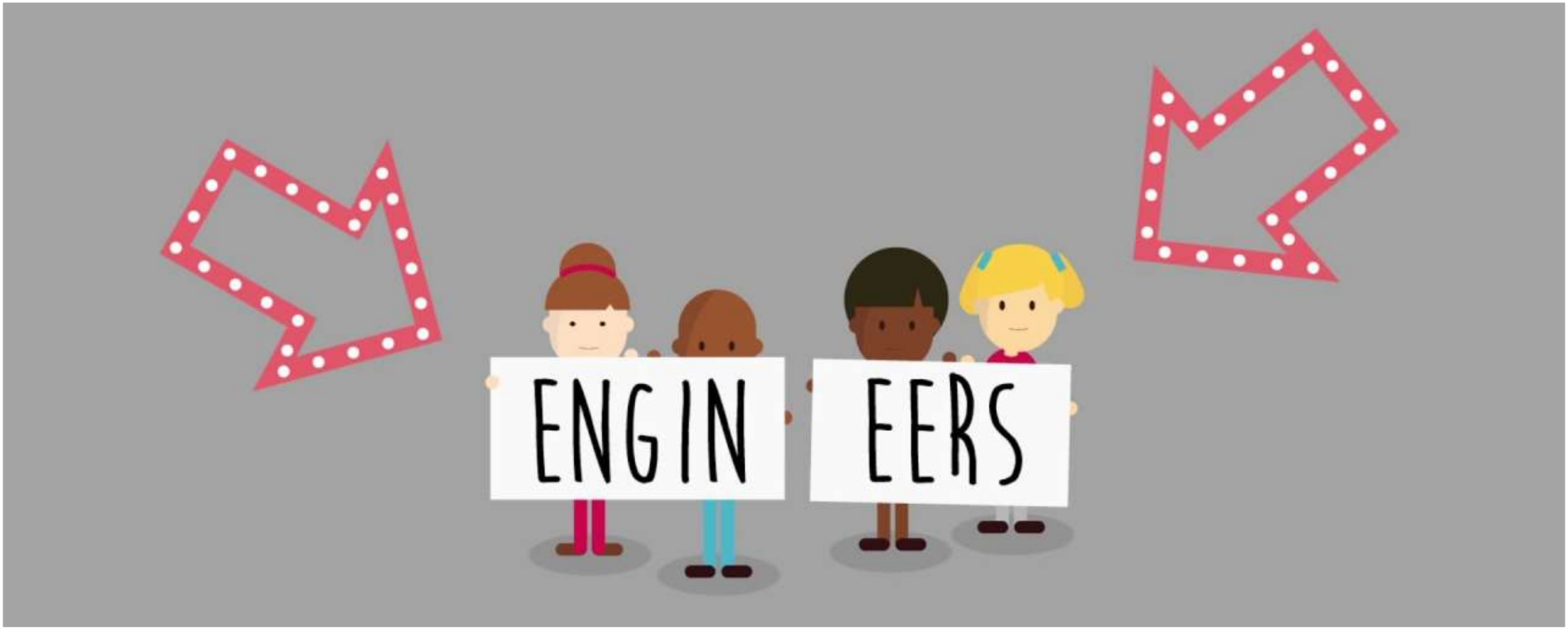
The following presentation was given at:

SCAF Workshop
"Mind the Gap: The Cost of Replacing Capabilities"

Tuesday 5th February 2019
The Royal United Services Institute, London



Workforce Planning

A Systems Dynamics Approach

What to expect

One of the core processes involved in providing military capability is the acquisition and maintenance of fighting equipment.

We often discuss the cost of equipment programmes, but programme delivery is predicated on sustaining a workforce with the necessary engineering capability.

Engineering capability can be modelled as an ecosystem where the rate of recruitment (births), the rate of development (growth) and the rate of retirement (deaths) need to be balanced in order to satisfy a demand signal.

Using a case study, we will describe a systems dynamics approach to understanding engineering capability based on a workforce ecosystem. We will show how this model can be used to examine the challenges relating to the supply of engineering capability underpinned by suitably qualified and experienced personnel and responding to a changing demand signal.

Model architecture

Demand

- Programme and project information
- Project resource assumptions
- Consolidated resource requirements

Allocation

- Flexible allocation
- Reporting (Demand, Supply, satisfaction of demand and resource utilisation)

Supply

- Resource profiles
- Recruitment
- Development
- Leavers
- Retirees

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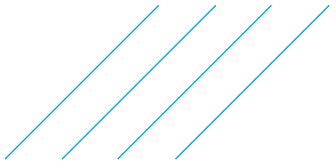

Format of this presentation

Preamble

Engineering Skills Framework

Workforce Planning Model

Future Developments

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Preamble

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In this section

Preamble

- What is military capability and how is it generated
- Acquiring and maintaining fighting equipment
- Systems dynamics

Engineering Skills Framework

Workforce Planning Model

Future Developments

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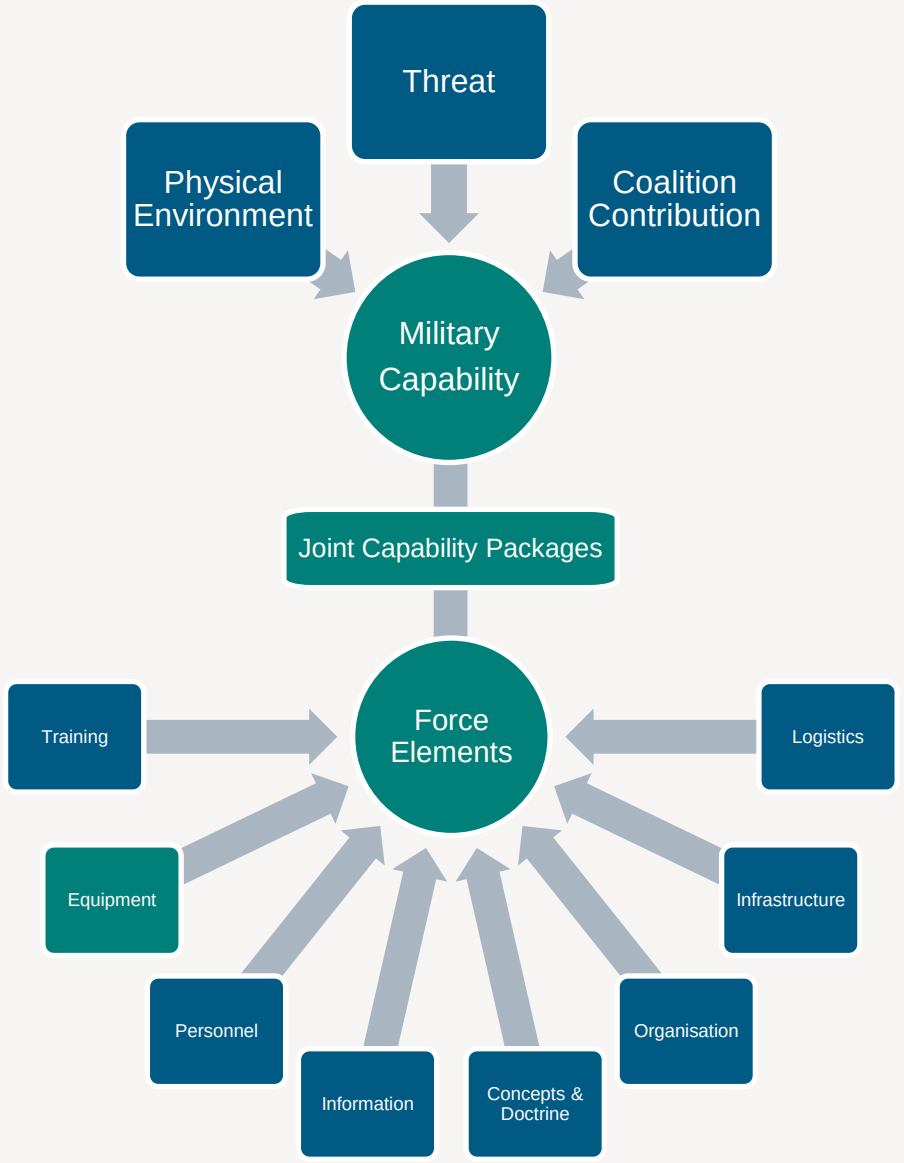
What is military capability

Military capability is the enduring ability to achieve a desired operational outcome or effect, and is relative to the threat, physical environment and the contributions of coalition partners.

