EMBRACING CHANGE IN RAIL SUPPLY

WHITE PAPER

SyntheSys TECHNOLOGIES

EMBRACING CHANGE IN RAIL SUPPLY

Things are changing fast in the rail supply chain. With £35 billion expected to be spent on new services and equipment in the United Kingdom (UK) alone – a supply chain expansion of 140 percent – the market looks set for a steady period of growth.

This investment comes at a time when the British rail network is being transformed by technologies like cab signalling and the digital rail ecosystem. With things changing so fast, rail supply businesses need to become more adaptable to compete.

There is a huge amount of investment to be won right now, but in rail every feast will cost you a famine. Ill-considered long-term investment in your engineering capabilities can leave you exposed when the good times stop. Improved technology is driving a lot of current growth, but with this comes pressure to look to the bleeding edge and make difficult decisions about unproven innovations.

Which technologies are going to make the most progress toward decarbonisation?

Is the industry going to be ready to embrace the full potential of augmented reality and automation?

Will the pace of change in smart cities, the Internet of Things and 5G be so fast that rail suppliers will have to embrace them now?

Rail projects, from upgrading the remotest level-crossing to the digitalisation of the network as a whole, are getting much more complicated, and with this complexity comes a need for suppliers to be flexible and adaptable, ready to respond to, anticipate, and plan for change.

With the right skills, the right process and the right tools, rail suppliers see opportunities today to adapt to a more dynamic approach to engineering, enabled by the rigorous, modular definitions and models needed, to change direction, without slowing your pace.

The skills and tools needed to make this a reality are out there, developed by industries which have faced conditions like this before. Rail engineering could do much more today to better manage the change it faces now and in the future, through the greater application of systems engineering techniques.

It could have a more integrated supply chain, with clearer and more active coordination in projects that have to be ready to adapt and change direction.

It could have a development process which is better able to anticipate project risks and prevent incurring costs when a failure is spotted too late.

It could have the measurement capabilities it needs to proceed with confidence and speed on the journey of continuous improvement.
It could approach design and refurbishment with a military-grade approach to configuration management developed to anticipate how changing part of the system will change the whole.

And most importantly, it could improve its development processes to better anticipate and smoothly adapt to change.

Rail projects, from upgrading the remotest level-crossing to the digitalisation of the network as a whole, are getting much more complicated, and with this complexity comes a need for suppliers to be flexible and adaptable, ready to respond to, anticipate, and plan for change.

CHANGING REQUIREMENTS

Moving goalposts can seem like a fact of life in rail engineering. Nobody wants their project requirements to change in the middle of their work,but it happens to everyone.

According to the Project Management Institute's global 2019 'Pulse of the Profession' study[1], project managers in manufacturing industries overwhelmingly report inaccurate requirements gathering and poorly defined opportunities and risks, as the primary causes of project failure.

Getting clients to articulate their needs can often be an extremely frustrating process. Half the time – even more if the buyer isn't the same person as the one with the technical need – they don't even know what they want themselves.

No process can pull information out of the void when it doesn't exist, but there are tools and skills which can guard your requirements gathering against the risk of change, both in terms of identifying and addressing gaps and ambiguities at the outset, and making your project definitions and models more adaptable to change when it does come out of the blue.

Systems Engineering (SE) – the field of engineering concerned primarily with the emergent behaviour of complex systems – has started to reach the rail supply industry and is making waves but could still be embraced more broadly and more deeply. In particular, systems engineering takes a robust and scientific approach to requirements management that cleanly and specifically identifies ambiguities and gaps in stated stakeholder needs.

The best way to get a straight answer is to ask a straight question, and the systems engineering process is very good at generating straight questions, requiring you to ask them of as broad a range of stakeholders as possible.

