April 2021

Equipment Support Modelling Guide

Book 1

Support Modelling Introduction

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This guidebook has been produced by the Team Defence Information (TDI) Support Modelling and Analysis Working Group. TDI is a joint United Kingdom defence industry and Ministry of Defence (MOD) collaborative association which advises defence information policy and pilots new ways of working to transform the defence ecosystem (www.teamdefence.info). The Support Modelling and Analysis Working Group is one of many TDI working groups. These groups consist of MOD and defence industry Subject Matter Experts (SMEs) who meet regularly to develop and share knowhow.

The United Kingdom Defence Support Strategy published in November 2020 calls for several “strategic outcomes” to be delivered by 2025. These include development of an information led enhanced decision-making capability across the Defence Support Enterprise. Establishment of a pan Defence support modelling strategy and capability are fundamental for the delivery of this, and other strategic outcomes detailed in the strategy document.

Modelling aids development and operation of equipment support solutions. To the uninitiated, modelling and the range of modelling techniques and tools can be confusing. The primary aim of this guidebook is to therefore provide an easy-to-understand overview of equipment support modelling.

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This guidebook offers the perspective and opinions of those involved in its creation. It should not be quoted as if it was a specification or a code of practice. Claims of compliance cannot be made to it.

The guidebook is issued as one of a series. Others to follow include:

- Support Modelling and Analysis across the Equipment Lifecycle.
- Support Modelling and Analysis Categories.
- Support Modelling and Analysis Management.

Some of the modelling techniques addressed in this guidebook are complex and their implementation requires expertise. For those not familiar with this domain, it is recommended advice and guidance be obtained from modelling SMEs before using these techniques. This is particularly the case for development and use of quantitative models. The TDI Supportability Modelling and Analysis Working Group are available to provide modelling advice and guidance. The group can be contacted via the TDI website (address at the end of the first paragraph above).

This guidebook does not identify the many third-party software tools which could be used to underpin support modelling. This information will be provided in one of the other guidebooks identified above.

Context

Currently there is an overheated Defence equipment programme which could be up to £15 billion overcommitted[1]. This over commitment provides a clear focus for MOD to determine how the Defence budget could be better managed or reduced. This includes equipment support cost which can be up to 70% of whole life cost[2]. The financial over commitment is influencing Defence planning and budgeting with projects seeking cost reduction. This situation prompts a renewed emphasis on equipment support affordability and cost management.

Figure 1 Budget, Support and Equipment Operation Interrelationship

As illustrated in Figure 1, due to the increasingly difficult challenge of balancing complex equipment operation and availability requirements within a reducing support budget, there is a need to better understand and optimise support system performance, cost, and risk. This is particularly the case when support is outsourced to industry. These imperatives result in a clear need to better comprehend and use modelling techniques and tools.

This guidebook is primarily for MOD and defence industry Project Managers, Support Operation Managers and Business Leaders who would benefit from support system modelling outputs to better understand and decide on support options, costs, and risks. This is mainly to reduce through-life support cost whilst maintaining or improving operational availability and mission effects.

Scope

The guidebook addresses modelling for supportability and support system design, deployment, operation, and withdrawal. This includes support operation, economic, and risk modelling. Although this guidebook has a defence connotation the modelling principles are applicable to any complex equipment and its associated support system.

[1] Shepard News Defence Notes, Opinion: Make or Break Time for UK Defence 18th January 2020
[2] United States of America Department of Defence Operating and Support Cost Estimating Paper

Modelling Introduction

In our minds we often 'model' concepts and ideas without 'labelling' what we are doing. In the broadest sense, a model is any representation which helps understand the world whenever common sense or direct observations are inadequate. Models are tools that help to translate our experiences into an anticipation of future events, enabling us to make decisions about what to do[3].

Models can help to comprehend a complex world that is beyond immediate understanding and help with informed decision making. A model is often used to underpin analysis. However, analysis can be performed without a model or modelling. Analysis is defined as 'a detailed examination of anything complex to understand its nature or to determine its essential features'[4].

Model Definition

A model is any structure used to find out about something we deal with. This contrasts with situations where we simply try to understand things directly. When modelling is used in science and engineering, it augments our capabilities in several ways. Building a model requires us to make explicit assumptions and boundaries, and that makes it possible to share and use the model more widely, and to test it more rigorously. It becomes possible to create a narrative about why things happen, and what might happen, which can then be used to inform and explain a decision[5].

Model Based Systems Engineering

Model Based Systems Engineering is a Systems Engineering method that focuses on creating and exploiting domain models as the primary means of information exchange between engineers, rather than on document-based information exchange[6].

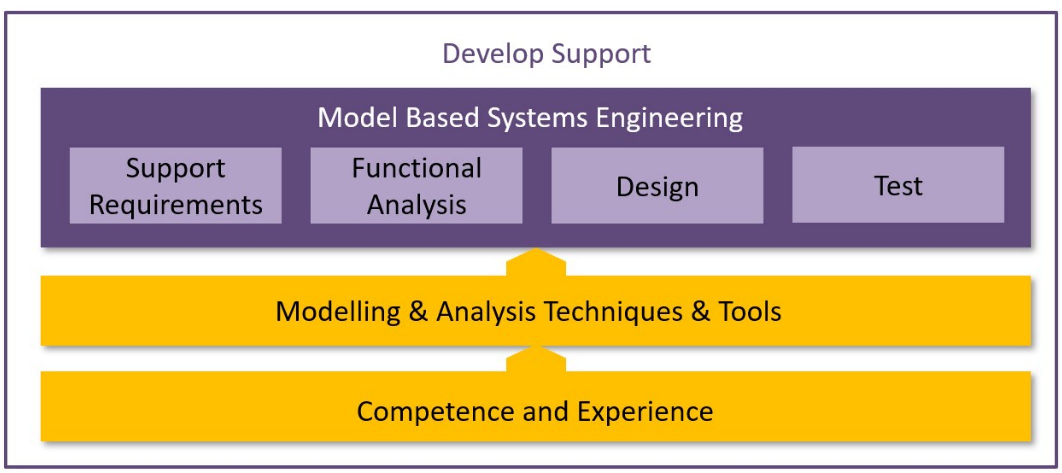


Figure 2 Model Based Systems Engineering Structure.

[3] Computational Modelling: Technological Futures
[4] merriam-webster.com
[5] Computational Modelling: Technological Futures
[6] Wikipedia

As identified in Figure 2, Model Based Systems Engineering consists of four stages all of which can be underpinned by analysis and modelling activity. Model Based Systems Engineering offers a method used as a top-level structure for support solution development and improvement. The systems engineering process will include a range of support SMEs, for example: maintenance, supply, engineering, human factors, commercial, etc. In this context support is the 'system' and the Model Based Systems Engineering structure is used as a backdrop for support system development.

Support Requirements

Analysis of support requirement is focused on capture, assessment, viability, and contradiction i.e., is it possible to meet each requirement and do individual requirements conflict with each other. In the context of this guidebook, a set of support requirements are established and used to direct support system design. Requirements' analysis is usually performed by a range of SMEs and its outcome is a key input to directing support modelling activity, especially development of Business Questions (see further information below).

Output from requirements' analysis is agreed between MOD and industry, signed off at an appropriate level and held under configuration control within a Master Data and Assumption List (MDAL). The requirements set and MDAL provide a key input to subsequent modelling activities.

