MODULAR SWITCHES AND CROSSINGS: A PROJECT TO DEVELOP A METHOD OF RENEWING CROSSOVERS AND TURNOUTS WITHIN EIGHT HOURS

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SUMMARY

This paper introduces the concepts of continuous improvement, waste, Lean and Systems Engineering gained through lessons learnt by the author while working on Network Rail's 'Modular Switches & Crossings' project in London in 2008. This experience combined with other work on track renewals projects, fundamentally changed the author's approach to problem solving and encouraged the questioning of current methodologies used in this area.

Through real life examples that are relevant to the rail industry, continuous improvement techniques such as Lean are demonstrated to be successfully applied. The successes and failures shown in each of the examples are a useful way to present the proof of these concepts to the rail industry.

1 INTRODUCTION

The author has prepared this paper with the intention of passing on knowledge gained through experiences on a railway improvement project, the Modular Switches and Crossings project, completed by Britain's Network Rail. It is hoped that the reader will gain an appreciation of how a different approach to the whole life cycle of railway projects can deliver benefits to the industry at large.

Network Rail completed the Modular Switches and Crossings Project in 2009, a project 'aimed at reducing S[witches] & C[rossings] renewals down from 54 hours to eight hours with the added benefit of an average cost reduction of 25 per cent and a guaranteed standard quality throughout the network that can increase safety, as well as reduce maintenance' [1].

As is often the case when looking back, a confluence of pressure was building around this time. Network Rail was coming under increasing pressure to provide greater operational flexibility at the weekends, which meant simply shutting the railway for engineering work every weekend was no longer acceptable. Figure 1 shows this reasoning due to the large growth in passenger kilometres over a 23-year period up to 2010.

As the same time, representatives from Network Rail had also visited track renewal sites in Europe at the invitation of some of the European contractors. During these visits they had seen what was being achieved in much shorter track access windows on the Continent.

The concept of a 'seven day railway', as proposed in Network Rail's Strategic Business Plan [3], further developed the idea that the railway should be open for business when the customer wanted to use it, and that maintenance work should be performed in low demand periods, or without causing disruption.

The importance of this 'seven day railway' depends on one core premise; performing maintenance in a less disruptive manner is an important proposal and is worth investing in.

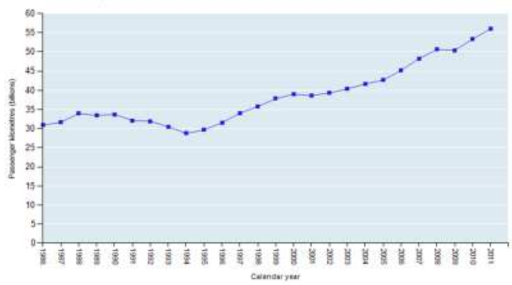

Figure 1: Growth in Passenger Kilometres, Great Britain Annual Data 1986 to 2011 (billions), Office of Rail Regulation [2]

[Note: While S&C is used in the UK to mean Switches and Crossings, and in turn this is a general term for crossovers and turnouts, this paper has been written for an Australian audience, where S&C can also mean Signals and Communications. To avoid any potential confusion, the author will use the full spelling of Switches and Crossings throughout this paper.]

2 PROJECT SET UP

The travelling public's and freight haulier's desire to use the railway with fewer disruptions, led to the initiative to set up a dedicated project team to review the industry's best practices and propose a route to improvement. A tender was subsequently put to the market for a research and development project to expose the constraints to achieving switches and crossings renewals in shorter possessions, and develop methodologies, technologies and improvements to overcome these. Network Rail planned to set up a joint team with experts from within Network Rail working side by side with experts from across the European railway industry.

A joint venture called VCV, comprising VolkerRail (Netherlands and UK), Corus Steel (UK) (later to become Tata Steel), Vossloh (France) and Leonhard Weiss (Germany) was chosen to work with Network Rail on the project. Figure 2 shows the makeup of the VCV team.

Figure 2: VCV team organisations

The project team was approximately a 50/50 split between client and contractor members. The project was split into work streams and a lead was appointed from both VCV and the client for each. The lead was chosen on an expertise, experience and knowledge basis, not because of whom they worked for. This meant that contractors were working for client bosses and vice versa.