Capability is made up of force elements (ships, aircraft, Army formations, other military units and force enablers) combined into packages by joint force commanders, and tailored for particular operations or missions.

Each force element is provided by one of the single Services or a joint organisation, and requires the integration of the eight Defence lines of development: personnel, training, equipment, logistics, information, infrastructure, concepts and doctrine and organisation.



How is military capability generated?

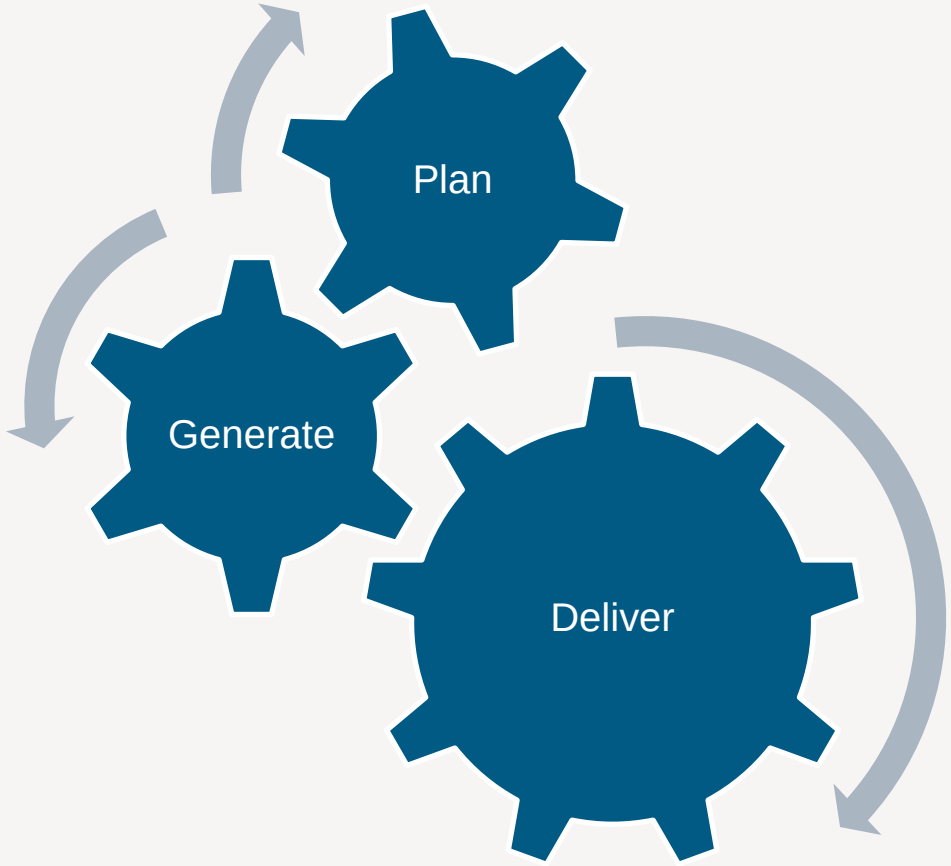
The core processes involved in providing military capability are:

recruiting and supporting military personnel;

training individuals, units, tactical formations, joint formations, and joint and combined forces;

acquiring and maintaining fighting equipment; and

providing the support services required to deliver operational success.



Acquiring and maintaining fighting equipment

Defence Equipment and Support acquires and supports through-life equipment and services as part of its core programme and to meet urgent operational requirements.

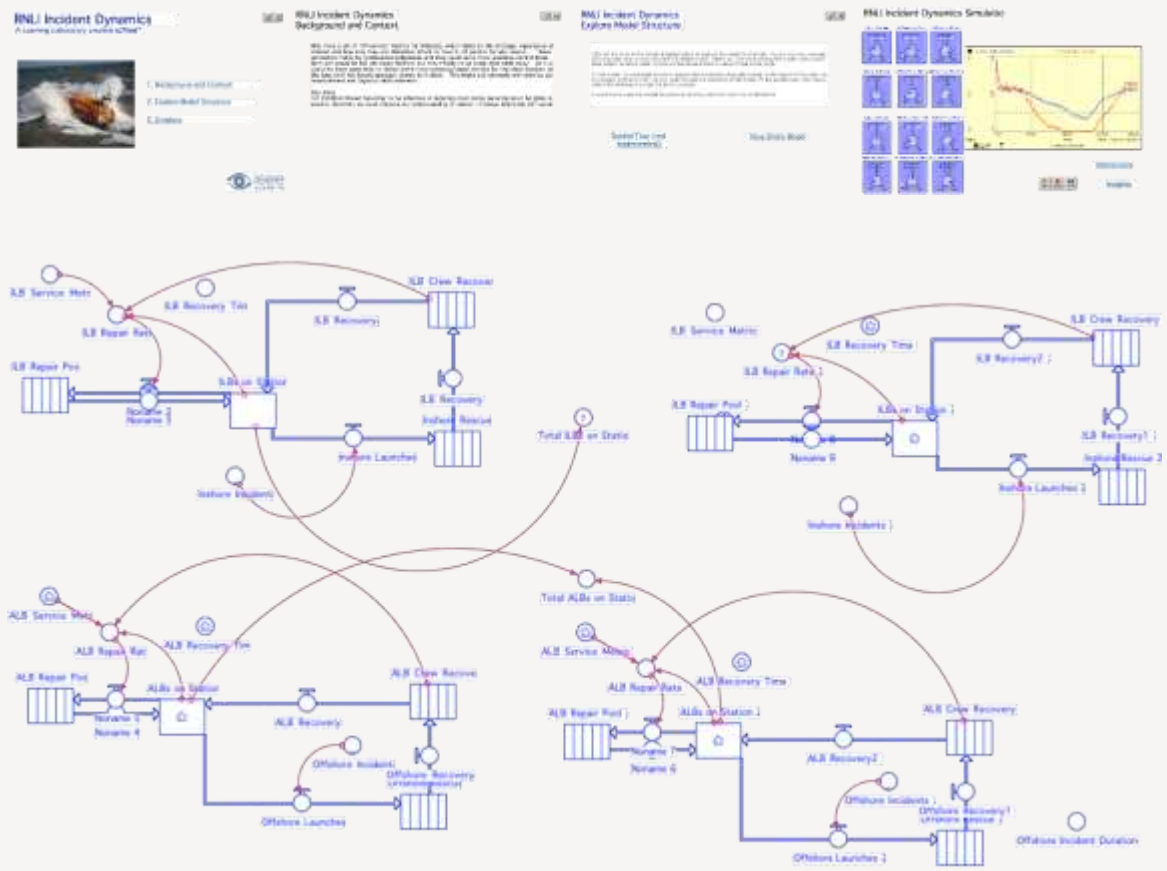
As well as sustaining the UK's Armed Forces with the delivery of materiel and the movement of personnel worldwide, it is also responsible for HM Naval Bases and the British Forces Post Office. It works closely with industry to seek and deliver effective solutions for Defence.

System Dynamics

System dynamics (SD) is a way of visually representing complex systems and how the different elements relate to each other.

The approach allows the relationships between different factors (cause, effect, impact, outcomes) to be explored over time.

SD has been widely applied as a problem solving tool across a range of disciplines from workforce planning to financial modelling.