Systems engineering treats the requirements engineering process like formulating a scientific hypothesis. The philosopher of science Karl Popper famously said that for a statement to be considered scientific, it must be falsifiable: you have to be able to tell the difference between a world in which the statement is true and a world in which its false. Similarly, systems engineers work towards requirements by which it is possible to tell the difference between a system that achieves them and one that doesn't.

The requirements that result are – among other benefits – clear, verifiable, functional, minimal and consistent. The systems engineering process guides you to as complete a description of the product as possible at the earliest stages of design, and when change does happen at a later stage, gives you a robust and speedy way to fully understand the implications and adapt.

[1] PMI (2019). Research Highlights by Industry and Region 2019.

WEST COAST ROUTE MODERNISATION:

The spiralling costs of poor change control

The West Coast Main Line is the busiest mix-use railway in Europe, connecting many of the largest cities in the UK. In the course of a vast modernisation programme between 1998 and 2008, Network Rail worked with partners to deliver reduced journey times, increased capacity and refreshed infrastructure.

The project was beset with problems, and spiralling costs not only significantly contributed to the collapse of then-privatised Railtrack, but required the intervention of the Strategic Rail Authority (SRA) in 2002 to rescue the programme's objectives, after the forecast cost had risen from £2.5 billion to £14 billion.

A later review by the National Audit Office concluded there had been several failures in the management of the project prior to the SRA's intervention, including a lack of clear governance arrangements and direction, failure to engage stakeholders, and the use of untried and unproven new technology. But it also identified scope creep from a lack of tight specification and change control, as a major source of spiralling programme costs.

Although the project was trying to apply good requirements management, even from its early stages, in practice the project design and scope had been largely left to the management of Alliance contractors, because Railtrack lacked the engineering expertise to participate in Alliances as an informed and equal partner, or the ability to challenge contractor-developed ever-escalating scope.

The change in project definition was out of control and nobody was competent to control it. By the time the SRA intervened, the wrong requirements, and requirements that did not correctly balance cost with other business objectives, were being managed.

A key part of restoring the programme to a relative success in subsequent years was refreshing the project requirements to be better aligned to objectives, and in the end significant savings were achieved by focusing the project on its core aims.

The Right Tools

SE-based requirements management has a long track record of success, though until recent years that track record mostly developed in a few specific industries like aerospace and defence, where managing complexity and mitigating risk had been particularly challenging.

As other industries take the next technological steps and have to manage change in a more complex environment, these techniques have ever-broader application.

Nonetheless, because of this history, new adopters can hit the ground running with tools developed and refined for those industries with deep SE experience.

IBM® Engineering Requirements Management DOORS® Family and IBM® Engineering Requirements Management DOORS® Next have been in use by several key players in the rail industry for some time as vehicles for requirements management.

Embracing and controlling change requires rigorous, atomised project definitions and a clear and immediate view of the implications when those definitions have to adapt to new circumstances.

With the right tools and skills to support this mindset, your engineering process could become much more dynamic and adaptable.

CHANGING PROCESS

By now, every leader in manufacturing has heard of continuous improvement, and how it can provide models to articulate the value and work plan of specific improvement initiatives. We all understand how to plan, do, check and act on an incremental change, but the irony is the hard part often turns out to be making sure those changes are continuous (and, sometimes, making sure they are improvements!).

Any conversation about the sustainability of Continuous Improvement (CI) usually starts and ends with a question of culture. It can be a further irony to find out that a notoriously nebulous and unmeasurable property of your organisation is what is holding back the potential of a programme fundamentally designed to bring rigor and specificity.

No matter how mature your lean management operations are, there will always be people in the organisation who want to do things the old way, even if you can demonstrate with a scientific level of certainty that the new way is better for your organisation, your customers and your employees.

The conventional wisdom is that attitudes like this persist when continuous improvement initiatives are forced out from the centre rather than growing organically from the grassroots.

This is especially true when that comes in waves, like specific CI projects or Kaizen events. We don't dispute that, but it can feel like a catch 22 when the problem is precisely that a proportion of your employees aren't engaging with the CI journey.