3 METHODOLOGY

Two primary concepts, or approaches were adopted for this project:

1. The use of Lean Thinking
2. The use of Systems Engineering.

3.1 Lean

The Lean Thinking, or 'Lean', is a cultural approach to solving problems and improving systems for the benefit of the customer. Lean is not a set of tools, or a series of hoops one must jump through. It is about taking a fundamentally different approach to problem solving.

Many improvement projects are initiated because there is a need to reduce costs or reduce staff, or change a service offering. These are all valid reasons for change, but often the needs of the customer are neither understood nor considered. Projects that are intended to reduce costs, might increase customer waiting time, while projects that are intended to reduce staff might mean customer service is damaged.

Lean is an approach that ensures any improvement project is aligned with meeting the needs of the customer. According to Womack and Jones, 'Lean thinking is *lean* because it provides a way to do more with less - less human effort, less equipment, less time and less space - while coming closer to providing customers with exactly what they want' [4].

Lean projects are supported through the use of several techniques, one being Process Mapping. This technique is used to capture data on the process of creating value. From the perspective of the Modular Switches and Crossings Project, value was defined as providing new switches and crossings with:

- Reduced track access requirements (each possession and in aggregate)
- Increased installed quality
- Reduced installation cost
- Reduced rework.

A tool called 'Swim Lanes Mapping' (see Figure 3) was used to capture all the steps, process and actions that were undertaken to deliver this outcome for the project.

In general, when the current situation is mapped it is called a Current State Map. Following from this an exercise is undertaken to envisage what an ideal scenario might look like, this is then recorded in what is termed as a Future State Map.

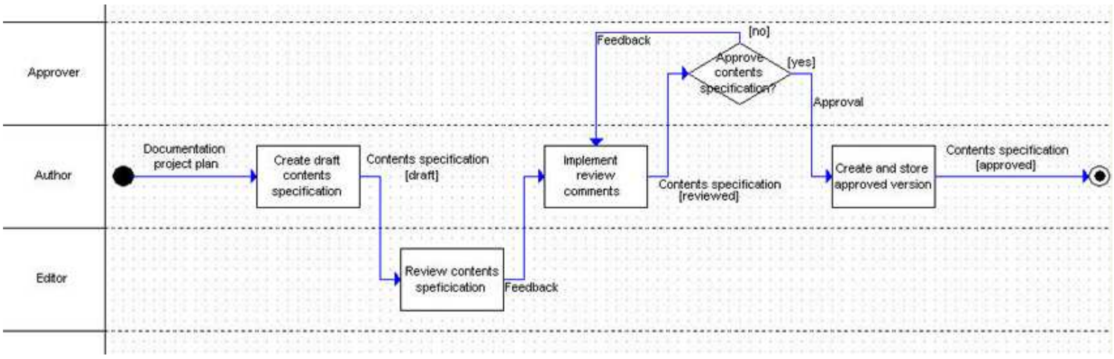

Figure 3: Swim Lane Mapping [5]

To complement the Lean approach and provide a defined outcome early in the project, the concept of using a systems engineering model had been proposed from the outset.

3.2 Systems Engineering

The use of a Systems Engineering approach focused on using a system validation v-model. As shown in Figure 4 a system v-model involves establishing the required outcome, system requirements, acceptance criteria and success factors of a project in the early stages, and then validating each decision against that model. If the decision or option does not fit with the prescribed output, it would then need to be revised.

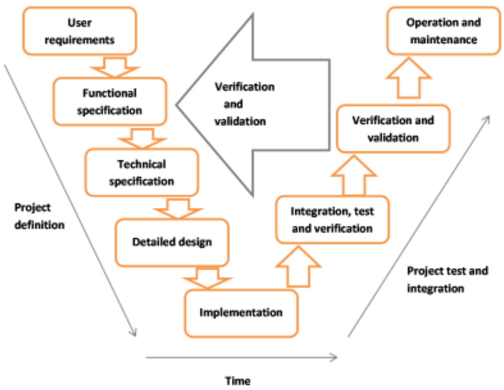

Figure 4: Systems validation model (v-model)

4 DEFINING THE PROBLEM

The initial focus of the VCV team therefore was to define the problem. This involved mapping the current state and then defining a future state. As discussed earlier, a technique called Swim Lanes Mapping was used to define the current state of switches and crossings renewals undertaken by Network Rail.