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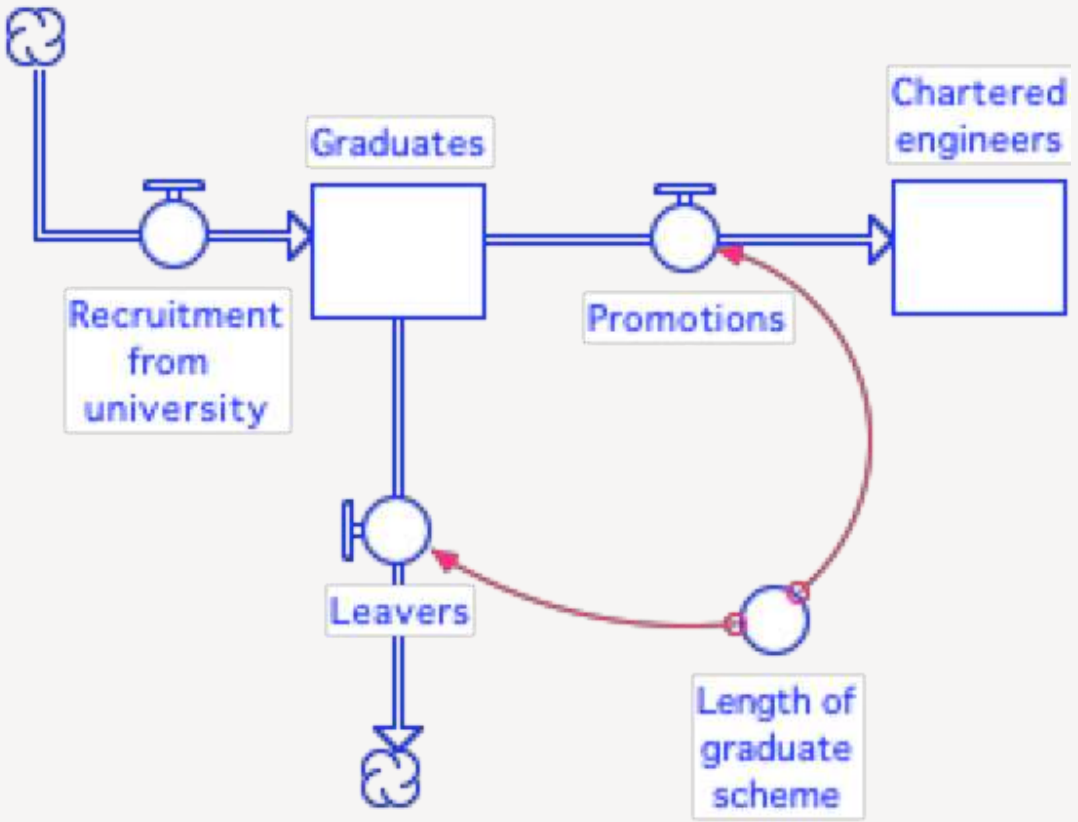
System Dynamics

Systems dynamics models are based on a series of “stocks” and “flows”.

A “stock” is a quantity that either grows or depletes over time – e.g. Graduates or Chartered engineers.

A “flow” is a connector that drives the increase or decrease – e.g. Graduate recruitment / leavers / promotions.

All ”flows” are controlled by equations that are driven by user assumptions and model conditions e.g. Length of graduate scheme.



Tool selection

iThink / Stella is a systems dynamics software program produced by ISEE systems.

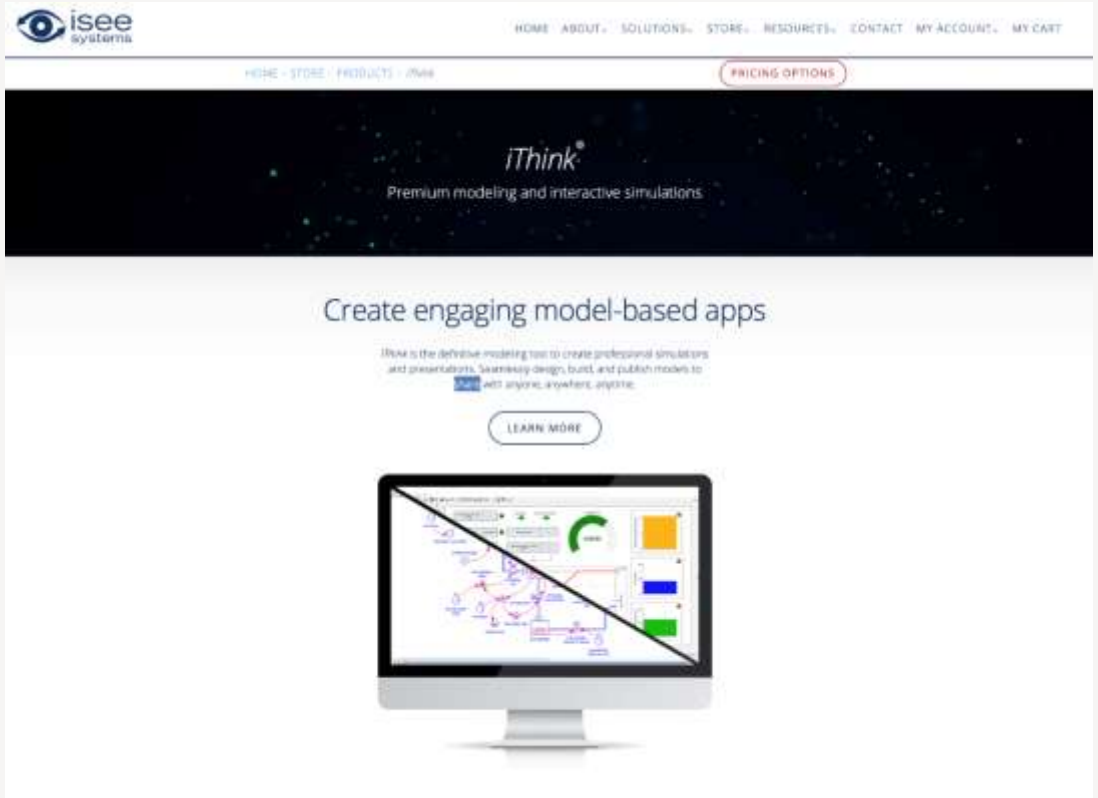
It follows SD principles and uses stocks and flows to enable the modelling of systems

Further information about the tool can be found on the ISEE website:

https://www.iseesystems.com/

A number of useful example models have been published on the ISEE website and can be accessed at:

http://xmile.iseesystems.com/



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Engineering Skills Framework

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In this section

Preamble

Engineering Skills Framework

- Describing the Engineering Skill Framework
- Application of the Engineering Skills Framework for Work Force Planning

Workforce Planning Model

Future Developments

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Engineering resource definition

There are essentially two ways to define engineering Suitably Qualified and Experienced Personnel (SQEP).

SQEP1 (Standard) Roles are used as a proxy for engineering competence. If a person is deemed able to carry out a Standard Role it is assumed that they meet the minimum required skill levels (Aware/practitioner/expert) for their grade in the appropriate engineering competence.

SQEP2 (Domain) The allocation of resources to demands is not only a function of engineering experience and qualifications, it is also a function of the domain in which the engineer is operating, i.e. Aeronautical engineers cannot be expected to undertake naval architecture roles.

Engineering skills framework

The ESF defines a number of engineering life cycle based competence groups e.g. 'Understanding the Requirement' and competence areas e.g 'Requirements elicitation' together with indicators for levels of knowledge and experience e.g. Expert, Practitioner, Supervised Practitioner, Aware.

The ESF also defines a number of SQEP1 standard role definitions e.g. ‘Requirements Engineer’, that are a combination of competencies and the appropriate level of knowledge and experience.

The ESF also defines standard roles for governance roles (e.g. ‘Chief Engineer’) and generic roles (e.g. ‘Project Engineer’).

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Standard role grade mapping

A ‘Standard role’ is defined by a competence profile . All engineering posts at a particular grade can be classified into one of these roles – onto these domain and functional specialisms can be added.

Grade	Technical Dev. Partner	Principal Engineer	Head of Specialn	Chief Engineer	Senior Engineer	Project Engineer	In Service Engineer	Reqmnts Engineer	Domain Specialist	Functnal Specialist
1*	X	X								
B1	X	X	X	X						
B2			X	X	X	X	X	X	X	
C1					X	X	X	X	X	X
C2						X	X	X	X	X
D						X	X			X
Graduate								X		
Apprentice								X		

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Grads and Apprentices do not have a ‘role’ as such, therefore no engineering role type is identified.

Quantifying workforce competence

The C2 grade illustrates an extreme case representing a ‘multi-skilled’ work force. The C1 grade illustrates a more realistic example. Of 30 engineers, 22 can perform the PE role, 5 the RM role etc.

Grade	Number	TDP	Principal Engineer	Head of Specialn	Chief Engineer	Senior Engineer	Project Engineer	In Service Engineer	Reqmnts Engineer	Domain Specialist	Functnal Specialist
1*											
B1											
B2											
C1	30						22	5	10	5	3
C2	20						20	20	20	20	20
D											
Graduate											
Apprentice											

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Note the model does not show how the ‘competence units’ are mapped to an individual.

Rules for changing role on promotion

For all grade/roles up to C1
Roles are assigned on promotion to the next grade.

B2 grade/roles
B2 Heads of Specialisation (HoS) need to have been C1 Functional Specialists.