There is a subtle difference between empowering your employees and just letting them get on with it. Empowering your employees is about giving them the tools and the skills they need to take a personal interest in the initiative, and making it feel like it is something they have ownership over. Making it easy for them to do that certainly doesn't hurt, either.

Continuous Improvement is fundamentally a scientific exercise, concerned with hypotheses (plan; "we would be more efficient if we did it this way"), experiments (do; "let's try it out in controlled circumstances"), measurements (check; "were we actually more efficient"), and publishing theories, (act; "this is better and it should be generally accepted and promulgated").

Throughout all this, evidence is king, just like in science, and you can't empower your employees to take a scientific attitude to your process without giving them ownership of and access to the evidence. If you can't measure performance, you can't improve performance, or at the very least it becomes difficult to say if your performance has improved or not.

By giving employees real-time access to your continuous improvement metrics, properly documented and measured, you can give them the information they need to make continuous improvement experiments a routine, straightforward and interesting part of their day. Being able to see weak points in your process through data can stimulate your employees into having ideas for incremental improvements, and focus attention on those areas most in need of change.

Cross-team transparency can also foster an attitude of collaboration and healthy competition with respect to CI objectives. But most of all, robustly and efficiently measured metrics allow a decentralised CI culture to increase performance without increasing risk.

The key to derisking change is information: knowing where you are; where you're going, and what's happening along the way.

This is as true for your business process as it is for your products.

MALAYSIA HIGH SPEED RAIL:

Progressive Assurance

Although the proposed Kuala Lumpur-Singapore high speed rail link, which promises to cut the journey time between the two cities to 90 minutes, has been beset with political problems, a lack of engineering sophistication has certainly not been holding the project back.

Using IBM® Engineering Lifecycle Management tools has enabled the project not just to manage a complex set of hierarchical requirements, but also track progress and process with ad hoc intelligent metric and analytic reports, which are able to handle the evolution of metrics used as the project advances. Project-wide hazard logs, assumptions and departure registers were included in the platform, which allowed the establishment of workflow controls and traceability relationships. This allowed impact views to be created so that every change in every register could be assessed before implementation.

The 'MyHSR' project dashboard consisted of a series of widgets, including shortcut links to specific modules and the project metrics. There was also a personal dashboard for each user that could be tailored for their own specific 'to do' list. By providing transparent and real-time access to project data and metrics, the project is set to make an empowered continuous improvement philosophy accessible to the whole team.

Transparency as an Agent of Change

The key to unlocking this level of transparency is in tools which enable an instantaneous real-time view of your project at every stage of its life cycle: integrating a single source of truth across requirements, design, configuration, workflow management and all aspects of quality, as well as generating repeatable templates that allow you to retain improvements between as well as within projects.

Transparency is ensured by providing access to those features through a dashboard that gives you a real-time view of what's going on at every stage of the life cycle, across specialised and fully integrated applications.

IBM® Engineering Lifecycle Management is designed with these objectives in mind. Breaking down walls between your engineering teams and your engineering data can help ensure that the continuous improvement journey really is continuous and brings everyone in to making it a reality.

COMMUNICATING CHANGE

Getting suppliers to understand your needs can be a time-consuming and costly negotiation. Every business finds themselves dealing with suppliers who will find any way they can to misinterpret your instructions, even when your requirements remain relatively static.

Keeping everybody in the loop in rail engineering used to be much easier but as stakeholders demand a more dynamic engineering process to reflect better technology, greater assurance and more integrated systems, the process of sharing information with your own supply chain and ensuring traceability becomes much more error-prone and demanding. When project managers and engineers have to devote too much of their attention to the often tedious work of contract management, they have less time to focus on objectives like safety, efficiency, reliability and productivity.

Engineering works better when it's more joined up, precisely because it allows change to be handled with minimal interruption to your team doing what they do best.

