“Development of Innovative Approaches for Life Extension of Railway Track Systems”

Acknowledgement

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Summary

This is a PhD Thesis by portfolio and is the output of research, development and the practical application of processes for railway track asset management in the UK between 2004 and 2013 and the subsequent development of innovative solutions. There are two major sections to the portfolio; firstly the background, literature review and development phases; and secondly two specific projects. The projects consisted of major works on the UK West Coast Main Line and targeted schemes involving Eurostar and Humberside. The author is a chartered civil engineer and has spent the whole of his career (32 years) in railway civil engineering mainly in design, maintenance and management and culminating in undergraduate and postgraduate teaching. Railway Infrastructure Life Extension is a specialist area that has not been studied before in this depth and was initially related to specific problem solving. However, it is now clearly accepted that UK railway privatisation was a success and after passenger journeys increased by 80% in the period 1996 to 2012, there was substantial strain upon the infrastructure. This portfolio is informed by and considers the current and future challenges faced by railways from a safety, performance and efficiency angle.

The study is supported as strategically important work being entirely appropriate and relevant to the industry by the two sponsors, Dr Ilias Oraifige, Senior Academic and Reader at the University of Derby and Ken Mee, Managing Director of Quality and Safety Services Ltd. The term "life extension" was uniquely created and applied to railway infrastructure by the author and his teams during the early phases of this project and became the industry standard phrase for the work involved. The historical background and literature review of the research is included to enable the reader to understand the context of the work undertaken previously where the author acted as the major driver behind the work under industrial conditions commencing in 1997. The author has had a direct involvement in the practical application of the techniques and processes through various senior positions in the UK Rail Industry. The work resulted in testing of equipment in live locations including quantifiable risk assessments and actual benefits to safety, economics and performance.

The author held a number of key roles relevant to the study. From 1995 – 2000 he was Regional Director of Balfour Beatty Rail Maintenance and set up the Central Maintenance Group at Sandiacre, Nottinghamshire. This was a team of engineers, supervisors and staff employed to carry out heavy maintenance principally on the Erewash Valley line. From 2000 – 2003 he was Engineering Adviser to the Rail Regulator where he was appointed as the government representative on the Hatfield Recovery Board and sat on various working committees including the Wheel Rail Interface System Authority (WRISA). This was a significant contribution to the recovery of the UK rail system to normal working following the Hatfield

Accident. A key contribution during this time was the understanding of the impact of track quality upon asset deterioration. From 2004 – 2007, the author, in his role as General Manager of Carillion Rail Ancillary Projects, was commissioned to set up an organisation to develop and provide innovative and original solutions for life extension and refurbishment of railway track systems in the UK. The principle objective was to build upon previous work done during the final years of the UK contracted-out railway infrastructure maintenance term contracts. The innovations chosen for development were related to delivering economic access to facilitate heavy maintenance and the development of new techniques to extend track life.

A number of projects and case studies and their specific solutions are identified and reviewed. Of particular strategic importance is the use of the “Railvac” Swedish ballast removal machine developed in the UK between 2004 and 2012. The culmination of the work is the incorporation of the principles and ideas into the UK National Policy under the ongoing strategy approved by the Office of Rail Regulation for 2014-2019.

The author has published a number of papers in support of the thesis which have been presented at conferences in London and Spain.

CONTENTS PAGE

FIGURES

TABLES

1. CHAPTER ONE LITERATURE REVIEW

1.1 Introduction

This study tracks the development of the concept of life extension through two decades where the author has been a principal contributor to significant policy changes to railway asset management in the UK. The studies began as essentially palliative means to maintain rail safety and performance and developed into complex treatments with predicted life through an economic and technical evaluation of activities. The approach was developed from the methods known as heavy repair or refurbishment; an early example of sustainability where the key objective being economic use of resources. The first examples were based on traditional techniques with formation treatment trials to aid with rapid implementation and took place on the Erewash Valley line in Derbyshire, UK. The first major development was based on specialist methods and access techniques where the West Coast Main Line project work was undertaken.

Figure 1: Railvac in a complicated track area with extensive cabling (Source: London Underground)

Subsequent technical developments were then utilised using techniques and innovative machinery from Europe. These involved resin injection, heater re-stressing and vacuum ballast removal. The key element to UK use was the requirement for comprehensive vehicle and product approval processes to be carried out involving external agencies. The basis of the technology was a non-intrusive approach with the aim of avoiding removal or disruption to railway infrastructure. The widespread publicity of the use of the techniques to solve particularly challenging situations and the pressures from the UK government to find further economic savings led to the adoption of the activities throughout the UK.

1.2 Historical Review Railways - Key Changes 1940 - 1970

The need for UK Railway leaders to balance strategic business objectives and track investment has been around since the 1960's when significant technological changes in terms of road use and motorway building took place. The UK government was reviewing its post Second World War policy for railways which resulted in the publication of the Beeching Report: "Reshaping of British Railways" (1963). The main driver to deliver cost reductions was the closure of many lines around the country. There was little need to consider the detailed track renewal policies as the major system costs at the time related to operational staff and rolling stock. In some cases, lines were closed that where the track itself was in very good condition. The option of finding more economic ways to prolong asset life was simply not a priority.

In conjunction with technological advances in the motor industry, the rail infrastructure industry pioneered and succeeded in a major mechanisation revolution which increased the productivity of track renewal and maintenance. This was first considered in 1939 with the invention of the first mechanical rail ballast tamping machine. The immediate advent of the Second World War slowed down development but the first machines were used in the London North Eastern Region of British Rail in the early 1950's. Many discussions took place around the country and a formal engineering discussion took place at the Institution of Civil Engineers in London in 1953. Campion et al (1953) describe the [British Railways Board] aim as being;

> *"thinking afresh about the problem of how in future to maintain railway track in a satisfactory condition at the lowest cost and in the most efficient way. To justify the use of such heavy track it was necessary to reduce the overall cost and, in particular, to reduce the man-power required to deal with it; that would involve, it would probably be agreed, a certain amount of mechanisation, with mechanised gangs covering a considerable length of railway, combined with small gangs doing the normal inspection and patrol work."*

Following these trials a complete change was made to the UK organisational structure of track maintenance using mobile gangs and mechanised activities. The nature of these changes were fully described by Dean et al (1959) where,

> *"this was a revolution similar to the industrial revolution itself"*

This took place over 10 years where processes were not only mechanised but changed in a fundamental logistical sense to include the use of road vehicles to transport manpower, tools and materials.

It is a notable key feature of the many changes in processes that were taking place at the time in other areas of rail construction activity including track renewal mechanisation. This clearly appeared to be a complementary driving force behind the strategies to change maintenance systems as this was at the time also mainly a manual process. This in itself contributed to major cost savings and Dow (2008) describes these developments which indicate a clearly innovative and bold approach being taken to reduce costs.

1.3 Early Developments Involving Extending Track Life

As the overall UK railway use contracted between 1960's and 1980's, it became necessary to review some of the national holistic policies for renewal of track. The renewal policy followed a standard set of criteria associated with the age and condition and was generally site and location related. There were no clear distinctions between the speed and tonnage or any view of the business case for complete heavy renewal. This is why it is evident that track was renewed as a cyclic exercise and there are many examples of a mile of continuously welded rail on concrete sleepers on a rural line consisting only of timber jointed track. Coincidentally, at the end of this period in the early 1980's there was move to adopt a business management approach by dividing the UK railway network and creating distinct business sectors to balance and focus the total costs of railway provision.

Also at the time, some very astute engineers at the time were conscious of a business focus need particularly in relation to finding methods to extend track life through a heavy maintenance approach. This was an early form of asset management as applied to railway track and the Australian experience is described by Wallsgrove (2007);

> *"Asset Management emerged out of several strands, from maintenance engineering and from the economics of infrastructure assets, systems engineering and even an early 'holistic approach' in the 1970s known as "teratechnology". In its current form I believe it was first adopted in Australia a decade later. A senior manager in one rail company, State Rail Authority in New South Wales, seized on it in about 1992, encouraged by an enthusiast*

who had brought his RAAF (Royal Australian Air Force) plane maintenance experiences to rail."

In 1982, the UK rail authority, British Railways Board, restructured the organisation into separate businesses, each having clear accounting systems related to assets, expenditure and income.

There were new financially driven pressures on the rail infrastructure engineers from the business managers that 1982 changed the emphasis of ownership and regarded an element of railway track as being an asset that would be treated as depreciating in value and therefore a key financial balance sheet item. The newly created "business" engineers in British Rail were challenged to find solutions involving some kind of life extension rather complete renewal. At a meeting of the newly appointed business engineers held at the Institution of Civil Engineers in London, Reynolds (1994) suggested that condition related maintenance would be more effective than cyclic maintenance particularly where track is nearing the end of its life. As stated above, this asset management process was beginning to become much more sophisticated in the mechanical engineering industry.

There was a need to experiment with asset management, diagnostic monitoring and whole life costing. The railway responded with a new concept uniquely created and known as "1 in 3 re-sleepering" and was developed strategically in the early 1980's, initially in Scotland, as a way of extending the life of expired track and assuring basic safety considerations. The routes were generally rural, low speed and low tonnage and were normally of timber sleeper construction from the 1950's and 1960's. The method was simple but effective; manually replace every third sleeper with a new timber one. In most cases the rail itself still has sufficient depth, so the treatment was successful. This approach is described by Chorley and McLeod (1986) and continued well into the 1990's and is still being used to good effect in many areas such as in the Highlands Region of Scotland. The author had experience of this type of process during the mid 1980's when he was Permanent Way Maintenance Engineer for mid Wales. This concept is currently a key feature of asset management in Wales today, according to Andy Franklin, Industrial supervisor for this project and currently the Route Asset Manager for Track in the Wales Region of Network Rail. He indicated that the latest 5 year budget (CP5) includes for the patch replacement of 7500 timber sleepers per year on the rural routes in Wales and the Marches (border between England and Wales).

It is important to clarify the distinction between 1 in 3 and patch re-sleepering. 1 in 3 was designed to extend the overall life of a route by making it fit for planned rail traffic in a staged process and with a second or third treatment over a number of years the whole route was replaced. In this scenario some defective or rotten sleepers were allowed to be left in place providing there was a sound sleeper either side. This is allowed under the standards for maintenance (Network Rail, 2005). Patch resleepering may be defined to be localised replacement of a group of sleepers with a view to longer term asset replacement and is often associated with a renewal strategy. In fact, current methods use a combination of 1 in 3 and localised replacement. The process is regularly used on many private and preserved railways where the maximum useful life of materials is a requirement of their survival.

Figure 2: Patch re-sleepering on the Ffestiniog Railway at Porthmadog, Wales, UK, 2013 (courtesy: Ffestiniog Railway Ltd.)

At the same time in the early to mid -1980's, most of the UK railway was managed at a very economic level by experienced engineers and staff who made the best out of the continuing reduction in their budgets and often found further efficiencies. Certainly, this was evidenced by the overall track renewal strategy of the then Chief Civil Engineer of British Railways Board, Max Purbrick, (Johnson and Long, 1981) where track managers of the time, introduced, on a widespread strategic basis, the concept of "cascading", where track assets were moved from main to secondary routes – an early attempt at what we now call "sustainable recycling". This was a rediscovered technique from earlier in the 20th century when engineers of the time identified proportions of materials that were recovered from main line renewals work and reused in branch lines or sidings or even cut up for fence posts.

In the main, there was much evidence around that the track asset stock was deteriorating and potentially this was an unsustainable position. A major report, "Review of Railway Finances" (HMSO Serpell Report, 1983) indicated that perhaps again the government may have to consider closures unless further investment was made. However, throughout the 1980's the main line strategic routes were being progressively upgraded and all jointed track was being replaced with continuous welded rail (CWR) even on the slow lines or relief lines of major routes. Nutbrown et al (1986) describes the benefits of this process and its contribution to the reduction of maintenance costs.

There were also business benefits due to the potential increases in speed available on continuous welded rail (CWR). These overall benefits could not be applied to switches and crossing units which were often expected to last a longer time. These units are still in place today and can be treated using the refurbishment strategies now in place and identified in the Network Rail Track Asset Policy Manual (Network Rail , 2011b).