For grades B2 to 1*
B1 HoS needs to have been B2 HoS.
TDP 1* needs to have been TDP B1
TDP B1 needs to have been B2 Domain Sp.

Grade	Technical Dev. Partner	Principal Engineer	Head of Specialn	Chief Engineer	Senior Engineer	Project Engineer	In Service Engineer	Reqmnts Engineer	Domain Specialist	Functnal Specialist
1*	X	X								
B1	X	X	X	X						
B2			X	X	X	X	X	X	X	
C1					X	X	X	X	X	X
C2						X	X	X	X	X
D						X	X			X
Graduate						X				
Apprentice						X				

Colours highlightavailable career paths.

Relating ESF to WFP - demand and supply

Demand for Engineers

Projects will be carried out by project teams comprising a number of posts (including partial posts)

Each post will have a grade

Each post will be linked one standard role

Supply of Engineers

Each person will have a grade

Each person will be allocated to one or more standard roles, this will result in the creation of a “unit of competence” that can be used in the allocation routine.

Workforce Planning Model

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Contents

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Overview of Model

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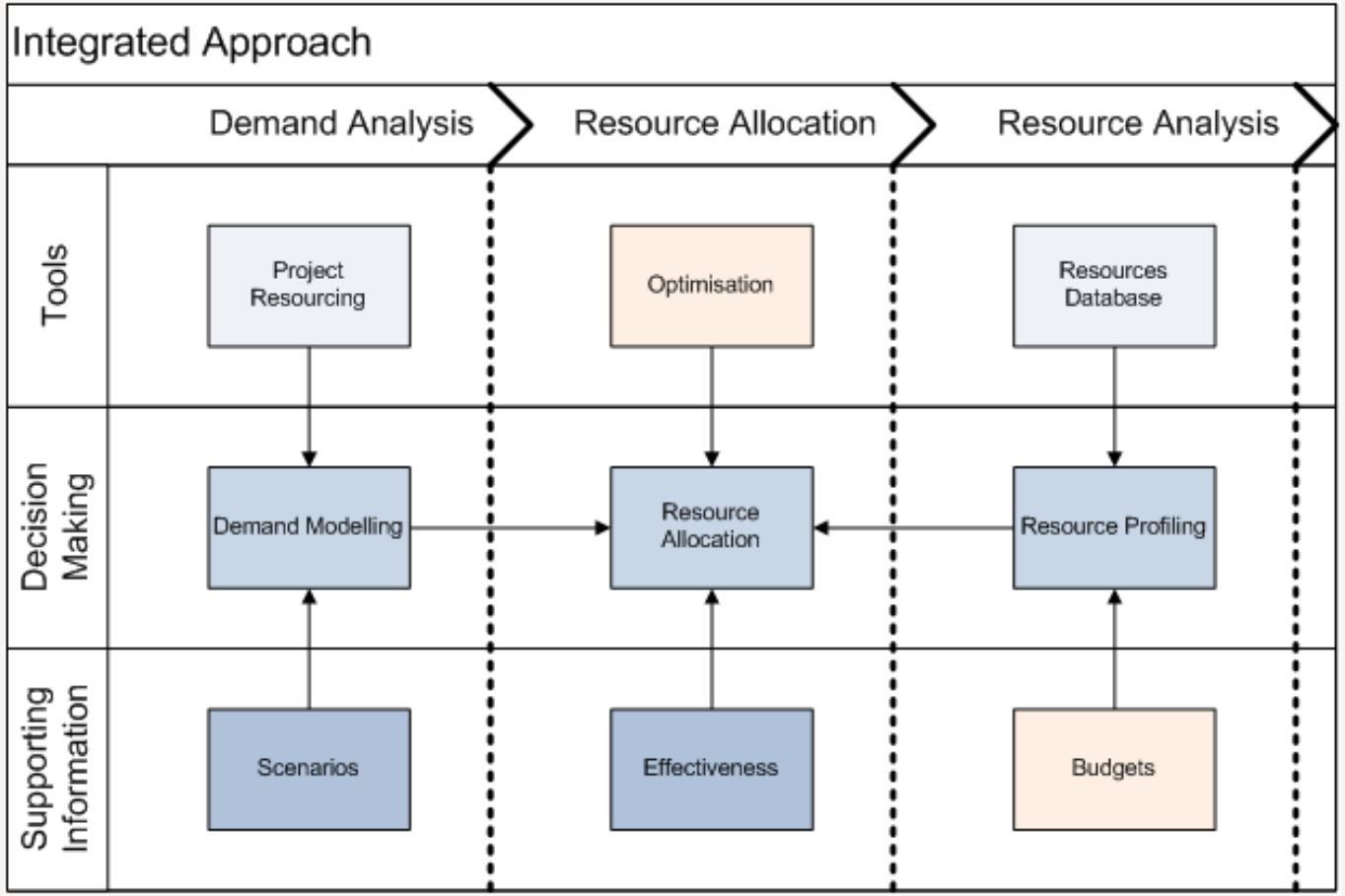
Decision making architecture



Suggested improvements

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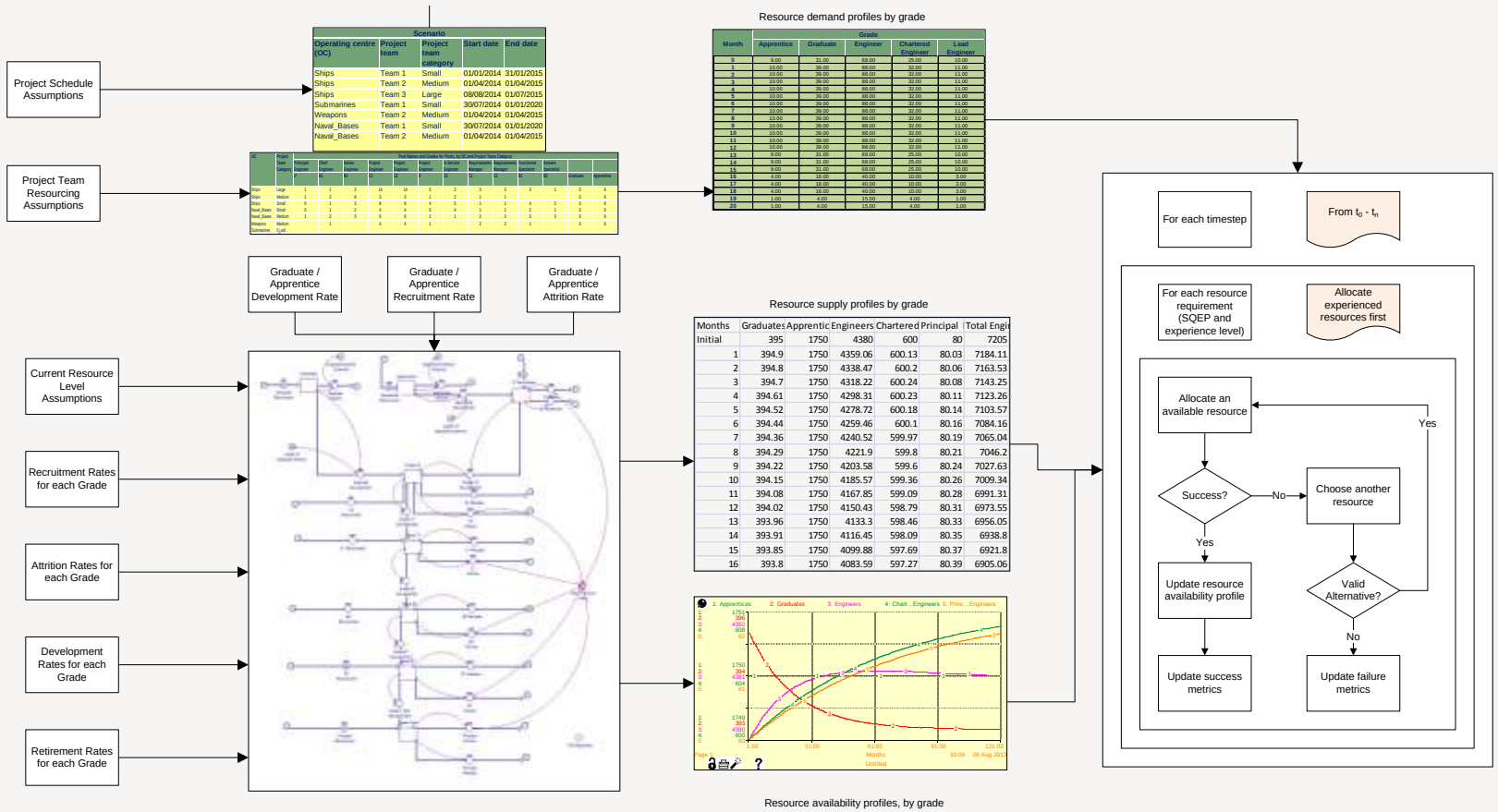
How it works

The **demand** generates a profile of resource demand for a period of 1 to 10 years starting at a user selected start date (including T0) using project resourcing rules and a user specified scenario (programme schedule).