What this would mean is moving past ad hoc communication with suppliers – passing emails, documents and spreadsheets – and towards a way of handling shared information which retains a single source of truth, even between partner companies.

Such an approach would need product and task information to be specified in a standardised format that is designed to meet the needs of everyone expected to use that information.

It would also need to be responsive to change, and enable seamless propagation of any updates to project goals, specifications or standards down your supply chain, while keeping everyone on the same page by guarding against errors, miscommunication and poor traceability.

Even systems engineering standards and associated on-premise tools have historically struggled to streamline the process of communicating with suppliers, but with the advent of collaborative solutions like IBM® Engineering Lifecycle Management, businesses have an opportunity to introduce a single source of truth across the supply chain.

Solutions like this provide web browser access to the full development cycle from requirements through to verification and validation. Because of strong information security protocols with role-based access which provide the commercial protections needed when collaborating on a sensitive development project, these tools greatly enhance the ability to view and share data, not just among the internal development team, but also with third parties in the supply chain.

Furthermore, by enabling compatibility with the industry standard Requirements Interchange Format (ReqIF), these tools enable systems engineering to move beyond bespoke point-to-point integrations between applications and engage the supply chain in development, even where tools and practices differ and where sever-client access to data has historically presented a problem for collaboration.

IBM® DOORS® Family and IBM® DOORS® Next allow the export of requirements in a cross-platform XML format, which can then be imported into a wide variety of ReqIF capable tools across the supply chain, while remaining locked within the host database and closed to editing. Once the supplier has finished deriving and refining their level of requirements from the parent databases, a ReqIF file is returned to the parent and synchronised.

By setting things up this way, you can significantly diminish the burden on engineers to spend time communicating effectively and traceably. At the same time, you can make sure everyone's information is accurate, up-to-date, secure, traceable and as complete as they need it to be.

THE MELBOURNE METRO:

Collaboration in the Cloud

Still ongoing, the Metro Tunnel project in Melbourne is one of the most complex civil engineering projects in Australia's history. Over eight years and costing around £6 billion, the plan is to construct twin 9km metro tunnels under central Melbourne, dramatically increasing peak capacity on many of the city's suburban rail lines.

The demanding project requires coordinating around 7,000 construction workers and other professionals, ongoing collaboration with a wide variety of independent contractors, and constant communication with numerous stakeholders. Using traditional requirements management methods with such a diverse array of independent engineering contributors would have led to siloed data and a lack of common standards, which could have taken weeks to process into a form which would give you a sense of the actual state of work, by which time it would be out of date.

Instead, Rail Projects Victoria (RPV) adopted IBM® DOORS® Next to manage their requirements collaboratively in the Cloud. This tool enabled all suppliers and other stakeholders in the project to work from the same, single privacy and intellectual property. When the requirements change, IBM® DOORS® Next allows that to be processed through a project-wide workflow that highlights the interdependencies between requirements across all parties, and when the request is approved, it is immediately propagated across all of the suppliers, with the impact on their subsystems clear and unambiguous.

By introducing standardised requirements management and a common platform, RPV has significantly improved its ability to handle change in a complex supply chain, and mitigate the associated expense, risk and delays.

Read more about this case at https://www.ibm.com/case-studies/rail-projects-victoria-watson-cloud-engineering

Bringing in the Whole Team

Even before you think about external stakeholders and your own supply chain, supplying to the rail industry involves the input of multiple functions and capabilities. Product, design, development, manufacturing, quality, compliance and more, will have an input into your process and will all need to be kept on the same page through change.

All of these disciplines have a unique and highly valued set of skills, but as a result of their different perspectives, it can be challenging for them to keep one another's needs in mind.

A single source of truth matters in your own process, too: not just in terms of how the part of the product any individual is concerned with fits into the whole, but also understanding the needs, expectations and process of other functions can have significant advantages. Joined-up development undoubtedly needs the right tools to support it, but those tools are only as valuable as the skills of the people operating them, and the processes that need to be put in place. This is what makes the difference between teams that grumble about an additional layer of compliance and teams that feel enabled to do their jobs better by the tools provided to support them.