1.4 Railway Infrastructure Asset Data

Currently there are 17,052 km of open railway route in the UK; this compares with 28,100 km in 1961. (Source: Association of Train Operating Companies, ATOC, UK: Strategic Rail Authority) This followed many line closures between 1963 and 1973 (HMSO Beeching Report, 1963)

World Country 2003	Open Track km	Electrified Route km	Passengers carried millions	Freight Carried Tons Millions	Infrastructure Costs £ per train km passenger	Infrastructure Costs £ per train km freight
Australia	9474	1900	47.3	156.5	2.8	2.9
France	29269	2400	879.4	120.7	4.3	1.0
Germany	36054	14505	1681.7	267.9	5.1	4.0
Italy	16288	11166	548.5	82.3	2.3	2.1
Netherlands	2812	2064	314.0	25.9	1.1	0.8
Switzerland	3231	3231	269.0	62.3	2.0	3.3
Sweden	9882	7638	61.2	42.8	0.4	0.3
UK	**17052**	**5142**	**999.9**	**88.9**	**4.4**	**2.2**
USA	233820	36917	23.3	1632.1	1.6	2.0

Table 1: Comparison of Railways in World Countries; Source Thompson (2005)

There are some interesting comparisons between countries that have a large network of railway lines (Table 1). Costs in Europe are quite high in general, however, with notable exceptions on the smaller networks such as Switzerland, Sweden and Netherlands. Germany remains high but the costing has not fully recovered from the reunification 25 years ago. Some of the innovations used in this study have come from these countries indicating an efficiency culture. It can be seen that UK remains the highest of the countries in terms of cost of track maintenance (Nash et al, 2003). However, the passenger numbers carried per kilometre is one of the highest metrics.

The graph below indicates the increases in passenger journeys particularly since privatisation in 1996. Passenger journeys in Britain are recovering and, following a slowdown at the beginning of the recession, are continuing to grow at a fast rate. More investment in the rail network is urgently needed if overcrowding is to be contained.

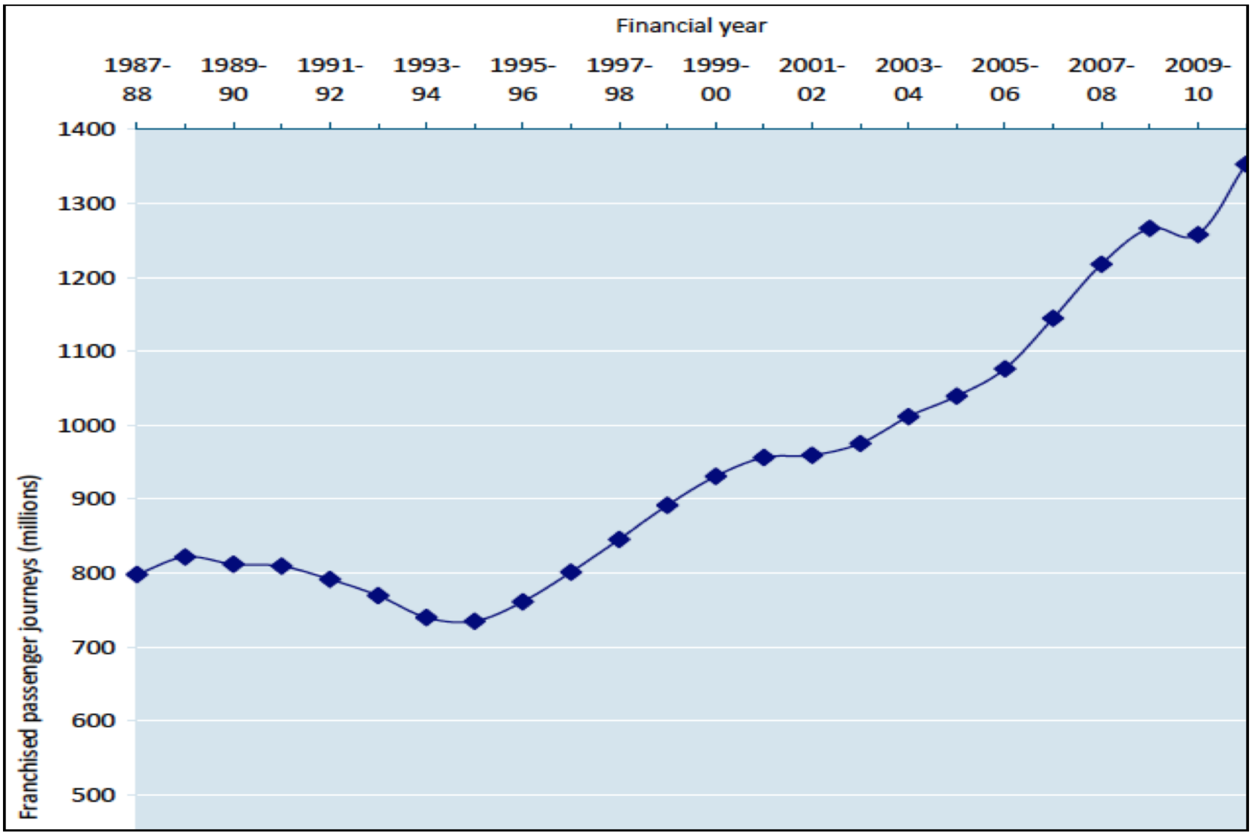


Figure 3: Rail Passenger Journeys in the UK - 1987 to 2011 (Source: ORR, 2011)

It is clearly indicated that the utilisation of the UK railway is at a high level and this potentially requires a very efficient asset management process. This is especially relevant when there are pressures to reduce the time available for both routine and investment related maintenance and renewal of track.

1.5 The Developing Concept of Heavy Maintenance

The UK government has now accepted that this concept has proved to be vital to the continuation of a sustainable railway infrastructure for the foreseeable future (ORR, 2011).

Hitherto, there has been an intrinsic development of the concept of heavy maintenance as this was a strategically important aspect of the management of a mixed traffic railway environment where budgets and government support were a limiting factor. The performance of the railway from a safety and train punctuality perspective often took priority over some early attempts at whole life costing. To explain this significance it is necessary to consider the issues of work planning from both a long and short term angle.

Access to the track to do maintenance and repair work was usually available during short periods where passenger trains were not running or freight trains could be slowed down or diverted. This was typically at nights for possessions of 5 hours (1130hours – 0430hours) or weekends where up to 12 hours (2200hours – 1000hours) was often available. Longer periods could be arranged but the planning horizon could be up to 2 years to accommodate well communicated timetable alterations.

Pressure from train operators not to disrupt train services indicated that methods of working were urgently required that minimised access to the tracks. The development work involved in the pursuit of further innovative processes that could reduce the time required for access was a vitally important feature of the UK railways. As indicated earlier, until the late 1990's, the type of heavy maintenance of track being carried out was by no means, new or even basically efficient, but was a development of older practices. Many attempts had been made to mechanise activities and new items of plant had been developed to provide a more robust output, examples of these are described by Currie (1978) and included excavation and consolidation techniques. Changes in processes to reduce maintenance costs were high on the strategic agendas for the UK railway management, who were beginning to adopt an early principle of asset management. The balance and relationship between capital investment and maintenance were being assessed rather than a direct approach towards replacing life expired assets. A good example of this was the renewal of jointed track with continuously welded rail which was in effect a modernisation but the new system eliminated rail joints which significantly reduced inspection and seasonal maintenance activities. The problems associated with rail joint maintenance were discussed at a forum at the ICE by Nutbrown et al (1986) where the contributory negative effects of continuing to maintain aged jointed track resulted in broken rails and "wetspots" (these being defined as ballast failure in localised areas around rail joints associated with heavy impact loading). The USA engineers have for some 20 years been defining the condition of ballast using physical measurement of rail deflections under load according to Hay,(2003).

In the mid to late 1980's, there were significant financial pressures on railway finances overall due to UK government intervention which affected track renewal budgets. However, this was exacerbated by the exponential increases in the cost of track labour associated with the economic conditions and as labour costs on the railway at the time were normally fixed this led to a track renewal reduction.

1.5.1 Recognition of Asset Issues - The Track Renewal Backlog

By 1990, there became a realisation from many railway civil engineers in the UK that there was a significant track renewal shortfall in annual activity leading to a backlog and that this was a culmination of many years of budget reductions in the UK nationalised rail industry. Gamble and Blackwell (2001) argue that acquisition of knowledge relates to content management, where there may be lots of databases but finding the common link and coming to conclusions that have major influences on asset management can be critical. Savage (1994) indicated that British Rail had a computer system called “GEOGIS”, designed to identify age of assets. This updated and replaced original documents that were manually drawn known as “Age of Road” diagrams, and this new system when populated had the potential to allow national strategic analysis.

An asset replacement backlog of this nature, where the implications of reductions in activity usually have a cumulative effect, is often known in strategic business terms as a “bow wave effect”. Scully, M (2006) explains this in the context of defence spending in the USA with regards to the replacement and repair of military equipment.

A number of track studies were carried out at the time that indicated that at the current rate of renewal track systems were expected to have a life of over 100 years. Ratledge and Thompson (1992) identified this situation in their report to the British Railways Board on the age profile of track on a set of Inter City routes. The diagram, Figure 4, below shows the impact of the existing ballast renewal rates over a 20 year time span; this assumed that there would be reduction immediately post privatisation in 1996 and no increase in traffic associated with the provision of new train services. This background of a continuing backlog indicated that a radical new interventionist approach was needed which could deal with the long and short term issues and the development of innovative systems.

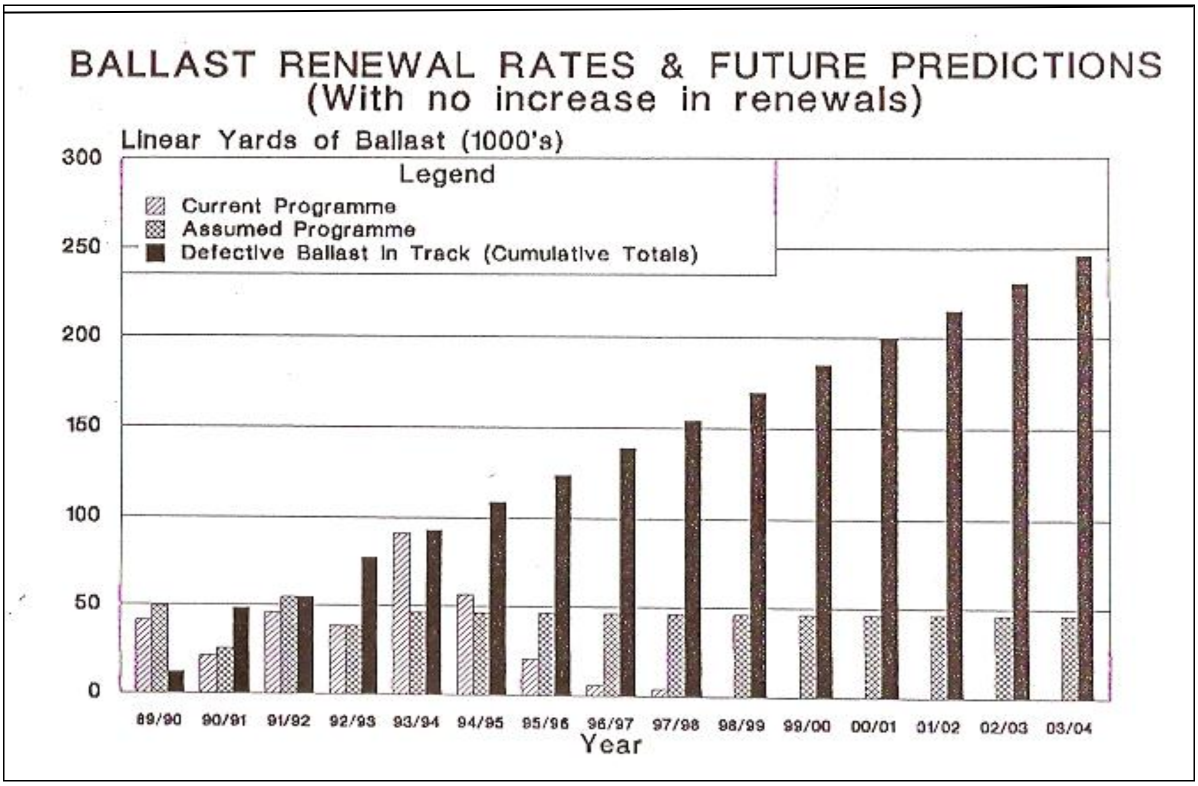


Figure 4: British Rail Midland Cross Country Ballast Renewal Forecasts 1990-2004 (Source: Ratledge and Thompson,1992)

1.5.2 UK Railway Privatisation influences

The major external influence upon the way that the national track asset was managed was the UK railway privatisation process that took place between 1993 and 1996. This politically driven model was based upon the assumption that the UK railway was at a steady state. This was defined as the position where investment in track and infrastructure was fundamentally balanced against known deterioration profiles and a reducing rail traffic business. This concept was clearly underpinned in the green paper documentation which finally led to the passing of the Railways Act in 1994. (HMSO, 1993) There followed a period of commercial and contractual negotiation and positioning between the newly created “infrastructure client and owner”, Railtrack PLC, and its “contractors”. These contractors were former British Railways Board infrastructure delivery organisations who were restructured into infrastructure maintenance and track renewal units. A legal asset transfer process followed to create wholly owned subsidiary limited companies which were later sold to the private sector with five to seven year maintenance contracts. The overall arrangement including rolling stock was publicised for its successful elements which related mainly to the injection of private capital into the provision of new trains and this was reported by Welsby and Nichols (1999) but there was very little clear evidence of a well managed infrastructure asset base.