The **supply** component generates a grade/role profile for a period of 1 to 10 years starting at a user selected start date (including T0) using an initial workforce and a set of user defined assumptions.

The **resource allocation** component takes demand & supply and uses rules to create an implicit resource schedule. Generates reports showing the satisfaction of demand and the utilisation of resources will be generated.

WFP – how it works... grade



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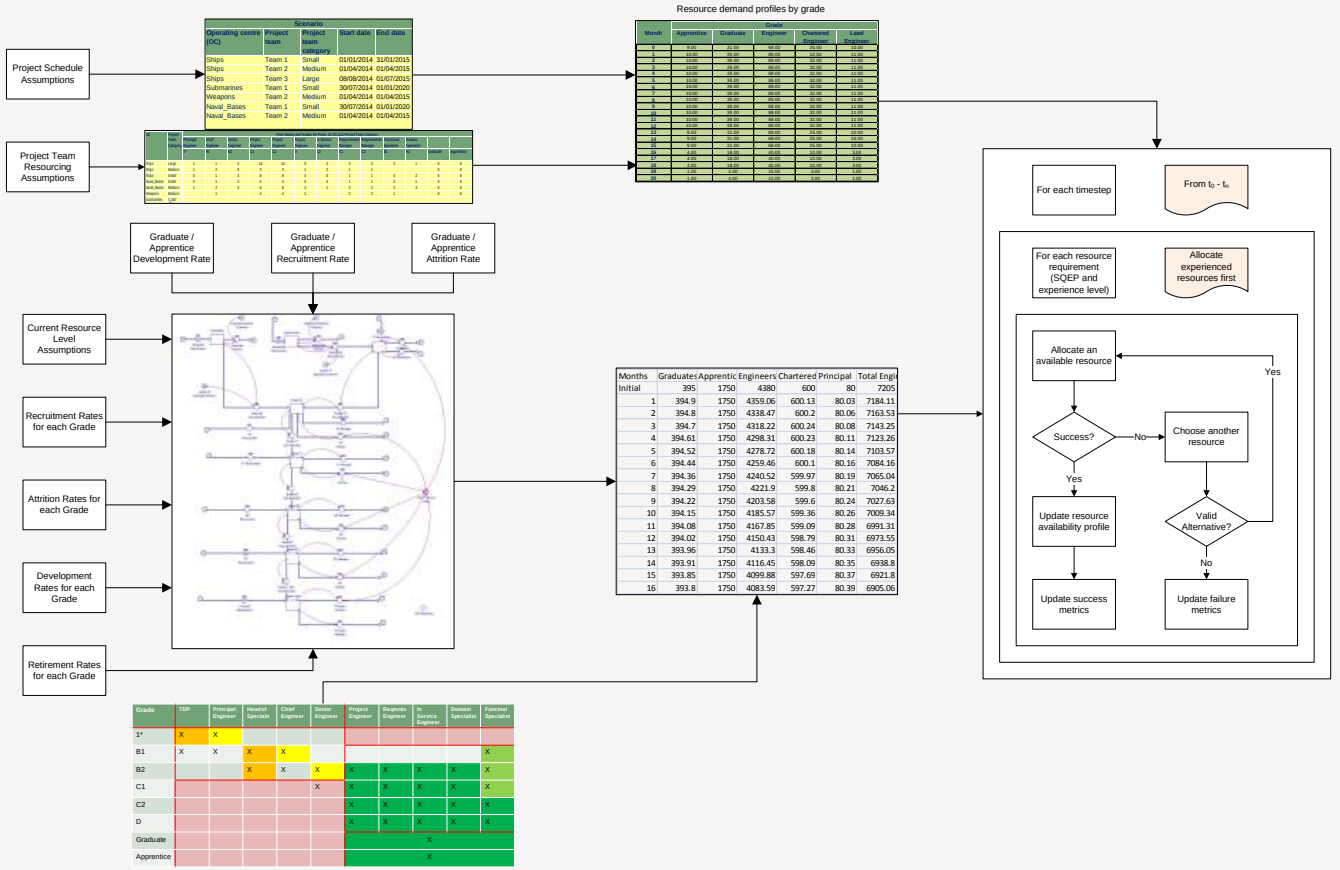
WFP – how it works... grade/roles



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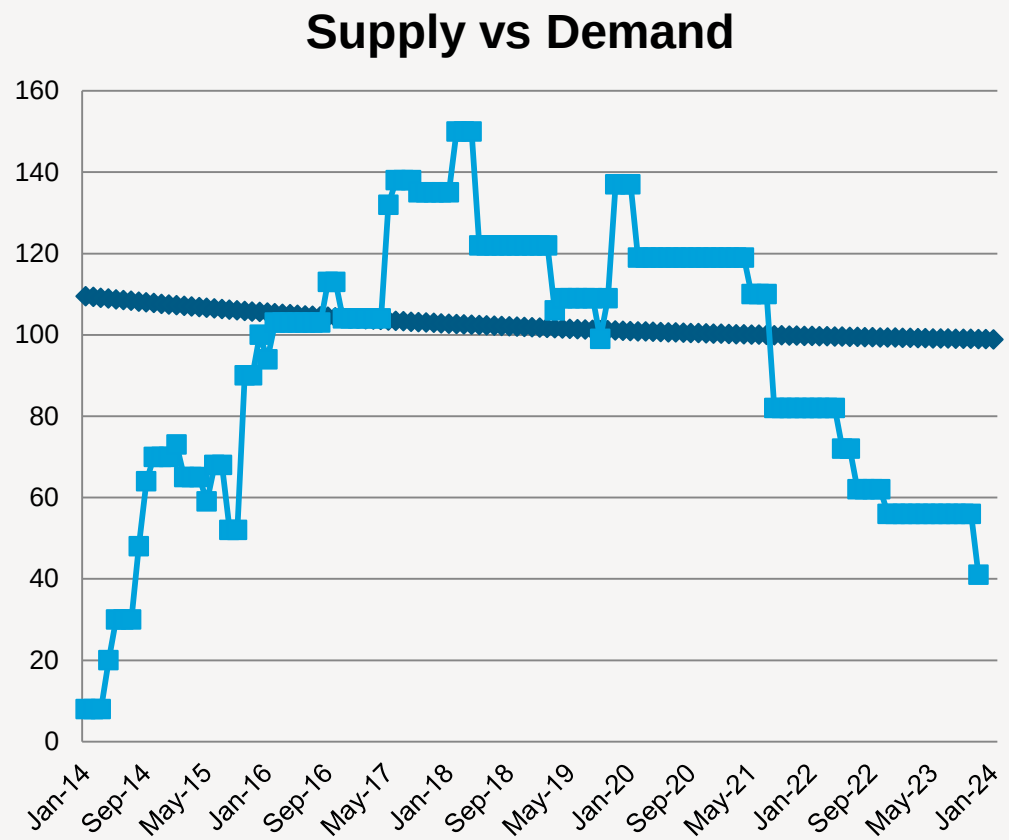
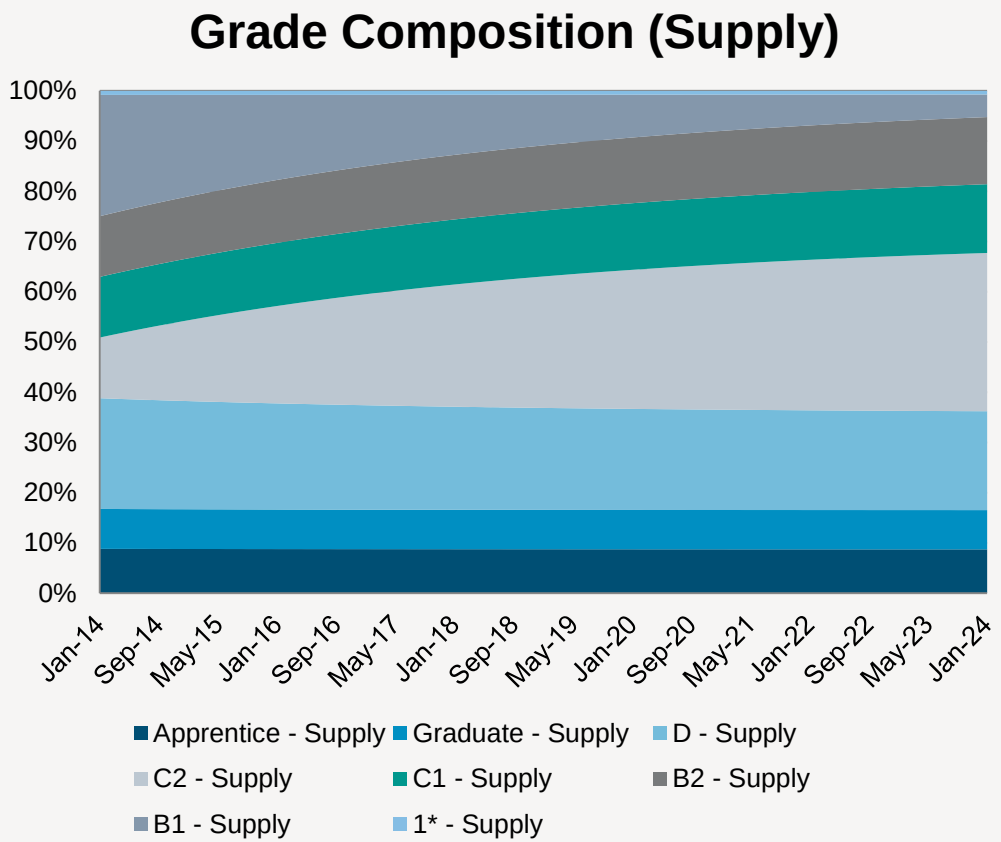
Example outputs





