Managing Risk and Cost with an EA Approach

Mike Brownsword
Atego
Suite 701, 7th Floor, Eagle Tower
Cheltenham
GL50 1TA, UK
www.atego.com
+44 (0) 1242 229300

Joe Silmon[1]
Centre for Railway Research and Education,
University of Birmingham
Edgbaston
Birmingham B15 2TT

+44 (0) 1249 441142

Abstract - *The use of Architectural frameworks and enterprise architectures within the defence industry is well understood and accepted, however in other industries it is relatively immature. This paper focuses on the application of the TRAK architecture framework within the rail industry.*

Almost all consumer and industrial goods are currently carried by road for most of their journey. This has been the default choice for decades because of its convenience and low cost. The feasibility of moving high-value products from road to Rail with the intention of reducing CO2 emissions needs consideration through the application of EA. The EA will include innovations in technology and the challenges associated with a change in rolling stock concepts.

This paper proposes to develop a number of scenarios by which the benefits of introducing novel types of freight traffic to the network can be calculated, these scenarios will include;

- *The evaluation of the effects and needs of new types of train service on the supply chain and traffic management;*
- *Consideration of energy usage and carbon footprint with reference to well-to-wheel analysis and the Carbon Trust conversion factors and*
- *The capability gap between electrified and non-electrified lines.*

This will be achieved by embedding the scenarios in a model of the network using the TRAK Architecture Framework. The TRAK framework provides a number of views that can be used as a basis for formal analysis and assessment. The analysis will be implemented by applying parametric constraints to different views of the architecture, the results of which will be discussed here.

Keywords: Rail, Architecture Framework, TRAK, MBSE

1 Introduction

1.1 Systems Engineering in Rail

The railway network of any developed country is a hugely complex system. It will consist of many thousands of distributed parts which nonetheless interact with each other in ways which must be carefully managed. In the UK, a history of development by many different railway companies reflects the current state of affairs, with over 26 different companies responsible for running trains, as well as a multitude of other firms providing support functions behind the scenes.

Systems Engineering provides an approach to understanding and improving systems as a whole, it takes into consideration distributed parts, functions and resources and provides candidate solutions to the problems at hand. The intention is that candidates are traded off against each other so that the optimal solution is provided. Systems Engineering is focused on solving problems that incorporate large numbers of systems, organisations and varied customers [1,2].

Systems Engineering can support the rail industry though the use of modelling and the application of a context based approach to understanding needs, resources and systems, this can help by improving the understanding we have of the whole system and the way in which we communicate that information. Increased understanding and improved communication will undoubtedly lead to an overall reduction in complexity.

[1] Since the work in this paper was finished, Joe Silmon has joined Invensys Rail and can be contacted at joe.silmon@invensysrail.com

1.2 Architecture Frameworks

There are a number of definitions of architecture that can be considered [3,4,5] which can be reduced to a number of common themes including;

- Defining major system elements
- Identifying relationships between elements
- Exploring interaction between elements
- Taking account of processes
- Considers both Structure and behaviour
- Evolution over time.

Architecture Frameworks as defined against IEEE 1471/BS ISO 42010 are one tool which systems engineers can use to capture Architectures in a common, consistent way. There are a number of architecture frameworks available [6,7,8,9,10] however, many of them are focused on Defence or IT applications.

Each framework will have its own focus based on the reason it was developed; for example, MODAF focuses on the procurement of defence systems. Advantages and disadvantages of each framework can be identified and compared. Information such as the number of views or viewpoints, terminology used, breadth of application may all be issues which need to be considered before choosing a framework.

2 Approach

The intention of this work is to apply a model based systems engineering approach to provide a set of consistent models. The consistency between the models will improve the ability to analysis and compare the information contained within them. Based on the ability to create consistent models an automated set of analysis will be applied directly to the models.

2.1 Architecture Framework Selection

The systems engineering process for any moderately complex project requires the capture and storage of information about a large number of elements, such as requirements, functions and components. Just as important are the relationships which link elements to one another, as these allow for traceability. Architectural modelling is the practice of creating models, usually with computerised tools, of real-world systems, along with the concepts and requirements linked to them.