This period and its historical features had a significant impact upon the ability of the professional civil and infrastructure engineering fraternity to optimise the overall track asset. The reorganisation changed the principles from an engineering lead asset management approach to a contractual financial framework. This new system would have worked if knowledge of the asset had been kept with the client organisations, however most of this key asset knowledge was lodged in the newly created and acquired private companies such as Balfour Beatty PLC. Counter (2003) studied the impact of this upon investment decision making in the rail sector and evidence shows that decision making was flawed with tragic consequences (see Section 3.2)

A comment from Franklin (1994);

"With regard to track standards, experience in South Wales at the moment is that quality appears to be descending partly due to the increasing backlog of ballasting items, possibly due to the fact that a lot of our relaying is in serviceable material."

This renewal shortfall, which could also be described as an unsustainable age profile, was not clearly identified as an asset liability during the reportedly "halcyon" days of the privately owned infrastructure company Railtrack PLC between 1995 and 2000 and its ever increasing share price. Wolmar (2005) explains that there many key business valuation issues that were not seriously examined or recognised during the privatisation process and certainly not identified as a financial liability through the sale process. The share price of Railtrack PLC rose from £3.80 in 1996 to over £17.00 in 1999 which reflected the value of the company and its investment portfolio.

This remained until disaster struck for the company in 2000 on the East Coast Mainline when a high speed passenger derailed due to track condition, the accident resulted in multiple fatalities. According to Wolmar (2005), the Hatfield accident in 2000 had significant consequences upon the infrastructure owner who was eventually forced into administration by the government.

1.5.3 Asset Management Developments after Hatfield Rail Accident

The Office of the Rail Regulator (ORR, 2012) in 2000 commenced reporting of the number of temporary speed restrictions associated with track condition. There were indications that an increased level of track renewal was necessary and as it was a condition of Railtrack's licence that it maintained its asset at a steady state actions were required. In financial terms this is known as the Regulatory Asset Base (RAB).

It was recognised that the extent of the track renewal backlog was so large it was not possible or practical to simply increase the level of investment for four identified reasons:

1. Financial constraints associated with government support for rail.

2. Resource limitations within the UK sector to physically undertake work; machines, materials and skilled personnel, the provision for which had ramped down anyway due to Railtrack reductions in track renewal activity from 1995 – 2000. There was also the impact of the downsizing of organisations for sale at privatisation

3. Access to track without unreasonable disruption to rail traffic involving track closures and temporary speed restrictions that would affect timetables..

4. The business case for complete renewal was not clear on many routes where passenger traffic was light or freight traffic intermittent, unpredictable or not clearly sustainable, especially rural areas. It was difficult to justify rail investment when road investment and bus replacement could be more efficient.

The author had discussions with a number of stakeholders which included Railtrack and latterly Network Rail, the infrastructure owner, train and freight operating companies and the supply industry. It was reported at the time that there were substantial knowledge management issues in the UK Infrastructure Industry following privatisation (Counter, 2003).

One of the principal drivers for the development of alternative approaches was the rising costs of infrastructure renewal which was due to the post-privatisation contractual framework within the industry. This was fully identified when the contracts for track renewal had gone through the second tranche of re-negotiation in the early 2000's. This should have been foreseeable in terms of the creation of separate businesses within a fully privatised track maintenance and renewal industry but was exacerbated by the enhanced safety regimes involved.

The reasons behind this were identified by Wolmar (2005) and related to the known worldwide benefits of a vertically integrated rail business structure where resources were optimised and shared across areas. There is clear example of this historically when the finances of British Railways Board are considered between 1976 and 1994. The author was involved in 1984 in the planning and allocation of manpower in this area and the resources were mainly used on a marginal costing basis from the maintenance organisations at weekends and much preparatory work and follow up works were not charged to renewals budgets such as follow up tamping and site clearance.

A further significant reduction in the level of track renewals took place between 1994 and 1998, especially in the Midlands region of the United Kingdom. This was analysed and investigated by the Office of the Rail Regulator in its report, ORR (2001) as part of the review of finances for Control Period CP3 covering the period April 2004 to March 2009. This reduction had more financial impact on the former British Rail Inter-City sector areas of the UK than those run by the British Rail Regional Railways sector where a lower level had been on the agenda for around 6 years as part of an alternative business lead approach. Vincent and Green (1994) indicate that investment in track renewals in 1993/4 during the final year of the Inter-City business sector was £41.0 million and the highest for the previous 5 years. The Regional Railways sector had been managing reduced track investment for some time previously and had had some experience of balancing investment against traffic and natural deterioration.

In summary, all types of track configuration and routes had been affected by the track renewal shortfall over a period of fifteen years. This included the high speed and high tonnage investment dependent routes previously known as Inter-City and the low speed, low traffic rural routes both having suffered from a lack of focussed asset management for track maintenance or track renewal.

When Network Rail Infrastructure Ltd. was created in 2002, there was a combination of legacy policies, contracts and asset conditions to be tackled by this new UK Rail Authority. The initial approach was to recommend massive increases in investment as a solution to the asset age and this was embedded in national policy. As the decade progressed an agreement was made in early 2009 for a significant funding under Network Rail Regulatory Control Period 4 from 2009 to 2014. According to Railway Strategies Magazine (2009), this allowed for £35 billion of overall spending with £22 billion on investment in infrastructure improvements and projects. A key caveat for this agreement between ORR and Network Rail was the undertaking of efficiency improvements related to the complementary areas of innovation and asset management. The concerns regarding the forward investment plans involving complete track renewal were being questioned in the UK parliament. It was announced that an independent review would take place, and this was reported in mid 2010 according to BBC News records (2010).

1.6 The Life Extension Development Strategy

The author was aware of the UK rail industry's substantial asset management problems which were colloquially known by many in the industry as "Deferred Renewals" (Counter, 2003) and there was much evidence gathered by the ORR of a perceived need for solutions. Investigatory work began in earnest in 2000 which involved gathering information from many sources and preliminary reviews were made of alternative technologies available worldwide. It was timely therefore to commence carrying out research and development in this area as there was an urgent and probably an extremely pertinent need to develop new practices to extend track life. The following four major objectives have remained constant throughout the course of this study and remain the same today:

1. To maintain, facilitate and promote the safety of rail infrastructure.
2. To avoid disruptive temporary speed restrictions to normal train running, thereby maintaining the performance of the railway and reducing unforeseen and cumulative delays.
3. To find timely economic solutions through technical innovation and the application of appropriate technology and complementary management techniques.
4. To restore an optimised steady state position on UK rail infrastructure through effective asset management.

1.6.1 Consultations leading to the Study

This study and the subsequent research and piloting work in the area of life extension commenced in 1993 and although in the first stage it was merely a support process for the existing organisations it was clear that there were opportunities to change national policy through the adoption of many of the innovations. The author undertook a wide range of consultation with senior officials in government, principally in the Office of Rail Regulation including Michael Beswick, Colin Brading and Peter Doran where he was previously employed at the Engineering Adviser (Track) between 2000 and 2003. During this phase there were positive messages to the author regarding the development of innovative processes to optimise track asset management. Industrial contacts were developed with Senior Engineers in Network Rail including James Dean and Andy Jones who were involved in the development of a holistic approach to asset management. Other contacts in active contractors to Network Rail including Balfour Beatty PLC and Carillion PLC (The author was employed by Carillion between 2004 and 2007) were consulted to clarify the objectives and the considerations of any approaches that could be adopted. There appeared from the industry wide consultation that there was great potential to develop solutions to the problem of UK track asset management and find innovative processes to plug the perceived gap in knowledge.

1.6.2 Latest developments in UK Government Intervention

A vitally important milestone recently achieved and a catalyst for future strategic policy change was the publication of the Roy McNulty Report (HMSO, 2012) into Rail finances for the next Network Rail Control Period. This is known as CP5 and covers the regulatory timescale from 2014 to 2019. There were a number of respondents to the consultation of this latest government report on rail financing who advocated the adoption and indicated the advantages of a type of recycling strategy when commenting upon methods of closing the national rail efficiency gap.

Ford (2011) comments,

"This [high level of renewal on branch lines] would appear to be an example of those preaching the virtue of whole life costing whilst missing the fact that replacing jointed track with cascaded continuous welded rail and concrete sleepers on lightly used lines is about as "fit and forget" as you can get in rail infrastructure. All you need is to stop cutting up perfectly reusable CWR into lorry-sized lengths for disposal."

1.7 Methodology for the Study

There was very little technical literature available on this subject within the two relevant professional institutions, the Permanent Way Institution and the Institution of Civil Engineers. The former has been publishing papers for 120 years in its specialist area of track operation, maintenance, renewal, and construction with over 2000 technical papers published in its regular quarterly journal. The papers written by the author and co-authored by Professor Abid Abutair, Dr. David Tann and Andrew Franklin were awarded the PWI Silver Prize in 2011 and 2012.

The research was carried out over a number of chronological phases:

1. 1998-2000 Life Extension trial works in Railtrack East Midlands Region
2. 2000-2004 Review of Post Hatfield 2000 Rail Accident recovery.
3. 2004-2007 Development and piloting of new techniques.
4. 2007-2009 Consolidation of use of novel techniques with new applications
5. 2010-2013 Investigation phase involving reviewing the success of schemes through site analysis and client feedback

2. CHAPTER 2 INITIAL DEVELOPMENT PHASE

THE CONCEPT OF LIFE EXTENSION - NEW TOOLS AND TECHNIQUES

2.1 Heavy Maintenance Developments East Midlands 1996 -2000

There were many technical and managerial challenges associated with managing a secondary rail route in the early years of UK Rail Industry Privatisation. The problems included a large backlog of track renewals, a depleted and de-motivated workforce and a changing unknown traffic pattern. There was formal pressure applied by the Health and Safety Executive (Her Majesty's Railway Inspectorate Branch) by the issuing of an Improvement Notice in 1997, (see Appendix 10.1). This was regarding the safety of passenger train and freight operating companies and was imposed upon the then rail infrastructure owner Railtrack with an order to remove temporary speed restrictions particularly on the Erewash Valley railway lines in Derbyshire and Nottinghamshire.

These speed restrictions had been applied in the majority of cases to maintain safety as the track configuration had largely become life expired in both overall structure and in places could have involved a risk of failure of a multitude of individual components. Murthy et al (1987) and Brocciolone et al (2007) argue in their papers that it is difficult to identify where the limits of safety can be determined by normal measurement and monitoring systems. In many cases in the UK the track structure can deteriorate quickly under sudden rainy weather conditions.

There had also been a number of serious derailments of freight trains that were attributed to track maintenance failings. Brown (1997) carried out a study where he considered the overall management but initially stated that he has discovered that there had been no track renewals on the route (which included 102 single track miles) for 5 years.

The challenges faced in this area were not only technical and asset age specific but also related to the changes in organisation that the maintenance staff had gone through during the period 1990 to 1994. This was a clear example of human de-motivation applied to the railway track maintenance industry. Green (1983) describes these issues in terms of the challenges or railway resource planning and organisation but the major point made was the potential lack of confidence amongst staff when faced with difficult economic railway situations. This could specifically be described as "being used" to poor track conditions.

The concept of "unconscious incompetence" as discussed by Collison and Parcell (2001) indicates that even though staff appeared to be generally motivated, they were not fully aware of the consequences.

Figure 5: Poor Alignment due to Insufficient Maintenance Erewash Valley 1997(Source: author)

There was a need for engineering management intervention with two main outcomes; firstly, a requirement for greater diligence in track inspection and repair and secondly, investment in heavy works to facilitate safe operational continuity. The author was thereby commissioned by Railtrack to provide scope and specifications for the design and delivery of life extension schemes. This was a new concept with associated commercial and contractual challenges, specifically the liability issue for safety and longevity of repairs. The author consulted current professionals at the time around the industry and identified traditional and new technical solutions to the life extension of railway track. Bonnet (1996) indicated the seriousness of ballast degradation upon the maintenance of line, level and riding comfort. He also recommended the development of intervention led replacement rather than repair after failure.

2.1.1 Heavy Maintenance Activities Erewash Valley

During this stage in the development process a number of current practices and new ideas were implemented as part of the urgent variation contract to the RT1A (Counter, 2003) which was implemented to attempt to restore train performance and re-open some closed tracks. There are some basic principles which require resolution; Profillidis, V (1986) states that if you wish to use mechanical means a necessary pre condition is that the ballast be sound, free of soil contamination, of proper granulometric size and of adequate mechanical strength.

