MAXIMISING VALUE IN RAIL SUPPLY

WHITE PAPER

SyntheSys TECHNOLOGIES

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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 technology through the digital railway. The opportunities are there for those ready to step up and take them, but it's not always straightforward to adapt your business to this new reality.

Although new technology is delivering better value for passengers and freight users, for suppliers, this transformation can put pressure on the bottom line. As the rail network becomes more complex, all suppliers have to look again at how they deliver value for their customers in the face of the higher cost of quality.

Rail systems with greater capabilities mean more effort for those who work to keep the network up-and-running. Greater software content in the rail network pushes up costs for everyone who has to interact with it. More bespoke and specialised components drive up time-to-market for those who develop and maintain them.

These challenges are only going to get harder as the years go by, and rail suppliers which can't adapt will face an uncertain future. Every little piece of infrastructure, every part of a train, increasingly needs to be looked upon as a detail in a big picture rather than as something more discrete, with its own discrete maintenance schedule and separately identifiable requirements.

Rail suppliers must adapt to this new reality to keep delivering value. Walls need to come down and communication needs to step up. The pace of change in technology demands it of us, but it can't happen without the right skills, the right process and the right tools.

To keep delivering value, the rail industry as a whole needs a 'left-shift' in its approach to development, extending all the way across design, engineering, construction, maintenance and refurbishment. Left-shifting is about reducing risk by moving certain processes, especially testing, to an earlier stage in your product's life cycle, pushing as many costs as possible to after you have assurance that you are building the right product in the right way. In an ideal world, you would know almost everything about whether your plans are going to work before you go anywhere near anything physical. Left-shifting would bring an engineering mindset to more parts of rail supply, and delivering better value by getting it right the first time, on time and every time.

The skills and tools needed to make this a reality are out there, developed by industries which have faced conditions like this before. Rail supply could do a lot, today, to deliver greater value in the face of the change it faces now and in the future:

- It could be better equipped to keep things in budget when the objectives at the end of the project are in danger of changing from where they were at the start.
- It could mitigate risk by discovering and addressing defects at an earlier stage of the product life cycle, before incurring the associated costs.
- It could be using a more transparent workflow, giving managers and stakeholders a clear and real-time view of what's going on and what's being spent. And most importantly, technology could be working to the advantage of the rail supply industry, by helping it understand the value of its products in the context of the ever-changing and ever-smarter network.

Finding ways to deliver better value is always a challenge but running headlong into a problem isn't always the best way to solve it. Often, it's better to spend five minutes before you launch into looking for solutions, thinking instead about how to make the problem easier to solve.

RIGHT THE FIRST TIME

As the systems used in the rail network become more complicated, finding out that something needs to change in the middle of work, or that the task you were given in the first place wasn't exactly right, becomes an ever more expensive risk in construction and engineering.

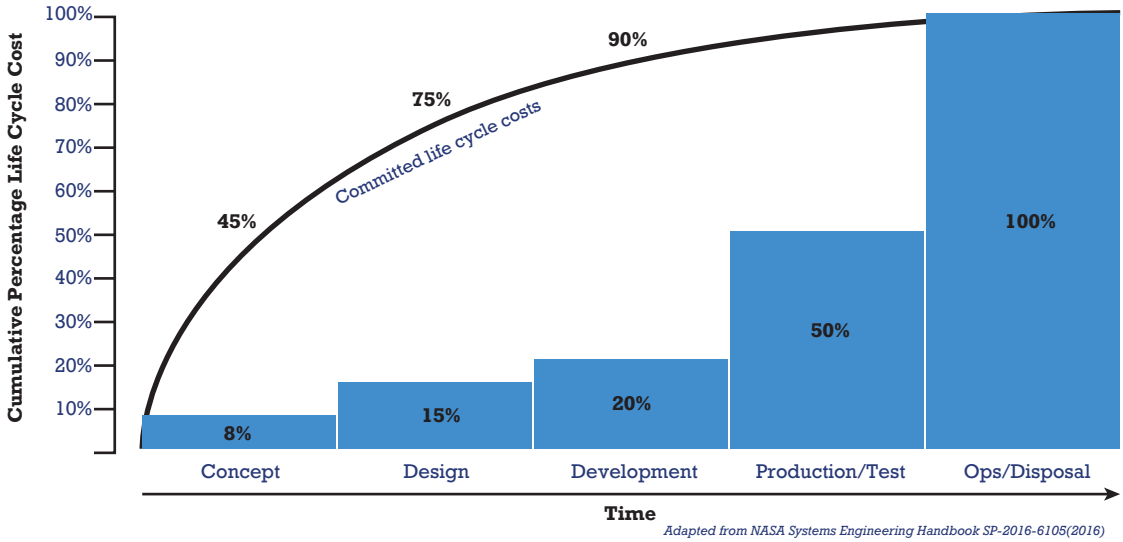
According to the Project Management Institute's global 2020 'Pulse of the Profession' study, Project Managers (PMs) in the construction industry report poor upfront planning as the primary cause of project failure[1].