This enabled the team to develop an understanding of the current constraints associated with the current system of renewal and the current methodologies. In turn this led to the development of new methodologies, a review of the suitability of existing plant and equipment, and the review of the current standards for signalling, track, overhead electrification and commissioning.

4.1 What is Modular?

The origins of the use of the term 'Modular' in the context used by Network Rail, is not clear. Concurrently with the Modular Switches and Crossings Project, Network Rail started using the term Modular to describe various development projects. These ranged from Modular Signalling to Modular Platforms and Modular Station Footbridges. The general premise was clear, to develop a set of standard deployable methods, systems or products that would reduce the time and the cost of undertaking railway work.

In the context of the Modular Switches and Crossings Project, the author believes Network Rail had a clear vision of what the Modular Solution looked like, however they did not have a clear route to achieving that vision, hence the need for the project.

From the experience of the author, Network Rail's definition of Modular Switches and Crossings could be described in the following way:

- The renewal of a turnout or crossover in a manner that causes no, or minimal disruption, to the railway's customers
- This would be achieved through using standard turnout or crossover designs, repeatable processes and innovative techniques, all undertaken in non-disruptive possessions.

This description does not delve into the detail, but it gives a clear overview of the expectations of the project.

During the definition phase of the project there was optimism about how much of the planned Switches and Crossings Renewal Programme could be performed using the modular system. As the constraints on current and future techniques were revealed the degree to which sites would be suitable for the Modular System became less certain.

To give a little more detail – a modular site was one that could be approached using the rules as set out in our systems requirements. As an example, a crossover on a two-track railway in open country with overhead electrification, would be modular. However a crossover on a two-track railway on an underbridge may not. It was necessary to define these parameters as a detailed review of existing switches and crossing units revealed that a surprising proportion were in locations that would not be considered modular. The types of issues encountered were platforms, other turnouts and crossovers, nonstandard layouts, underbridges, tunnels and nonstandard track intervals.

These factors undermined the premise of the project and it became apparent that a large number of switches and crossing units would not be suitable for the pure modular process.

5 PROBLEM DEFINITION

As previously mentioned, the initial step was to understand the problem that the industry currently faced. Network rail had several initiatives happening in parallel to achieve this. One of the most significant projects was to map the ‘End-to-End Process’ for the renewal of a set of points. The intention of this end-to-end mapping was to understand all the steps necessary to renew a turnout or a crossover, however this was complicated by the nonstandard process of switches and crossings renewal across Network Rail. In addition, the official process was not followed and there were numerous shortcuts and workarounds made because the process was not understood and did not work. One of the objectives of the end-to-end mapping process was to highlight areas of waste in the system. Waste is a term used in Lean terminology to mean any activity or process that does not add value to the customer. There are eight categories of waste:

1. Rework
2. Over production
3. Inventory
4. Transport
5. Waiting
6. Over processing
7. Motion
8. Under used human potential.

The mapping of the end-to-end process revealed opportunities for improvement at every stage of a switches and crossings renewal project. There was waste of all forms in the process. In the design approval process for example preferential engineering (over processing, motion, and rework), approval delays (waiting and over processing), scope creep (over production) were just a few of the issues identified.

When the team looked at switches and crossings manufacture and delivery, the opportunities continued. Issues were identified in multiple inspections (over processing leading to rework), assembly, strip down, delivery and prebuild (rework, transport, motion, over processing, waiting, inventory).

A further opportunity for improvement involved the way in which point equipment was fitted. Initially the point operating equipment was fitted at the manufacture stage, to enable inspection of the complete unit. However, to allow transport to site the point operating equipment had to be stripped down. The whole switches and crossings unit was then transported to site, rebuilt and the point operating equipment refitted, and finally once in track the point operating equipment was setup and tested. This process involved all the wastes listed earlier in this section.

