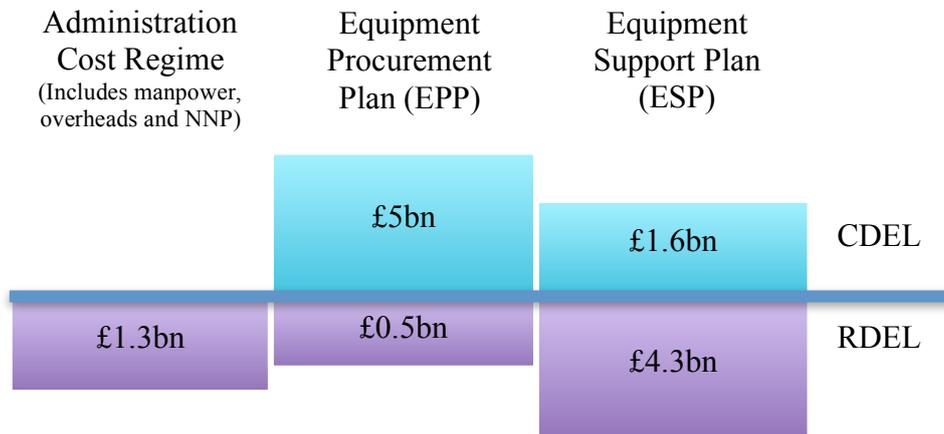


Figure 5: CDEL and RDEL budgets across DE&S cost areas from (Gray 2009), page 149

Quality of expertise available is further compounded by the <length of time available for training>. This is also caused by <manpower flexibility> and affects the amount that staff can build up skills in project-related areas:

“Frequent changes of roles render it very difficult for staff to build up the range of relevant skills or develop deep expertise in relevant areas” (Ibid. page 179, section 8.5.3)

These two causes leave DE&S with a smaller skills pool than is required - a decrease in the <quality of expertise available compared to project requirements>. However, posts still need to be filled (however qualified a person is for that post). Military personnel most often take these posts because military personnel are more available (than civilians) and because their routes to promotion are different. As the Gray report explains:

“This scale of involvement by military personnel ... is highly likely to result in skill shortfalls” (Ibid. page 180, section 8.5.3)

3.2.4 Recommendations from the Model and Comparison with Gray Report

An analysis of the behaviour in model 2 leads to a number of recommendations for the system-of-interest. These are summarised here in Table 3.

Recommendation	Description from Model
Increase the demand for MOD resources for project through Contracting for Availability (CfA)	Increasing CfA means that there is greater demand for MOD personnel to remain in post. This decreases flexible manpower and so encourages positive reinforcement in the HR loop.
Separate manpower spending from project resource spending	The amount of money for investment in manpower is currently linked to total resource funding. By separating manpower spending, this link is broken and so is one part of the reinforcing loop.

Recommendation	Description from Model
Decrease the number of military personnel on a project in areas that require position experience	Breaking the link between the quality of expertise available compared to project requirements and number of military personnel on project ensures that positions for which this non-military expertise is required – excluding areas where military expertise is paramount – are staffed by skill-specific personnel only.

Table 3: Recommendations from the HR Loop

In comparison, the Gray report produces recommendations on:

- Ensure that military personnel who do not have programme management experience are only seconded to teams to provide advice on user needs, and do not occupy line management positions. (*Ibid.* recommendation 7.c.iv, page 192);
- Develop better skills in the workforce by increasing programme and project management skills and the resources of central technical staffs available to individual projects as needed. (*Ibid.* recommendation 7.b, page 191);
- Ensure that anyone as senior as a Project Team leader, military or civilian, be retained in post for a minimum 4-year double tour. (*Ibid.* recommendation 7.e, page 192);

This comparison shows that the main focus for the HR loop within the Gray report was the skills and expertise of employees. The SD model functionally covers the skills issue as well as providing a graphical representation of the possible changes that could be made.