Modelling Categories

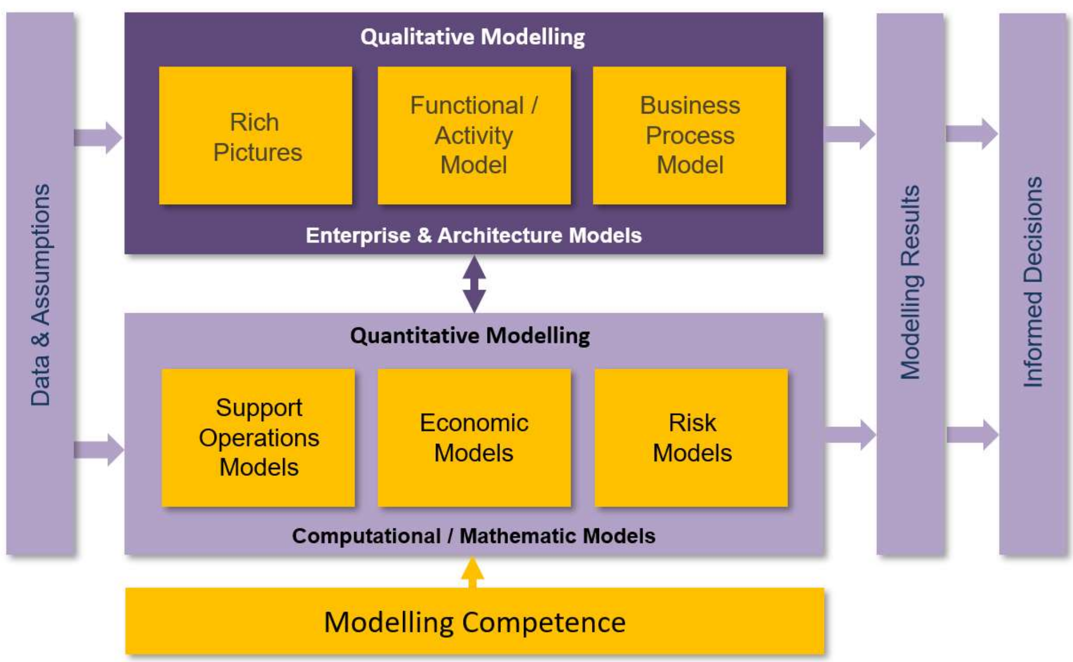


Figure 3 Modelling Categories.

As illustrated in Figure 3, and for the purposes of this guidebook, we can categorise modelling into the two areas of qualitative (visual and illustrative) and quantitative (computational / mathematic).

Qualitative Modelling

Figure 4 provides a fictitious example of a top-level enterprise rich picture (also known as an infographic or End State Visualisation) and Figure 5 a top-level activity or functional model. These simple to establish models provide a ‘quick look’ summary of scope and responsibilities.

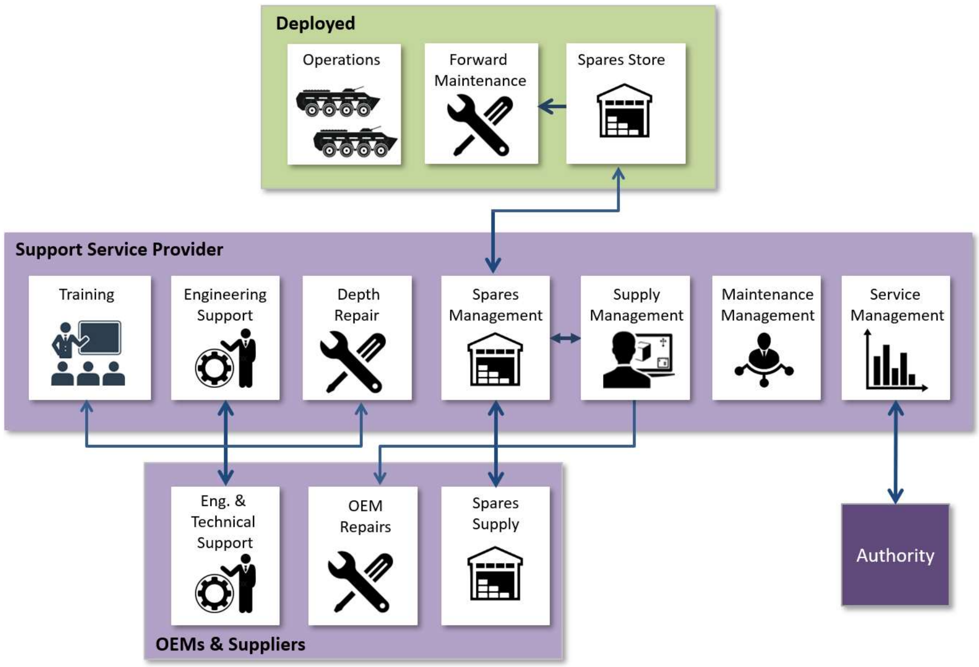


Figure 4 Example Enterprise Rich Picture

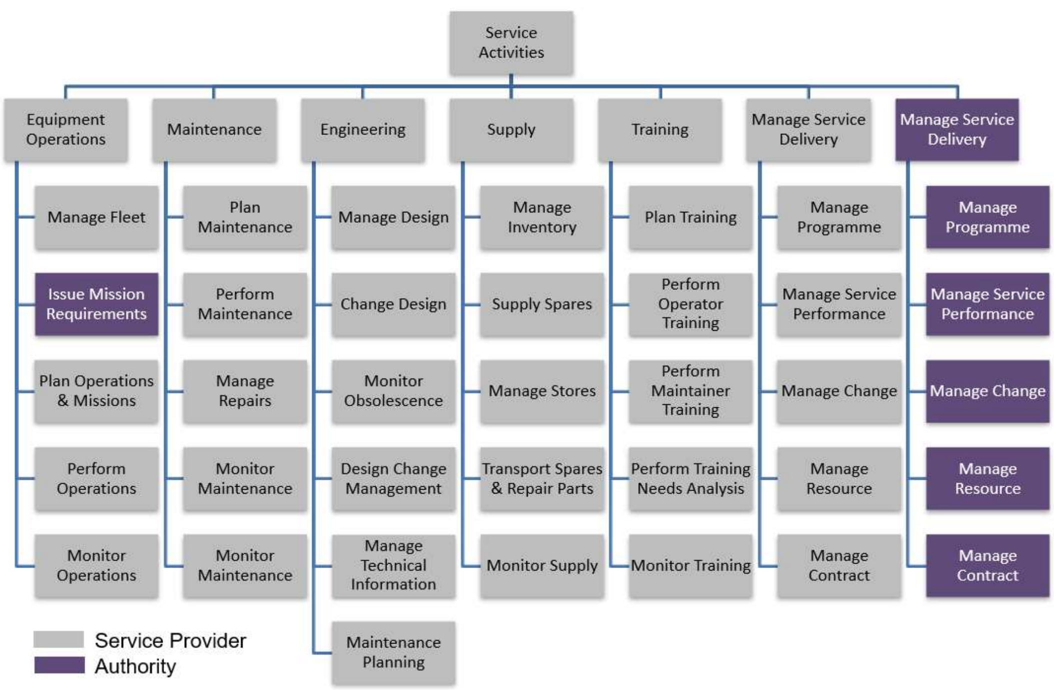


Figure 5 Example Top-Level Activity Model

Business process models use enterprise and activity models to inform development of a more detailed view of support service architecture. This includes activities (processes), inputs, outputs, enablers, controls, responsibilities, and dependencies.

Business process models can also be constructed in standard desk-top software tools such as Microsoft Power Point and Visio. However, these Microsoft tools have limitations, and it is often more appropriate to use specialist business process modelling tools.

These tools enable a hierarchal visualisation of the operation and support architecture and provide a range of different output formats including interactive web-based views. They also conform to the Business Process Modelling Notation standard.