In the problem under consideration, a model is needed to track the links between top-level capabilities (the changes being made as part of the hypothesis of low-carbon freight transport), concepts (the shape of services being provided) and the details of proposed solutions.

TRAK [11] was initially defined within the Rail industry although it is recognized that it applies outside of Rail. It is considered to be a generic, pragmatic, multi-purpose framework not linked to any industry or domain. As such it still proves to be an ideal candidate to be applied within the Rail industry, and hence will be used in this work.

Using the TRAK metamodel, with its well-defined perspectives, encourages consideration of concept-level decisions before detailed solution-level specifications are set. This is an important step forward in the way railway projects are usually managed, as there has been a problem in the past with timescales dictating tried-and-trusted solutions which are sub-optimal and incapable of fulfilling future requirements.

2.2 Tools

In this work tools are of particular use in the delivery of two main areas, architecture and computation. The architectural tool will be required to hold all of the information relating to the current and future concepts under consideration. The computation tool will be required to complete complex mathematical calculations relating to energy usage and savings.

Atego's Artisan Studio was used to model the architecture. This was completed by creating a TRAK profile within the tool, enabling the architect to work with TRAK terminology rather than UML or SysML which are the native languages of the tool.

The Simulink dynamic system modelling platform was used to calculate energy use for the train journeys proposed. Track data combined with the parameters extracted from the architectural model form a complete data set for traction simulation.

The Parasolver tool within studio provided the integration between studio and MATLAB ensuring that the properties defined in the model were those used within the mathematical analysis. The resulting CO2 emissions values can also be returned and stored within the architecture enabling a direct comparison of performance between concepts.

3 Case Study

3.1 Problem description

Governments around the world acknowledge that the emission of carbon dioxide from human activity is contributing to changes in the world's climate, and are taking action to reduce national emissions. Most such emissions arise from the use of fossil fuels, which are becoming scarce and therefore more expensive.

Transport systems are responsible for around 24% of total CO2 emissions in the UK [12]. They are therefore a major target for sustainable change. Currently, the transport network of the UK depends heavily on road-based transport, a historical trend which has been increasing since the middle of the 20th century, as the railways failed to compete with road haulage, which was rapidly becoming faster, more agile and more reliable. Freight lifted by rail decreased steadily between 1950 and 1995, when liberalisation of the rail industry in the UK allowed for a small amount of growth. In 2007, the amount of freight lifted by road was 2,001 million tonnes, compared with a figure for rail of 102 million tonnes.

Since businesses usually make sustainability decisions based on only one pillar (economic) of the three (economic, social and environmental) suggested by Brundtland [13], it is unsurprising that they have, thus far, chosen the mode of transport which allows them to provide a better service at a lower cost. The challenge for rail is twofold, as we move to an era characterised by the rising cost of activities with a high environmental impact:

- To demonstrate that rail can provide a service of the quality and speed that has come to be expected for transport systems
- To provide this service at a level of cost, environmental and social impact that compares favourably with the similarly-measured impact of road transport.

These challenges are based on the supposition that composite sustainability, rather than pure economic sustainability, will become the indicator by which choices are made in future. This is already becoming reality, as companies indirectly pay for their social impact through taxation, and for environmental impact through increasingly tough penalties for pollution and tax breaks for environmentally friendly investment.

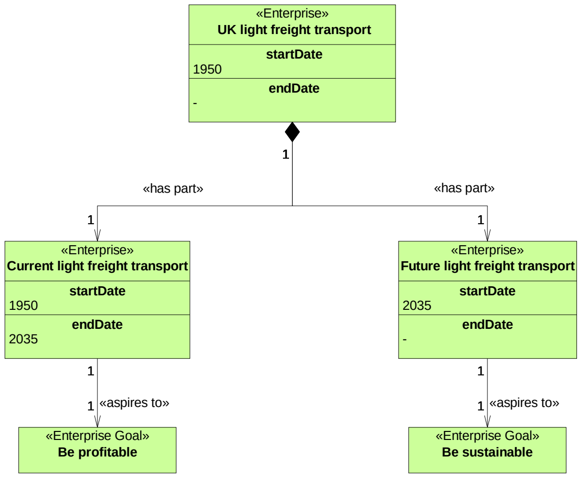

Figure 1 - [EV-01] Enterprise goals - light freight by rail

Figure 1 describes the project change in focus for freight services over the next 25 years: from an economy where decisions are based purely on economic sustainability to one which considers a composite of economic, social and environmental impact. The TRAK Enterprise element represents the overall enterprise and the two phases which comprise it. Enterprise Goals are used to model the aspirations of each enterprise phase.