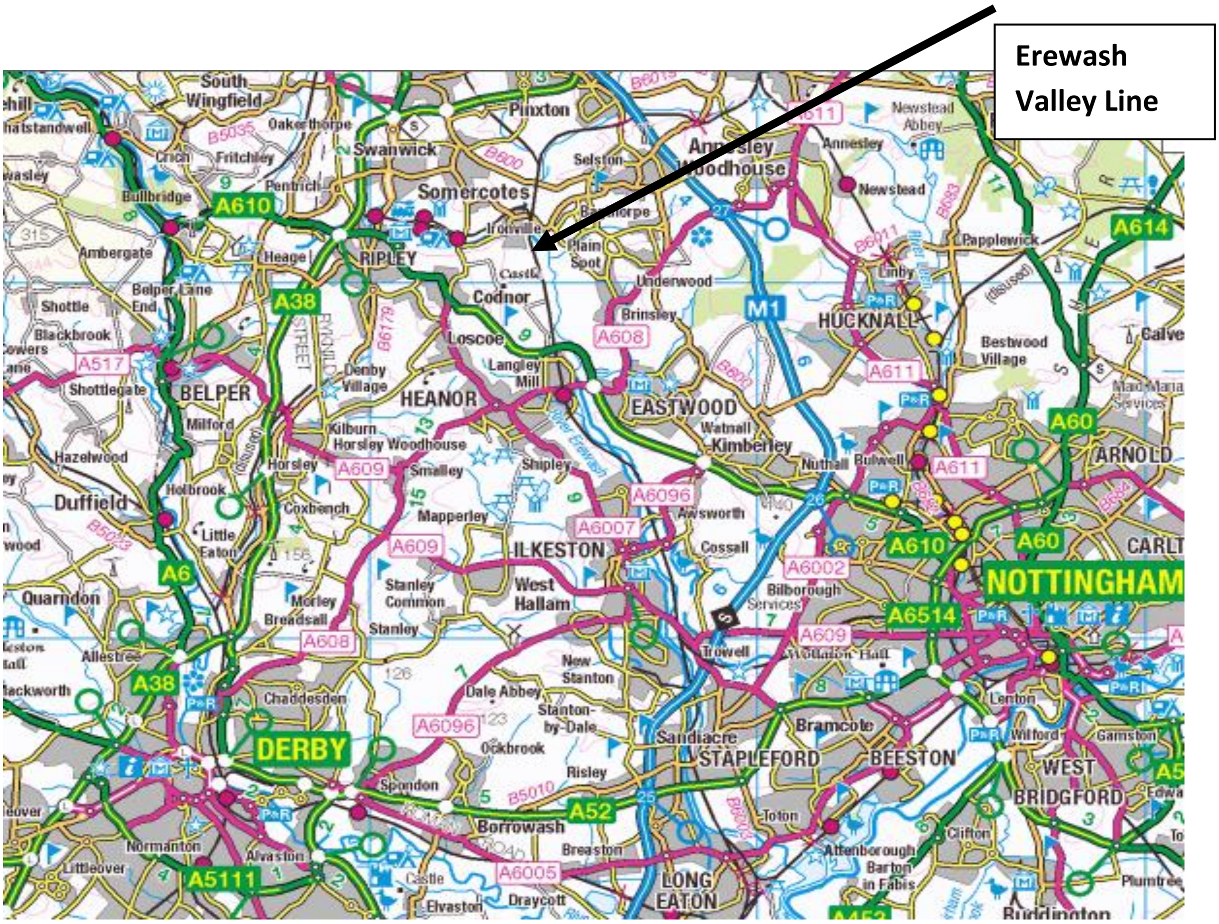


Figure 6: Location of the Erewash Valley line Derbyshire, UK (Source www.streetmap.co.uk)

This was associated with the renewals shortfall indicated in section 1.5.1. The effectiveness of the heavy maintenance or life extension processes were reviewed and the following list indicates the type of work involved:

1. Ballast replacement by manual techniques using hand tools – this was continued but is very labour intensive and it was always difficult to get sufficient consolidation especially under switches and crossings.

2. Ballast replacement by specially adapted machines – an example was the Matisa Gopher and other machinery which was tried but abandoned due to geotechnical blockages in the systems.

3. Ballast removal and replacement with chippings - this was successful in bringing track geometry back into specification. (Note: This was not the traditional "measured shovel packing"; a commonly used process for reinstating vertical alignment.)

4. Long timber and sleeper replacement – a key manual activity.

5. Timber repair through repositioning (sometimes known as "pulling through") – effective as an economic solution or where timbers were in good condition.

6. Replacement of steel keys with "panlocks" on bull head track track configuration. (Not necessarily a good idea as many current rail creep sites have been excacerbated by doing this without due consideration.)

7. Replacement of switch and crossing components including screws and bolts – an essential feature of refurbishment.

8. Weld repairs to all metallic track components including plain rail.

9. Welding up traditional sixty foot rail joints. (See above comments regarding "panlocks")

10. Component replacement and thicker pad installation.

11. Realignment of track vertically and horizontally using lasers and advanced total station surveying.

2.1.2 Process of Life Extension Treatment

The first stage was the development of feasibility in terms of practicability including justification and outline design. A bespoke solution was proposed utilising the options above and related to expected life of the asset and the time that the asset had to perform without re-imposition of a form of performance limiting speed restriction. These decisions were business related and usually required a dialogue between freight and passenger train operators.

The second stage was detailed design specification, planning and resource scheduling. As indicated above, many of these techniques were not particularly new or innovative but required a level of experience to determine the condition of the components. Because the asset as a whole was also virtually life expired, it was challenging to predict the residual life of individual components. This was especially difficult on routes with unpredictable rail traffic flows, where freight trains with heavy axles of 20 tonnes or greater were in abundance. A greater level of technical input was being considered to consider the impact of system and this followed on from further research in the field. Selig and Waters (1994) were one of the first to publish their findings that excessive tamping by both heavy and manual assisted means contributed to exponential ballast degradation.

The final stage of implementation of the individual project related to the commercial approval through a schedule of rates arrangement. This process was specifically related to outputs such as line reopening or reinstatement of normal speed of traffic.

Figure 7: Work in Progress - Early Life Extension Techniques Erewash Valley (source: author)

Interestingly, this aspect still has a major impact around the UK as a result of the contractual track access arrangements for freight, although paying charges for access have the right to increase the number of trains to meet their customer demands. An example of this issue is the track problems caused by Scottish Coal on the Settle to Carlisle line. Goldie, C (2004) describes the major project that was needed to restore this route to a steady state position. This indicates the sensitivity of the frequency of high tonnage axles upon such treatments. In many cases the expected life extension was delivered although in some cases further treatment was necessary. In all cases this kind of partial approach requires a high degree of monitoring which can be a costly ongoing burden.

Any partial attempt at support structure treatment, in this case whole scale use of small chippings to replace ballast, was limited in success. This was due to the underlying drainage, ballast condition including contamination and proportion of fine cohesive material. Future developments into investigating European techniques were based upon some of the lessons learnt in this early attempt at life extension.

2.2 Hatfield Rail Accident 2000

This accident initiated a major review of track maintenance and the quality of track geometry. The author was the Engineering Adviser to the Rail Regulator and was part of the UK “Hatfield Recovery Team” to establish causes and initiate plans to return the UK railway to normal operation (2000-2003).

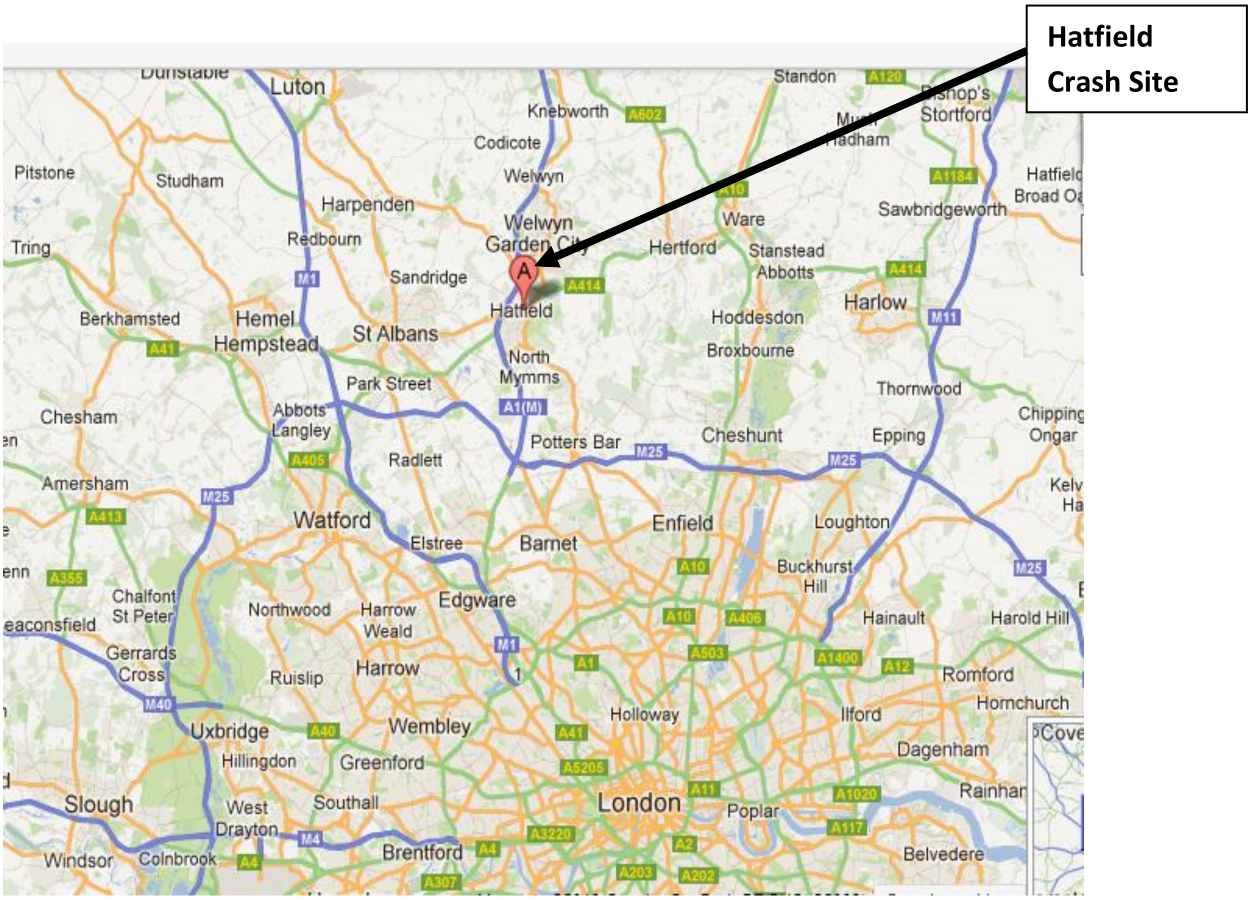


Figure 8: Location of Hatfield London UK (Source www.googlemaps.com)

An electric powered passenger train travelling at high speed (110mph) derailed in October, 2000, on curved track near to Hatfield, 20 miles north of London on the East Coast Main Line to Scotland.

The derailment was caused by the sudden catastrophic failure and breakage into 32 pieces of one of the steel running rails. The initial cause was established as severe rolling contact fatigue combined with deep rail-head cracking which had gone undetected for some months. It was quickly discovered that this was a widespread phenomenon and similar locations in the UK were discovered to have similar conditions on a widespread basis. The immediate aftermath was a significant reduction in allowable speeds around the country which virtually destroyed the national inter-city timetable.

The Hatfield Accident (Health & Safety Commission (HSC), 2002) initiated a review of the causes of significant increase in the phenomenon known as gauge corner cracking or alternatively rolling contact fatigue. (See Appendix 10.2) There was an identified shortfall in a nationwide focus of track quality (measured by geometric standard deviation) especially alignment at high speed. This could have been due to a significant change in traffic patterns which was a result of the privatisation of the railway industry. The steady state of rail wear may have been a function of many decades of mixed traffic patterns and a multiplicity of wheel profiles that caused a balance of wear and possibly prevented chronic rolling contact fatigue. As a result of the research work at the time initiated by the Office of the Rail Regulator there was an increased focus on Railtrack PLC to deliver improvements in track quality.

ORR was advised by the author in 2001 that track quality was major regulatory issue. It was then considered that track quality was a key licence requirement as it was not only a customer ride quality issue but an clear indication of the overall state of the track asset and whether the whole system was being managed at an optimum level. The level of track quality measured at the time by the amount in the good percentile group was linked to the potential for delays associated with temporary speed restrictions which was also measured. Subsequently, the ORR have changed the definition of track quality and adopted a more complex statistical approach (Doran, 2010).

2.3 Development and piloting of new techniques (2004-2007)

The author, in his role as General Manager of Carillion Rail Ancillary Projects, was commissioned to set up an organisation to develop and provide innovative and original solutions for life extension and refurbishment of railway track systems in the UK. The principal objective was to build upon previous work done during the final years of the UK contracted-out railway infrastructure maintenance term contracts. The innovations chosen for development were related to delivering economic access to facilitate heavy maintenance and the development of new techniques to extend track life.