In the same study, construction PMs reported that 41 percent of project budgets are lost in a case of project failure; more than any other industry. In all, the survey reported that 12.7 percent of total project and programme spending in the construction industry was wasted due to poor project performance. Every industry faces its own unique circumstances and challenges, but industry insiders don't need a study (though there are several) to know that construction has underinvested in the skills and technology necessary to reduce that waste.

When supplying to the rail industry, these problems are particularly acute, and never more than now. As the rail network becomes more complex and high-tech, understanding what your project requires of you, and securing guarantees that your objectives at the start will still be your objectives at the end, has never been harder. In those circumstances, it can be very difficult to guarantee value for your customer. The best way to mitigate these risks is to build a strong understanding of your project requirements at as early a stage as possible. The later in the project your requirements change, the more expensive that change will be, and those costs start accumulating very quickly. As the diagram below shows, life cycle costs of an engineering project tend to get locked in early in design and development, even if not yet expended. This can rapidly multiply the cost of changing design direction at a late stage. Naturally, this leads to budget and timetable overruns, or even cancellation.

Of course, getting to grips with this in the rail industry is no easy task. Depending on what you're building, the stakeholders who define what your project is supposed to achieve could include the Rail Safety and Standards Board, multiple Network Rail routes and regions, an end-user operating company, a rolling stock company, a wide variety of government and regulatory bodies, passenger groups, and many more. There's no magic bullet which can eliminate the need for these wide-ranging conversations. But what do exist are processes, skills and tools which can help project managers and others conduct this dialogue more efficiently, comprehensively and with scientific rigour.

[1]PMI (2020). Research Highlights by Region and Industry 2020.



Adapted from NASA Systems Engineering Handbook SP-2016-6105(2016)

In industries which have had to solve these sorts of problems for longer, these practices will be familiar as the skills and technologies associated with the discipline of Systems Engineering (SE). Systems engineering is about drawing 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.

In rail construction and engineering, one of the things that SE can bring to the table is a formalised process for generating project requirements, and sophisticated tools to support that process, which together are designed to ensure the definition of your project is consistent, complete and feasible at the outset. The sinking moment when you discover someone has forgotten to include something in your specifications, or that a vague instruction has led to your work not in fact meeting the required standards, can be left-shifted to the stage when as few costs as possible have been accumulated.

By knowing how to help your customer to give you what you need at the start of the project, you can ensure the value of your work isn't compromised by discovering a fault too late, and protect both yourself and your customer against unnecessary costs.

East London Rail Extension

Systems Engineering to Control Costs

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

Communicating Value

Keeping everybody in the loop in rail engineering used to be much easier. But as stakeholders demand a more dynamic process to reflect better technology, greater assurance and more integrated systems, the process of sharing information and ensuring traceability across your team and with your own supply chain becomes much more error-prone and demanding.

When project managers and other leaders 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, innovation, quality and value maximisation. Using SE requirements management techniques and technologies also enables much more efficient communication, by allowing all stakeholders, both up and down the supply chain, to work from the same, single source of truth.

By joining in with these processes, your work can respond to change seamlessly, participate in complexity coherently, and provide greater and better understood value than ever before.