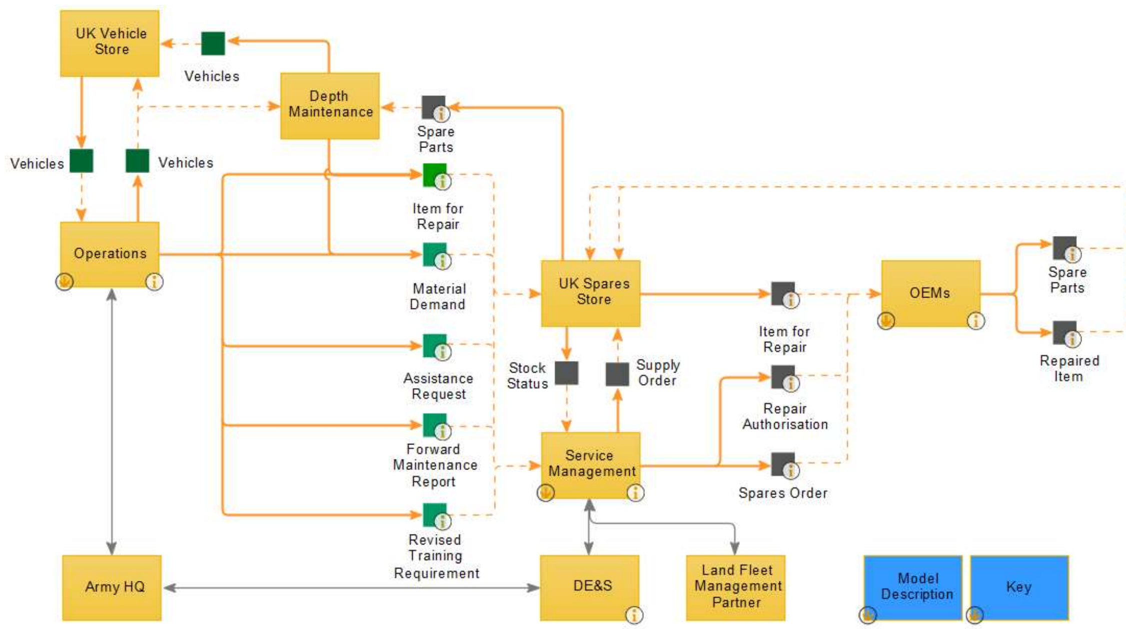


Figure 6 Example Business Process Model Top-Level

Figure 6 provides a fictitious example top-level support operation business process model. Each of the orange boxes in this example contains the detail of the business processes within in them.

Figure 7 (below) is a screenshot of the content within the ‘Service Management’ object in Figure 6. Each of the chevron process objects in Figure 7 contain further detail of the process breakdown (not identified in this document).

For brevity, this guidebook only identifies a few examples of qualitative techniques. There are many other qualitative modelling techniques and tools which could be used to aid support systems design and operation. This includes architecture framework techniques, standards, and tools.

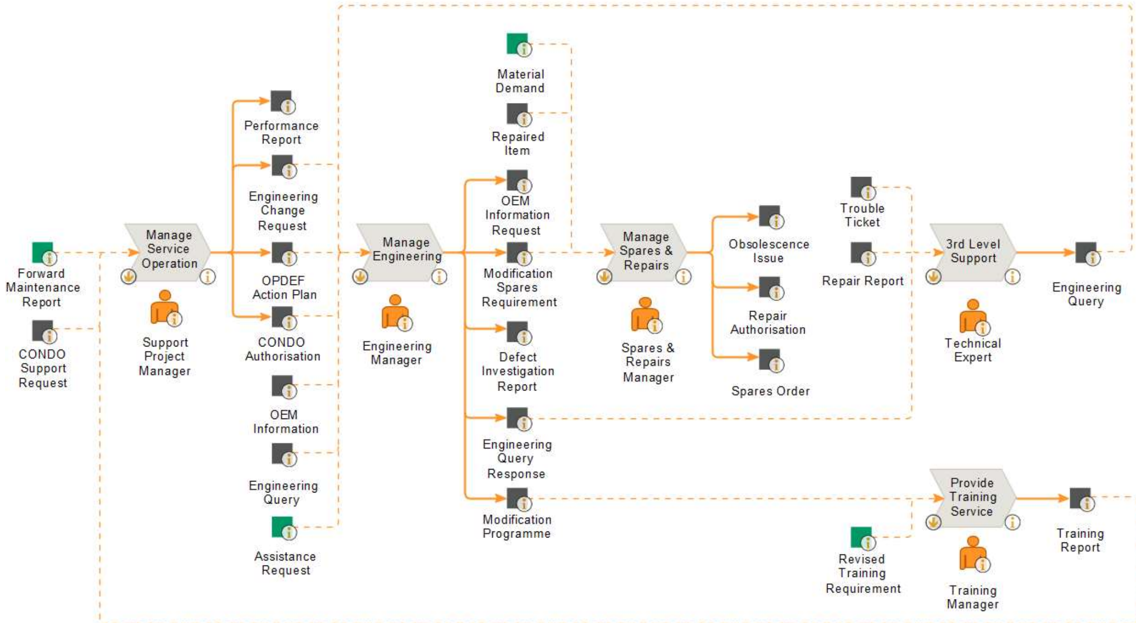


Figure 7 Example Business Process Model Map

Logistics Coherence Information Architecture Model

The Logistics Coherence Information Architecture (LCIA) grew from the 2006 Logistics Coherence Project which, jointly with Industry, defined rules, tools, and standards to enable the MOD and Industry to accelerate the transformation of end-to-end logistic information capability. It defined joint target architecture underpinned by common functions/activities, standards, information flows and measures of information performance, together with a compliance regime. Today, in simple terms, LCIA provides an MOD and defence industry jointly agreed generic description of the logistic and supporting enterprise/business functions that are performed irrespective of who undertakes the tasks. This model is used as a template for identifying logistic information needs to support through life capability.

The key rationale underlying LCIA is that logistics information has significant value for through-life decision-making and it needs to be treated and managed as an asset. Several projects responsible for introducing capabilities into service have not adequately considered the logistics information required to deliver support solutions, in-service operation, and other through-life management activities. Furthermore, many existing capabilities generate logistic information delivered in a large variety of inconsistent and incompatible formats that cannot be easily shared or utilised by current or planned logistics information systems.

The aim of LCIA is to identify the information that the stakeholders of a capability require to support in-service logistic decision-making.

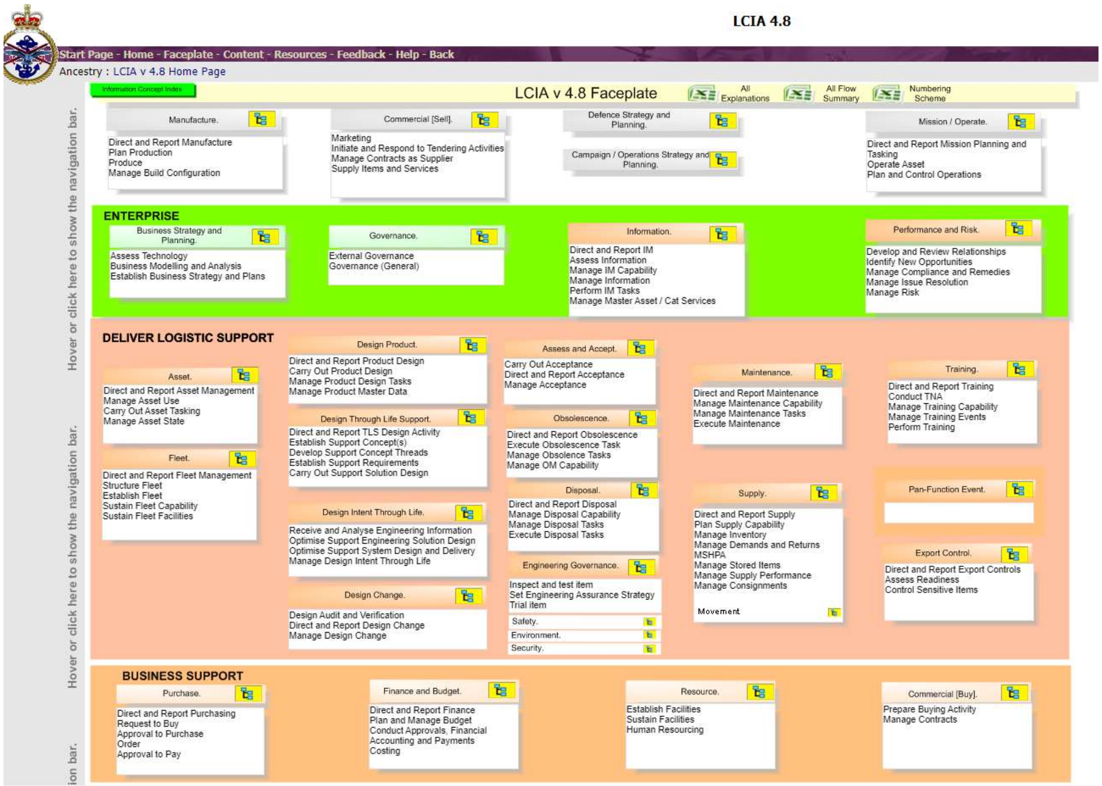


Figure 8 LCIA Top-Level Screen Shot

Figure 8 is a screen shot of the LCIA Face Plate or the top-level of the model. The LCIA can be accessed at www.modinfomodel.co.uk.