Being ready to adapt to change is more than a cast of mind: it requires a specific set of skills and tools. Embedding those throughout your organisation can make your development process considerably more dynamic and effective, while enabling project managers to focus on what really matters.

ADAPTABLE PRODUCTS

As railway operators increasingly look to improve their efficiency by extending the life of their assets rather than replacing them, rail refurbishment – and in particular rolling stock refurbishment – has become a foundational activity in keeping the UK rail sector moving.

A service designed to increase efficiency for your customers would ideally be as streamlined as possible as you provide it, but engineering for rail refurbishment can often feel frustratingly like reinventing the wheel. Reworking requirements and specifications can be tedious and expensive, and when the work involves replacing parts that are no longer available, or upgrading to meet higher safety standards, keeping control of your information becomes critical to managing risk.

The mindset that rolling stock – as well as other parts of the rail network – is a static product that won't undergo significant changes in the course of its life cycle should have vanished from the industry long ago, yet the tools used by rail engineering are often poorly equipped to deal with this reality.

Industries like aerospace and defence have always had to think in terms of engineering products with customisation and major in-life upgrades in mind, and the tools and systems engineering principles developed in support of those industries could now see greater applicability in the rail sector, both in terms of futureproofing new products and the refurbishment of existing assets.

A systems engineering approach to configuration management starts by distinguishing a special category of 'baseline' configurations, which are known to work. Deviations from that baseline are carefully tracked and interpreted in terms of changes to the requirements for the system.

Variant components are defined separately, and the design and modelling of a new configuration is built from the baseline out of these atomised subsystems, allowing you to minimise duplication of effort in reusing components. As a result, when you need to reuse requirements, you don't have to just duplicate the entire set of requirements and then manage them separately: you can reuse those components that are not changing, use the correct version of those that do change, and be able to add or remove components as necessary.

In a rail refurbishment context, being able to track the change in product requirements and configurations over time, and reutilise existing knowledge in new projects, prevents your engineers from having to go back to square one. Instead, they can start from where they ought to start, with the properties of the existing system known, understood and ready for change.

THE SIEMENS DESIRO:
A Train for all Seasons

Siemens Desiro Class 700033 at Blackfriars Station

The Siemens Desiro has been an extremely successful family of recent trains, with 170 of the 'City' models running on the British rail network alone, following their introduction five years ago. A major key to the Desiro family's success has been its flexibility and adaptability, which has allowed the baseline model to be adapted to a wide variety of purposes.

As a result of the ability to reconfigure the design both before and after sale to meet particular needs, it runs on British tracks under three separate class numbers: the 700, 707 and 717.

These models differ in safety features, power systems and interior features to meet the needs of the different routes, alongside providing options for the operator to achieve a wide variety of passenger capacities, lengths and configurations while the train is in operation. By building the Desiro with variants and reconfiguration in mind, it is able to serve a wider variety of markets in a manner that better serves the local need, and is futureproofed against the changing needs of the network.

Rethinking Your History

Those who cannot remember the past are condemned to repeat it, and those who don't retain previous specifications are doomed to re-engineer them. The benefits of configuration management go beyond the retention and easy reuse of existing work: by taking an atomised view of configurable components, engineering for refurbishment can become as much an exercise of putting together the right building blocks of existing designs, as it is one of creating something new.

Retaining your history in this way, as separable subsystems that can be reused rather than just through completed designs, allows your engineers to focus on what really matters: the genuinely new, and how it all fits together.

For this to work effectively, your tools have to be built around managing product variants and separable components rather than a linear progression toward a single integrated design. Planning for configuration management needs to be baked into your activity from the moment you start engineering your requirements. In the current environment, rail engineering needs to be using tools which build in change from the ground up.