The enterprise goals lead to a statement of the required capabilities. The service levels and costs are all linked to economic sustainability, which is an aspiration shared by both the current enterprise and the projected future one.

In this study, we focus on the environmental impact of the two transport modes, measured through energy use and subsequently in CO2 emissions.

In order to win substantial business from the roads, the railways must offer a service which is fast enough to compete with the best road-based logistics networks. The traditional image of a long, slow, heavy freight train is not best suited to this type of service. Insufficient capacity exists on the railways, in any case, to make room for many more such trains, as they interfere with passenger service capacity and have a punishing physical impact on the infrastructure. Instead, we propose short freight trains with power to mass ratios similar to passenger trains, allowing fast acceleration and maximum speeds equal to the fastest inter-city services, allowing the carriage of large amounts of freight to blend seamlessly with the daily passenger timetable. This removes some of the traditional constraints applying to rail freight, such as the need to run services out of peak hours, and the common practice of stopping trains in passing loops to allow faster passenger services to overtake.

The concept of a fast freight train is applied here to three common load units found in logistics systems worldwide:

- Shipping containers between 12190 mm (40’) and 16150 mm (53’) in length
- EURO pallets (1200 mm x 800 mm)
- Roller cages of dimensions 740 W x 830 L x 1800 H (mm)

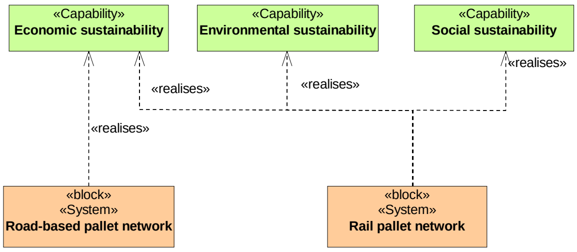

Figure 2 - [EV-03] Capability phasing - pallet network

The Capability Phasing view allows us to model the introduction of new sustainability capabilities by realising modal shift to rail.

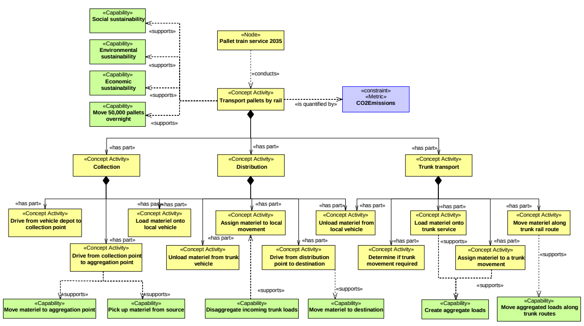

Figure 3 - [CV-05h] Transport pallets by rail

3.2 Results

The results which can be obtained within this study rely on the types of train being considered for future running. Once relevant types of train have been identified and any foreseeable improvements of the next 20 years accounted for the analysis can be carried out.

To develop such an understanding of current and future rail vehicles it is a practical first step to develop an understanding of a generic rail vehicle thus ensuring that all rail vehicles have a consistent definition. The generic rail vehicle has been developed using the TRAK solution structure view SV-01.

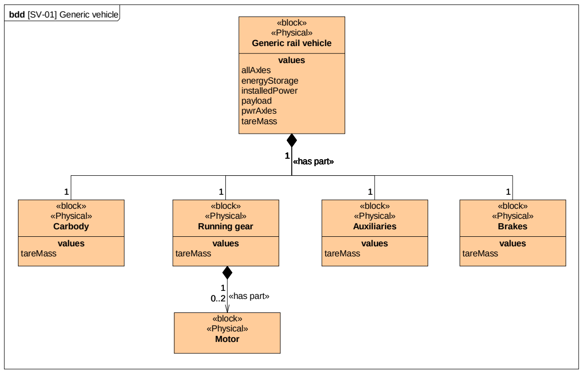

Figure 4 - [SV-01] Generic vehicle

Figure 4 provides the structure of a generic rail vehicle and this will provide the basis for all of the specific vehicles to be analysed. It is not only important to define the structure of the rail vehicle but also to capture the values that will be used within the analysis. Obviously in the generic vehicle it will only be the name of the value which is captured the true values will be captured against each vehicle. It is important to provide this consistency as it will ensure that direct comparisons can be made between the results of the analysis.