Quantitative Modelling

Due to their nature, qualitative models are focused on scope, organisation, activities, roles, and responsibilities. They do not address questions such as how many, how often and how much. These types of question are addressed by quantitative models.

Within the Integrated Logistic Support and Supportability Analysis domain there are specific quantitative analysis and modelling techniques. Examples include level of repair analysis, reliability centred maintenance and spares modelling. The approach described below is applicable to these support modelling activities and others which are not prescribed in the same way. This includes support operation simulation, support economic and support risk models. Economic models can include lifecycle or through-life cost and spend profile models.

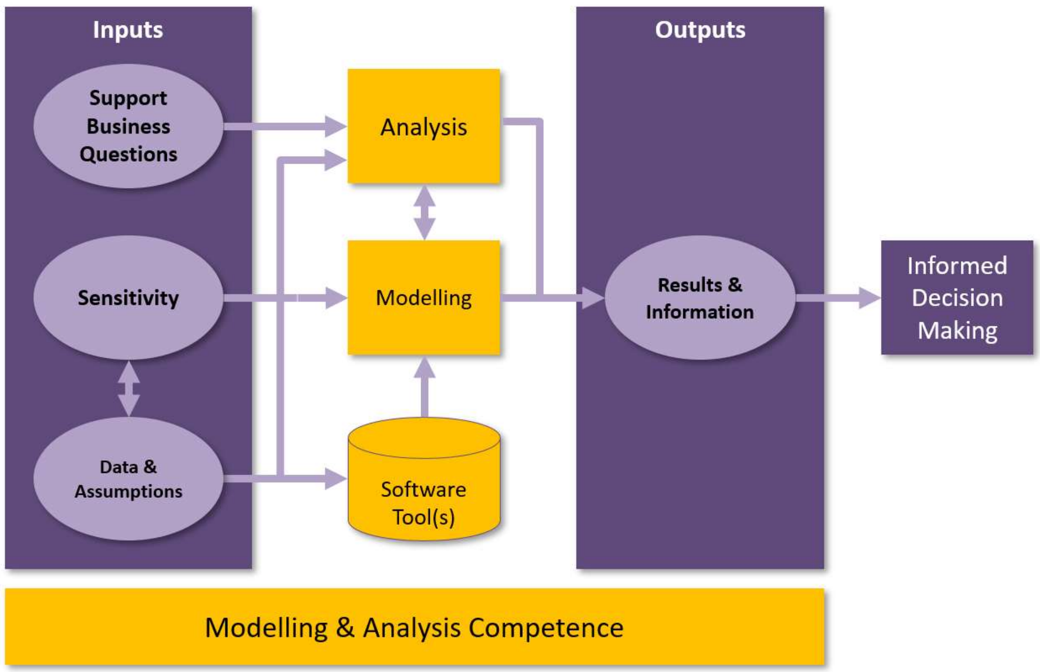


Figure 9 Modelling Structure

Figure 9 summarises the top-level quantitative modelling structure. In this perspective modelling underpins analysis which is directed by support business questions.

Business Questions

During the quantitative model lifecycle scope stage, business questions are established using support requirements and modelling experience. Business questions can address who, what, where, when, how (how many, how often, how much). For example, a business question might be.

> How many times will a maintenance activity be performed over a 10-year period and what resources will this maintenance activity require (people, spare parts, support and test equipment, facilities, technical information, etc.)?

Each business question is assessed to determine if a specific analysis technique is required to answer the question and if there is a need to perform modelling to underpin the analysis. In some instances, analysis could be limited to a discussion by appropriate SME's, or it could be much more complex and require a detailed modelling activity supported by software tools.

When modelling is required, the support business questions become key requirements for the modelling activity. These requirements are managed as a configuration-controlled business questions file within a software tool such as a Microsoft Excel and within the Project MDAL.

Business Questions, Analysis and Modelling						
No.	**Scenario / Question**	**What decision(s) will this inform?**	**Qualitative**	**Quantitative**	**Economic**	**Risk**
1	What is the scope of the support solution? Who is responsible for what?	Within the support solution, who will be responsible for what activities.	X			
2	What is the support organisation and what interdependencies are there between activities?	Structure of the support organisation, roles and responsibilities.	X			
3	What dependencies are there on the customer organisation?	Organisational responsibilities and degree of risk budget.	X			X
4	What is the amount and cost of maintenance over the contract period?	Resource needs and cost		X	X	
5	What resource will be required to perform the maintenance over the contract period?	The numbers of personnel, spare parts, repair parts, support equipment, tools and facilities required for the service solution.		X	X	X
6	What is the level of spares inventory required to achieve the availability requirement?	The quantities of initial and recurring spare parts to be procured and the associated costs.		X	X	
7	What can we do to affect the contractual performance and value proposition?	Structure and content of the service solution.			X	X
8	What are the drivers of cost and value?	Where we should focus attention during service design and operation			X	
9	What are the service delivery and management personnel costs over the contract period?	The numbers and skills of the service delivery team personnel			X	
10	What are the cost and technical implications of subsuming Government employees?	Understanding of the risks associated with the introduction to company employment of Government staff.			X	X
11						

Figure 10 Example Business Questions

As identified in the Figure 10 example, in this file each business question is recorded and, against each question, the decision of which analysis or modelling should be performed is recorded.

Model Development and Use

If modelling is deemed appropriate, there is a subsequent assessment to determine if a software tool or tools are required to underpin the modelling activity. The main options for a software modelling tool are to either use Microsoft tools such as Excel and Power BI or to use a third-party off the shelf software product. There are many potential third-party tools.

Once a software tool is selected the next step is to determine if there is an existing model appropriate to the requirement. If there is an existing model this can be used. Or an existing model may need to be modified. If a new model is deemed appropriate, to identify, confirm and agree the depth and breadth of the model, the "Model Development Life Cycle" identified in Figure 11 is followed. A description of each stage in Figure 11 (below) is provided in Annex B Model Development Lifecycle Stages.

Modelling requirements are discussed and agreed between the project manager and the modelling team or modelling SME. Once agreed, these requirements are documented in the model specification, the Modelling Plan (which can be a standalone plan or a chapter within another appropriate project document such as the Integrated Support or Programme Plan) and the MDAL.