QUALITY WITHOUT OVERDELIVERING

As the rail network starts to rely on ever more sophisticated technologies, the risks associated with project change become more difficult to manage. Different systems in the network interact in increasingly complicated ways. Not understanding how your work fits into this ever-changing big picture can be a huge risk; never more than now. It can be hard for rail suppliers to guarantee their product can retain its quality throughout the whole of its life cycle while avoiding the excess costs of overdelivering on what is actually needed.

These risks don't just arise as the network changes around your project while it is underway, but also in terms of how what you're building will react as the network changes in the future. The digital railway initiative demonstrates clearly that even the remotest level crossing needs to be able to adapt to the changing systems of the network, to say nothing of future pressures from accessibility and decarbonisation.

Delivering value in this environment isn't just about understanding your stakeholder needs as fully as possible, it's about having an approach to quality that puts the outputs of your work in terms of user satisfaction, the operating environment and how it integrates into the broader network both now and in the future -- in short, the value derived throughout the full life cycle of your product -- at the front and centre.

Your approach to quality, therefore, needs to be closely tied to your approach to value, and in rail your approach to value needs to be increasingly tied to how the network will change around your product in the course of its life cycle, and when change is likely to bring your product's life cycle to an end. Failing to look at it this way exposes both you and your rail customer to significant risks that undermine the value of your work.

Taking a whole-system view of quality allows you better calibrate your project objectives to stakeholder needs, not just in terms of raising the bar, but also in terms of preventing waste and improving project control. By left-shifting when you think about quality, and tying how you think about it explicitly into stakeholder needs, you can better guard your project against doing too much as well as doing too little.

The saying that quality cannot be "inspected into" products, has become a cliché at this point, but the more complicated your products and the network around them get, more and more quality activities need to be left-shifted to the earliest possible stage, not just to minimise the cost incurred when something doesn't come up to standard, but also to maximise value when quality is as much about what's going on around what you've built, as it is what's going on inside it. Without proper consideration of the emergent properties of the 'system of systems' formed by your product and the other systems around it, a defect may not emerge until after it has already been integrated into the network, when it is most costly to correct, to say nothing of how dangerous that could be.

Thinking about quality like a systems engineer is about thinking in terms of a hierarchy of complexity. When designing the system, we start with the broad needs of the client, turn that into specific requirements for the system as a whole, create an architecture at the system and then the subsystem level, and only then produce a detailed design for the individual elements.

Ensuring quality of a whole system is about going through that hierarchy in reverse: testing the reliability of individual components or modules against specifications, verifying the performance of subsystems against requirements, then validating the outputs of the system in terms of customer need. This is coupled with a clear recursive process for when standards are not met, to ensure definitions are revisited at the most specific level possible.

Managing quality in this way rests on project requirements being as specific and measurable as the hypothesis of a scientific experiment, with a clear and unambiguous difference between compliance and failure. When the definitions of individual components are derived from the context of a definition of the whole system, far more of the potential emergent defects in the whole can be detected in testing the individual parts. This means rework can be anticipated earlier and performed more easily and cheaply.

In other words, you start with a design and modelling process that is engineered to assure that stakeholder needs are being precisely met before your costs are sunk. Thinking about quality as a question of adherence to robustly defined stakeholder needs minimises waste and improves project control, by guarding against scope creep and overengineering. It's not about getting above the line, it's about hitting the bullseye, and systems engineering tools and skills can help you ensure quality without overdelivering and generating excess costs.

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 an equal partner, and 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.

Big Picture Thinking

Systems engineering allows the rail supply industry to take a whole life cycle view of its products, and better understand how they integrate with the rail network as a whole. The main driver of value that it brings to the table is helping you precisely target your project at stakeholder needs, no matter how complex: doing no more, and no less, than you need to.

For that reason, it has a strong focus on good practice in requirements engineering and using that to develop models of a system which can be used for simulation and anticipation of potential emergent issues ahead of time. Left-shifting quality is about embedding calibrated standards at every stage of the process.