3.3 Equipment Funding Planning and Performance (EFPP) Loop

3.3.1 Background

Each acquisition and support project run by DE&S is required to submit a project cost estimate. This happens at various stages within the development cycle. The accuracy of this cost estimate can be measured by the difference between estimated and actual costs.

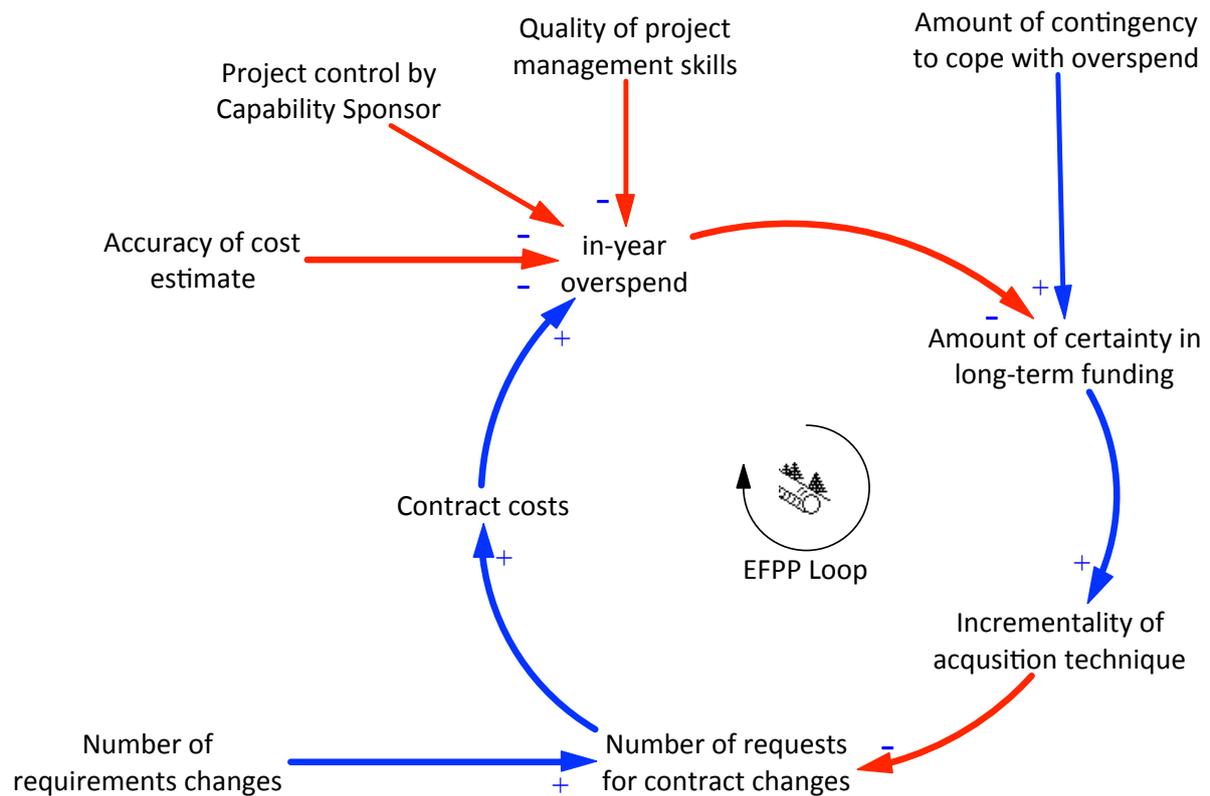
The cost estimates for the whole set of projects run by DE&S are aggregated into the EPP. From this plan, individual projects are provided with their annual budget, and costs are controlled on an annual basis. The amount that a project spends above their annual allocation is the in-year overspend.

The Capability Sponsor is the representative from the strategic side of the MOD with responsibility for a given capability. The Capability Sponsor assumes the role of customer to DE&S and it is the responsibility of the Capability Sponsor to control the both the project's budget and cost estimate (as shown in Figure 4).

Overspend is influenced by the amount of control that the Capability Sponsor has over the project. As this increases the in-year overspend decreases. This is down to the fact that if the Capability Sponsor does not control this well, no-one else in the system will pick up this job.