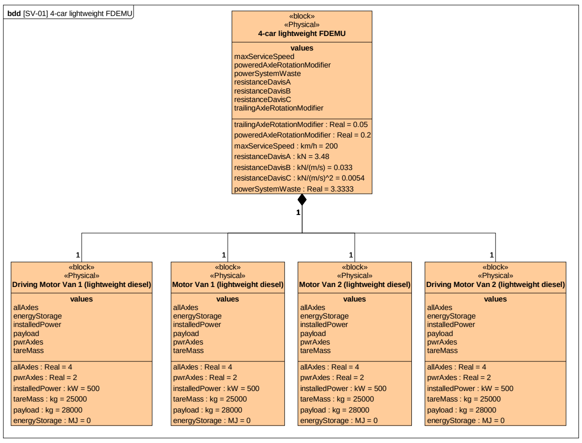

Figure 5 - [SV-01] 4-car lightweight FDEMU

*Figure 5***Error! Reference source not found.** shows the composition of a 4-car lightweight FDEMU (Freight Diesel-Electric Multiple-Unit), this makes use of four generic rail vehicles to provide the Driving Motor and Motor vans. It can be clearly seen that the level of information has increase with the addition of numbers against each of the abstract values defined for the generic vehicle. Values have also been defined for the 4-car set.

This type of instantiation has also been carried out for the other types of train identified within this case study. These include;

- 4-Car Heavy FDEMU
- Articulated Container Train
- 4-Car freight EMU (Electric Multiple Unit)
- 4-Car container EMU

The reason for developing these models is to be able to carry out multiple sets of analysis using the same base information whilst maintaining data integrity. Each analysis provides its own viewpoint of the system and as a whole they can be used to support trade studies for candidate selection and business cases future development. Each analysis has been carried out using a different technique or tool. The first mass and power budgeting uses an Artisan Studio add-on which outputs to Excel. This provides an understanding of the difference between the systems under comparison from a weight and power consumption perspective.

Rail vehicles differ from road vehicles in that the ratio of tare mass to payload is higher. This is because rail vehicle components and bodywork are much heavier. *Table 1* shows specifications for two options for the same train service. The lightweight train represents an aspiration to build lighter diesel trains over the next 25 years; the heavy train has specifications similar to high-speed diesel trains currently in service. Energy use is shown for the two builds, configured in four-car units, on a stopping freight service along the Cambrian Coast in Wales.

	Lightweight FDEMU	Heavy FDEMU
Tare vehicle mass (tonne)	25	40
Vehicle payload (tonne)	28	28
Energy use (kWh)	3004	3465
CO_2 (kg)	919	1060

Table 1 - Results of using the architecture to calculate vehicle masses

The second analysis, parametric analysis, has been used to identify and deliver relationships between the architectural model and the MATLAB model. The architectural model provides the input variables as in the previous analysis, however in this case each parametric usage relates directly to an area of the MATLAB model and can be used to execute the model recording the results within the architecture.

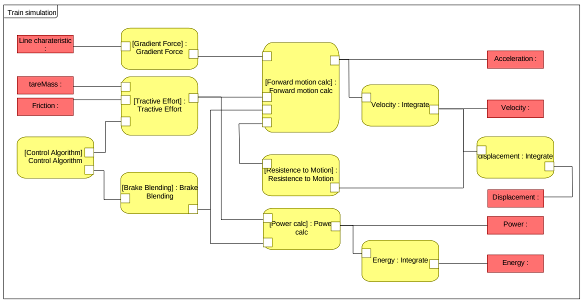

Figure 6 - Parametric Analysis

Using parametrics in this way not only ensures consistency within the architectural model but also with the dynamic simulation.

