Total Cost of Ownership of Rail Signalling Systems

Making rail infrastructure ownership more cost effective
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The Sponsor and the Author

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Executive Summary

Lifecycle costs are a well understood concept in networked infrastructure assets, for example, in utilities and telecoms. In the rail industry the concept is less widespread but no less useful a tool to inform resource allocation decisions or assess the relative merits of different rail signalling technologies across the whole asset lifecycle. Cost is not the only factor in implementing a signalling system, but it is an area that interests all rail infrastructure operators.

We set out to build a Total Cost of Ownership (TCO) model to quantify the cost of various lifecycle stages from scheme design through to implementation, operation and maintenance. We populated the model with real-life data provided by rail infrastructure operators from Europe, US and Asia Pacific.

We have normalised our findings to allow for differences in labour rates and track configuration; the resulting costs should be fairly comparable and therefore we can confidently draw reasonable conclusions about the distribution of TCO by life stage.

We draw four key conclusions:

1. Around 60% of the TCO of a rail signalling system is associated with the initial outlay for implementation (covering design, acquisition, installation, testing and commissioning). This compares with c.40% of costs related to the ongoing running of the system (covering operation, planned and reactive maintenance and penalties, where applicable).

2. The distribution in TCO costs in rail is notably less widespread but no less useful a tool to inform resource allocation decisions or assess the relative merits of different rail signalling technologies across the whole asset lifecycle. Cost is not the only factor in implementing a signalling system, but it is an area that interests all rail infrastructure operators.

Although the rail industry is quite rightly focused on reducing costs during the implementation phase, the quality of equipment and installation should not be ignored. Indeed high quality engineering during the implementation phase is critical in ensuring TCO is as low as possible, particularly as benefits and return on investment often accrue during the last few years of a project. In addition and increasingly common place thanks to increasing competition, operators are often lured into focusing on solely on price and not quality, the implications of which are often felt many years into operation.

2. Rail is a manpower intensive business. Labour costs for activities such as design, implementation and, most significantly, maintenance represent c.70% of TCO. The infrastructure industry, though not directly comparable to rail, does share some things in common - asset availability levels are demandingly high, infrastructure is capital intensive, it is regulated and most networks are more technically complex than a signalling system.

We have normalised our findings to allow for differences in labour rates and track configuration; the resulting costs should be fairly comparable and therefore we can confidently draw reasonable conclusions about the distribution of TCO by life stage.

3. Fault rates not only drive the cost of maintenance but also have a significant impact on network availability. We have seen various methods employed to reduce failure rates, two of the most effective have been:

i. Monitor and publish performance information at the team level. Field engineers need to feel their efforts have consequences both good and bad (appealing to pride) and bad (appealing to competitiveness). This has resulted in a 44% reduction in failures at one operator. A further enhancement to this is to set targets and reward performance, again at the team level – this tends to stimulate innovation (in working practice) and faster or more effective problem resolution.

ii. Condition-based asset monitoring. Being able to monitor a component to get early warning of imminent failure allows maintenance resource to be directed more economically and failures to be avoided.

4. Reducing TCO is the end goal once the distribution of costs across life stages and cost drivers are understood. We note several ideas - some big (entailing capital investment), some small (minimal cost) that both operator and equipment vendors can drive:

i. Modular equipment. Off-site assembly and testing of discrete standardised signalling modules enables a more efficient and robust approach to system testing. It also requires less time onsite thereby reducing disruption to the network and allows testing to be completed with fewer possessions (which is expensive as most of our operators were capacity constrained)

ii. Handheld technology to de-skill/improve quality of installation. Use of mobile handheld technology to run testing and commissioning scripts/routines allows elements of the testing process to be de-skilled which in turn reduces reliance on scarce engineering resource and allows a more methodical and robust approach to installation. The latter point was particularly stressed by an operator who conceded that the quality of installation was one of the biggest sources of subsequent equipment failure.

iii. In situ component reliability shared with equipment vendor. There was a surprisingly lack of information sharing between operator and equipment vendor, at best this was done in an ad hoc fashion. Where the feedback loop was well-established, unsurprisingly there was better product performance. This was particularly important as a high proportion of failures tended to be traced to a small number of components that repeated failed.