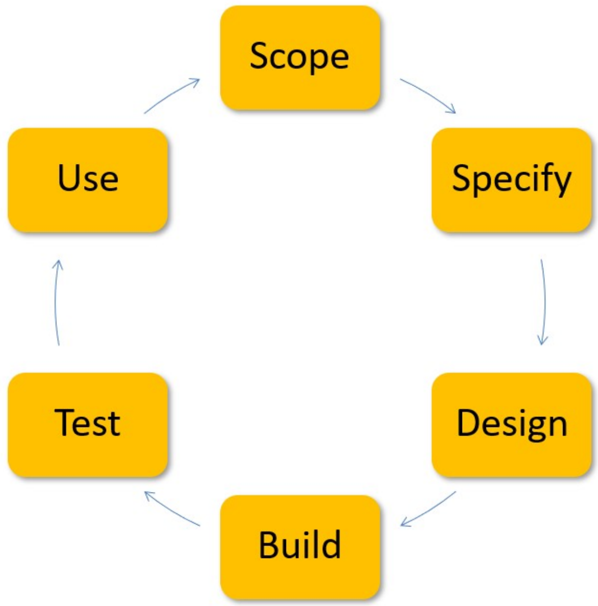
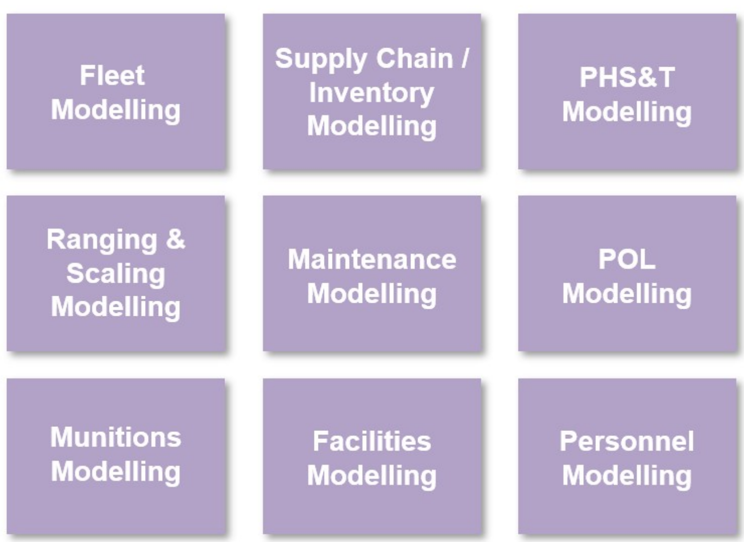


Figure 11 Quantitative Model Development Lifecycle Stages

The initial steps of, Scope, Specify and Design (also known as Concept of Analysis) are the basis of establishing a model which meets the stated requirements.

The Scope and Specification stages are where the modelling techniques and tools are determined as directed by the business questions. Whilst, for simplicity, illustrated as linear stages in Figure 11, Model design, build and test are iterative. For complex models, test may be performed by individuals other than the model designers and builders. During model use it may be deemed appropriate to modify the model with a revisit to the specification, design, build and test stages.



PHS&T - Package, Handling, Storage & Transportation
POL – Petroleum, Oils and Lubricants

Figure 12 Examples of Support Operation Modelling Topics

Figure 3 identifies different quantitative modelling types as support operation, economic and risk. Economic and risk models can focus on parts or the whole of support and address parts or the whole of the lifecycle. This is similar for support operation modelling and Figure 12 identifies some examples of different topics which could be modelled separately or together. A top-level or comprehensive support operation model could address the whole of support over a period. Simulation is often used for this type of model.

Due to the nature of specific project models containing proprietary data, it is not possible to share real models and related outputs in this document. However, Annex A provides an example of a demonstrator support operation simulation model with data cleansed to remove proprietary data.

In this guidebook economic and risk modelling has not been discussed in any detail. These topics are addressed in other guidebooks identified in the Forward section.

Data & Data Management

As illustrated in Figure 9, quantitative modelling requires data and assumption inputs. The model developer and user must obtain, understand, and manage the data required to establish and operate a model.

Data and assumptions are identified, collated, and managed. This is typically achieved via the use of the MDAL and in accordance with data management good practice such as that identified by the Data Management Association and their Data Management Body of Knowledge paper. The paper is a collection of processes and knowledge areas that are generally accepted as good practices within the Data Management discipline and cover the topics identified in Figure 13.

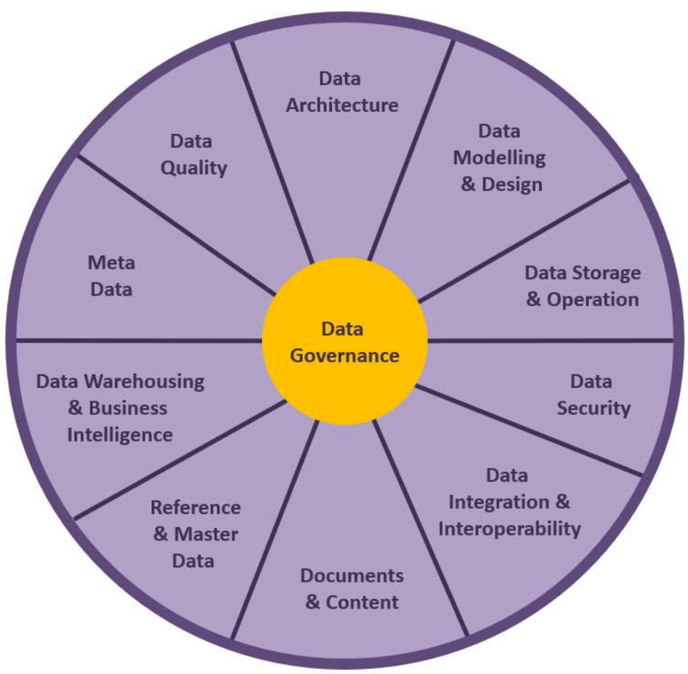


Figure 13 DAMA Knowledge Area Wheel

Data and assumptions sensitivity, which addresses assumptions or weaknesses in data quality, is a key part of modelling. This is via variation assessment for specific data inputs. For example, a predicted failure rate might be 500 hours Mean Time Between Failure. The sensitivity might assess variations to this prediction investigating the impact on the model outcome if the input was 300 hours, 400 hours, 600 hours, etc.

Competence

Managing and performing complex support modelling requires appropriate competence for both selection and use of techniques and tools. This includes the ability to determine the most appropriate technique and tool to provide an efficient and effective response to business questions.

There is also a relationship and trade-off between the size and complexity of a project and the potential modelling effort. This relationship needs to be clearly understood by modelling SMEs prior to deciding what will be planned and performed.

Model Test

Test is Step 5 of the Quantitative Model Lifecycle Model identified in Figure 11. All quantitative models should undergo an appropriate level of testing prior to use. As a general guide the more complex the model the greater the time and effort required to “Validate and Verify” (V&V). The need for V&V is included within the Modelling Plan.

In September 2014, the UK Treasury issued instructions to all Government departments regarding “Analytical Quality Assurance” also known as the AQuA Standard. The UK MOD are following this instruction. At the time of guidebook issue, the MOD Cost Assurance and Advisory Service lead governance on this topic and can be a point of contact for V&V advice and guidance. The definition of V&V below is from the AQuA Standard.

Validation - literally meaning to make valid, through the agreement of those judged competent to take such views. The central question that validation raises is the extent to which the right work is being engaged in, given the purpose and constraints placed upon that work. The key output from the validation process is a judgment, based on evidence, concerning the extent to which the work is 'fit for purpose’.

Verification - is concerned with the extent to which the work that has been agreed to is being done in the 'right' or 'accepted' way, given the 'art of the possible'. The key output from the verification process is a judgment, based on evidence, concerning the extent to which the agreed work has been conducted appropriately.

Benefits

The ultimate objective of modelling is to understand potential support performance, cost, and risk by providing substantiated information which will aid informed decision making about either establishing a new support system, improving an existing support system or withdrawal. Modelling output creates a narrative about why things happen, and what might happen, which is used to inform and explain a decision. In addition, the main benefits associated with support modelling as addressed in this guidebook are as follows.

- Build confidence between stakeholder communities in the potential or actual support system solution.
- Optimise the support system solution or operation.
- Provide clarity and insight of the support system scope and operation.
- Help with identifying and proving performance and value indicators.
- Reduce Cost and Risk.
- Support continuous improvement.