In other words, systems engineering is about getting it right from the start when you're dealing with complexity. It comprises a series of processes and techniques for analysing the properties of a whole as more than the sum of its parts, but more than that, it is a way of thinking about a project which keeps focus where it should be; what the value of your work is as a part of the big picture.

Systems engineering needs the right skills, the right process and the right tools. But with these in place, rail supply could respond to the complex challenges of the industry's ever more demanding needs by building its products more efficiently and reducing project risks.

LOW WASTE MODELLING TECHNIQUES

Every project manager knows how important it is to discover defects as early as possible.

Most project costs are already committed at a very early stage, and discovering a defect even in the course of building your product can be extremely costly. If a defect happens because of an unexpected interaction between different parts of the system, it might not even be discovered until the system is in use, with no recourse but to go back to the drawing board.

In rail, as the systems that run the network get more and more complicated, the potential for problems like this is getting bigger and bigger. Failing to anticipate defects early enough is an expensive source of waste, and a huge risk that damages the value your customers can derive from your work.

The original motivation for systems engineering, and still the core of its mission today, is to provide a way of thinking about projects that prevents precisely that sort of disaster. Scientific rigour in requirements and quality is a part of that story, and a major part of how that translates into value benefits is the modelling techniques that this rigour enables. Using SE techniques allows you to build models that help you understand every stage of your product's life cycle and anticipate how it will behave in the context of the network as a whole.

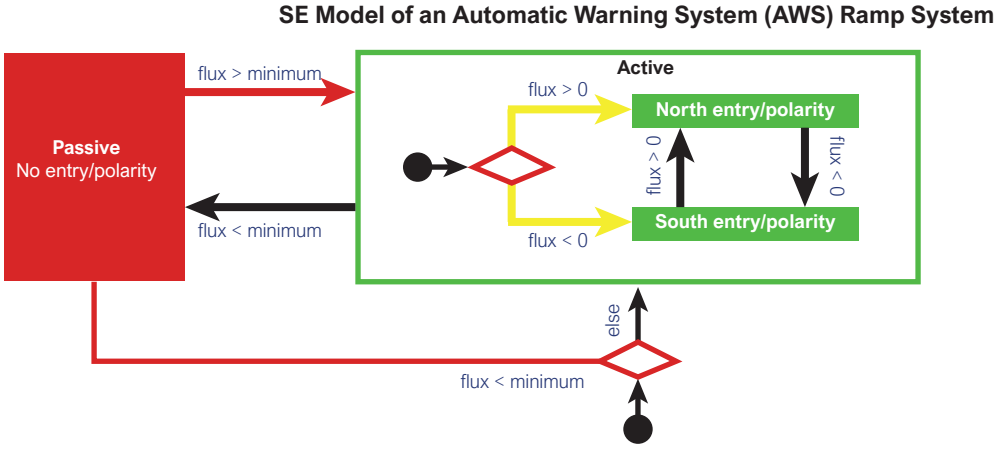
A formal systems engineering model is built out of black boxes, taking inputs from users and the environment and outputting stakeholder needs. Until you reach the finest levels of detail, the model is not concerned with how individual components work, but rather with the structure of a system as a whole; the inputs, outputs and interactions of system elements. It's about recognising that the structure of a system, rather than the specifications of individual parts, are what determines its behaviour as a whole.

As such, the models are nearly always built from the top down, with the system as a whole taking inputs from users and the environment and outputting 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, the benefits of a systems engineering model are not just confined to presenting a clear, coherent architecture to build from, it also allows the behaviour of the system as a whole to be anticipated prior to building, and sometimes even designing, anything physical. By helping you get it right the first time, these models directly and straightforwardly help you reduce waste even when your projects have clear and relatively fixed objectives. But where they really shine is in helping you cope with change.

In rail, stakeholder needs can change at any point in the product life cycle, either during development or as the network changes around your work. 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 they will mean for your product. This allows you to reduce the waste associated with project change, and even to add lifetime value, by designing your product to be more adaptable to changes in what's happening around it.

More and more rail suppliers need to think about their work in the context of the whole, and SE modelling is a fantastic tool to bring that to your business.