iv. Condition-Based Maintenance (CBM). Early detection of potential component failure (components reporting issues themselves) allows maintenance resource to be prioritised by need rather than routine and failures to be avoided. There’s a less capital intensive approach to CBM that compares usage data against statistical data to predict failures, this may appeal to operators who have large networks that make the retrofitting of sensors an unwieldy and expensive task.

v. Planned maintenance regimes that take into account the proximity of assets allow multiple components to be inspected during the same visit - this reduces travel time which can be equivalent to the time spent on an inspection. A further step to increase efficiency and consistency would be to link maintenance regimes to components in the asset register which could in turn drive a workload management system. Engineers could then have their scheduled tasks downloaded to their handheld device and update the asset history on completion of the inspection.

vi. Handheld technology as a training tool. The diversity of signalling equipment that needs to be maintained by an engineer presents a training challenge. Handheld-based maintenance instructions (checklists) linked to an asset register which holds the components maintenance history allows faster fault resolution; improved proportion of first time fixes; and can reduce the reliance on classroom training. Another tool is visualisation, where engineers can train in simulated 3D environments, this has been used successfully in the oil and gas industry to allow engineers to practice in real-life situations.

Idea Summary

Figure 1: Levers for implementation cost reduction

- Modular equipment
- Handheld technology to expedite and improve the quality of installation
- Earlier vendor involvement in signalling scheme design
- Condition-based asset monitoring and maintenance
- Handheld technology for training and issue resolution
- Monitor and publish performance to improve failure rates
- Share in situ component reliability statistics with vendors
- Design planned maintenance regimes that take into account the proximity of assets that need inspection
- 3D visualisation training tools

“the quality of equipment & installation should not be ignored.”

Savings levers for ongoing costs
Introduction

Historically, operators have based their signalling purchasing decisions on upfront costs, balancing required functionality against the lowest capital outlay. This disregards the Total Cost of Ownership which most operators have expressed an interest in but rarely have the time or data to calculate it.

By developing a TCO model, we believe operators can make better informed decisions on how to manage the whole asset lifecycle more cost effectively. It can inform trade offs, for example, of functionality against ease of maintenance. It can also improve the focus on reliability; very few operators assign a cost to delays caused by the system. If these were factored in perhaps more emphasis would be paid to optimising maintenance regimes and fault resolution before the purchasing decision was made. The value of whole life costing has been acknowledged by rail and metro operators and we know of at least three companies that have been successful at developing lifecycle costing for their network.

There are further benefits to using a TCO method in rail signalling:

- Solutions are procured to address whole life costs
- Encourages equipment vendors to develop products that support simpler installation, testing and maintenance. This does not belittle the importance of signalling functionality designed to increase capacity on the network
- Stimulates a debate at the operators that cuts across the silo-think that prevails in many large organisations
- A TCO model is a good way of getting procurement managers, planning and design engineers and maintenance managers to discuss how best to allocate resources
- It can help inform strategic decisions taken by the regulator and asset owner on the balance of funding required between capital investment and operating expenses
- TCO is underpinned by a financial model that can be used for managing and reporting financial performance

We set out our methodology for developing a TCO model for rail signalling, we share our key findings and suggest ways to reduce TCO.

The objective of the paper is to stimulate a debate in the industry between asset owners/ operators, equipment vendors and regulators. If you would like to learn more about our methods or indeed, if you would like to have a TCO model developed for your asset please approach either Credo or Invensys Rail.

We would like to extend our thanks to the operators that have kindly contributed their insights and time to help us populate the model with real-life data - you helped bring to life an otherwise theoretical concept.

Methodology

Approach

The TCO financial model was designed to address the drivers of cost at each life stage. We then collected real-life data from the participants to populate the model. Given the diversity in local conditions at each operator, we had to select a comparable ‘baseline’ section of route at each.

This was defined by the following characteristics:

- 30km route, principally used for commuter rail
- Computer based interlocking
- Track circuits or axle counters for train detection
- Electrified track
- In operation for over 5 years

Data was gathered through meetings with representatives from: strategy & planning; signal design; procurement; estimating; field maintenance and performance management.