Timeline

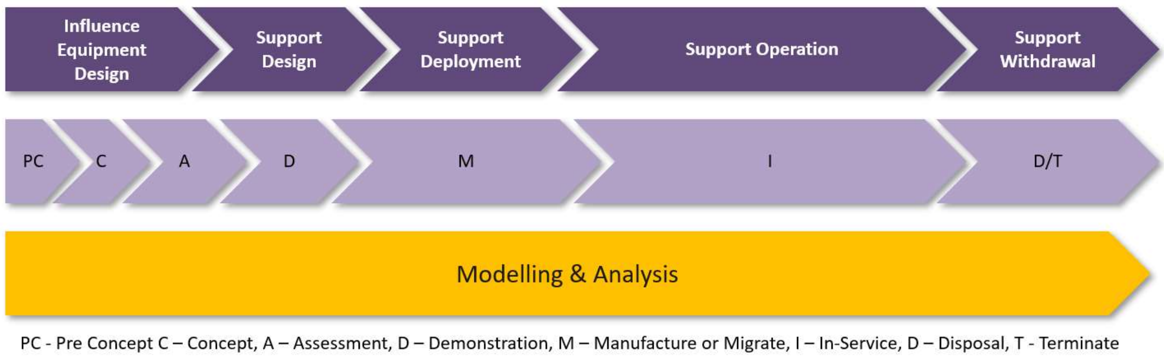


Figure 14 Modelling & Analysis Timeline

As simplistically illustrated in Figure 14, support modelling is appropriate throughout the equipment lifecycle. This is because it supports decision making at all lifecycle stages. Modelling should be considered and planned from the very beginning of any equipment or service programme.

There are however different types of modelling performed within the different lifecycle phases. For example, a part of Supportability Analysis is focused on influencing equipment design to ensure development of a 'supportable' product. This modelling would have to be performed when the equipment design is developing and is a part of the design process. This type of modelling would not be appropriate for an off the shelf equipment purchase. However, modelling the support operation and cost of such an equipment would be appropriate for this type of procurement.

Whilst Figure 14 has been illustrated as a straight -line process, it should be recognised that given the extended life of major defence equipment (often over 50 years from Concept to Retirement / Disposal), major elements of modelling will be revisited often during an equipment's life.

To support "Continuous Improvement" modelling capability is maintained throughout the in-service phase to model potential support enhancements and cost reduction opportunities.

On major projects an independent in-service assessment (Forecasting and Resource Planning and Supportability Audit) of project performance is performed. Pilot projects utilising this assessment have identified significant support performance improvements and cost savings.

Responsibility

Industry is responsible for equipment design supportability modelling. It is also often responsible, either directly or on behalf of the MOD, for modelling to determine optimum maintenance such as level of repair and reliability centred maintenance analysis. Other support modelling activities could be performed by industry or the MOD.

Responsibility is directed by the type of support arrangement being planned for the equipment i.e., organic or some level of support outsourcing. The intended support arrangement will determine who is responsible for the whole or elements of the support operation. For example, the outsourcing of parts or all of support to industry, via a long-term performance-based availability or capability contract, means industry is contractually responsible for large parts of the support operation with the MOD potentially responsible for 'Forward' support (under an availability contract) or receipt of an output or outcome.

In availability and capability contracts industry is responsible for the whole or most of the support design modelling. This is to ensure industry fully understands how its support operation will work and would include support operation, economic and risk modelling.

In an availability contracting situation the MOD would be responsible for modelling of the Forward support operation.

The MOD may use outputs from industry modelling to gain assurance the proposed industry support will provide the level of service required. This may include the MOD performing its own modelling at an appropriate level.

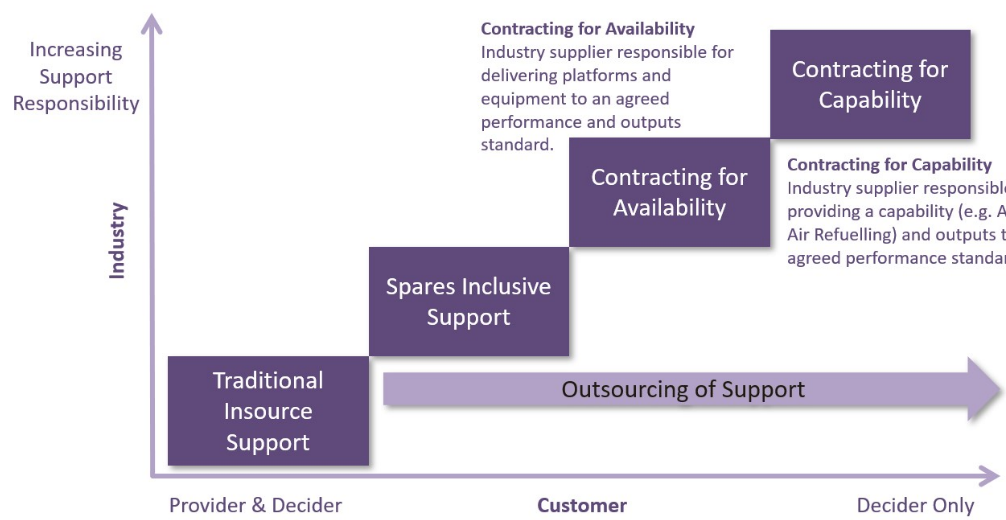


Figure 15 Support Options Matrix Elements and Support Outsourcing

The Support Options Matrix (SOM) is the UK MOD framework which provides a structure for a range of support options from traditional insource support to outsourced capability contracting. The top-level elements of the SOM are identified in Figure 15. The further to the right in the SOM framework the higher the risk transfer from the MOD to industry and thus more extensive modelling is performed by industry to understand and manage risk.

If over the lifecycle there is a change in support responsibility, such as closing an availability contract and shifting support ownership to a service organisation, responsibility for modelling would also need to transfer as appropriate.

Management

There are many factors to consider when contemplating or planning for modelling activity. This includes but is not limited to the following.

- Equipment and support operation complexity and level of cost.
- Equipment life cycle stage.
- The type of support arrangement.
- Techniques, standards, and tools.
- Management activities such as the collation of business questions.
- Model development effort, cost and likely return on investment.
- Project timeline and likely impact of modelling and analysis.
- Availability of model development and use competence.

The who, what, where, when and how of modelling is an important management activity and a key part of any project. If the equipment size, value, and complexity are high this will justify a range of modelling activity which must be appropriately managed and integrated into the project organisation. On larger projects there may be a Modelling Manager, or this may be the responsibility of a Service or Support Solution Architect. Whichever the role, this individual must be suitably qualified and will be responsible for the development and use of the Modelling Plan.