A second influence on the in-year overspend is the quality of project management skills where the quality of project management skills available has an inverse relationship with project overspend. One aim of project management is to implement the day-to-day, week-to-week plans to ensure work progresses to time and budget.

3.3.2 Model



Model 3. Equipment Funding Planning and Performance (EFPP) Loop

The EFPP Loop in Model 3 describes the fragility between in-year spend and long-term funding certainty. Without long-term funding certainty, incremental acquisition becomes more difficult to achieve and increases the risk to the DE&S of expensive contract changes. This unforeseen expense pushes expenditure over in-year estimates, decreasing long-term funding certainty.

3.3.3 Description of Behaviour

The <amount of certainty in long-term funding> is the amount by which each project within the EPP is sure of its funding for the phase of the project it is in. At present, the amount of certainty is low.

“Each April the DE&S team enters the new financial year with plans to conduct activity some 10 per cent greater than the available, and known, budget for that year. As a result, a considerable amount of time and effort goes on through the year to reduce expenditure within that accounting year.” (Ibid. page 28, section 3.6)

This is, in part, due to the low <amount of contingency to cope with overspend>, and also because of a large <in-year overspend> each year.

“Funding uncertainty arises from EPP over-programming / overhear, combined with inadequate “contingency” to cope with a short-term overspend in one project without adverse consequences for another” (Ibid. page 142, section 7.8.2)

<In-year overspend> itself is caused by four different issues. The first is that the <quality of project management skills> within DE&S is inadequate: *“the skill levels and qualifications held by project staff are often surprisingly limited, given the projects that they are managing.” (Ibid. page 179, section 8.5.3)*. As it is the project managers within DE&S who receive and control funding for projects – *“current budgetary arrangements allocate the EPP*

resources in-year to DE&S, rather than the Capability Sponsor as customer” (Ibid. page 159, section 7.14.1) – and project management skills are required to keep these budgets in check, poor quality project management skills lead to an increase in <in-year overspend>.

The second cause of an increase in <in-year overspend> is the <amount of project control by Capability Sponsor>. As shown in Figure 4, the Capability Sponsor provides the project within DE&S with a set of funded requirements. Thus, it is the Capability Sponsor’s responsibility to ensure that all requirements handed to the project are fully funded. However, the Capability Sponsor is not in a position to fully control the spending or requirements in a project once it has been initiated. This culminates in greater spending than is planned, leading to an increase in <in-year overspend>.

“The managers of the programme (i.e., the MOD Capability Sponsor) are unable to exercise restraint in curtailing the programme in out years. This leads to unrealistic forecast spending levels being embedded in DE&S” (Ibid. page 103, section 6.5.7)

The third cause of an increase in <in-year overspend> is a decrease in the <accuracy of cost estimate>. The definition of accuracy here is that as accuracy decreases, the cost estimate becomes less than is actually spent. Thus, by definition, if the cost estimate is inaccurate, the <in-year overspend> has increased.

The final way by which <in-year overspend> is increased is through an increase in <number of requests for contract changes> and <contract costs>, in part caused by an increase in the <number of requirements changes>:

“Given the uncertain funding environment on a year-to-year basis and the relatively long project development lead times during which time requirements can (and generally will) evolve, the MOD can often be in a position where it is a supplicant in requesting contract changes” (Ibid. page 143, section 7.8.7)

Using alternative, incremental approaches to acquisition can reduce this increase in the <number of requests for contract changes>. These incremental techniques reduce technical and integration risk to a project by splitting it into a larger number of smaller, more manageable deliverables. The success of this concept, however, hangs on the ability of DE&S to design and manage a tranche of integrated projects that, when integrated, provide the capability required. Thus, for a greater <incrementality of acquisition technique> to work, long-term funding certainty needs to be high.

“Alternative acquisition techniques which have the potential to mitigate the consequences of high technical risk (e.g., spiral / incremental / sub-system acquisition techniques) are militated against due to the relatively uncertain long-term funding environment” (Ibid. page 140, section 7.8.3)

3.3.4 Recommendations from the Model and Comparison with Gray Report

Below in is a summary of the recommendations we have devised from an analysis of the system behaviour in model 3.