We normalised our results for significant variables such as labour rates and track configuration (double, triple tracks). However, there are several cost drivers that drove diversity in the results and could not be normalised:

- Signalling equipment type
- Mix of labour internal vs external (external labour is at higher rates)
- Signalling complexity
- Maintenance regimes

There were other subtle differences that affect local operating conditions and indirectly impact our findings, for example, regulatory conditions (that can mandate inspections), asset ownership and management responsibility, cultural and management disciplines.

Participants

There are rarely more than a handful of operators in a single country, often there is just one rail metro operator per country, therefore, by necessity the study had to have an international perspective. The participants come from three regions - North America, Europe and Australasia. Three of the four participants are Invensys customers, one is not. They were self-selecting, in that they all had a desire to understand TCO. Credo conducted this study independently of Invensys to protect operator data and commercial confidentiality.

The intention of the study was not to benchmark operators against one another, rather to develop a TCO model that was representative for a typical operator. We couldn’t entirely resist making comparisons so where they provide useful insights or suggestions for reducing TCO, we make these observations.

The data we gathered was complete for three participants, we refer to them as Operator A, Operator B and Operator C, the fourth, Operator D contributed partial information and therefore was not included in all analyses.

TCO model structure

The model follows the structure shown in Figure 2.

- Services - these are costs associated with the signalling system. They are either ‘people’ costs (labour related) or ‘fact’ costs (such as equipment or other items with a definable price)
- Components - services are wrapped up into the component that they deliver
For example, take the testing of a new track circuit within a signalling system. Testing is made up of services such as the cost of an engineer, which would be associated with the track circuit component which in turn is part of the signalling solution. Each cost is then categorised in two ways:

• “People” or “fact” costs – as above, the cost is attributed to either labour related or specific, fact cost, refer to Figure 3

• TCO stages - each cost is also attributed to a TCO life stage

Figure 3: cost types covered in the TCO model

**TCO life stage and cost drivers**

**Setup**
This stage covers initial conceptualisation, business case creation, commercial arrangements and tendering. The driver of cost is man days required times day rate.

**Management**
Most signalling work will require a team dedicated to programme management. Initial estimates indicate that about half of this team is made up of specialist programme support; however this does differ largely by operator. Costs are calculated as man days times day rate.

**Design**
The design will cover circuits and data design as well as operational system design for re-signalling an existing route. Estimates indicate that about two thirds of design work is completed by specialist signalling design houses. As above, man days are used to calculate costs.

**Acquisition**
This is principally signalling equipment, construction and materials. We asked participants to provide costs for re-signalling an existing route to exclude the costs for major civil works or communications network installation. It is based on the final cost to the operator of equipment, as well as any labour costs required for obtaining the materials. We have used costs provided by estimating teams. Given the specificity of operator needs, vendor solutions are often custom designed.

**Installation**
Installation costs are driven by man days of internal and external labour. A further consideration, though not always assigned a financial cost, is possession duration which affects network availability while re-signalling work is performed.

**Testing**
Once installed, the system must be thoroughly tested before commissioning. A significant proportion of this work tends to be performed by external contractors, and costs are calculated in the model by man days required.

**Commissioning**
A similar level of external expertise is required for commissioning, a man day rate and number of days drives the cost.

**Operations**
The primary driver of operational cost is power consumption. This is determined using the following formula for each component of the signalling system: Component power cost = number of components * operating hours * power rating * cost per KwH

**Planned maintenance**
The amount of planned or preventative maintenance required for each component is determined top-down based on the number of engineers and a cost per head. We’ve also triangulated this based on a bottom-up method: Planned maintenance cost = number of components * inspection frequency * inspection duration (including travel time) * number of engineers performing inspection * cost per engineer hour

**Reactive maintenance**
Reactive maintenance refers to unscheduled repairs arising from faults that require engineer callouts. Again this was estimated top down based on the number of engineers in the maintenance team, proportion of time spent on reactive maintenance and a cost per head. We’ve also triangulated this based on a bottom-up method: Reactive maintenance cost = number of faults per annum by component type * fault response time (including travel time) * number of engineers present * cost per engineer hour