2.3.1 Automatic Track Warning systems (ATWS)

The first use of ATWS system was at Colwich, Staffordshire, UK on the West Coast Main Line to facilitate daytime heavy repair and replacement works on track using a German system in 2004. This allowed efficient use of track space in normally prohibited areas by working safely "between" trains. Previously the system adopted was reliant upon manual flag waving and intermediate lookouts. Trials also took place at the Royal Albert Bridge and Llanvihangle in Wales. A full explanation of the system on its major first scheme on the West Coast Main Line Project is given in Chapter 4. According to Wheeler (2004), the first use of these systems had not developed over recent years even to make systems of working safer, and further adaption and innovation was a wasted opportunity for innovation.

2.3.2 Railvac Ballast Vacuum removal Machine

The "Railvac" machine is a rail-mounted, self- propelled, high capacity vacuum ballast removal facility; in effect a full scale rail vehicle around the size of a large locomotive. The machine has a 250mm diameter tube with a tungsten tip connected to a hydraulic arm system with a remote control operating unit. The vacuum is a high power facility and can be used with a large variety of cohesive and large particle size non-cohesive materials. There is an integral hopper which collects the material and has side discharge chutes for the disposal of the spoil. The first use of Railvac alone on a working railway in the UK was at Didcot, Oxfordshire in 2005 and the author was responsible for its unique import and trials. There were significant management challenges including transportation of Railvac from Sweden and authorised use on Network Rail Infrastructure. Areas needing consideration were official vehicle acceptance (VAB) where braking, clearances, wheel profiles, traction systems and colour of ends had to be reviewed.

Figure 9: Railvac machine ex-manufacture in Umea Sweden (Source: Railcare SE)

2.3.3 Second Life System of Timber Repair

This is a system where track is repaired in-situ using a resin and specially designed coil inserts and was introduced in Switzerland and Germany where weather conditions are generally very harsh. A key part of the system involves the track being reinstated to a carefully redesigned horizontal alignment. Adjustments of up to 15 mm in horizontal alignment and track gauge can be made, which gives the system a huge amount of flexibility for uses and in some cases allow redesigns for speed and also rectification of design errors.

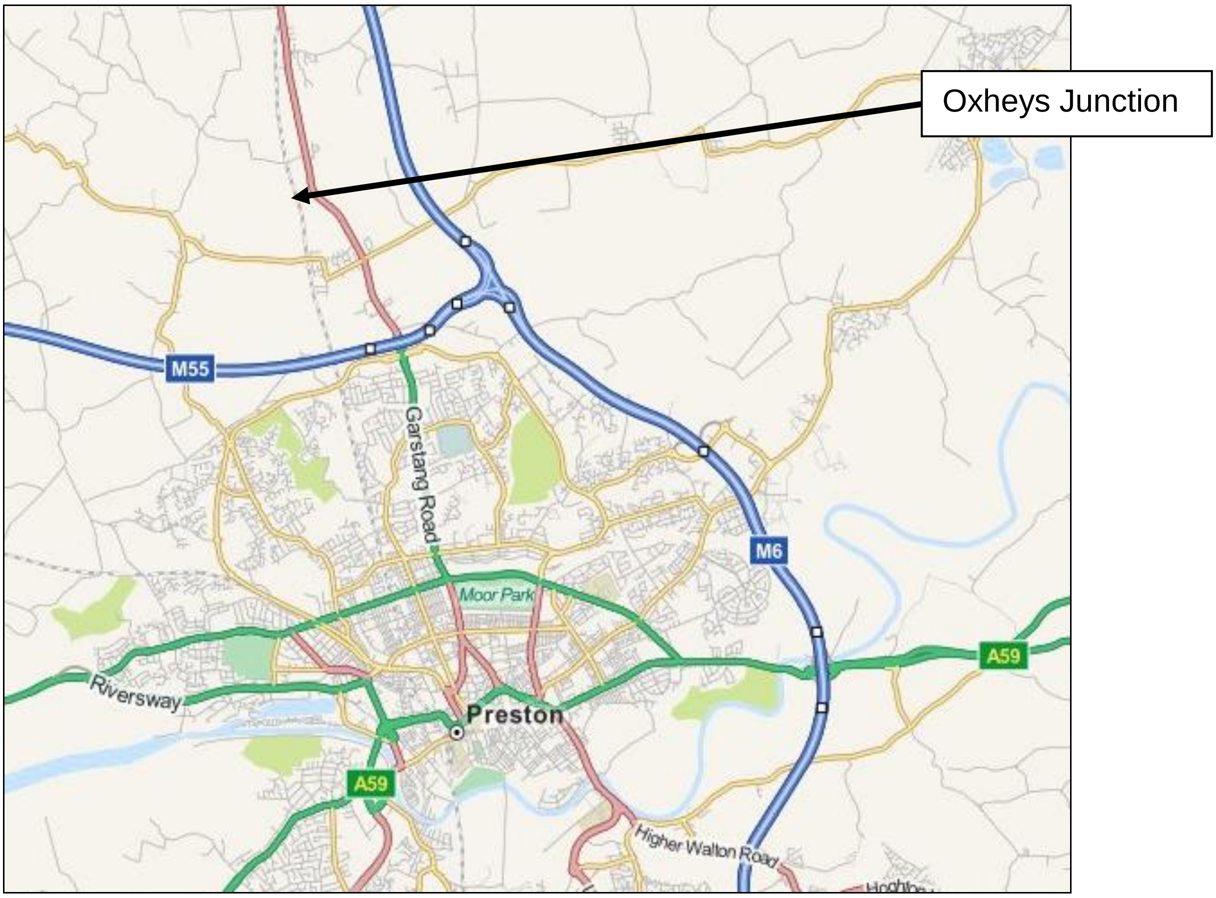


Figure 10: Location of Oxheys Preston UK (Source www.googlemaps.com)

This high speed rail junction was the first use of second life system in a UK high speed area near to Preston, Lancashire, UK on the West Coast Main Line and was introduced and trialled by the author and his team.

Figure 11: Second Life System in Progress Oxheys Preston UK (courtesy Sersa-UK Ltd.)

2.3.4 Heater Re-stressing of Rails

Heater re-stressing is an adapted European system for artificially stressing rails using gas heaters in order to equalise stress configurations and initiate stress free temperatures of 27 degrees Celsius. According to Profillidis (2006), this system is still used in Europe although they do attempt to "naturally" stress at around 35 degrees Celsius to optimise the stress zones. The first recent use of system took place at Stockport, Manchester, UK in 2005 where a newly laid and existing rail junction were identified as having unequal stress levels with the potential for track misalignments in extreme temperatures. This was further developed at Sunderland Stadium of Light station in 2006. According to Binks (2011) the most appropriate way of achieving a homogenous stress free temperature is by natural means or heating the rails. This was used in the 1960's but replaced by hydraulic stressing in the 1970's due to problems with gas equipment. The sophisticated gas heaters used now provide a very versatile solution.

2.4 Developments of Railvac Machine Process

In Ashford 2006**, t**he Railvac machine was used to rectify a long standing track geometry defect affecting the connection between the mainline and Eurostar services (see Chapter 5). The track was renewed and the fault was a combination of a "high spot" (track installation above design) and poor ballast condition. Work was also carried out at West Ealing in 2006 to remove a particularly challenging speed restriction following poorly performing renewal work and also at Newport in 2006 where logistical restrictions prevented the adoption of conventional techniques.

Figure 12: Railvac working at Stafford on West Coast Main Line 2007 (Source Sersa-UK)

2.4.1 Consolidation of use of techniques with new applications

In 2007 a Joint Venture between Sersa-UK and Railcare facilitated continuation of development work and this Joint Venture took over the Carillion Rail Management Role. Between 2007 and 2009, a number of new schemes were carried out each with its own unique problem solving aspects:

1. Gatwick Airport Station; a selective track lowering project in a complex area to improve alignment and rectify local ballast contamination associated with poor drainage.

2. Bedford; work in conjunction with Balfour Beatty "Zitrack" ballast stabilisation process to provide stability in a weak area of an embankment.

3. Yorkshire; a project involving high speed cable burying carried out urgently in a location with a high risk of cable theft and vandalism.

4. Penzance; an efficient and unique application to facilitate the construction work of under-track crossings and chambers for drainage improvements.

5. Stafford Station and Market Harborough; schemes to lower the track geometric profile after renewal activity to rectify vertical alignment errors. Figure 13, below, shows the complexity of the work in a high speed situation and the use of supplementary equipment; a high capacity road-rail dumper and 360 degree road-rail excavator with interchangeable bucket and tamping bank.

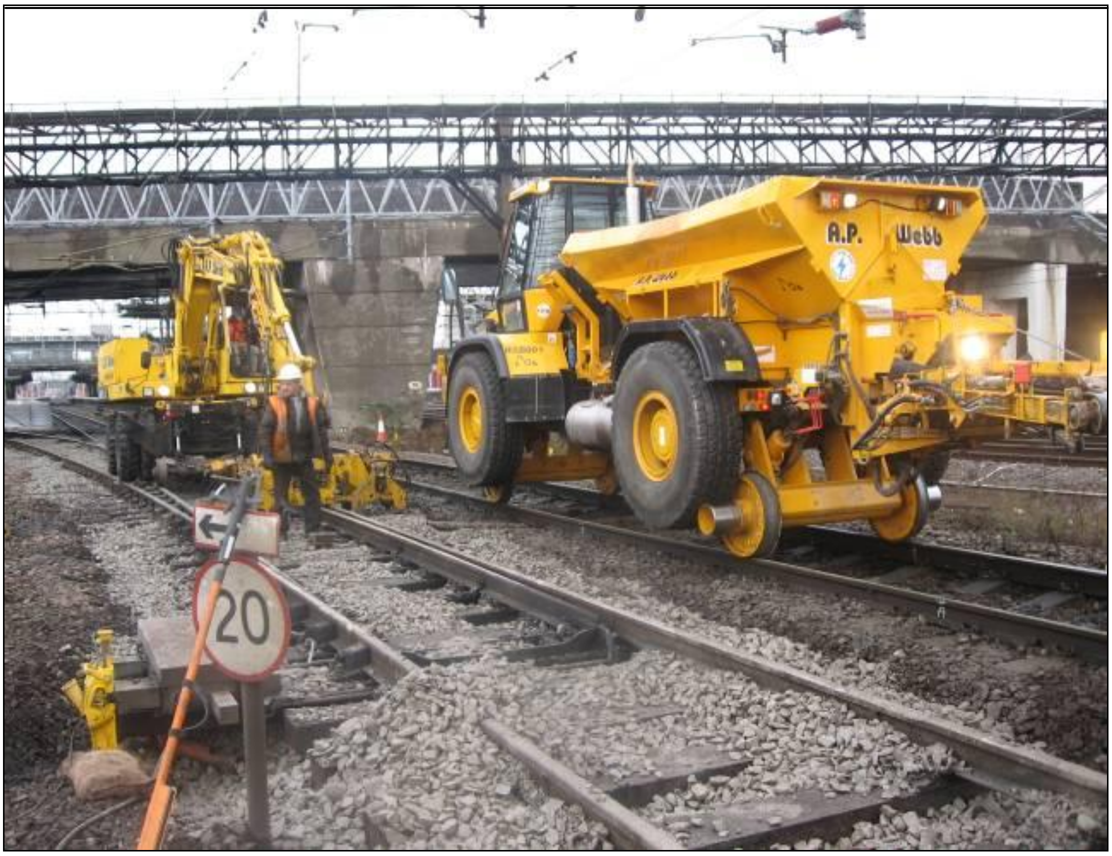


Figure 13: Railvac working at Stafford 2007 Supplementary Road Rail Plant (Source Sersa-UK)

6. Reading station; a site where the Railvac was a necessary and justifiable life extension tool although the location had particularly challenging access issues and it was only possible by using two 150 tonne mobile cranes in tandem to lift the machine into the site area.

7. Mearhead Branch; a specific use in an open plain line location to remove clay and replace with ballast. There were problems with poor drainage and formation failure, the track structure itself had quickly failed and vegetation taken hold. Railvac removed hard compacted clay. This was done midweek under economically viable arrangements.

Figure 14: Railvac working Merehead Branch 2008 (Source Sersa-UK)

There were a number of other technical developments including cutting through blue clay (very hard flinted material), sand excavation, detritus and organic materials, oil contaminated locations and spillages of other materials and fluids. Other vacuum systems and mechanical removal methods such as the "Matisa Gopher" and "Tubecube" have been adopted in the last 20 years. Figure 14 shows the Balfour Beatty Incorporated "Switch Undercutter" which uses a ditcher wheel and undercutter chain which works well in dry conditions, however set up time is high and output can be limited.