Site work also offered significant opportunities for improvement. Delays between subsequent activities were common on renewals sites, there was also rework when considering the temporary plating of joints and then welding. The process of installing rail, clipping up, unclipping, stressing and reclipping is another example that involves many elements of rework – ballast levelling then sleeper lining then tamping (rework, waiting and a form of inventory). This raised questions such as whether the track could be laid in its final position to avoid this over processing and rework, or whether the tampers should be got rid of.

The mapping helped to review the roles undertaken on site and get a clearer understanding of how staff could be used to fulfil multiple functions. Examples of this included issues such as excavator drivers who could be used for other tasks when their machines were stood down, or signalling engineers who could be used for other tasks following the initial disconnection activity.

As the definition and understanding of the problems progressed, the development of potential solutions gained pace. The use of a systems engineering approach ensured these proposals were verified against the systems requirements using the v-model. This further ensured the team was still addressing the problem that had been defined.

6 OUTCOMES

6.1 A different approach to Switches and Crossings renewals

As discussed at the outset, the purpose of this paper is to give some real railway examples to explain the concepts and ideas of Lean. The author has considerable expertise in on-site construction activities, which will be the main focus of this section.

Following the detailed analysis performed by the modular team, it was agreed to aim for a concept of using multiples of eight hour track access windows, with the objective of only shutting one line down at any one time. It was determined very quickly that both line possessions would be needed, but every attempt would be made to limit the use of the adjacent line for the engineering works.

Eight hours was chosen as it meant that one line could be shut on a Friday, Saturday and Sunday night from 11pm to 6am (and possibly midweek). This would cause some disruption, but as single line working would remain in place, a complete closure was avoided. This also meant the use of traditional 54 hour all line shutdowns could be eliminated.

However there were some serious barriers to achieving this objective, namely:

1. Single line working is not always possible
2. Working alongside live lines brings additional risks to staff and operational trains
3. Crossovers involve components that are common to both roads, bearers, rails, electrification equipment, signalling components
4. Spoil and new materials are usually removed and delivered via the adjacent road
5. There is virtually no line side access to the track in the UK.

It was therefore necessary for the team to develop a series of new or different ways of doing things.

6.2 Visible signs of change

A series of new and borrowed ideas were to be used to overcome the challenges of working in eight hour blocks:

1. Bearer tie
2. Bearer cutter
3. In line excavation and ballast laying machine
4. Tilting wagons
5. Heating matts for rail stressing
6. Concentration on Kirow cranes with a self-levelling beam
7. Modular signalling components
8. Pre-testing of points.

6.2.1 Bearer tie

To enable the installation of a crossover using possession on each separate line, hinged on the ability to lay a crossover in two halves and then ‘stich’ it together down the six foot. The solution to join two bearers in the six foot became known as the ‘bearer tie’.

The acceptance and implementation of the bearer tie was a major early win for the Modular Switches and Crossings Project team. The idea of a bearer tie is not new as they are commonly used in Europe with several different solutions developed by their railways. In the UK however, there had been a complete rejection of the idea.

The desire for the bearer tie was a grass roots level idea. Many engineers and supervisors had seen the use of a bearer tie in France, the Netherlands or Germany but were frustrated that it was not used in the UK. The modular team took this initiative and drove it through to implementation.

From an Australian perspective, the need for a bearer tie may be less obvious, a wider six foot means fewer through bearers, and more independent turnouts.

However, in the UK where track centres are often 3200mm, a high speed crossover can have many through bearers – 30 to 40 over a length of 30m.

Figure 5: Bearer tie [Steven Pearson]

6.2.2 Bearer Cutter

To enable the track to be removed in two halves, the long bearers needed first to be cut down the six foot. Developing a way of doing this safely without first removing all the ballast, was another challenge for the team. A further implication of cutting the long bearers down the six foot required the removal of the crossover rails, and therefore the signing out of use of the crossover and the securing of the point ends, a particularly sensitive issue in the UK. Figure 6 shows a concept for a bearer cutter developed by the project team.