**Delay penalty charges**
Most operators in this study do not have penalty charges levied by the regulator or train operating companies for service interruptions caused by a signalling fault. Penalties tend to depend on the industry structure - where the rail infrastructure operator is run by an entirely separate company to the train operating company (not just a different subsidiary within the same group), some form of penalty is not unusual. Where the rail industry is vertically integrated, penalties are rare but so are other forms of incentive to improve performance. We think penalties should be considered as part of the TCO analysis, where the regulatory regime does charge them, we have estimated them as: Delay penalty cost = total delay minutes due to signalling * cost per delay minute

Figure 4 below outlines the various stages that were considered in the total cost of ownership analysis.
Finding 1: The largest component of TCO is the initial implementation cost

Our analysis of TCO indicates that the largest proportion of costs in a signalling system - 60% of the cost over 20 years - is consumed during year 1 when the system is implemented. These costs cover design, acquisition of equipment and construction, installation, testing and commissioning. The implementation costs are for a major signalling upgrade and therefore would use existing trackside housing and communications.

This compares with 40% of TCO costs that are ongoing over the 20 years lifetime. They include the cost of maintenance (both planned and reactive) and operating costs, principally energy consumption by signalling equipment (this would also include air conditioning of signal housings). We have normalised our findings for track configuration and labour costs and present in Figure 5 the distribution of TCO costs expressed as an average of the participants in the study.

We elaborate on the differences between operators below. But one thing stands out as consistent, the TCO over 20 years is approximately $67m for the 30km baseline section of track at each operator. This was surprising given the diversity of each operator’s situation but it points to a handy rule of thumb - the signalling TCO per km of route is $2.2m. We would expect this figure to be lower for predominantly freight-based routes where the signalling requirements would be much simpler.

Variances between operators

The ratio of ongoing to year 1 costs varies notably between operators. The most notable variations by life stage are listed below. We indicate the drivers that are likely to account for a material proportion of the variance in Figure 6.

“the TCO over 20 years is approximately $67m for the 30km baseline section of track at each operator.”
Comparisons with telecoms

The relative proportion of implementation to ongoing costs is useful to contrast against other industries. The telecoms industry has some relevant parallels to rail signalling. High infrastructure availability levels are critical, the industry is regulated, it’s technology intensive, the infrastructure is distributed and combines physical assets and computer processing, the asset owners are being driven to deliver efficiencies. This last point has been more marked in telecoms companies as most are publicly held and shareholder influence encourages more radical thinking than a benevolent state owner.

There’s one key message from the data in Figure 7 - implementation costs are almost double in rail compared to telecoms.

The disparity is partly down to differences in technology between the two industries. The modularity of design and open interfaces that can be found in telecoms does not yet exist in rail. In telecoms, this has driven innovation and a lot of competition which has seen equipment prices tumble. So much so, equipment vendors are expanding into services as they see their equipment sales being eroded by competitors from lower cost economies.

Another difference between the two industries is that the telecoms equipment market is much bigger than the signalling market and the turnover is 10-20 years in telecoms rather than 20-30 years in rail. This makes innovation pay off in telecoms.

Signalling vendors on the other hand are constrained by unique country signalling rules which limit their ability to recoup development costs across multiple clients. Further there has been less demand for open interfaces as operators tend to allocate vendors to a particular geographic region or route.

ERTMS heralds a step change in the industry and should help the signalling market open up. Standards are, for the first time, common across nations for ERTMS signalling. This should mean the associated technology becomes standardised and simpler too. But ERTMS is not a mature technology in terms of uptake. We notice that many operators have done trials or are making tentative moves to implement ERTMS in part of their network. There’s quite a way to go before we reach a universally common signalling platform that allows equipment vendors to achieve the scale economies that we see in other technology-driven industries.

Better performance through greater planned maintenance intensity?

The single largest variance between Operator A and Operator B in Figure 8 is the remarkably higher proportion of costs spent on planned maintenance at B. In absolute terms, B spends over twice as much on maintenance as A. Why might that be?

The principal reason is the more onerous inspection regime at Operator B (mandated through safety regulations) that require inspections to take place at a specified frequency. Unlike in other countries, these regulations are set and audited by the regulator, the inspection regime is not at the discretion of the operator. Failing behind on inspections is not an option.

