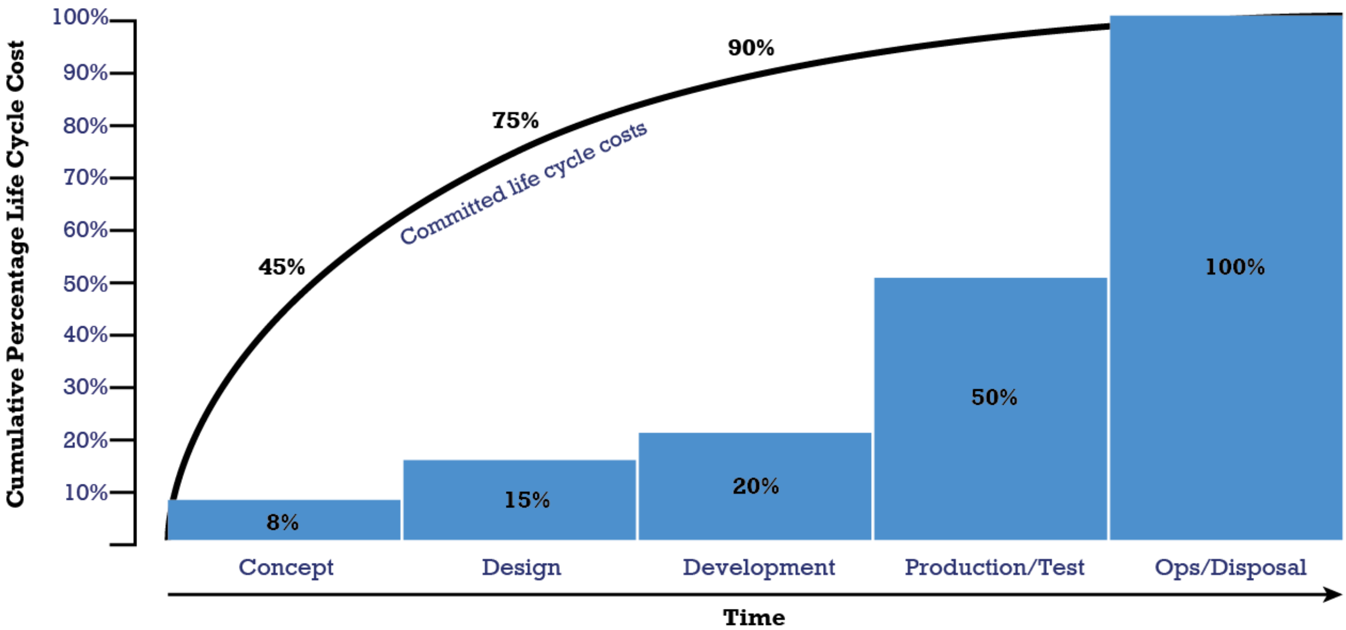
# Engineering a Better Railway for Northern Ireland
Better Planning

## Better Planning




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

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 a system can be extremely expensive. If a defect happens because of an unexpected interaction between different parts of the system, it might not even be discovered until it is in use, with no recourse but to go back to the drawing board.

Systems Engineering (SE) activity can help engineers anticipate and address those defects at a much earlier stage, as much as possible before the associated costs have been committed. The two main ways it does this are through a rigorous, scientific approach to requirements management and stakeholder engagement, and modelling techniques designed to anticipate the behaviour of the system as a whole and in its context.

An SE approach to requirements is designed to cleanly and specifically identify ambiguities and gaps in stakeholder needs. Getting stakeholders to articulate their needs can often be an extremely frustrating process. Half the time – even more when the stakeholder is not a technical expert, as can often be the case in rail – they don't even know what they want themselves. The best way to get a straight answer is to ask a straight question, and the SE process is very good at generating straight questions.

SE 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: it has to be possible to tell the difference between a world in which the statement is true and a world in which it is 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.

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If an SE process for generating requirements is followed, it is immediately and specifically visible when individual requirements are not clear, verifiable, functional or minimal, as well as when they are together incomplete or inconsistent. As a result, the question that needs to be answered either by stakeholders or by engineering is specified precisely and robustly.

At the same time, SE is good at generating requirements for a project when there isn't a possibility of addressing specific technical specifications with the stakeholder, in fact, stakeholder conversations should avoid technical details as much as possible. Instead, focus should be on the functional description of the asset, the 'use case'; a problem that needs to be solved, or an opportunity that they want to pursue. The context and environment for the system – its basic inputs and outputs – should be understood as clearly as possible while the system as a whole is still being treated as a black box In a systems engineering process, only then do engineers start to formally investigate the sorts of systems which could solve the stakeholders' problem.