Figure 15: BBI Undercutter ballast and formation preparation machine (Source: bbinc.com)

However, they have not been fully successful especially in a challenging formation conditions. The effect of tamping, inconsistent drainage and uneven traffic loading can quickly bring conditions back to poor if treatments are not effective according to Aursudkiy (2007) and McDowell et al (2003).

These techniques and solutions works were further analysed as part of this research study through site visits, site investigations and interviews with local engineers, national track asset engineers from Network Rail. In 2011, the author and his colleagues from Carillion Rail made contributions from these studies that were considered at the Office of Rail Regulation CP5 study for future UK government rail spending plans. There was pressure from the UK Government treasury to investigate additional mechanisms for reducing rail expenditure as part of the economic saving analyses.

A supplementary issue emanating from recent incidents associated with track condition was public safety, the ORR also having legal responsibilities in this area. There were also ongoing pressures from the safety and performance monitoring part of ORR to carry out works quickly to alleviate safety, quality and performance issues without major disruption and cost.

2.4.2 Future Strategy - Further application and development (2010-2012)

Refurbishment is now seen as a legitimate task in itself (NWR Track Policy, 2011) and a valid alternative to renewal where full renewal could be avoided for a variety of operational and business reasons. The contractual railway franchising framework has developed and continued with performance payments related to time lost by train companies. This could be due to failures, speed restrictions and extended possession periods. Joksimovic and Vanderwark (2011) argue that these issues form part of the associated project maintenance strategies in order to optimise maintenance processes and should be built in as potential failures.

There has been a continued use in specialist locations and particularly an upturn in the use of Railvac, mainly due to a streamlined procurement process from Network Rail and devolution of financial authority.

Figure 16: Railvac Re-Ballast and Refurbish Double Junction at Meadow Lane Trent UK 2010 (Source: author)

Figure 16 shows a typical location where the Railvac was used in Derbyshire. The track itself was repairable in terms of individual components and replaced worn rails, however the underlying ballast structure was life expired and contaminated with coal spillage (as seen in the foreground). As a structural and foundation material, ballast only works if it is well drained. The Railvac was an ideal tool for this location for ballast excavation because it could be used during short possession times with little disruption and under the cover of a continuous 20 mph speed restriction because it was a slow speed freight route.

A review was made in July 2010 by the owners, Railcare SE, which dictated the return of the UK Railvac machine to Sweden for adaption and major maintenance. It was in the UK for 5 ½ years and returned to Sweden at a cost of £17k per journey for major bogie work. The cost of return was balanced against the use in the UK and potential use in the home country and its return was in doubt due to economics of the UK operation specifically usage.

However, it coincided with a change of policy and delegation of budgets to local UK rail engineers which led to an increased order book developed in autumn/winter 2010/11. During early 2010, operators had to be flown into UK for every shift, because the workload was sporadic at this time. When workload picked up and more guaranteed multiple shifts were available, this led to a more economic use and helped to develop a more sound commercial future.

There were many potential uses for the current machine during the next two years. However, further use was restricted by its physical size and the fact that it is outside UK loading gauge and cannot always travel by rail from delivery point to site. Hence, at Reading it had to be craned into its working position. Given this limitation, the owning company, Railcare SE, agreed to build a machine specifically to fit the UK structure loading gauge and traffic technical requirements. This coincided with "refurbishment" beginning to return to the Network Rail policy agenda, and now, much is made of the concept of "cascading", where track assets are moved from main to secondary routes; an early attempt at what we now call sustainable recycling.

The benefits of using this equipment appeared to provide essential options for delivery in terms of improvements to the asset management of the rail system and improvements to the efficient delivery of work activities. Papers were then prepared in support for Network Rail's development of a business case for the use of Railvac equipment. This supplementary documentation was provided in response to a request that was made by Nigel Turnbull, the Network Rail Plant Development Manager in 2009. The scope of work considered included track maintenance, renewal and enhancement programmes.

Railvac equipment, working within a production line process using dedicated delivery teams, could provide significant support to future UK rail policy. Network Rail operated a 'Transformation Programme' that is designed to meet the current challenges through the CP4 control period. The benefits obtained from the use of this equipment in a production line scenario include safety, efficiency, track access and production elements.

2.4.3 UK Specification Machinery

Structure gauge or loading gauge of vehicles is a significant feature of the potential transfer of international rail mounted machinery between countries. There are a surprising number of variations both within and between countries, particular when comparing UK and Europe.

The figures below have been prepared by Profillidis, V (2006) and show the complex differences which are not only height and width but also relate to lower and upper detailing of the design of rolling stock. The track gauge (space between the rails) is not normally a problem as most European countries are 1435mm.

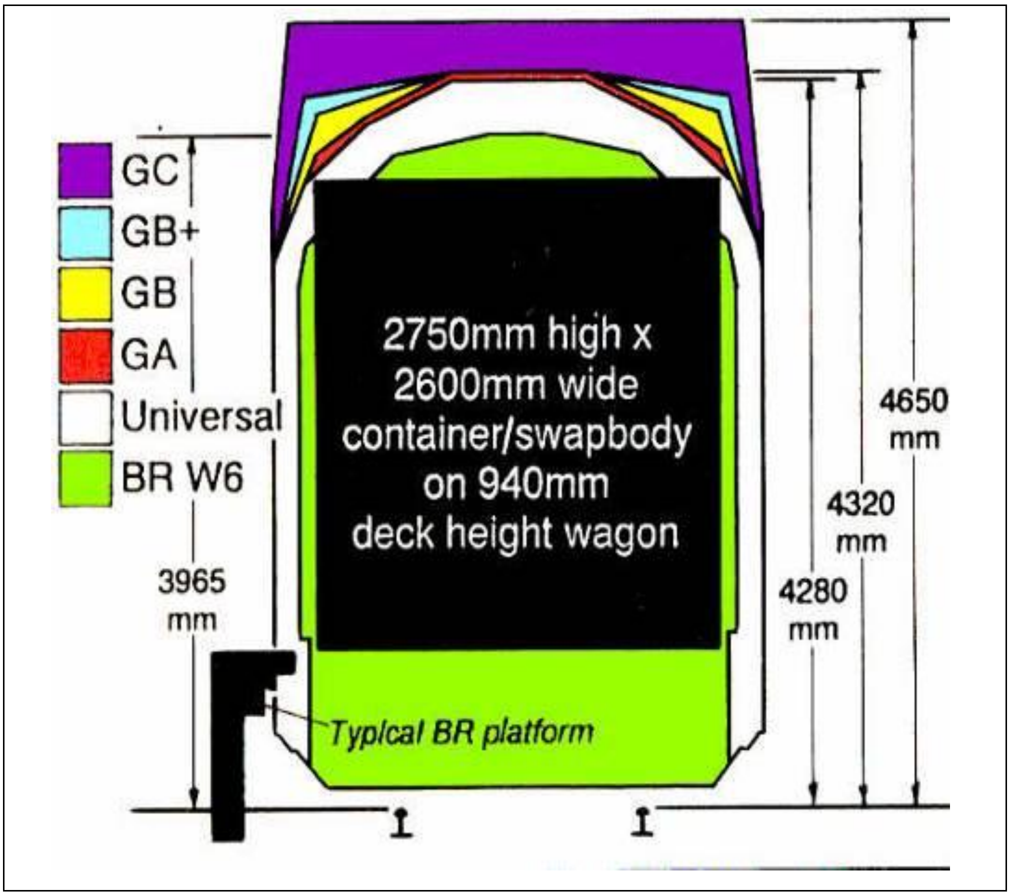


Figure 17: Diagram showing the difference in Structure Gauges (Source Laserail Ltd.)

Explanation of nomenclature:

GC	*Standard European Structure Gauge*
GB+ GB GA	*Special Designated European Route Clearance Gauging Profiles*
Universal	*European Full Clearance; includes all UK main routes*
BR W6	*Standard UK normal gauge (limited exceptions apply)*

The figure above shows the normal limited BR W6 gauge which dominates the routes in the UK. The GC (or UIC) gauge is typical of the European countries where trains are not only significant taller, up to 685 mm in height but also wider. This causes particular problems at the lower end of the profile where platforms are situated.

The Swedish Railvac could not pass through all platforms in the UK, so alternate arrangements have been made. (See chapter 5 where the Ashford station was avoided.)

A machine system that complied with UK structure gauge specification would have significantly lower operational costs than the current UIC gauge machine, primarily as a result of the significant reduction in the cost of transportation to and from site. However, it must be pointed out that even the current UIC gauge machine has provided Network Rail and other route providers with significant efficiencies over the past 4 years and did continue to do so until a UK version was ready to work in the UK.

Railvac machines are already in use across the world, including Europe and North America. Two of these machines are currently in use on London Underground infrastructure for ‘wet spot’ eradication. It was a significant development to have a machine is available for use in the British rail market and this UIC gauge machine that has been used extensively on Network Rail Infrastructure, primarily for switch and crossing reballasting and wet spot removal.

The machines are built by a joint venture between Disab SE and Railcare SE, both Swedish companies. In Britain, they are operated through Tube Lines Ltd. within London Underground and by Bridgeway Consulting Ltd. on Network Rail Infrastructure. Bridgeway took over this role in 2011 which was previously carried out by Carillion Rail and Sersa UK.

3. CHAPTER THREE

PROJECT ONE – INNOVATIONS IN SYSTEMS AND MACHINERY

3.1 Introduction

This chapter identifies and reflects upon the challenges of introduction and piloting new systems and machinery within the UK Rail industry. The challenges that are faced fall under the three distinct categories of technical, procedural and the human element. New techniques and innovative applications of technology are an essential feature of the continuing future development of the UK rail infrastructure industry. Throughout the last 20 years, introducing new machinery has appeared to become an increasingly difficult process. This was mainly due to the privatisation of UK railways which introduced a complex matrix of approvals and an enhanced reluctance by commercial organisations to take measured risks. This chapter identifies successes, describes the key processes and reflects upon potential barriers and opportunities and concludes with a reflective review of the application of appropriate technology and management systems to deliver a strategically important scheme for a UK national rail project. Lessons learnt are identified over the last 6 years and a review of the effectiveness of the current technical standards and procedures. The chapter will conclude with a reflective review of the application of appropriate technology and management systems to deliver UK government objectives for cost reduction in the long term. Recommendations are suggested for future "streamlining" of processes.

3.2 Background and Context of Approval Frameworks

The UK rail industry under the auspices of the British Railways Board (BRB) had centralised systems in place for approvals of rolling stock from its creation in 1947. There was a need to approve vehicle selection and specifications for trains built by private companies in the UK and abroad. The organisation for approval was at this time the BRB's in-house research organisation based in Derby. The areas covered included physical structure gauge, construction materials and structural design, traction and braking characteristics, wheel profiles, axle design, suspension systems, crashworthiness, and a whole host of operating compatibility issues including electro-magnetic impact upon the signalling and electrification infrastructure.

3.2.1 Privatisation Impact on Approval Frameworks

The full privatisation of the UK rail industry in the 1990's created a matrix of organisations that were involved in approvals processes, these were known as Vehicle Acceptance Bodies, which are in place today. (Rail Safety and standards Board, 2012). The relevant technical standards were originally managed by the newly created infrastructure owner Railtrack PLC who were the custodian of the standard setting process. In 2002, inquiries concluded following the Hatfield Rail Accident, that an independent authority known as Rail Safety and Standards Board (RSSB) should be created to oversee the process.

The current situation is that consultancy companies are licensed by RSSB to carry out the vehicle approval and acceptance process for which they have contracts with train manufacturers and suppliers. This suite of approval processes applies equally to the builders of civil engineering on-track rail-mounted equipment whether it is allowed to move under normal traffic conditions, ie as a “train” or within lines temporarily closed for engineering works. These arrangements are colloquially known as “possessions” or “blocks” in the UK.

3.2.2 European Approval Frameworks

European systems are very similar and there has been a major involvement by member states of the European Economic Community to standardise these systems through open access and interoperability arrangements. However, there are individual requirements within each state and each one retains the rights to approve local or national arrangements with regards to electro-magnetic compatibility and operational safety requirements. Giannakos and Profillidis (2001) indicate that within some economic communities particularly Europe, there is a great deal of cooperation and willingness to allow cross border running. However, the physical structure of vehicles sometimes does not seem to hold the same significance as track gauge, electrification and signalling operation. The principal and usually obvious barrier is the physical structure of the railway lines in the UK which are generally smaller in structure than Europe, Australia and USA. This is related to the size and proximity of bridge openings, tunnels and platforms.

3.2.3 Timescales and Simplification

The use of new materials, technical equipment and technical processes has been controlled by the UK infrastructure owner on a consistent basis for a long time and this is known as the product approval process. This mandatory process is detailed in the Network Rail Product Acceptance Standard (Network Rail, 2011a). Usually, there is a system of testing, piloting and impact evaluation relating to quality safety and environmental considerations.