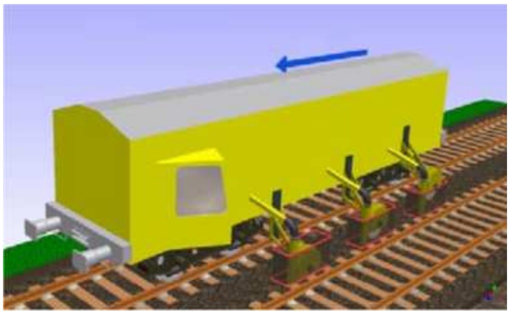

Figure 6: Bearer cutter

6.2.3 In-line excavation and ballast laying machine

The problem of removing the old ballast and replacing with new material, was one of the largest challenges for the project, and an area in which the author was heavily involved. The problem of removing spoil when the adjacent line is open to traffic is that with the old track removed there is no rail based access. This is a formidable problem.

One option was to use a ballast cleaner prior to the removal of the track. The theory was that once the bearer cutter had removed the six foot section of the crossover, the track was effectively a piece of plain line and could be excavated and re-ballasted with a ballast cleaner.

Using an undercutter was another option, but again access from the side is problematic on lots of the network and the quality of the cut was questionable. Another question raised was where the new stone would come from. These options were considered in some detail and working models for each was developed. However a better 'Modular' solution was needed.

The need to use the adjacent line for the removal and supply of materials was key to delivering the engineering work in the short possessions required. With this realisation, attention focussed on using the adjacent line to mount a machine able to excavate and place ballast in one pass as illustrated in Figure 7, Figure 8 and Figure 9. The working head of the machine would be combined with MFS (Material-Förder und Siloeinheit, translated to Material Hopper and Conveyor Unit) style wagons to remove spoil and supply new material.

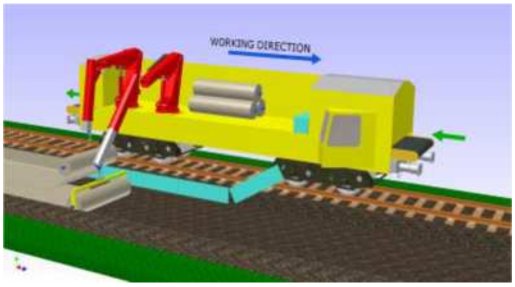

Figure 7: Laying of geo-textile

Figure 8: Laying of first 150mm of ballast with compaction

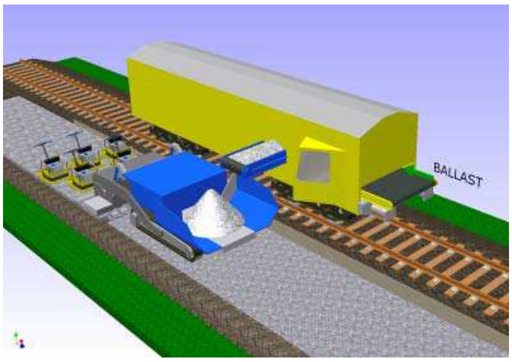

Figure 9: Laying of second 150mm layer of ballast with compaction

6.2.4 Tilting wagons

Tilting wagons are another example of borrowing an idea from somewhere else, and they are certainly not a new concept in Australia. However, the use of tilting wagons in the UK had previously not been possible, but discussed for many years prior to the Modular Switches and Crossings Project. The UK loading gauge, combined with the extensive use of crossovers with through bearers, had prevented them from being used. The adoption of the bearer tie provided a new way of facilitating the use of tilting wagons and ensuring the layouts could fit on the wagons and within the UK loading gauge.

The introduction of the tilting wagons had also been a desire of many in the industry for a number of years, and with the adoption of the early deployment of the bearer tie the next logical conclusion was to place an order for the wagons. The benefits to the industry were so apparent that this was done prior to the conclusion of the project. Figure 10 and Figure 11 show the layout and use of the tilting wagons.

These wagons have been another success of the project.