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Resource Demand Model

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Project resourcing assumptions

Each operating centre is asked to estimate the resource requirements (numbers, grades & SQEP1) for a selection of team types, for example:

- Platform procurement team – complex project, full CADMID cycle
- System procurement team – normal project, full CADMID cycle
- Business change project team – complex project, IT procurement CADMID cycle
- Infrastructure project team – simple project
- UOR team –simple project, reduced CADMID cycle
- Customer Support Team

For use in the model this was then further summarised into small, medium and large teams.

Example resource demand input

Subset of team post requirements with grades showing posts with different grades and grades with different posts.

OC	Project Team Category	Post Names and Grades for Posts, by OC and Project Tea							
		Principal Engineer	Chief Engineer	Senior Engineer	Project Engineer	Project Engineer	Project Engineer	In Service Engineer	Requirements Manager
		1*	B1	B2	C1	C2	D	C2	C1
Ships	Large	1	1	3	14	14	5	2	3
Ships	Medium	1	2	8	3	3	1	2	1
Ships	Small	0	1	3	8	8	4	5	1
Naval_Bases	Small	0	1	2	4	4	5	4	1
Naval_Bases	Medium	1	2	3	6	6	2	1	2
Weapons	Medium		1		4	4	1		2
Submarines	Small								

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Demand scenarios

A demand scenario for SQEP engineers can be created by considering a programme/project schedule that includes:

- Project domain (operating centre)
- Project complexity – complex, normal, simple
  - Or Project value (as a proxy for project complexity)
- Project phase (different phases in the CADMID cycle require different types of engineering input
- Project start and end dates

For use in the model this was then further summarised into small, medium and large teams.

Example scenario input

Programme scenarios will comprise a number of project teams of different sizes, start dates and end dates.

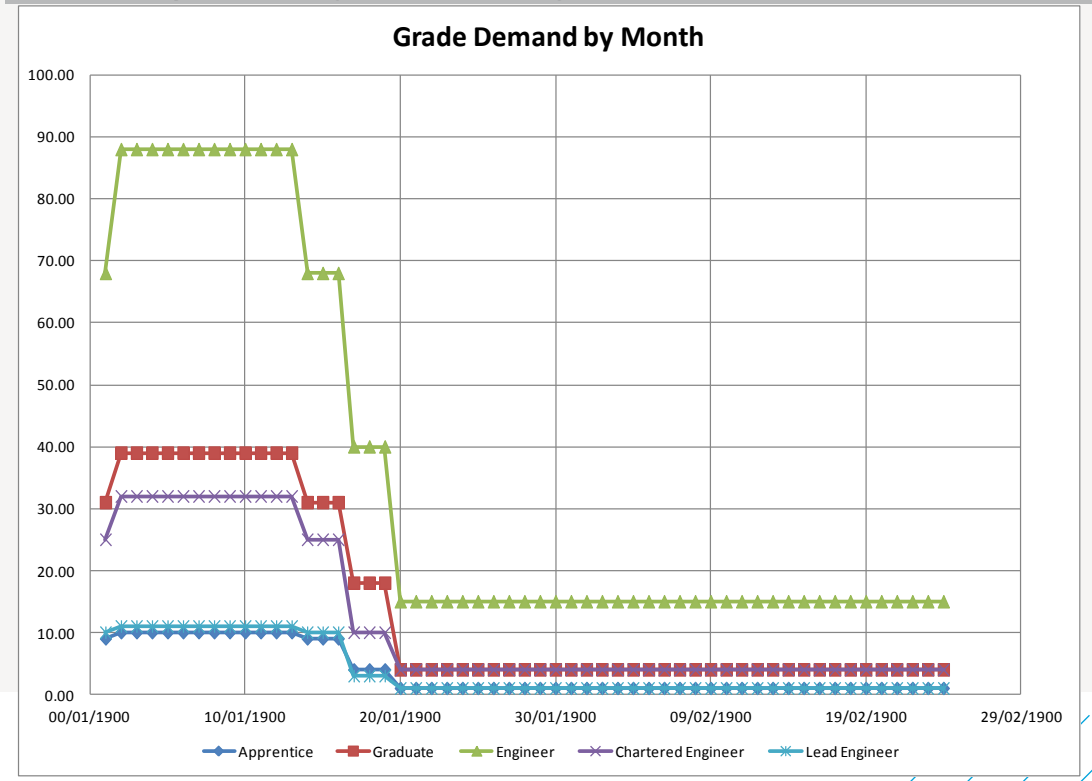
Scenario				
Operating centre (OC)	**Project team**	**Project team category**	**Start date**	**End date**
Ships	Team 1	Small	02/01/2014	31/01/2015
Ships	Team 2	Medium	01/04/2013	01/04/2015
Ships	Team 3	Large	08/08/2013	01/07/2015
Submarines	Team 1	Small	30/07/2013	01/01/2020
Weapons	Team 2	Medium	01/04/2013	01/04/2015
Naval_Bases	Team 1	Small	30/07/2013	01/01/2020

Example demand modelling outputs

A demand profile for each grade and for each of the template roles,

We could ask each of the operating centres to provide demand profiles, but this would not allow us to “test” our resource profiles by considering alternative scenarios.

Month	Grade				
	Apprentice	Graduate	Engineer	Chartered Engineer	Lead Engineer
0	9.00	31.00	68.00	25.00	10.00
1	10.00	39.00	88.00	32.00	11.00
2	10.00	39.00	88.00	32.00	11.00
3	10.00	39.00	88.00	32.00	11.00
4	10.00	39.00	88.00	32.00	11.00
5	10.00	39.00	88.00	32.00	11.00
6	10.00	39.00	88.00	32.00	11.00
7	10.00	39.00	88.00	32.00	11.00
8	10.00	39.00	88.00	32.00	11.00
9	10.00	39.00	88.00	32.00	11.00
10	10.00	39.00	88.00	32.00	11.00
11	10.00	39.00	88.00	32.00	11.00
12	10.00	39.00	88.00	32.00	11.00
13	9.00	31.00	68.00	25.00	10.00
14	9.00	31.00	68.00	25.00	10.00
15	9.00	31.00	68.00	25.00	10.00
16	4.00	18.00	40.00	10.00	3.00
17	4.00	18.00	40.00	10.00	3.00
18	4.00	18.00	40.00	10.00	3.00
19	1.00	4.00	15.00	4.00	1.00
20	1.00	4.00	15.00	4.00	1.00



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Resource Supply Model

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Supply modelling overview

Two “supply” models were implemented in order to address two specific sets of policy “levers”.