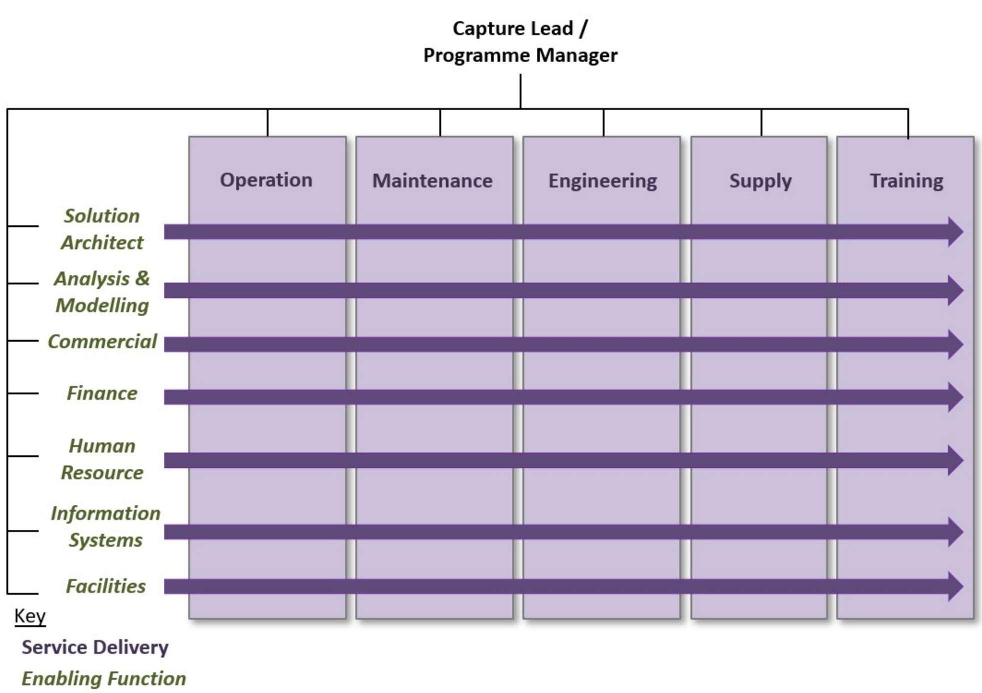


Figure 16 Example Project Organisation

Figure 16 provides an example of a support project organisation with the Solution Architect and the Analysis and Modelling as enabling functions which support the service delivery functions. This example organisation would be appropriate for large projects. This is particularly at the support design phase where the solution architect takes prominent role.

Advice & Guidance

As identified in this guidebook, some modelling techniques and tools can be complex, and their implementation requires expertise. If you are seeking to use a modelling technique or tool and you would like advice or guidance this can be obtained from a modelling SMEs or the TDI Supportability Modelling and Analysis Working Group. The group can be contacted via the TDI website (www.teamdefence.info).

Annex A Example Support Operation Simulation Model

As quantitative models contain proprietary data, it is not possible to share a real model and related outputs in this document. This annex therefore provides an example demonstrator support simulation model with modified or redacted data. The original model addressed a range of military vehicle fleets and their utilisation over time.

Business Questions

A summary of the business questions for the model were:

- What are the viable options of vehicle mix in different locations?
- What is the planned and unplanned maintenance impact on operational availability?
- What is the quantity and cost of spares and repairs over time?

Model

To address the business questions, it was decided to use a simulation software tool and establish a model which would provide both a visualisation of situational change over time and selected associated data outputs. Use of this type of model aids 'what if' and change analysis providing statistical confidence.

Data

The data included operational plans, equipment configurations (including failure predictions and maintenance data) and supply data. It also included comparative cost data for repairs and spare parts.

Item Reference Number	Part Description	Repairable	%RSR	Arising Rate	Spare Cost (£k)	Repair Cost (£k)	Initial spare %
1	Engine	Y	95	10000	22	5.5	4
2	Engine Control Unit	Y	90	15000	8	1.6	3
3	Gearbox	Y	85	20000	12	4.8	2
4	Front Axle	Y	90	10000	4	2	4
5	Rear Axle	Y	90	8000	4	2	5
6	Sighting System	Y	75	6000	5	0.75	6
7	Gun Control Unit	Y	90	6000	16	3.2	6
8	Fuel Pump	Y	95	12000	2	1.5	3
9	Alternator Assy	Y	95	15000	5	2	3
10	Washer Wiper Control Unit	Y	95	4000	10	2	9
11	Display & Control Module	Y	90	10000	10	1.5	4
12	Display & Control Assy	Y	90	12000	8	4	3
13	Distribution Box	N	0	19000	2.5	0	2
14	Cable Harness Assy	N	0	40000	3	0	1
15	Bonnet	N	0	5000	4	0	8
16	Shock Absorber Rear	N	0	5000	2	0	8
17	Shock Absorber Front	N	0	5000	2	0	8
18	Windscreen	N	0	3000	10	0	13
19	Rear Window	N	0	7000	5	0	5
20	Side Door Window	N	0	7000	5	0	5

Figure A1 Spare Parts Data

For the demonstrator model the real data was reduced in size with the data changed to fictitious values. Figure A1 is a summary of the spare parts input data. This includes data such as percentage Repair Survival Rates (%RSR), predicted failure rate (Arising Rate) and an initial start-up spares quantity (Initial spares %).

Operational Profiles						
Fixed/Variable	Fixed	Fixed	Variable	Fixed	Fixed	Fixed
	Operation Duration (Days)	Frequency (per year)	Arisings (per day)	Fleet Size	Standard Operational Fleet Size	Min Operational Fleet Size
Location 1	30	5		175	140	75
Location 2	30	3		150	115	60
Location 3	30	1		50	40	20
UK Vehicle Store				145		
				520		

Fleet Size	
Vehicle Type 1	100
Vehicle Type 2	70
Vehicle Type 3	120
Vehicle Type 4	100
Vehicle Type 5	130
TOTAL	520

Forward Stock Levels		
Fixed	UK	10
Fixed	Location 2	50
Fixed	Overseas	20
Fixed	Depth Stock	200

Supply Chain Times		
Fixed	Time (Days)	Reverse Time (Days)
Supply to UK Stores	60	90
UK Stores to Location 2	30	60
UK Stores to Overseas Maintenance	30	120
UK Stores to UK Maintenance	20	30

Figure A2 Operations & Supply Data

Figure A2 identifies some of the operation and supply data with actual locations and vehicle types removed and replaced with generic data. For some of this data there is an option to input fixed or variable values. In this model, when variable is selected, stochastic mathematics is used to randomise values. This is often described as ‘Monti Carlo’ simulation.

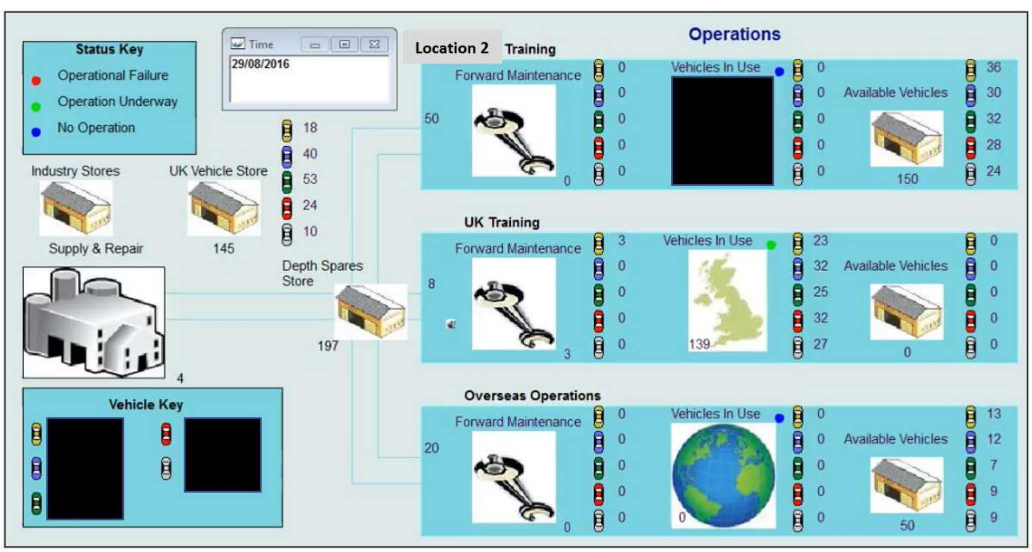


Figure A3 Top-Level of the Simulation Model

Figure A3 is a screenshot of the simulation model top-level. This can be viewed as the simulation is running. As can be seen in Figure A3, parts of the model view are redacted (black oblongs) to hide specific project related information.