But does twice the cost equals better reliability? To answer the question, we’ve looked at the number of delay minutes resulting from signalling faults, refer to Figure 8. The answer, superficially, appears to be yes, a doubling of maintenance costs at Operator B (ostensibly planned maintenance) is associated with delay minutes that are one-tenth the amount at Operator A.

That is a remarkable performance difference. But we note the reduction in delay minutes is not solely attributable to more intensive maintenance - a harsher environment and greater signalling complexity are likely to account for a higher number of faults at Operator A.

A closer look at the drivers of cost reveals that the railway signalling is a manpower heavy activity – nearly half the costs are related to labour, refer to Figure 9. This is a combination of internal staff (30% of TCO) and external resources (19% of TCO) used for signalling design, installation or testing.

Our main observation is the degree to which operators have embraced the use of external resources for installation. Where skills are scarce or have low utilisation it is normal to use external resources - activities such as design, testing and commissioning are often outsourced. Less widespread is the use of external resource for installation which is the second most labour-intensive life stage after maintenance. Attitudes vary between operators on the use of external resource.

In the UK, the approach has been to outsource installation (signal renewal) as it is an infrequent task and using external labour, albeit at higher rates, gives the operator higher labour force utilisation and greater flexibility.

Finding 2: Labour is the main cost driver

A closer look at the drivers of cost reveals that the railway signalling is a manpower heavy activity – nearly half the costs are related to labour, refer to Figure 9. This is a combination of internal staff (30% of TCO) and external resources (19% of TCO) used for signalling design, installation or testing.

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Figure 7: Comparison of TCO split in rail vs telecoms

<table>
<thead>
<tr>
<th>Year 1 cost</th>
<th>Ongoing</th>
<th>Ratio of ongoing: year 1 costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail</td>
<td>$80</td>
<td>50%</td>
</tr>
<tr>
<td>Telecoms</td>
<td>$100</td>
<td>60%</td>
</tr>
</tbody>
</table>

Source: Credo analysis

Figure 8: The relationship between maintenance cost and delay minutes

<table>
<thead>
<tr>
<th>Operator</th>
<th>Total maintenance cost pa</th>
<th>Total delay mins pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>$1,100,000</td>
<td>776</td>
</tr>
<tr>
<td>A</td>
<td>$460,000</td>
<td>5,550</td>
</tr>
</tbody>
</table>

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Figure 9: TCO by life stage and cost type

<table>
<thead>
<tr>
<th>Life stage</th>
<th>Rail</th>
<th>Telecoms</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>10%</td>
<td>5%</td>
<td>15%</td>
</tr>
<tr>
<td>Acquisition</td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
</tr>
<tr>
<td>Installation</td>
<td>30%</td>
<td>20%</td>
<td>50%</td>
</tr>
<tr>
<td>Testing</td>
<td>30%</td>
<td>15%</td>
<td>45%</td>
</tr>
<tr>
<td>Maintenance</td>
<td>20%</td>
<td>40%</td>
<td>60%</td>
</tr>
</tbody>
</table>

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In the UK, the approach has been to outsource installation (signal renewal) as it is an infrequent task and using external labour, albeit at higher rates, gives the operator higher labour force utilisation and greater flexibility.
Finding 3: Technology use and engineer motivation markedly improves failure rates

Once the signalling system is in place, the focus switches to performance. Performance is a measure of reliability and delays to passenger journeys. Three out of four of the operators in this study describe themselves as capacity constrained particularly during peak hours of commuter traffic. Delays caused during these periods have far reaching consequences.

The cost of delays
The cost of delays is threefold:
1. Bad press is never a good thing in rail; with a public image to protect and a passenger charter to uphold, most operators prefer to remain out of the newspaper headlines and away from political scrutiny.
2. Revenue deterioration is a real consequence if customers have alternative modes of transport they can resort to rather than rail. There is evidence to suggest that passengers value certainty of journey time over the actual journey time – the message is deliver on your promise.
3. Financial penalties. At some operators there is a real financial cost associated with delays which can be as much as US $80 per minute of delay. These are effectively penalty charges that are levied by the train operator or regulator for delays caused by infrastructure performance.