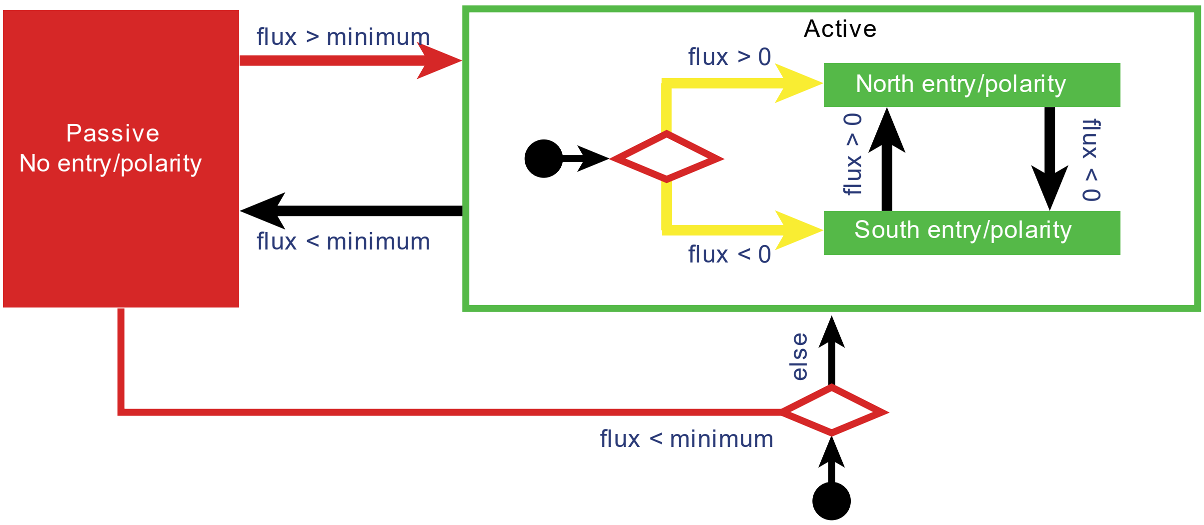
As well as the direct benefits of specifying project objectives with such a high degree of precision, this approach to requirements also enables systems engineers to construct sophisticated models of assets, which can anticipate many potential problems before committing to development costs. These models touch on every aspect of the life cycle and are designed to predict the behaviour of a system taken as a whole.

A formal SE model is built out of black boxes, taking inputs from users and the environment and outputting stakeholder needs. Until the finest levels of detail are reached, 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 designers, testers and operators, it also allows the behaviour of the system as a whole to be anticipated prior to proceeding with development, and potential defects to be anticipated and addressed before many of the associated sunk costs.

**SE Model of an Automated Warning System (AWS) Ramp System**




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

## Network Rail Performance Modelling: Network-Wide Systems Engineering

Many enduring customer objectives for railway systems, like journey times, reliability and capacity, are best understood as properties of the network as a whole rather than of any specific system. As such, the effect of making changes to individual systems is not always easily understood in terms of these goals, and it is difficult to make a sure value case for improvements except when responding to a fault that has already happened. After many years of developing piecemeal models and techniques addressing specific aspects of railway performance, by 2012 Network Rail was able to present an integrated whole-railway model of the effect of faults and perturbations on the reliability of the network, as a basis for taking investment decisions.

By taking a whole-system view of the railway, Network Rail has been able to anticipate the most promising areas for investment in terms of meeting ever-growing capacity demands. For example, in an early test of the model's performance, it was able to not just predict the actual service level achieved on the West Coast Main Line, but also identify that delays less than the three-minute reporting threshold were in fact a major obstacle to increasing capacity on the line.

In other words, the model revealed that by only monitoring delays of three minutes of more, Network Rail had no reliable data on a critical constraint on capacity, and as such had been prioritising the wrong kind of reliability initiatives.

As a result of this discovery, the industry started working to change the way it collected data on delays and accelerated initiatives to help drivers stick more closely to the timetable. The model is now being adopted as the UK industry standard railway-level analysis tool.

*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.*

## Discovering Defects Early

According to the Project Management Institute's (PMI) global 2020 'Pulse of the Profession' study,[1] project managers in both the manufacturing and construction industries reported poor upfront planning as the primary cause of project failure. An earlier global study by the 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 can reduce this waste considerably.

SE approaches to requirements and modelling can cut costs and reduce risk by 'left-shifting' the moment when the team discovers something is wrong to before the associated costs have been committed. By defining stakeholder needs appropriately and translating that functional understanding of the project into scientifically rigorous specifications, engineers can be sure they are building the right asset the right way. By using that rigour to model the behaviour of the system in context before building anything physical, it becomes possible to uncover more potential defects than would be possible with a traditional design process.

In other words, SE can help avoid having to do rework after costs have already been sunk. By reducing the financial risk of rail projects, systems engineering could help struggling rail networks improve project performance and make a better case for future investment.

**This information sheet is an excerpt from SyntheSys Technologies White Paper about Engineering a Better Railway for Northern Ireland. Read the full White Paper [here].**

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

[2] PMI (2014). Requirements management.