Figure 11 Tilting wagons with bearer tie stored on bearer [Network Rail]

6.2.5 Review of switches and crossings stressing standard

An independent review of the stressing standard was underway as the Modular Switches and Crossings Project commenced. The issue involved the stressing of the internal rails of the turnout. The distance from the back of the switch to the crossing nose joint for the high speed turnouts could exceed 36m, and according to the standard it was necessary to stress this section of rail.

As will be discussed in the following section, the project team proposed to install the switches and crossings at a neutral temperature of 27°C. Any method used to achieve this would require amendment of the standard. Although a review was undertaken, the problems around delivering a panel to site and installing it at the correct temperature and then welding it in, were so difficult to

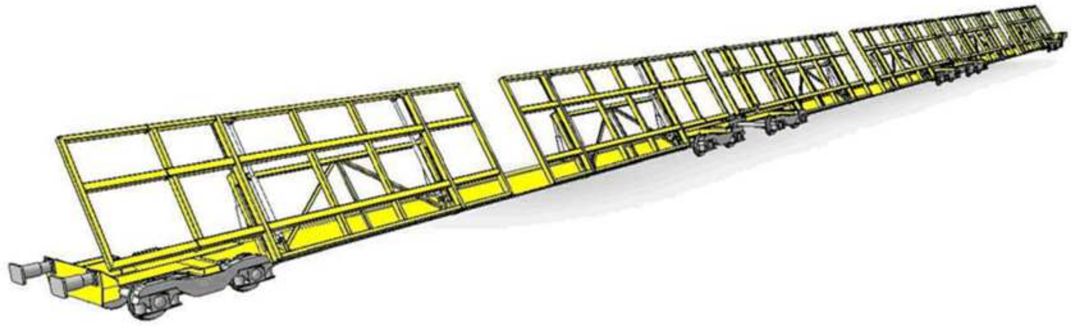

Figure 10: Tilting wagons configuration [Network Rail]

overcome it did not prove necessary to make any changes to permit this at the time of the project.

The issue of stressing the internal rails in the turnout was not resolved as part of the Modular Switches and Crossings Project and still continue with several schools of thought on the best route forward.

6.2.6 Heating mats for neutral temperature installation

Early in the project it was decided to investigate ways in which the panel could be installed and welded in at the neutral temperature of 27°C. Two research projects were initiated separately to the Modular Switches and Crossings Project, but in coordination with it.

The first research project addressed the problem of finding a way of raising the rail temperature to 27°C and keeping it at that temperature until it was welded into the surrounding track. Attempts were made to wrap the rail in a heating material like a giant electric blanket. However, attaining and maintaining the required temperature proved very difficult and eventually this initiative was dropped. The second research project looked at the method of anchoring the rail and the panel to enable the track to be stressed prior to the crib and shoulder ballast being placed [6].

6.2.7 Kirow cranes

As part of the Modular Switches and Crossings Project, a review of track installation machines was undertaken, with Kirow Cranes, PEM-LEMs and the Desec reviewed to see how they might fit into a Modular renewal process.

Kirow rail mounted cranes (see Figure 12) had been used for switches and crossings renewals in the UK since 2001 [7], when they were first introduced by GrantRail. These machines proved very versatile and popular for switches and crossings installations. Prior to the introduction of the tilting wagons the use of these machines was limited by one key factor. It was necessary to have a prebuild area (for line-side assembly of the switches and crossings) in close proximity to the renewal site.

Using the Kirow rail crane in combination with the tilting wagons removed the need for a nearby prebuild area. The utility of the machines was further developed by the introduction of the panel clamping and lifting attachments. These were lifting attachments that were factory fitted to the panel and effectively 'snapped' onto the lifting beam on the crane. All panels had their centres of gravity calculated and the lifting attachments were fitted to ensure a level lift on the first attempt.

Figure 12: Kirow with adjustment beam between jib and lifting beam. [Network Rail]

A further development is the self-levelling beam for the Kirow crane. In some instances it was not possible to achieve a level lift, this device allowed for a limited adjustment of the position of the panel to compensate for any out of level lifts. This was also useful for the 'butting' up process for panel relaying.