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

The SWORD Project - Modelling for Efficiency

Network Rail's 'Digital Railway' programme is a large-scale overhaul of the entire network's Control, Command and Signalling (CCS) systems, with the potential to hugely increase the safe capacity of the network while reducing cost. The programme will ultimately replace every lineside signal on the network with cab signalling systems, but in the meantime, some existing infrastructure will reach the end of its life and require immediate replacement.

The SWORD (Self-powered Wirelessly Operated Distant signal) project was the result of exploring cost-effective options for these 'temporary' signals. The idea was to remove the need for long lengths of fixed copper cable between the signal and its control point. At the time, model-based systems engineering and simulation-based validation were relatively new approaches to Network Rail and CCS, but there was a need to verify and validate the SWORD system more quickly, cheaply and safely than would have been possible with a traditional prototype. By building a systems engineering model of SWORD, Network Rail was able to validate the system through simulated testing, produce a better specification for stakeholders, ensure end-to-end traceability of the system, and maintain an adaptable model for any future specification changes.

This case study was adapted from "Verification and Validation of a new type of Railway Signal using MBSE and Simulation", Stephenson, Vine & Towers, November 2018.

Planning for Change

Production methods like Lean, Kaizen and Six Sigma are effective at reducing waste and providing assurance throughout the construction process but providing similar assurance before you start building anything physical requires a different set of tools.

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[2]. 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.

SE modelling requires appropriate technologies to support your team, as well as the skills to operate them, 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.

[2]PMI (2014). Requirements management.

THE VALUE OF TRANSPARENCY

The rail industry has always required thinking about the long term. Almost any rail project is better thought of as enhancing an existing system rather than creating a new one, and once a system is integrated into the network, it's generally required to last a very long time. Adapting to the interface with legacy systems at the same time as futureproofing your own designs is always a difficult balancing act, and the rail industry has to think in longer time horizons than most.

The complexity of this task is only going to grow, and traditional project management and construction management processes could be supplemented by techniques developed by industries which have always faced this level of interdependence and sensitivity to change. The value case for these techniques is often just a matter of helping you get it right earlier and more often, but the tools developed to support these processes can have significant benefits to project control, enabling you to continuously track and optimise the value you are delivering for your rail customer.

Transparent, real-time information on your project is critical to ensuring that you are delivering on spec, on time and on budget, and traditional tools have often been of limited use in providing that, especially when a project is being delivered through or assisted by multiple subcontractors or a complex supply chain. Systems engineers have developed many procedures and tools for managing project information in a way that guarantees rigour in your objectives, your process and your quality assurance. Research has shown that systems engineering activity has a significant, quantifiable return on investment, which can be as high as 7:1 in projects where little or no systems engineering activity has been employed at all[3]. What's more, systems engineering tools can help you control your project, and ensure you are delivering the value you planned to deliver. By making your process more transparent to ongoing value engineering, not just for the full duration of your and your partners' work, but throughout the full life cycle of your product, these tools can help you enhance quality, mitigate risk and lower costs.

What these tools enable you to do is maintain a single source of truth about the project, which persists not just along the full life cycle of the project but across all stakeholders and partners who are working to achieve it. By moving these tools into the cloud and enabling cross-compatibility, different teams, including those from partner organisations, can all feed into and draw from the same, real-time feed of project information.

Delivering value is easier and less risky when those who need to know have a clear picture of what's actually going on.

[3]Honour, Eric. "Systems engineering return on investment", PhD diss. University of South Australia.