Recommendation	Description from Model
Increase the amount of contingency in the equipment plan	Contingency increases long-term funding certainty.
Prohibit requirements changes after contracting point	The cost of a project increases when requirements are changed after contracting point. To change this, the system either needs to ensure requirements changes are prohibited once contracts have been placed, or not place contracts until all requirements are known.

Recommendation	Description from Model
Ensure long-term funding certainty	Incremental acquisition is seen to bring unacceptable risk to a project. Without knowing that the funding will be there in the future, a project, and therefore contracts, cannot be split.
Introduce process for use of more incremental acquisition	Introducing a policy variable to the model for increasing incremental acquisition will ensure the acquisition decision is not taken purely on a cost basis.

Table 4: Recommendations from the EFPP Loop

In comparison, the Gray report recommends:

- A rolling 10 year budget should be agreed for the MOD that encompasses manpower, estates, equipment and support funding (*Ibid.* recommendation 2, page 86);
- Creating a demonstrably affordable long-term programme to promote incremental development with contingency provided in the programme for coping with unexpected overruns (*Ibid.* commentary to recommendation 3, page 32); and
- DE&S to be contractorised as a formal Go-Co⁵ (*Ibid.* recommendation 8, page 201).

A comparison of the outcomes of the two analyses shows that both have similar conclusions. The qualitative SD model of the EFPP loop includes the recommendation to prohibit requirements changes after contract point.

3.4 Further Observations

In all three models, recommendations came out of qualitative system dynamics model that did not make it into the formal recommendations of the Gray report. It is not clear whether this is because these were not seen as significant enough to be classified as recommendations, or because their influence on the system was not fully recognised.

A good illustration of the usefulness of the model in informing recommendations at different points in time is the size of fixed in-year budget in the OS loop (model 1). In the present financial climate, increasing the size of the fixed in-year budget is not a sensible recommendation, as the department is being forced to make cuts. However, a change in the financial climate coming out of the recession would make this variable feature in future recommendations.

Capability revision is a difficult issue. On the one hand, if capability is not revised, a project will deliver equipment that is not the most up-to-date; on the other, revision causes further delay and project overspend through requirements changes. Here, model 1 provides a good illustration not of a recommendation from the model, but as an early warning to a project that, with delay or long lead times comes the increased risk of revision.

In model 3, the Gray report recommended resolving problems with requirements changes after contract point (and a number of other issues) by entirely changing DE&S from a Government Department to a Government Owned – Contractor Operated entity (Go-Co). From a modelling point of view, this entire change in structure of the system-of-interest will drastically change the behaviours within the enterprise. Thus, the qualitative SD model will also drastically change. It is very difficult to tell with the qualitative model exactly which behaviours this will prohibit or encourage.

4 DISCUSSION

To model or not to model? The answer to this question is usually based on the fidelity and confidence of the data available and whether there are advantages to be gained through

⁵ A Government Owned – Contractor Operated entity.

modelling. It was felt that there was sufficient confidence in the report itself for it to be a valid data source from which to develop models. The value in this research has been to make explicit the feedback loops that were present in the data and thus enable the implications of these loops in terms of system dynamics to be discussed and interventions proposed to mitigate them. There is an argument for all such audits of complex systems, such as the Gray report, to include models to bring a more concise and formal way of presenting findings and crucially revealing causes of dynamic behaviour.

The purpose of the modelling was to develop dynamic models from the Gray report with a view to testing the premise that this method can create a way of tracking performance of an organisation system, and allowing performance auditing that is in a useful form for the system. The method employed built initial models directly from a textual analysis of the Gray report that were then further refined by a processes of group model building by defence consultants with significant experience of the workings of the defence acquisition enterprise system. Recommendations arising from an analysis of causal loops within the model were then compared with those contained in the Gray report itself. With this context in mind the question of model validation is less about whether we have testable predictions than whether the value of the models enhance the recommendations for change in a system – the fundamental aim of performance auditing. Validation for these models is essentially “*white-box*” (Barlas 1996), examining whether the structure of the models explains how observed behaviour is obtained i.e. theory-like or “*causal descriptive*”. Again following Barlas, the models we have produced are just one possible representation on a “*continuum of usefulness*”. Therefore what is important is how the modelling process is embedded within the wider processes of project, programme and enterprise performance measurement such that the value is constantly reviewed and models updated to reflect reality and experience of procurement delivery.