6.2.8 Prefitting of point operating equipment

The point equipment is clearly visible on the panel in Figure 12. This pre-fitting was another key initiative of the project. Being able to fit the point operating equipment in a factory environment was an important aspect of reducing site work and improving quality. It was important to select a point actuator that could fit safely in the four foot, allow access for tamping and not be damaged by the panel lifting process.

The SPX In-Bearer Clamp Lock with SO Backdrive was adopted to form Network Rail's Hy-Drive system [8]. The system benefited from the absence of extended bearers for the mounting of the point machines, which meant the panels fitted onto the tilting wagons. The use of an in-bearer point drive also ensured all bearers could be tamped. Furthermore, the in-bearer mechanism chosen also enabled a consistent soffit level for the panel with top of rail to bottom of bearer being consistent for all bearers in the layout.

Although the pre-fitting of the point operating equipment eliminated some wastes, it still did not achieve the vision of the mapped future state, or the true vision of what Modular was. The goal for future developments in this area is to make point operating equipment "plug and play".

Figure 13 Point operating equipment preinstalled on panel. [Steven Pearson]

6.3 Less visible areas of attention

In addition to the changes made to the methodology of renewals on site, the Modular Switches and Crossings Project also addressed a number of less visible issues surrounding switches and crossings track renewals.

6.3.1 Standardisation of switches and crossings designs

At the initiation of the Modular Switches and Crossings Project, Network Rail was grappling with the number of unique crossover and turnout designs and configurations that were being installed on the network. They were concluding a review of what were then called RT60 layouts at this stage of the project. These layouts had been developed by Network Rail's predecessor, Railtrack (the RT designation), in response to the need to modernise the design of switches and crossings. The preferred rail section for these layouts had been CEN60 rail (the 60 designation). Railtrack had opted to allow the three major switches and crossings manufacturers in the UK to develop their own solutions for RT60. As a result this further complicated the situation and led to the introduction of further variations of switches and crossings.

To summarise the situation, at this point the UK had, and indeed still has, three rail profiles in common use on the network. Two of these profiles are currently being used for switches and crossings, namely 113lb (56kg) and 60kg flat-bottom rail. Over the years there had been a number of other rail sections that had been used in switches and crossings – bullhead rail 95lb and 98lb and flat-bottom rail 109lb, 110lb. Each of these rail types had been used in vertical and inclined configurations dependent on the controlling regional railway, which all led to a complex mix of configurations.

A further historical complication with switches and crossings design has been the non-standard layout of the network in the UK. Every region had a different standard six foot, and there is little straight track in the UK so the majority of units were on curves. In addition, a significant proportion of the switches and crossings do not take the form of a conventional turnout or crossover, but are slips, double slips, double junctions, diamond crossings and a whole range of other increasing complex layouts.

Network Rail's review of the design of switches and crossings led to the adoption of one 60kg configuration to be known as NR60 (Network Rail UIC60). Additionally, a new 56kg configuration was agreed. Each of these configurations then had variants for crossovers and turnouts of different speeds.

The rationalisation already mentioned was an important step in the process to have a modular solution. Network Rail also sought to encourage the use of a standard six foot for these layouts, as well as the preference for layouts on straight track. However to cope with the legacy issues of the UK it was necessary to have the flexibility to install on curved track and non-standard six foot. The radius of the curve and a wide six foot however, may influence the ability to load the panels onto the tilting wagons.

A benefit of the use of standard layouts will over time lead to a reduction in the number and type of spares that will be necessary for the maintenance teams to have available as replacements.

Network Rail state that they operate approximately 33,789 km of track with approximatley19,000 turnouts on the network [9]. The annual renewal program across the whole network is between 300 and 500 point ends.

6.3.2 Approvals process

Network Rail had long been accused of employing engineers who each individually had a preference for how things should be done. It was possible for the Network Rail Project Engineers to prevent the approval of the design of a new junction arrangement purely because they had a preference for a certain rail joint configuration, or they thought they had a better solution (despite the scope or specification mandating the proposed arrangement). The design might comply with the standard, but the ultimate sign-off relied on the Project Engineer and led to individual preferences having to be incorporated into the design. This in turn would lead to a design being reworked several times.