The final analysis, MATLAB simulation, can be considered to be the most complex and whilst the previous analyses can be run in seconds, this is likely to take several minutes to an hour, depending on the length of simulation and the power of the platform running it. On one hand, the benefit of having multiple analysis sets is to provide confidence in the system model before committing large amounts of time and resource to running complex simulations. On the other hand, the integration of architectural and quantitative analysis provides designers with the power to make architectural changes and simulate the effects of those changes on the system without spending time reconstructing models. This makes it much easier to evaluate changes in parameters, but also, more importantly, it allows a near-real-time simulation of changes to solution *architecture*. If this were done directly in the quantitative analysis tool, it would require more manual programming, whereas we have shown that the process can be automated.

Error! Reference source not found. shows the output of the MATLAB model, illustrating how the simulated train performs over one of the case study routes, from Barking to Carlisle via Tamworth, where a stop is made for loading and unloading of pallets.

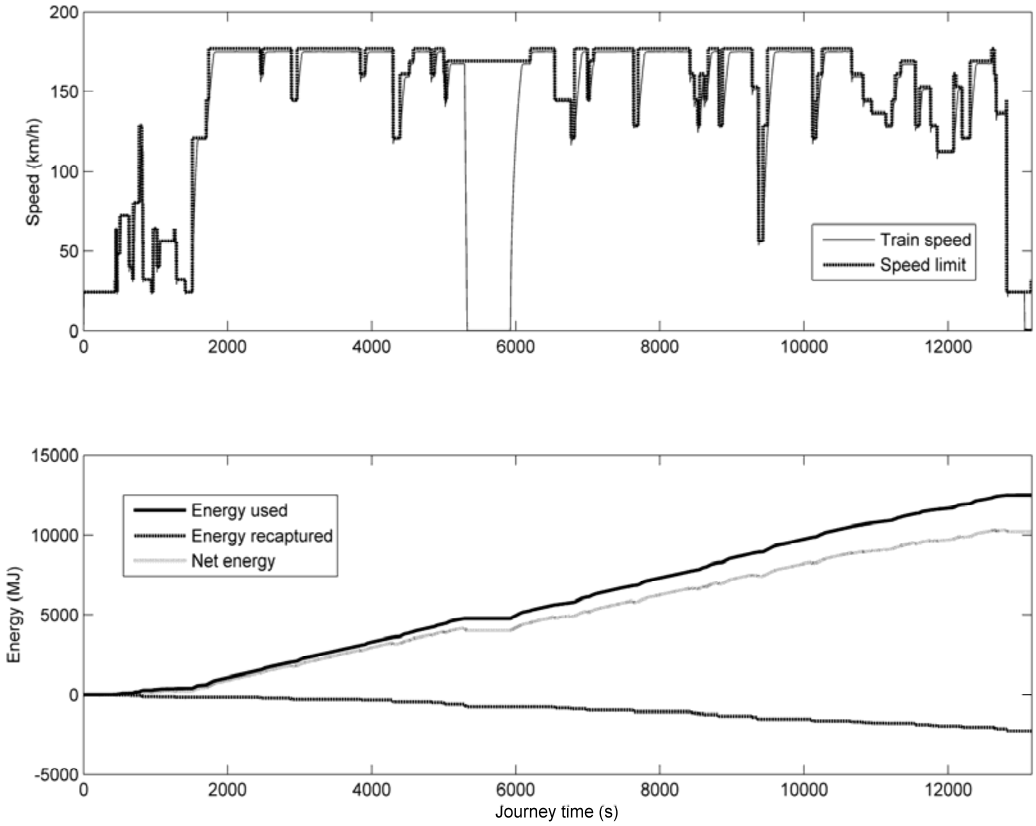

Figure 7 - Output of the MATLAB model, showing speed and energy performance of the Freight EMU carrying pallets from Barking to Carlisle via Tamworth

Pallets	Energy	CO2 (kg)	
	(kWh)	Gross	/tonne-km
Lorry	7335.0	2244.5	0.0374
FEMU 2010	2837.2	1755.2	0.0319
FEMU 2035	2837.2	1113.9	0.0186