Penalty regimes are not commonplace and some would argue that penalties are perverse instruments as they reduce the money available for maintenance and renewals work. A further cost, though not explicitly measured, is the increased burden of reactive maintenance – more delays, more callouts, more engineers required, more cost.

Reducing delays through motivation
Operator B performs their maintenance activity in-house and for many years performance had languished. A performance management expert was hired from outside the rail industry and one of the first things that he did was begin measuring performance at a more detailed level. Realising that accountability for performance lay in the hands of the maintenance managers and their crews, he began disseminating this information downwards rather than just upwards.

The effect was startling, between 2003/04 and 2006/07 there was a 44% reduction in the number of failures across the network, refer to Figure 11. The reduction was attributable to competition between crews keen to better than their peers, changing behaviours is a powerful force.

“Between 2003/04 and 2006/07 there was a 44% reduction in the number of failures across the network.”

![Figure 10: Reduction in signal failures after introducing motivational measures](image-url)
Lessons from field engineer motivation:

- Making field engineers accountable for performance is empowering. Field engineers need to feel their efforts have consequences both good (appealing to pride) and bad (appealing to competitiveness).
- Monthly progress updates motivate continued effort. The pressure needs to be kept on.
- Comparisons encourage collaboration between crews this leads to innovation (in protocols and regimes) and faster/ more effective problem resolution. Engineers are naturally curious folk and have an appetite to learn.
- Discretion to use minor capital works budgets. The maintenance crews were given flexibility on how best they could use a fixed capital budget. This meant they had to think smartly about how they used this resource - for tools, signalling cards, or even better transport to get to site.
- Financial incentives can provide a further boost to performance improvement. After a while, 3 years at Operator B, failure rate improvement slowed down. This is partly because there is a natural limit to the level of improvement from doing things consistently well. But possibly also because pride and competitiveness can only be leveraged so far. The team at Operator B is in the process of designing a better compensation system that will reward improved performance, this will hopefully help to sustain the journey of improvement.

Reducing delays through technology

Operator C implemented a series of measures to reduce delays on one of their worst-performing metro routes. The route was under five years old and had failed to attract the passenger ridership that it was designed to take. This had not been helped by the poor reputation that the route had developed for being unreliable.

The solution Operator C implemented was led by engineering and involved three steps. The first step was to improve resilience and iron out teething problems with the original implementation – additional power supplies, hardware and a software refresh. The second step was to make more of their engineers available during peak hours to resolve failures. The final step was to introduce asset condition monitoring to alert field engineers to potential failures before they occurred, an early warning system. They decided to trial the solution first.

The condition monitoring sensors were retro-fitted to existing components. The engineers focused on the most critical components for the trial: those that were hard to reach, exposed to lightning strikes or intensely used. This allowed them to limit the scope of the trial and take maximum advantage of the benefits.

Early indications are positive; see chart 12 - failures have declined dramatically since 2005. The operator confirms that the 3-pronged approach has reduced the number of delays affecting passengers. It has helped to increase ridership on the line which Operator C, who also operates the trains, is delighted with.

Key facts: condition-based monitoring technologies

- A concept that is widespread in process industries such petrol refining where the impact of a failed component can halt production or create a safety hazard, both of which entail significant cost.
- The concept exploits the fact that any electrical component can communicate information about its status (current, vibration, temperature, the number of operations performed etc) that can be used to predict imminent failure, indicate operation beyond expected norms or can simply isolate a component that has already failed. The status signals can be fed back to a control centre that monitors unusual patterns and alerts engineers to intervene even sometimes before the component has failed.
- For example, points are prone to failure as they have moving parts. If a set of points starts to operate slower, or draw more current, performance trends can be computed to indicate an imminent fault. This can create a failure log for the maintenance crew to be called out with an appropriate level of priority.

A simpler approach to condition-based monitoring is to simply record the number of operations an asset has experienced. For example, the number of trains that have passed over it. Linking this usage data with statistical data that can predict when a particular asset is most likely to fail, allows engineers to intervene ahead of actual failures. This approach has the advantage of being simpler and less capital intensive as the implementation does not require sensors to be retro-fitted to assets.