In summary, there are two distinctly different processes; vehicle acceptance and product acceptance; each having markedly different systems and timescales. Any innovations have to go through these processes and although there are clear standards to be complied with, my experience has been that timescales can vary enormously. For example, around 1998, in the early days of privatisation it was taking up to 2 years to get tamping machines approved to work on UK railways.

The key issue is an overall commercial imperative that is either directly or time related to problem solving. Where a flexible risk-based approach has been adopted with personnel who can appreciate the holistic view and the urgency is accepted by all participants, rapid introduction and piloting can be achieved to deliver and adopt innovative new technology.

3.3 Consultancy Visits to European Countries

3.3.1 Railvac Operations Sweden

In September 2004, a team from the UK including myself and a Network Rail engineer visited a working site in Umea, Sweden where the "Railvac" machine was working. This was a night shift and the work involved ballast removal in a switches and crossings location to facilitate replacement. It quickly became very clear that there was great potential in the UK, where geotechnical conditions were potentially more demanding. A number of other applications were observed including cable burying. The machine was a large self-propelled vehicle consisting of a 80 tonne storage and discharging tank with a powerful vacuum system. The innovation aspect identified was not only the power level but the hydraulic arm with a tungsten metallic cutter tube that had similarities to a powerful multi positioning excavator scoop. (Railcare/Sersa-UK, 2009). This was the key distinguishing feature of the machine. The team had observed similar ballast extraction equipment in Europe but this feature not only had the power but a complex operational console that controlled not only the arm but the movement of the vehicle.

3.3.2 Other Operations Northern Europe

In late 2004 and 2005, a team from the UK visited a number of sites in Germany and Switzerland where they witnessed new innovations in track repair and maintenance invented by the Swiss company, Sersa. The process called "second life system" was applied to timber track layouts and involved the installation of stainless steel inserts and fast setting resin to reinstate structural integrity and lateral alignment (Sersa Second Life Product Catalogue, 2010). The railway administrations in Europe were very keen to obtain systems to enhance the life of expensive track assets. They also had a requirement to limit possession time to 7 hours and maximise the use of non-intrusive processes. The heater restressing system was viewed in Switzerland at the same time. The system is used in place of hydraulic stressing needed to install rails at the stress free temperature of 27 degrees Celsius. It was identified that it could be more efficient at homogenous stress distribution overall and adjacent to junction trackwork. The principal author visited Zollner GMB in Kiel, Germany where the automatic track warning systems (ATWS) known as Autoprowa® were in use on sites in the vicinity. This system uses both wired and wireless advanced train detection systems to give staff time to move out of the way of high speed trains (Zollner Autoprova Warning Systems, 2012).

3.4 Investigation of Appropriate Applications and Locations

The next stage in early 2005 was to find suitable applications. The author was already in post as the General Manager of Carillion Rail Ancillary Projects and it was at this point that the organisation was expanded to develop these systems. Each group of innovation pilot schemes was assigned to a project manager who appointed delivery teams. A safety, commercial and technical support organisation was created with expertise in these areas. The whole group was managed by the author as a business unit with the remit that in every case, the schemes were accepted only with a commercial rate of return that was within the range of cost recovery plus overheads and required contribution. Even in these early days, clients were able to justify the use of these innovations on the basis of value engineering principles. In this way, this was a unique development area where the innovations had so much intrinsic value that even on a potentially trial basis it could be demonstrated that there were significant financial and performance savings.

Coincidentally, although different teams were used the first live pilot use of Railvac Vacuum reballasting machine and the Sersa Second Life Timber Treatment System was on the same day in February 2005.

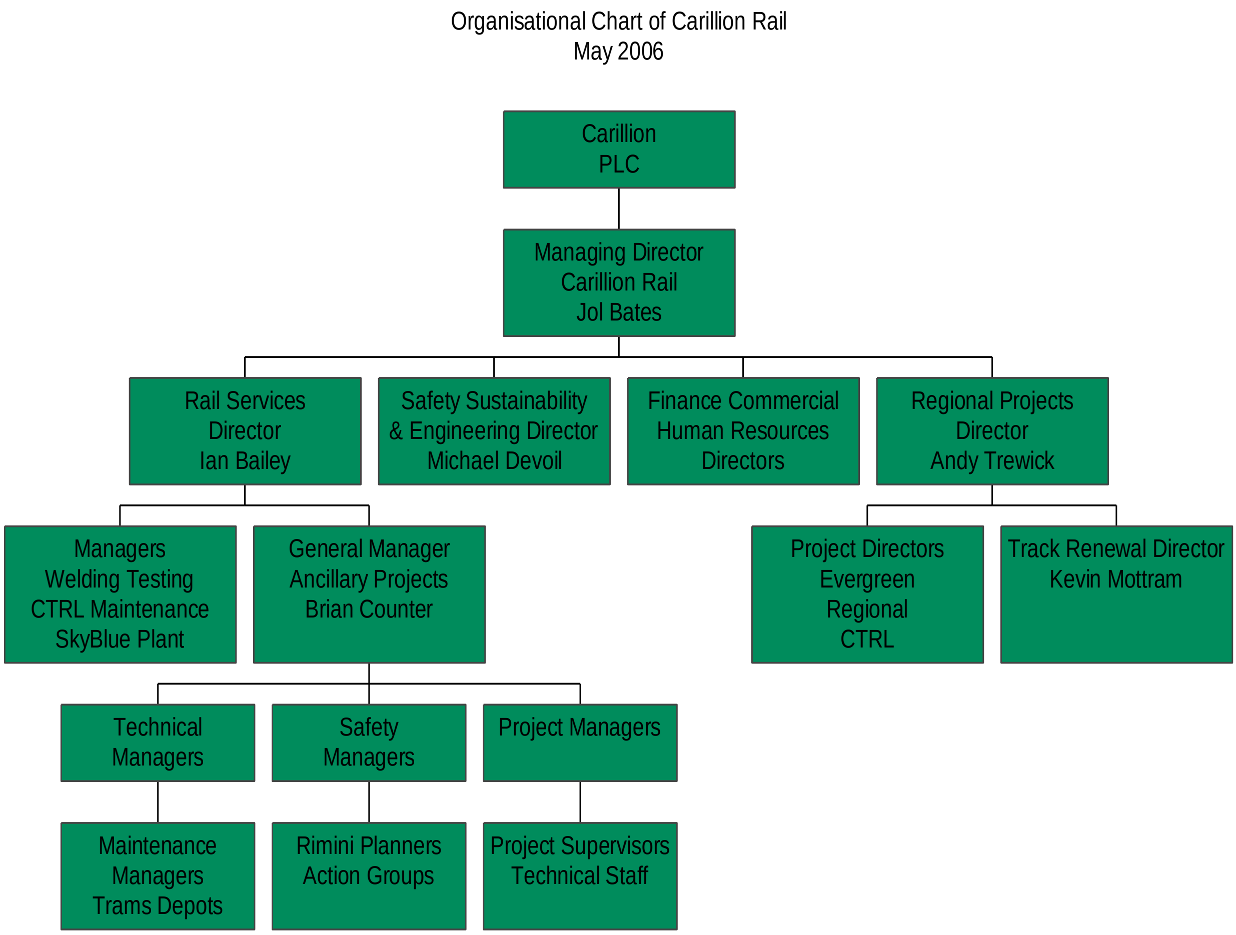


Figure 18: Carillion Rail Organisation Chart (Source: Carillion PLC)

3.4.1 Initial Trials of Vacuum Reballasting Machine Didcot UK

The use in the UK of the Railvac vacuum reballasting machine took place at Foxhall Junction, Didcot, Oxfordshire. This was a landmark test and piloting exercise on a mainline railway in the UK where the machine was allowed to travel self-propelled on Network Rail Infrastructure. There were major logistical and regulatory challenges:

1. First use of Railvac in the UK as a stand- alone self-propelled machine

2. Management challenges involving client and contractor

3. Transportation of Railvac from Sweden to UK

4. Regulations relating to the use on Network Rail Infrastructure VAB Vehicle Acceptance and EAC Engineering Acceptance; this was known as a temporary non-compliance.

Figure 19: Railvac vacuum reballasting machine showing tungsten tube Switch and crossing layout at Foxhall Junction, Didcot, UK. (courtesy Railcare)

The figure below shows how the new ballast is placed close behind the excavation to prevent undue sagging of the track. This excavation was carried out over and existing sand blanket without damaging the protecting geotextile. It can be see that It is also not necessary to disconnect and cables from the track.

Figure 20: Railvac vacuum reballasting machine showing excavation Switch and crossing layout at Foxhall Junction, Didcot, UK. (courtesy Railcare)

3.4.2 Initial Trial of Timber Resin Treatment Preston UK

The author was able to convince the engineers in Network Rail to allow the first UK use of the "second life system" which subsequently took place at Oxheys, near Preston on a high speed location on the West Coast Mainline in the North West of England, UK. The reason for the trial was related to the condition and recorded track quality at this location and the continued pressures to find solutions to its physical problems without complete renewal. Following a wide review of similar locations suggested by the rail infrastructure maintenance and WCML project teams a technical decision was made to use Oxheys.

Figure 21: Completed high speed turnout Oxheys West Coast Main Line

The proven track record of implementing new and innovative processes by the author and his team on the WCML project (see Chapter 3) made a significant contribution to this approval and test site. Further work in support of this type of improvement was carried out by Cornish et al (2011) when they identified trends in failure statistics for switches and crossings in many parts of the UK. The degradation of both vertical and horizontal support by timber has a major contributory factor to failures of switch mechanisms.

There were, however, also other major challenges relating to the application of this new technique in a high speed operational location on a trial basis:

1. Network Rail Product acceptance (by formal certificate) in principle and the associated national and local conditions applied with respect to curing, monitoring and integrity.
2. UK COSSH regulations compliance (HMSO COSHH, 1996)
3. Track geometry re-design and requirements for significant adjustments, up to 15mm in a lateral direction and approval of any slues.
4. Possession and access to the track to carry out the trial.
5. The technical analysis of resin curing times to confirm integrity prior to either removal of push/pull tie bars or full open linespeed running.

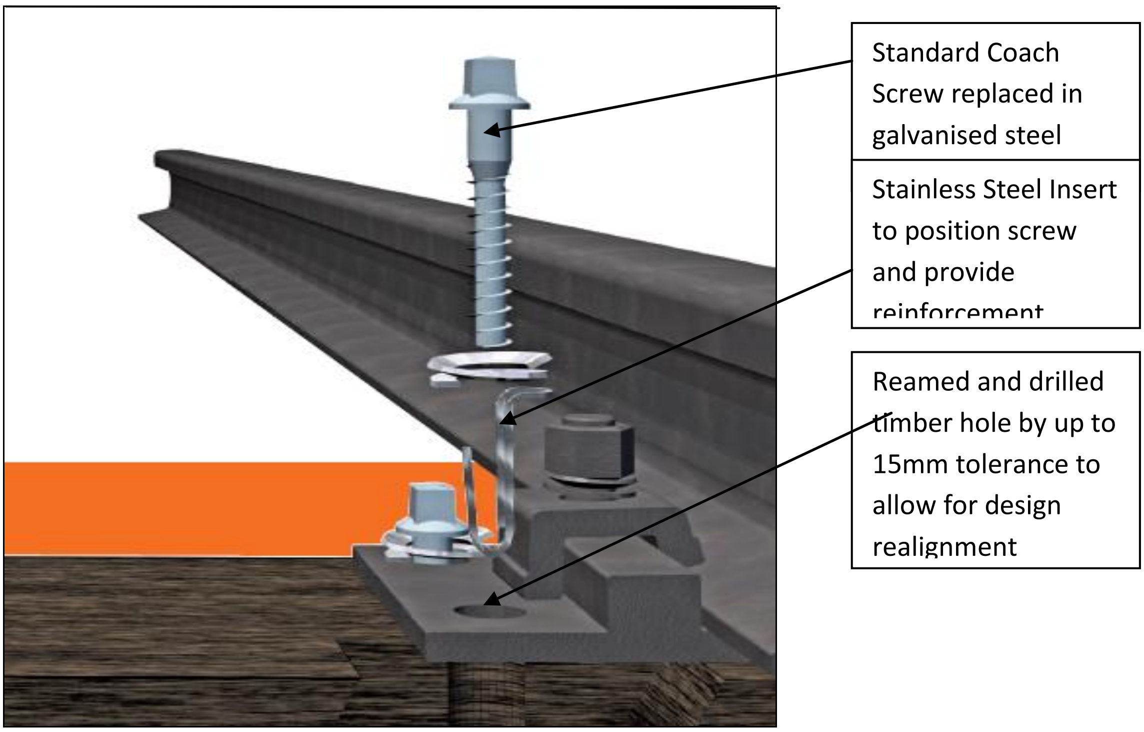


Figure 22: Sersa Second Life Timber Treatment System (courtesy Sersa-UK Ltd.)