Table 2 - Energy use and CO_2 emissions for pallet lorries and the future pallet train

The energy use and CO_2 emissions results are shown in table 2. There are two rail variants. The 2010 version gives the emissions calculations based on the current UK energy mix. The 2035 version gives emissions based on an energy mix with a reduction in fossil fuels (from 81% to 50%). The results show that a move to rail would realise an immediate reduction of 15% in CO_2 emissions with no improvements in energy mix, rising to 50% with an improved energy mix. They are therefore encouraging, in that the objective of reducing emissions through modal shift would clearly be met if this system were to be introduced.

4 Conclusions

This paper has presented an approach to understanding and defining a business case for long term change in the rail industry. It identifies that if the rail industry is to move towards being a sustainable entity it must consider and further define its capabilities in this area. It can use multiple views from frameworks such as TRAK to enforce rigour behind these capabilities ensure the generic concepts are understood, considered and consistent. This consistency may be with other rail organisations or with other industries carrying out similar tasks.

The approach uses best practice in the form of Architecture frameworks and Model Based Systems Engineering to put engineering rigour into the discussions around sustainability and carbon neutrality.

The approach also shows that it is possible to achieve a good cohesion between Architecture frameworks and tools such as modelling, analysis and simulation offering a consistent way to define and re-use information for system design trades and analyse. Automating the link between architectural and quantitative analysis increases the power of organisations to justify change, by allowing the easy evaluation of multiple possibilities in terms of solution parameters and architecture.

The case study results clearly show that modal shift from road to rail, using current infrastructure, could result in immediate reductions in CO_2 emissions, improving over time as the electrical energy mix moves away from fossil fuels.

5 References

[1] Holt, J, 'UML for systems engineering – watching the wheels'(second edition), IET publishing 2004

[2] INCOSE 'Systems engineering handbook', INCOSE publishing, 2004

[3] Pressman, R: 'Software Engineering: A Practitioner's Approach: European Adaptation', McGraw Hill Publications-Europe, 2000

[4] Schach, S. R.: 'Software engineering with Java', McGraw-Hill International Editions, 1997

[5] Sanders, J and Curran, E.: 'Software Quality: Framework for Success in Software Development and Support', ACM Press Series, Addison Wesley, 1994

[6] The Ministry Of Defence Architectural Framework, 2007

[7] DoDAF Architectural Framework, version 1.5, 2007

[8] NATO Architectural Framework version 3, 2007

[9] Unified profile for the Department of Defense Architectural Framework (DoDAF) and the Ministry of Defence Architectural Framework (MODAF), 2008

[10] The Open Group Architectural Framework (TOGAF), version 9, http://www.opengroup.org/architecture/togaf9-doc/arch/

[11] Plum, N. TRAK Enterprise Architecture Framework, pub. Department for Transport, 2011, http://trak.sourceforge.net

[12] Department for Energy and Climate Change, 2011: Uk Climate Change Sustainable Development Indicator: 2009 Greenhouse Gas Emissions, Final Figures, http://www.decc.gov.uk/assets/decc/Statistics/climate_change/1214-stat-rel-uk-ghg-emissions-2009-final.pdf

[13] Brundtland, G.H. : Report of the World Commission on Environment and Development: Our Common Future; United Nations, 1987

Joe Silmon graduated with a Masters in Electronic and Electrical Engineering from the University of Birmingham in 2004. Joe worked for Bombardier Transportation within the Mainline & Metros division before returning to University to undertake his Ph.D. in "Operational industrial fault detection and diagnosis: railway actuator case studies". Joe has worked as a systems modeller and analyst on a number of European Commission projects including SELCAT, Innotrack and the InfraGuidER project which aims to produce environmental guidance for railway infrastructure managers. Joe contributed to this work whilst a Research Fellow at the University of Birmingham, but has recently joined Invensys Rail as a Systems Engineer.

Mike Brownsword is a Consultant Engineer with Atego. He has over 15 years working in various industries including rail, aerospace, and defence as a systems engineer and systems modeller. He is a Member of the IET and is a Chartered Engineer.