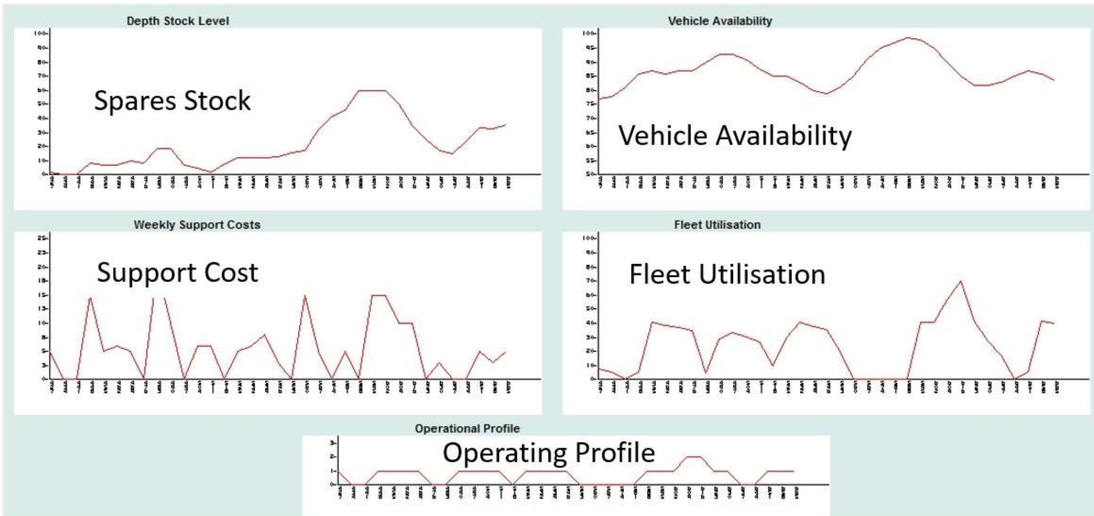


Figure A4 Simulation Model Metrics

Figure A4 is also a view available as the simulation model as it is running. This view is focused on five specific metrics identifying what is happening as the modelling is performing its calculations using is mathematic formula and the input data. At the end of a model run there are further outputs which provide detail of the outcome. This includes identification of the specific spares used, repairs performed, fleet availability achieved and costs for various areas such as spares and repairs.

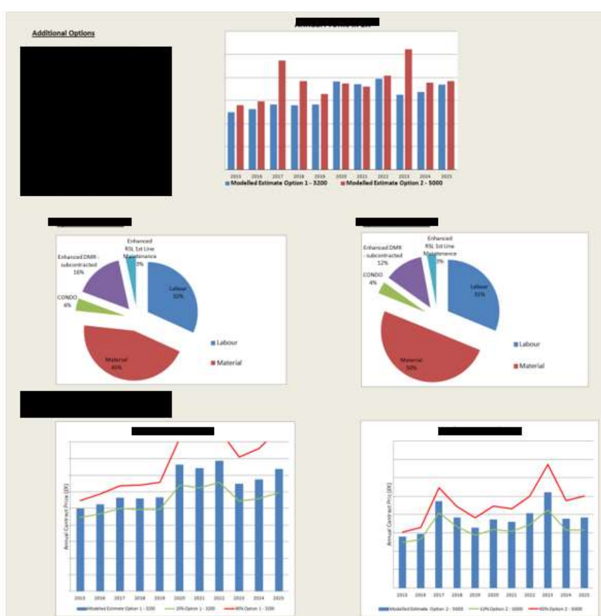


Figure A5 Example Presentation of Model Data Output

Figure A5 provides an example of how model data is presented. In the example model data is taken from the simulation tool into a Microsoft Excel spreadsheet where it can be manipulated and input to Power BI. Power BI is then used to present the data. Other tools could be used to perform this activity.

The intention of the information in this annex is to provide an insight about the sorts of quantitative modelling the guidebook addresses. Again, due to the nature of these types of model, it is not possible to provide exact details of how this works. If you are interested in obtaining more detailed information about any of the modelling addressed in this guidebook, please contact the TDI Supportability Modelling and Analysis Working Group via the TDI web site.

Annex B Model Development Lifecycle Stages

This annex contains a brief description of each of the quantitative model development lifecycle stages identified in Figure 11 . This process is applicable to the modification of an existing model or development of a new model. This is to identify, confirm and agree the depth and breadth of the model, the "Model Development Life Cycle". The first three stages of the lifecycle are also known as Concept of Analysis (CofA).

Scope

This initial stage assesses model requirements, i.e., the nature, scale and complexity of the model required. This is a critical stage in development because it will significantly impact on the nature of the modelling required, e.g., if human resource is to be included or if platforms are to be modelled by individual equipment.

Such decisions are fundamental and require a good understanding of the outcome required of the model and the vision for achieving it. Issues to be considered at this stage are;

- Business Questions and required outputs
- Model inclusions and exclusions
- Level of detail in the input and logical assumptions
- Understanding how the model will work
- Levels of Flexibility and Adaptability
- Estimating the time and resource required to develop the model
- Who will use the model and their modelling competence?

The time and effort expended on developing the model scope will be dependent on; the type of model, complexity and the significance of the decisions it will support.

Another consideration at the scoping stage is how the model will be tested. This includes the testing approach and testing time and effort. For complex models a Test Plan should be established and further enhanced as the model development stages are performed.

Specify

To specify is to define the logic of the model in sufficient detail to provide an unambiguous statement of how the results will be calculated. In order to ensure the required outputs are achieved, the inputs and the model logic should be agreed.

It is possible to specify by 'input' e.g. detailed functional requirements or by 'output' e.g. what the model should achieve. There is also the issue of 'requirement creep' and the problem that in many cases the model requirements are not clear at the outset. This is often because the recipient of the modelling output is not sure exactly what is required at a detailed level and has limited knowledge of modelling capabilities. When this is the case, it is important to establish a specification that has some flexibility. This specification and the model will develop as the modeller and recipient establish a better understanding of requirements and modelling capability.

As with the model scope, the time and effort expended on developing the specification will be dependent on the type of model, complexity and the significance of the decisions it will support. For complex models, such as those used to design a supply chain, a specification document can be 30 to 40 pages. For simpler models it could be a few pages.

Design

The model design process will be directed by the technique(s) and software being used. A spread sheet model design is perhaps the most flexible because third-party software tools often dictate the structure and content of the model. Whichever software is planned the design needs to determine the most effective structure for the model considering aspects such as configuration / version control, assumptions control, required scenarios and flexibility.

The model designer should also consider ease of use. A good design can make the model easy to use, whilst a clear specification will explain how the model works. There should be a focus on the important issues. Spending time on the model scope will make sure the model answers the right questions. Ease of user understanding is important and helped by the use of good design and build techniques.

Build

The build stage is where the construction of the model takes place and, as with design, will be directed by the technique(s) and software being used. It is a common error to commence this stage before its predecessors have been properly completed. This can lead to;

- A model that is more complex than originally expected and takes longer to build
- Assumptions being made that were not part of the original brief
- A lack of common understanding about what the model is doing.

Prior to model creation a detailed technical review should take place which will assess the proposed model design. This will determine whether the design is acceptable in terms of requirements and specifications and will produce answers to the questions posed.

Test

Model testing should root out errors and inconsistencies and increase confidence in the model outputs. Model testing should be performed in accordance with the model test plan. There are different levels of testing some of which can be done by the model builder with others being performed by an independent person. Testing can also include model users and users of model outputs.

Use

The model user may be an individual working within a bid team or a specialist analyst/modeller. To realise the usefulness of a model, the modeller needs to understand how to;

- Present useful information to help make decisions
- Present sensitivities and scenarios to understand the important drivers in the business
- Control the evolution of the model when changes are required.

There may be many instances of using the model before changing circumstances or requirements necessitate re-examination of the scope.

Annex C Acronyms

AQuA	Analytical Quality Assurance
DAMA	Data Management Association
LCIA	Logistics Coherence Information Architecture
MDAL	Master Data and Assumptions List
MOD	Ministry of Defence
SME	Subject Matter Expert
SOM	Support Options Matrix
TDI	Team Defence Information
V&V	Validation and Verification