ANTICIPATING RISK

As rail systems become more complex, the risks associated with project change become more difficult to manage. Different components in the network interact in increasingly complicated ways. Keeping sight of the big picture while the individual parts adapt to new technologies is a critical mitigation of risk, but engineering doesn't always have the tools it needs to do that.

All rail products exist as part of a larger system, and successful rail engineering needs to understand not just how its product fits into that system as it stands, but how it will react as the system changes in the future.

The introduction of cab signalling shows that even rolling stock needs to be able to adapt to the changing systems of the network, to say nothing of future pressures from accessibility and decarbonisation.

Network-wide systems like control, command and signalling also have a great deal of complexity and emergent behaviour in their own right, and exist in a constant state of flux: never more than now.

The risks of engineering in an environment like this are huge, especially because without proper consideration of the emergent properties of the system as a whole, a defect in a new product may not emerge until after it has already been integrated into the network.

The best way to mitigate these risks is, naturally, to find a way to anticipate such problems before they arise, and use a development process which is designed around seeing its output, not as an isolated component, but rather as a detail in a big picture. If the product itself needs to change, your understanding of the associated risks needs to change with it.

Systems engineering is the best toolkit available to engineers for managing such risks. It draws on the science of finding patterns in organised complexity, and the analysis of the emergent properties of a whole, rather than the specific behaviour of individual components. The critical shift in understanding that systems engineering brings to the table is that it is the structure of a system that generates its behaviour, more than the mechanical details.

A huge part of that is in its scientific approach to requirements engineering, which generates specific, unambiguous and testable requirements using the same method as a scientist uses to generate the hypothesis of an experiment. Taking this approach to requirements enables an approach to modelling systems that can treat the parts of the system as black boxes, 'system elements', which take their inputs from their environment and produce outputs. These 'system elements' are organised into systems, and then even into a 'system of systems', which is a model for systems with very independent components and a function that firmly rests on emergent behaviour, like a railway network or a supply chain.

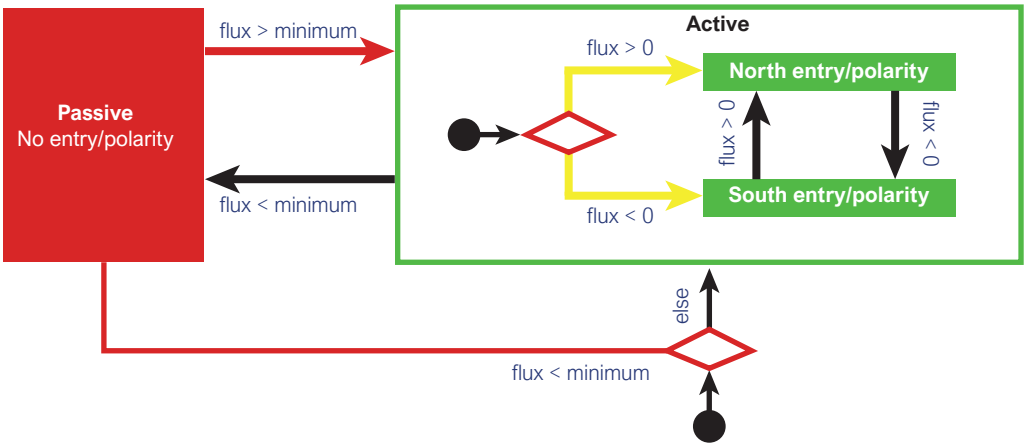
These models are generally built from the top down, defined first in terms of broad stakeholder needs. As requirements get clarified and detailed, the model progresses down equivalent layers of complexity, at each stage fundamentally treating subsystems and individual elements as black boxes that transform inputs into outputs.

As such, using a systems engineering model allows the behaviour of the system as a whole to be anticipated prior to proceeding with development.