The grade profile model allows the user to investigate the impact of the following policies on the overall number of people in the selected population:

- Recruitment policies
- Retention policies
- Promotion policies

Once the policy assumptions are set the grade/role profile model allows the user to investigate the impact of engineering skills development policies such as:

- Up skilling
- Temporary promotions

Grade profile model

Assumptions

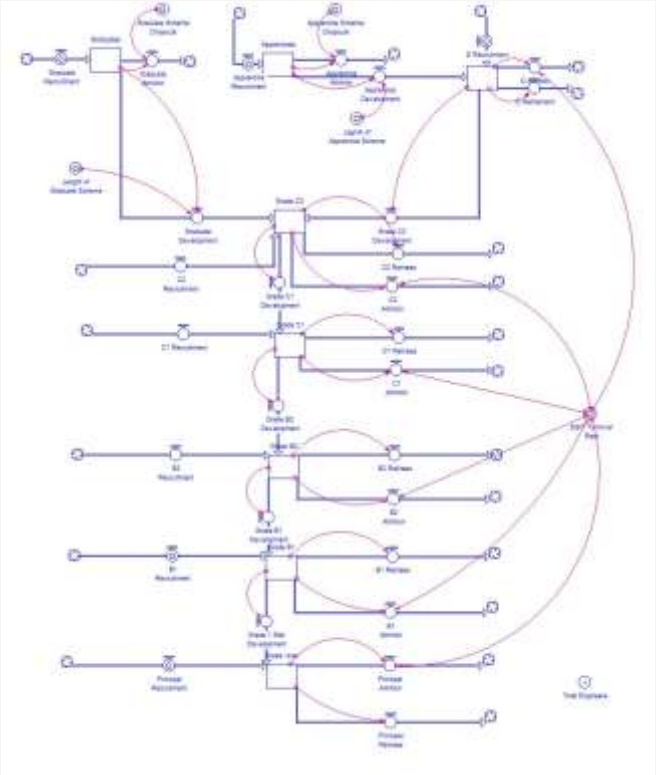
Pre-defined starting populations are set by the user.

The populations vary over time depending on the rate of inflows and outflows that are controlled by the user interface (control knobs).

For basic users a single set of rates is used, and some of the rates are either “fixed” or the same value is used for all populations (e.g. Attrition rate)

The model allows advanced users to vary the all rates used in the simulation on an annual basis

Model schematic



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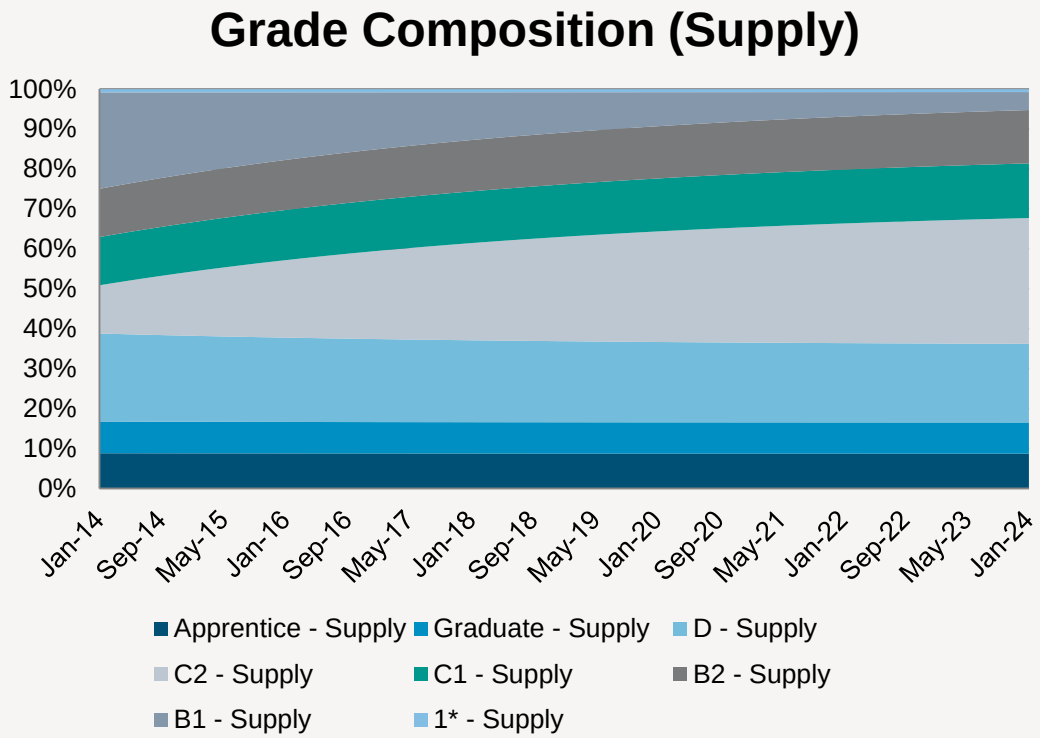
Grade profile model - outputs

Resource profiles for each grade, showing the profile of resource availability over time

Months	Graduates	Apprentic	Engineers	Chartered	Principal	Total Engi
Initial	395	1750	4380	600	80	7205
1	394.9	1750	4359.06	600.13	80.03	7184.11
2	394.8	1750	4338.47	600.2	80.06	7163.53
3	394.7	1750	4318.22	600.24	80.08	7143.25
4	394.61	1750	4298.31	600.23	80.11	7123.26
5	394.52	1750	4278.72	600.18	80.14	7103.57
6	394.44	1750	4259.46	600.1	80.16	7084.16
7	394.36	1750	4240.52	599.97	80.19	7065.04
8	394.29	1750	4221.9	599.8	80.21	7046.2
9	394.22	1750	4203.58	599.6	80.24	7027.63
10	394.15	1750	4185.57	599.36	80.26	7009.34
11	394.08	1750	4167.85	599.09	80.28	6991.31
12	394.02	1750	4150.43	598.79	80.31	6973.55
13	393.96	1750	4133.3	598.46	80.33	6956.05
14	393.91	1750	4116.45	598.09	80.35	6938.8
15	393.85	1750	4099.88	597.69	80.37	6921.8
16	393.8	1750	4083.59	597.27	80.39	6905.06



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Grade/role profile model

Assumptions

Role/grades are expressed in terms of a SQEP capability, this means that the total SQEP capability may exceed the headcount. However, if there is an issue with people not being SQEP then the total SQEP capability may be less than the headcount.

At each time step of the model the number of staff in the population is multiplied by the appropriate % to give a total SQEP capacity.

Graduate and apprentices are not differentiated by role.

Role allocation matrix

Grade	TDP	Principal Engineer	Head of Specialn	Chief Engineer	Senior Engineer	Project Engineer	Reqmnts Engineer	In Service Engineer	Domain Specialist	Functnal Specialist
1*	X	X								
B1	X	X	X	X						X
B2			X	X	X	X	X	X	X	X
C1					X	X	X	X	X	X
C2						X	X	X	X	X
D						X	X	X	X	X
Graduate						X				
Apprentice						X				