A powerful next step would be to link performance data to the asset register to provide an integrated view of asset performance. This can help uncover systemic issues. For example, recurring failures isolated to a single component could point to an issue that goes beyond the component, possibly related to the track configuration or environmental factors.

Condition-based monitoring points to a new approach to maintenance - one that is driven by focussed intervention rather than routine inspections. The concept is being embraced by the UK rail infrastructure owner as part of its move to an ‘Intelligent Infrastructure’. Given the material cost of maintenance, in UK rail this is delivered by c15,000 engineers, a smarter approach to maintenance could make a material impact on both reliability and operating costs.
Total Cost of Ownership of Rail Signalling Systems

Finding 4: Ideas big and small can reduce TCO

In our meetings with operators, we met with representatives from various departments – engineering, procurement, design, performance, strategy & planning. Nearly all of them had ideas or examples for reducing TCO. This is the next logical step in the process once the distribution of costs across life stages and cost drivers are understood. The ideas ranged from simple ways to incrementally reduce failure rates, others required material capital investment.

We present a selection of the ideas for which there was existing evidence or where operators anticipated material savings to TCO. They affect different life stages and the onus of development or initiative is biased to either the operator or the signalling vendor.

i. Modular equipment. Off-site assembly and testing of discrete signalling modules enables a more efficient and robust approach to system testing. It also requires less time onsite thereby reducing disruption to the network and testing to be completed with fewer possessions (which is expensive as most of our operators were capacity constrained).

ii. Handheld technology to de-skill/ improve quality of installation. Use of mobile handheld technology to run testing and commissioning scripts/ routines allows elements of the testing process to be de-skilled which in turn reduces reliance on scarce engineering resource and allows a more methodical and robust approach to installation. The latter point was particularly stressed by an operator who conceded that the quality of installation was one of the biggest sources of equipment failure.

iii. In situ component reliability shared with equipment vendor. There was a surprising lack of information sharing between operator and signalling vendor, at best this was done in an ad hoc fashion. Where the feedback loop was well-established, unsurprisingly there was better product performance. This was particularly important as a high proportion of failures tended to be traced to a small number of components that repeated failed.

iv. Condition-Based Maintenance (CBM). Early detection of potential component failure (components reporting issues themselves) allows maintenance resource to be prioritised by need rather than routine and failures to be avoided. There’s a less capital intensive approach to CBM that compares usage data against statistical data to predict failures, this may appeal to operators who have large networks that make the retrofitting of sensors an unwieldy and expensive task.

v. Planned maintenance regimes that take into account the proximity of assets allow multiple components to be inspected during the same visit – this reduces travel time which can be equivalent to the time spent on an inspection. A further step to increase efficiency and consistency would be to link maintenance regimes to components in the asset register which could in turn drive a workload management system. Engineers could then have their scheduled tasks downloaded to their handheld device and update the asset history on completion of the inspection.

vi. Handheld technology as a training tool. The diversity of signalling equipment that needs to be maintained by an engineer presents a training challenge. Handheld-based maintenance instructions (checklists) linked to an asset register which holds the component maintenance history allows faster fault resolution; improved proportion of first time fixes; and can reduce the reliance on classroom training. Another tool is visualisation, where engineers can train in simulated 3D environments, this has been used successfully in the oil and gas industry to allow engineers to practice in real-life situations.