The Modular Switches and Crossings Project sought to remove this power of veto for non-essential items, or for preference engineering. Network Rail's engineering group was also going through a change at the time of the project, and consequently the opportunity to improve this area of delay and rework was significant.

At the time of the writing, the design approval process remains an ongoing issue that remains a target for Network Rail's improvement teams.

7 FUTURE STEPS

As has already been discussed, the Modular Switches and Crossings Project delivered several improvements to the industry. However, other improvements have unfortunately taken longer to develop or gain acceptance.

7.1 Plug and play signalling systems

From the outset of the project the concept of developing signalling components that could be pretested and plugged into the signalling system was a core objective.

The intention was to be able to have couplers that enabled the components to be plugged together to build the system in a modular way. This would also help with maintenance, since components could be changed over easily.

This is an ongoing area of development, with some ideas such as using plug couplers for connecting location cases now being adopted. Although in this area there is still some way to go to achieve the full vision for the project.

7.2 Multi skilling

It is common to have skilled workers only undertake one function on site, often using only part of their potential shift time. One example of this is the signals and communications staff. Signalling disconnections are a vital first step for a track renewal, however it is usual for the signalling and communications staff to undertake this activity in the first one or two hours of a possession. They then leave and come back towards the end to reconnect and test the new installation.

If these workers were to work the full shift and undertake other activities such as operating machines or carrying out surveying tasks, it would be possible to reduce the labour requirements for these projects.

8 LESSONS LEARNED

In addition to the changes to the process for renewing switches and crossings, there were other valuable lessons gained for Network Rail and the individuals involved in the project. Perhaps one of the lessons learnt by the client was the variation in the configuration of switches and crossing units on the network. This in turn meant that the use of the modular solution was more constrained than had been initially thought. It became clear that a one size fits all solution was not going to work. This led to the realisation that the initial vision of the project would not be achieved in its entirety.

The author also learnt some important lessons whilst working on this project, namely:

1. Do not expect people to change instantly. Challenge them, ask them to look at a problem differently and allow them go on their own journey
2. Ask questions and don't tell people the answer
3. Flexibility – the concept of a 'pure modular' site was soon knocked down and replaced by a series of options and tools that could be used in combination to achieve a better result on all sites, regardless of local constraints.

The other major learning for both the client and the team members, was the application of Lean Thinking to the problems being experienced by the railways. One of the key lessons for the author was the impact of the lack of understanding within the team of what Systems Engineering and Lean meant in practice. Most of the team seemed to understand the premise of Systems Engineering but struggled when it came to the review of their proposals and ideas. It was unusual to have to demonstrate the compliance of one's solution against predetermined requirements. This in turn caused resistance and frustration within the team.

Engineers also seemed to especially struggle with Lean, using a concept rather than something that involved a set of rules or strict processes, was especially hard. Many of the team had come from a hard dollar contracting environment where performance is measured against the outputs of discrete sections, often in isolation. Engaging them to think about what is best for the overall project, and ultimately the customer, was a challenge that was never really overcome. Despite these challenges the use of Lean Thinking and Systems Engineering continues to support the Modular Switches and Crossings Project.

9 CONCLUSION

The Modular Switches and Crossings Project delivered significant changes to the way switches and crossings were renewed in the UK. New tools and techniques such as tilting wagons, the bearer tie, the development of the lifting beams and systems, and some plug and play signalling components, have delivered the ability to undertake more work in the same possessions, or enabled the use of shorter possessions.

There is still considerable opportunity to improve the process further and Network Rail continues to develop and explore these opportunities.

To drive the project forward Network Rail must keep the customer, that is the passengers and the freight, at the centre of everything they do. Railways exist solely to provide a means of transportation for people and goods. Anything that prevents the provision of this service is a problem and should be eliminated or reduced to the greatest extent possible.

New ideas are not the enemy. New ideas are the opportunities that provide a means of moving the industry forward, improving customer service and reducing costs. There are huge opportunities to improve the efficiency of railway projects of all kinds, especially those that involve the disruption of normal operations. Collaboration and shared goals can deliver these new ideas, and the reinvention of some old ones to drive improvement.

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