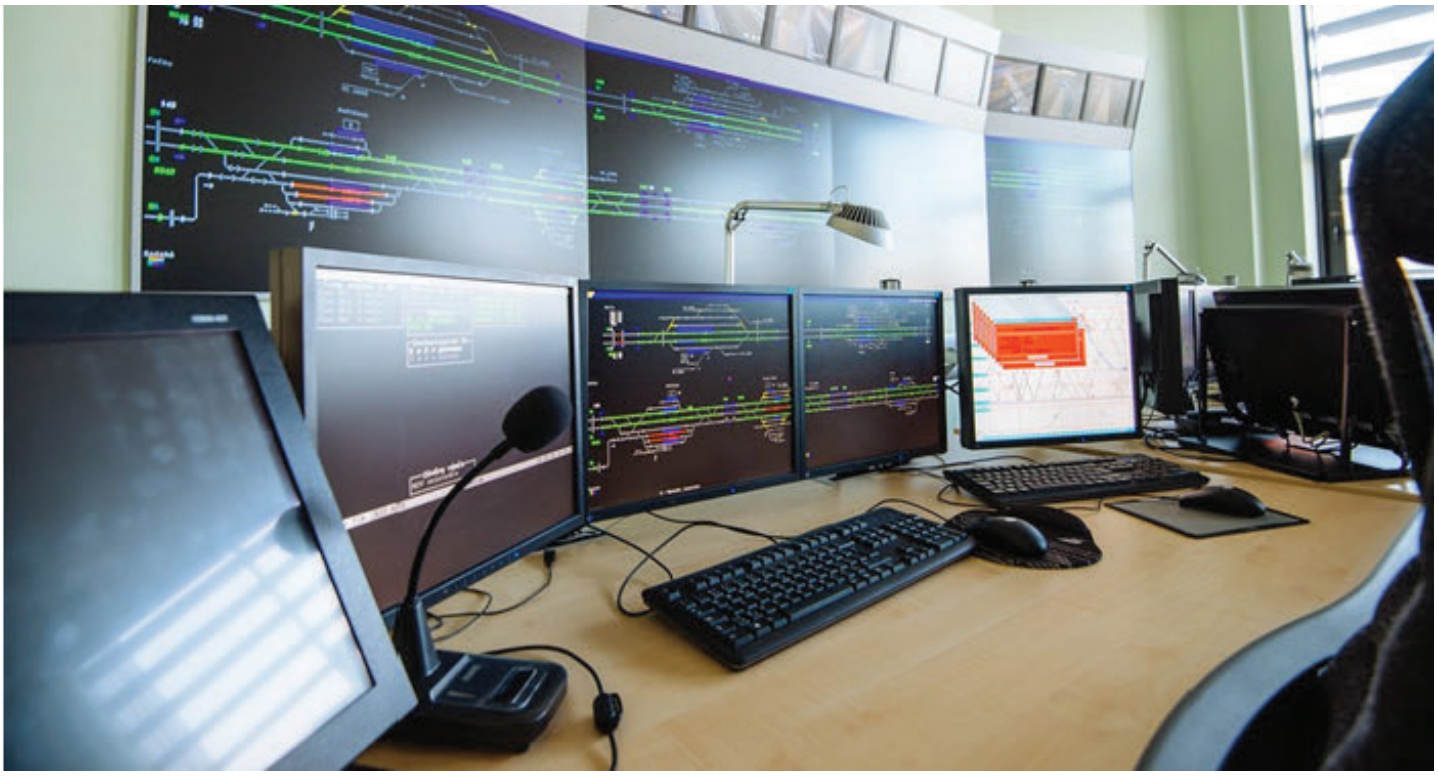
Invensys Rail Dimetronic

Cutting Time to Market by 40 Percent with a Single Source of Truth

Implementing European Rail Traffic Management System signalling is a safety-critical smart railway project underway throughout Great Britain and set to take up to 30 years.

Invensys Rail Dimetronic was involved with the development of the underlying systems from a very early stage and wrote around a million lines of code in the course of those projects. That code was handled by multiple teams spread across global locations, so making sure everyone was on the same page was an extremely challenging task.

By implementing tools which enabled them to maintain a single source of truth – in their case, a precursor to IBM® Engineering Lifecycle Management – they were able to streamline information sharing considerably.



Using these tools enabled them to reduce time-to-market by up to 40 percent, and by moving away from manual testability and traceability they were able to focus their people and resources on product goals like safety instead of more tedious tasks.

A single source of truth also allowed them to be sure that what they were doing at the highest levels was integrated with the lowest levels, provide people with real time access to information, obtain very accurate and personalised reports about the state of the project, and link project requirements directly into the code.

Transparent Tools

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 value engineering experts and the real-time data they need to do their best work can ensure you really are delivering the best value you can for your customers and bring everyone in to making that a reality.

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