A key question in the qualitative modelling debate is: if the system were not modelled, how would the recommendations be arrived at? Ultimately, although traditional performance evaluation is structured around rigorous interrogation of data, final recommendations come from an expert, consensus view of how to solve the issues raised (although companies that carry out these independent evaluations can have proprietary frameworks for addressing this). This is surely an area that warrants further research: finding a middle ground between simulated modelling and the non-structured art of the professional; using qualitative models to lend systematic rigour to expert analysis and decision-making.

One further issue with this modelling approach is that it is bound by the structure of the current system. As observed with the recommendation in the Gray report to change the DE&S organisation into a Go-Co (Section 3.3.4), the qualitative model is more suited to incremental changes. Using the causal loop analysis will not necessarily create large structural changes to the organisation. However, if the group model building process were to include the group of people performing the audit – rather than, in this case, being presented purely from an analysis of the SD models – then these structural changes may well still appear, as the process encourages group discussion and mutual understanding.

Two associated issues are raised when examining the validity of the claims made here as to the efficacy of this approach: will this approach be similarly as effective with other publically-available performance audits; and does an initial performance audit even need to exist. To test the first, a number of existing project, programme and enterprise audits could be used. The second could be established by replacing the performance audit with primary data and performing extensive internal (to the organisation system) group model building.

One other question we have not answered here is: whether using an existing performance audit to create a qualitative system dynamics model from which we can make

recommendations for system improvement can be applied in other industries (outside the defence domain) and at other levels of abstraction (for a single product, or for a single lifecycle stage of a project, for example). We would look to transform this into a further research proposal.

Another research proposal arising from this work is to re-run the process again, but from the system of interest's perspective; i.e. within the DE&S organisation. This process would surface the limits of application of the model; the level(s) within the DE&S organisation where the models could be used (whole enterprise, programme, individual projects etc.). It would also give a better understanding of how the behaviour, presented by the Gray report in high-level, generalised terms, is applicable across the whole of the enterprise; as the functions within the DE&S organisation differ, so too may the exhibited behaviour.

5 CONCLUSIONS

This research has successfully devised and tested a method for analysing the performance of an enterprise organisation system, towards a framework for tracking and creating a performance audit of an enterprise, programme or project system. This was performed using a group model building process based on an initial causal loop model derived from a contemporary, publically-available review of defence procurement by Bernard Gray. This approach allowed the complex issues raised by Bernard Gray to be discussed and programmed into a qualitative system dynamics model by a small team of defence consultants. Through this, we could then devise a set of recommendations based on the analysis of the causal loops in the model and compare these to those published in the test case we were using.

For performance tracking to remain, this method requires instantiation as part of a continuous review process. Otherwise, by leaving the model after a one-off creation exercise, its value would rapidly decrease, as it would quickly become an inadequate representation of the real-world system. Therefore, assumptions and models must be continuously updated to reflect either greater insights into behavioural programming (due to an increase in knowledge and/or experience) or alternations of the model through intentional organisational change by the system-of-interest.

The method suggests that qualitative system dynamic models would make a valuable addition to significant reports on organisations, such as the Gray report, in order to adequately communicate complex arguments over mutual causality and make explicit system dynamics, especially when these reinforce patterns of behaviour detrimental to the organisation's aims and objectives. The inclusion of such models would also provide a systematic approach to recommendation creation. In turn this may help draw the sting of criticism that an audit report could attract from people within the audited organisation who may not have experienced the same process of discovery. This method also assists in providing that discovery by every reader who endeavours to understand, from their own experience, what the model is telling them.

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