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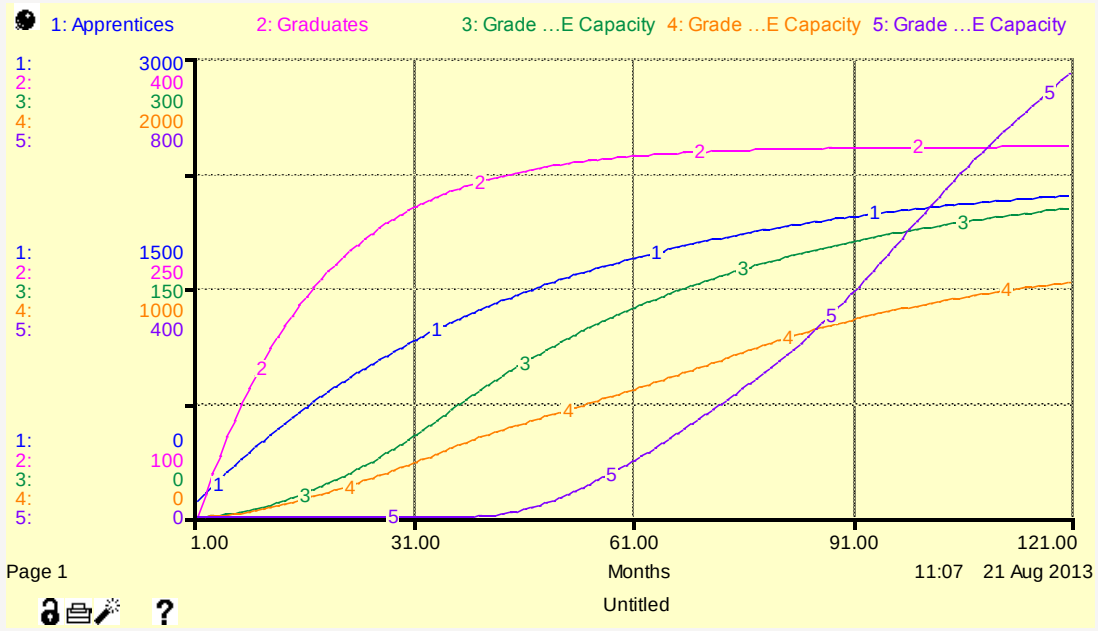
Grade/role profile model – outputs

Capacity for each grade/role combination, showing the profile of competence over time

Months	Apprentices	Graduates	Grade D PE Capacity	Grade C2 PE Capacity	Grade C1 PE Capacity	Grade B2 PE Capacity
Initial	100	100	0	0	0	0
1	147.78	114.17	0	0	0	0
2	194.49	127.51	0.35	1.04	0	0
3	240.17	140.07	0.77	3.01	0	0
4	284.83	151.9	1.34	5.82	0	0
5	328.5	163.04	2.03	9.38	0	0
6	371.2	173.53	2.85	13.64	0	0
7	412.96	183.4	3.79	18.53	0	0
8	453.78	192.71	4.84	24	0	0
9	493.7	201.46	6.01	30.02	0	0
10	532.72	209.71	7.29	36.54	0	0
11	570.89	217.48	8.69	43.53	0	0
12	608.2	224.79	10.19	50.95	0	0
13	644.68	231.68	11.8	58.79	0	0
14	680.36	238.17	13.51	67	0	0
15	715.24	244.27	15.32	75.58	0	0
16	749.34	250.02	17.23	84.49	0	0
17	782.69	255.44	19.23	93.72	0	0
18	815.3	260.54	21.33	103.25	0	0
19	847.18	265.34	23.53	113.06	0	0
20	878.36	269.86	25.81	123.12	0	0
21	908.84	274.12	28.18	133.44	0	0
22	938.64	278.13	30.64	143.99	0	0
23	967.78	281.91	33.18	154.75	0	0



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Resource Allocation and Metrics

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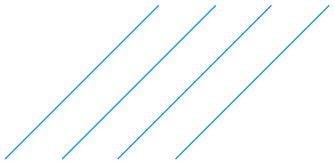


Resource allocation

Allocate resource to demand (i.e. 10 demands = 10 resources)

Allocate SQEP1 resource to job (i.e. 10 demands for SQEP1 = 10 SQEP1 resources

- If there are not enough SQEP1 resources with sufficient experience
- Report the shortfall or choose an alternative, this could be based on a lower grade or an alternative role choice
- Report effectiveness of workforce based on allocation success and criticality of role (criticality is a function of grade and role)

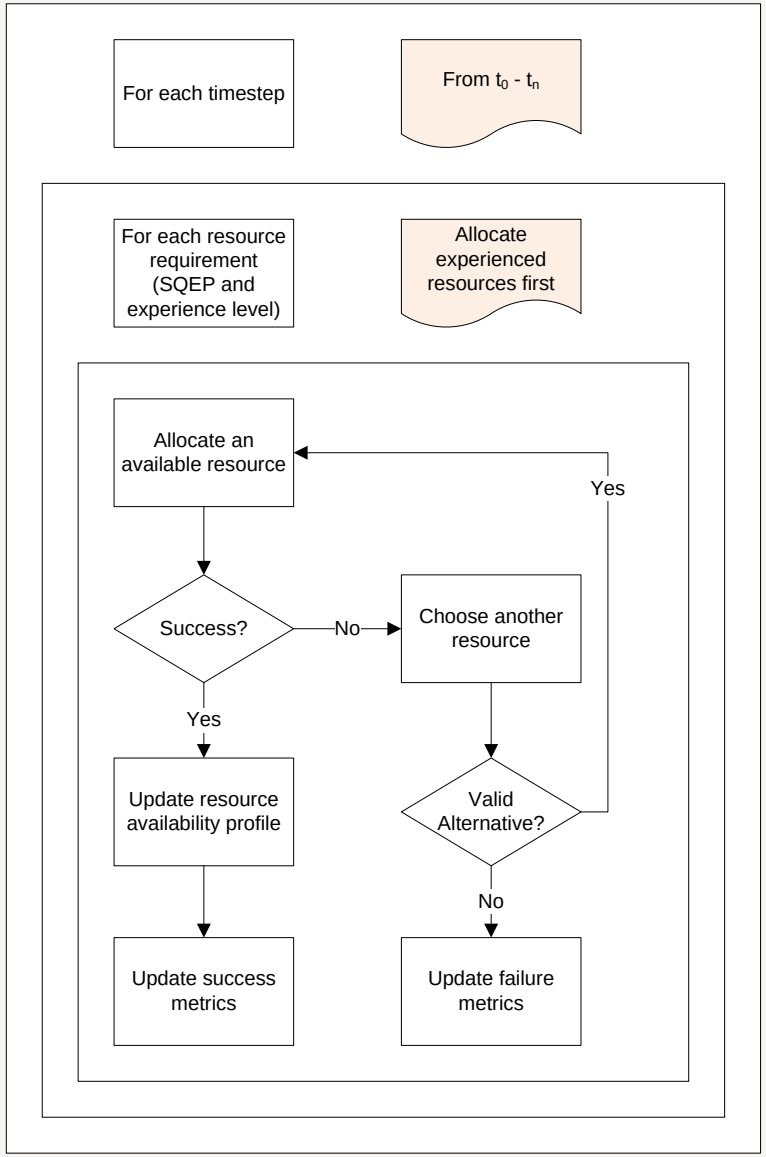
Resource allocation flowchart

The basic allocation routine for posts/ grades and roles/SQEP engineers is a simple subtraction of supply from demand.

Alternative resources are chosen only after the basic allocation has been completed. The following rules are used:

- Less experienced, same SQEP (temporary promotion)
- Same experience, alternative SQEP (assume development/training will take place)

The gaps and surpluses between demand and supply are recorded.



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Effectiveness measures - examples

The measures of effectiveness are based on the algorithm's ability to follow the rule set , the satisfaction of demand and the utilisation of resources. Measures can be broken down by OC and SQEP.

Measure of effectiveness	Score	Narrative (analyst supplied)
Primary rule set	70%	Most resource demands for grade or grade/role met
Secondary rule set	20%	Some demands met by resource who are the right role but are on temporary promotion
Demand satisfaction	100%	All project demands met
Resource utilisation	95%	Supply exceeds demand by 5%

Future Developments

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Budgets

This functionality would form part of a future optimisation model.

In this version of the model optimisation is a manual process, so the budget functionality was limited to recording assumptions underlying the resource profiling component so that they can be compared with subsequent runs.

Example budget data

SQEP	Cost of recruiting	Cost of maintaining SQEP	Cost of developing SQEP	Next SQEP
Graduate	£3000	-	£5000	A (or range)
A	£5000	£500	£3000	B
etc				

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Optimisation

An optimisation algorithm would seek to maximise the effectiveness of the resource profiling model, changing the investment in recruitment / retention / development in order to maximise the measures of effectiveness based on the algorithm's ability to follow the rule set, the satisfaction of demand and the utilisation of resources.

SQEP2

The allocation of resources to demands is not only a function of engineering experience and qualifications, it is also a function of the domain in which the engineer is operating, i.e. Aeronautical engineers cannot be expected to undertake naval architecture roles.

In the current version of the model it is possible to model these SQEP2 populations independently by constraining the scope of the demand and supply models.

Movements between SQEP2 populations can be represented by changing the recruitment numbers and attrition rates.

Questions

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