In rail systems, where components are so heavily integrated into a network with complex behaviour, this can be a critical mitigation of risk.

EAST LONDON RAIL EXTENSION:
Systems Engineering as Risk Mitigation

SE Model of an AWS Ramp System



Adapted from "Verification and Validation of a new type of Railway Signal using MBSE and Simulation", Stephenson, Vine & Towers, November 2018.

The 1990s saw two major eastward expansions of the London rail network: the extension of the Jubilee Line to Stratford, and the first stage of the Docklands Light Railway (DLR) extension.

The projects began within a year of one another and were expected to take roughly similar amounts of time. The DLR extension was delivered within the agreed fixed price, and performance requirements were fully met, but the Jubilee Line extension took 21 months longer than planned and cost around two-thirds more than the original budget.

The DLR extension was delivered from the outset using an SE approach, including formalised system requirements, modelling and simulation, and a comprehensive set of integration tests.

By contrast, the Jubilee Line extension made little effort to maintain a whole system view, and very little provision was made for the huge extent of work necessary on the existing Jubilee line for the project to succeed. The extension was regarded as a bolt-on to the existing railway, and the integration work was not understood until a late stage. Several key decisions were not taken until much later than would be recommended by SE practice, and an SE approach to stakeholder and interface management might have resulted in significant cost and time savings.

Of course, some of the differences between the projects can be attributed to the approach to management and external factors, but the evidence from authoritative accounts of the project suggests that the Jubilee Line extension could have avoided a number of late changes and delivered savings, had good SE practice been adopted from the start.

This case study was adapted from those maintained by the INCOSE Transportation Working Group, available free at:

https://www.incose.org/incose-member-resources/working-groups/Application/transportation

Derisking Change

A global study by the Project Management Institute (PMI) found that for every pound spent on projects and programs, 5.1 percent is wasted due to poor requirements management[1]. The techniques and processes of systems engineering, especially the ability to model complex systems early in development, can reduce this waste considerably.

But the advantages don't stop there. For one thing, SE modelling and requirements management can significantly improve your relationship with your own supply chain by introducing a single source of truth and clear specifications, which can be passed down to suppliers in a traceable way. But the main benefit of an SE model in the long run is how easy it makes it to plan for change. Stakeholder needs can change at any point in the product life cycle, either during development or as part of a midlife upgrade to the system. By developing and maintaining an SE model, your organisation could have a relatively easy way to adapt to the impact of those changes, and determine quickly and cheaply what those changes will mean for the functionality of the system as a whole.

SE modelling requires appropriate technologies to support engineers, but those technologies are already very mature, thanks to industries which have been using systems engineering techniques for some time.

As rail continues to become a more complex environment, the rail supply industry could benefit from using SE modelling in its work.

[1] PMI (2014). Requirements Management.

LET'S TALK

FOR SALES, SERVICES & TECHNICAL ENQUIRIES

CALL:

+44(0)1947 821464

EMAIL:

CET@synthesys.co.uk

VISIT:

www.synthesys-technologies.co.uk

FOLLOW US ON LINKEDIN:

http://bit.ly/2ruSaWJ

REFERENCES & COPYRIGHT

Images are from Wikimedia or Pexel Free and are free to reuse.

The ‘Cumulative Percentage Lifecycle Cost’ graph is adapted from the NASA Systems Engineering Handbook, which is in the public domain.

The China Star case study is compiled from various news articles.

The ‘SE Model of an AWS Ramp System’ diagram is adapted from an academic paper freely available online. Written by Network Rail and a consultancy as a submission to an INCOSE conference.

The SWORD project case study is adapted from that same paper.

The Invensys Rail Dimetronic case study was adapted from one of IBM®’s own case studies for selling DOORS®.

The East London rail extension case study was synthesised from two case studies prepared by the INCOSE Transportation Working Group. These case studies are freely accessible online.

SyntheSys
TECHNOLOGIES

90501TTA3502