Idea Summary

Figure 12

<table>
<thead>
<tr>
<th>Idea</th>
<th>Life stage affected</th>
<th>Cost</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. Modular equipment</td>
<td>Testing &amp; commissioning</td>
<td>Capex</td>
<td>• Reduced trackside testing time&lt;br&gt;• Standardised building blocks&lt;br&gt;• Minimise network disruption/track access</td>
</tr>
<tr>
<td>ii. Handheld technology for installation</td>
<td>Installation</td>
<td>Capex</td>
<td>• Script-driven procedures improves quality of installation&lt;br&gt;• Unit testing can be delegated to lower skilled engineers; reduces reliance on scarce resource</td>
</tr>
<tr>
<td>iii. In situ component reliability</td>
<td>Maintenance</td>
<td>Minimal</td>
<td>• Reduced failure rates&lt;br&gt;• Improved component design</td>
</tr>
<tr>
<td>iv. Condition-based maintenance regimes</td>
<td>Maintenance</td>
<td>Capex</td>
<td>• Failure rate improvement; delay avoidance&lt;br&gt;• Reduced maintenance effort – intervention prioritised by need rather than periodic inspections</td>
</tr>
<tr>
<td>v. Planned maintenance regimes</td>
<td>Maintenance</td>
<td>Minimal</td>
<td>• Improved/maintenance productivity (reduction of travel time)</td>
</tr>
<tr>
<td>vi. Handheld technology as a training tool</td>
<td>Maintenance</td>
<td>Capex</td>
<td>• Faster fault resolution; improved proportion of first time fixes&lt;br&gt;• Maintenance history linked to asset record</td>
</tr>
</tbody>
</table>

Incremental improvements

Other practical ideas put forward by operators that we believe are worthy of mention for their simplicity and pragmatism:

• Replacing signal lamps LED versions that last up 20 times longer than traditional bulbs. This not only reduces the maintenance burden but consumes less energy.

• Rationalising signal boxes and rooms to a fewer number of central rooms. At one operator, this resulted in 300 signal boxes being reduced to control centres with significant associated cost savings.

• Half life extension of interlocking cards every 15yrs – to prolong life and reduce frequency of faults prior to full life replacement every 25 - 30 yrs. Interlocking failures are often complex to resolve and can therefore cause long delays, this may not be cost effective but can certainly help avoid detrimental headlines complaining of long delays.

“A further step to increase efficiency and consistency would be to link maintenance regimes to components in the asset register.”
Thoughts for the future

Finally, some thoughts from us based on observations in other industries that might be useful to consider for the rail industry:

- An appreciation of TCO opens up new ways of financing for major projects, as has been fairly commonplace for many years in both the telecoms and the aerospace industries. As we have seen, on average 60% of a project’s lifetime cost occurs during the implementation phase, as a result many projects require a cashflow and investment profile that mirrors this, namely a significant investment in the first few years. Unfortunately, for many operators, the full benefit of a new project, for example in terms of additional capacity, often only accrues a number of years into the operational phase. This delay in gaining the full benefit and a front loaded investment profile can be a significant issue for stakeholders whose accountability and time horizons are often considerable shorter.

- An alternative, illustrated in Figure 13 below, is to match the cashflow to the benefit profile over both the implementation and operational phase. Aside from the obvious cashflow benefits, a longer term relationship between vendor and operator has a number of other benefits such as a better understanding of developing operational needs, improved maintenance and the enhancement and improvement of equipment throughout its lifetime.

Commercial alignment

- Globalisation of trade and growing competition from rapidly developing economies has led to equipment price reductions, which on the surface at least, seem attractive to purchasers. Evidence from telecoms and the IT industries suggests it can be costly to focus on solely on purchase price at the expense of quality and robustness, issues which can occur many years after installation.

- Greater vendor involvement during design. Early contractor involvement in design e.g. UK Highways and Defence procurement has been shown to reduce the cost of bidding for the vendors and helps the operator to arrive at better-priced solutions.

- “Contracting for performance”. This model exists for engines in the airline industry where the engine manufacturer not only provides the aircraft engine but provides an availability guarantee. The engine manufacturer is the exclusive maintainer in this highly controlled physical environment. A similar idea exists in fixed and mobile telecoms where a partner, usually an equipment vendor, is chosen and given responsibility for the whole equipment lifecycle typically 10-20 years. Everything but asset ownership is transferred to the partner under a long term performance-based contract.

Both vendor involvement and contracting for performance drive efficiencies in asset management and improvements in asset availability. The involvement of an equipment vendor helps innovation and best practices from various operators to be disseminated across the industry. It also cuts across the silo mentality and competing objectives of departments e.g. procurement focus on price, engineering focus on functionality, maintenance focus on reliability.

We recognise these ideas may have commercial or technical implications that may limit their suitability in the rail industry. However, they have helped transform the economics, efficiency, safety and reliability in aerospace and telecoms, there may be adaptations of these models that make them viable in rail.

Figure 13: Traditional V New Investment profiles