Figure 23: Sersa Second Life Timber Treatment System (courtesy Sersa-UK Ltd.)

3.4.3 Initial Trial of Automatic Track Warning System Stafford UK

The first use of this system took place at Colwich, West Coast Main Line, in July 2004 to facilitate daytime heavy replacement of track timber work in traditional restricted working areas (red zones). This trial increased productivity by 60% and allowed the programmes of work to be accelerated, saving 9 -12 months on the project.

Figure 24: Autoprowa Warning Systems (courtesy Zollner-UK Ltd.)

The initial trials were instigated from an economic perspective. It is possible that the origins were from a British Rail system developed in the 1970's known as "Peewee". This was an advance warning system operated by an advance lookoutman who released a plunger when he observed a train. The use of a train operated warning by utilising a temporary treadle would be able to save manpower. This was the first concept at Colwich so in many respects it could be considered as emerging technology. The use was approved by the client, Network Rail with two specific issues that contributed to the rapidity of introduction:

1. The approvals process was less stringent as other proprietary systems had been in use in the 1990's, although they were fixed locations, but the technology related to the track treadles had been used for some years. This was originally the system used for public level crossings in the UK.

2. There was a local risk assessment process in place which supplemented the Network Rail "Rimini" process and involved testing and proving the systems from a "fail safe" perspective.

The author was responsible for the works and for the safety, technical and commercial liaison between the client, the suppliers and sub-contractors and his company Carillion PLC. A key aspect of this was the quality assurance of the equipment and to this end, this involved visits to the factory in Kiel, Germany. Clearly, the author was also responsible for the delivery of the work and the authorisation of the risk assessments and method statements above.

There was a clear strategic influence at this stage due to publicity around the UK rail network of the application of ATWS for productivity and safety related refurbishment work. The use of ATWS was discussed by Wheeler C. (2004) in terms of the need for the UK rail industry to pursue and adopt ATWS on a widespread basis.

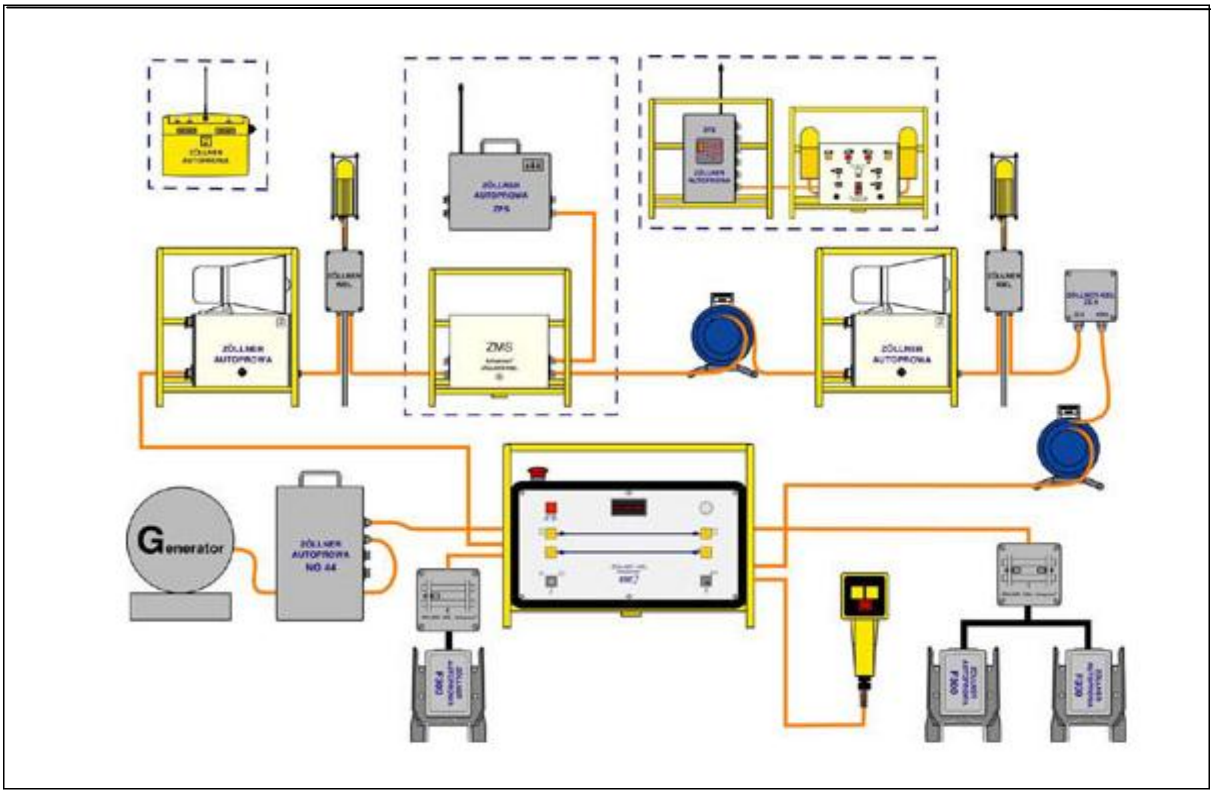


Figure 25: Circuit Diagram Autoprowa Warning Systems (courtesy Zollner-UK Ltd.)

The diagram above indicates the complexity of the system. The central feature is the control unit (bottom centre) which has a mimic diagram to indicate the working arrangements. To the right and left of this are the treadles which are located a the beginning and end of the affected line sections. Above the control unit are the warning devices which consist of flasing yellow lights and horns. All parts are hard wired but a further development which was under trial was the use of wireless connections and this is indicated by the dashed boxes.

3.4.4 Initial Trials of Heater Re-stressing Manchester, UK

This was the first use of the system for re-stressing switches and crossings adjacent to recently renewed plain line at a rail junction. Theoretically and to be compliant to standards the stress free temperature is required to be 27 degrees Celsius. When track is installed or adjusted in cold temperatures, as it normally is in the UK, there was a need to remove calculated amounts of rail and adjust switch rails to equalise stresses. In many areas such as the junction at Slade Lane in Manchester, it was traditionally not possible to do this, due to the interface between old and new track. The opportunity to use this process would make long term savings and would relate to a reduced inspection regime as the risk was less and a saving in maintenance as the stress in the layout was equalised. Carillion PLC had been involved in the track renewals and the author was approached to offer some solution. The approval process was completed rapidly due to the following:

1. The process followed existing technical standards regarding stress.
2. As theoretical temperature requirements were met in a more natural way than artificial stressing a locally agreed approvals process was possible.

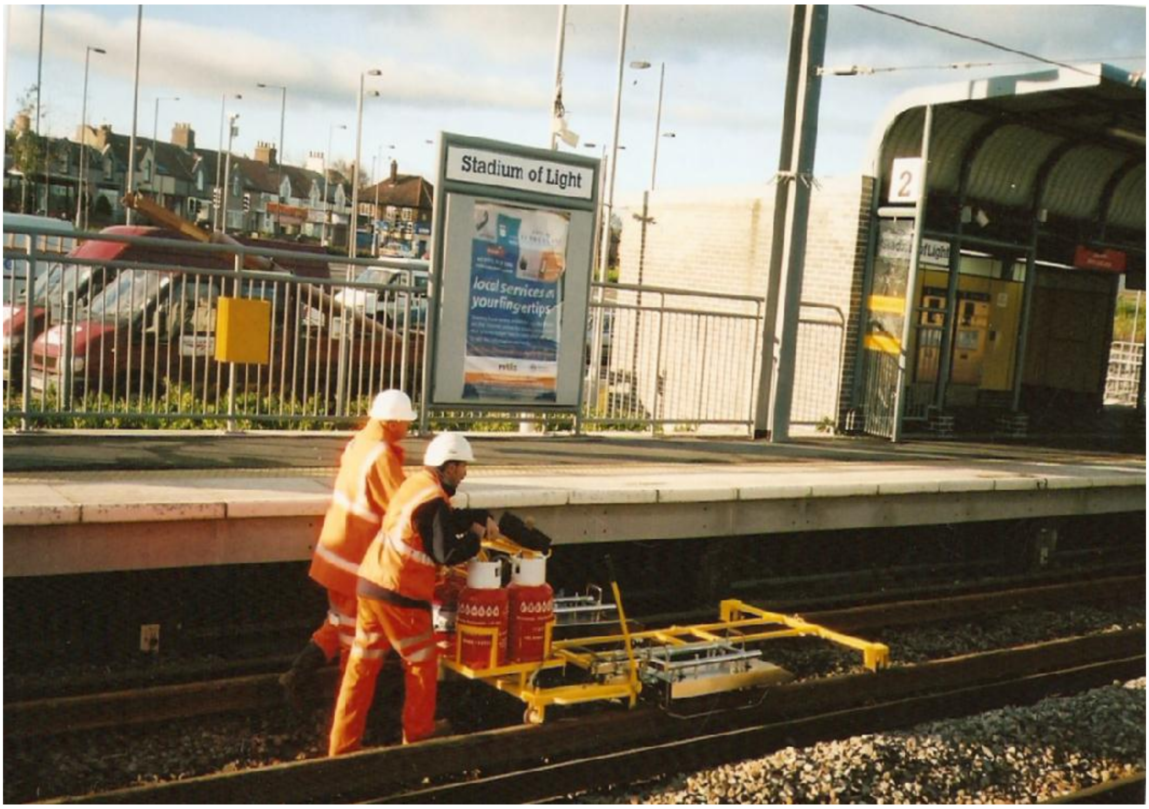


Figure 26: Sersa heater rail restressing System (courtesy Sersa-UK Ltd.)

3.5 Review of Rail Approval Processes in the UK

There is a complex process for approval and acceptance within the current UK rail industry which relates to two specific organisations. The Rail Safety and Standards Board (RSSB), a part of the Department for Transport, oversees the vehicle acceptance process for the UK network specifically related to trains and train borne mechanical plant. Network Rail Infrastructure Ltd. as the owner of the track oversee their own track product acceptance process for Railvac and other systems specifically relating the track integrity. The following sections detail and review the experiences of these processes.

3.5.1 Product Acceptance and Approval

This a Network Rail process that involves a number of steps including commercial, quality assurance, and technical approvals from their professional heads and other experts within the rail industry. A key feature is compliance to relevant health and safety regulations particularly Control of Substances Hazardous to Health Regulations (HMSO, COSHH, 2009), Lifting Operations and Lifting Equipment Regulations (HMSO, LOLER, 1998) and Powered Plant Utilisation and Working Equipment Regulations (HMSO, PUWER, 1998). Usually the process involves testing, live piloting and monitoring. The process has recently been streamlined and segmented to make timescales appropriate to risks. The innovations that had to formally go through this process were Second Life System (SLS) and ATWS (Automatic Track Warning System) known by the German name as Autoprowa. Companies applying for such approvals must hold the relevant company approvals sometimes known as a Contractor's Safety Case.

In the case of the SERSA Second Life System, the material and process affected the structural stability of the track and there is a direct safety of line issue associated with the required strength of resin within specified timescales and also an issue of its durability and life. Also, the resin had to be assessed from a chemical perspective regarding its on-site mixing process and paying due regard to the UK COSHH regulations (HMSO, COSHH, 2009). The resin used in Switzerland could not be used as it was assessed as containing carcinogens, therefore an alternative was proposed and agreed called Edilon. The Zollner Autoprowa® Product Acceptance required that the system had to be assessed for the integrity of its fail-safe mechanism whereby a signal from a track mounted treadle would register the approach of a train and give appropriate warnings to trackside personnel. This was particularly important when working at junctions and on bi-directional lines. A less stringent but key factor would be the fixing mechanism to the rails and the lack of any interference to the normal running of trains. Previous systems of a similar nature were trialled so there was some precedence to this application. The Railcare Railvac Machine Product Acceptance was informal as this was classified as mechanical ballast removal and only the appropriate method statements were subject to the product approval process

3.5.2 Vehicle Acceptance and Approval

A Vehicle Acceptance Body for Engineering Acceptance of Rail Vehicles is categorised as capable of dealing with Design Scrutiny, Construction, Vehicle Maintenance and Specialist types specifically including on track Machines and road rail mounted maintenance machines. There are a number of authorised certification bodies (normally rail engineering companies) who have specifically authorised competent persons that are licensed by RSSB (2005) to carry out such approvals and there are specific criteria which must be followed to assess suitability and in most cases set down conditions. It is usually quicker to refer to some other similar application to establish any possible “case law”. The process involves an assessment of the following:

1. Structure of the body of the vehicle: this includes the steelwork, rigidity, flexure and construction (welded, bolted, etc); this includes as-built and current condition. Train crashworthiness is also an area of some interest.

2. Running gear of the vehicle including axles and specifically the track gauge tolerances and extent of hunting (movement laterally), wheels, bearings, axle mountings, bogies, suspension systems, again this includes as-built, adaptions, conversions and current condition.

3. Braking systems as-built and current condition

4. Traction systems including motorised or free axles

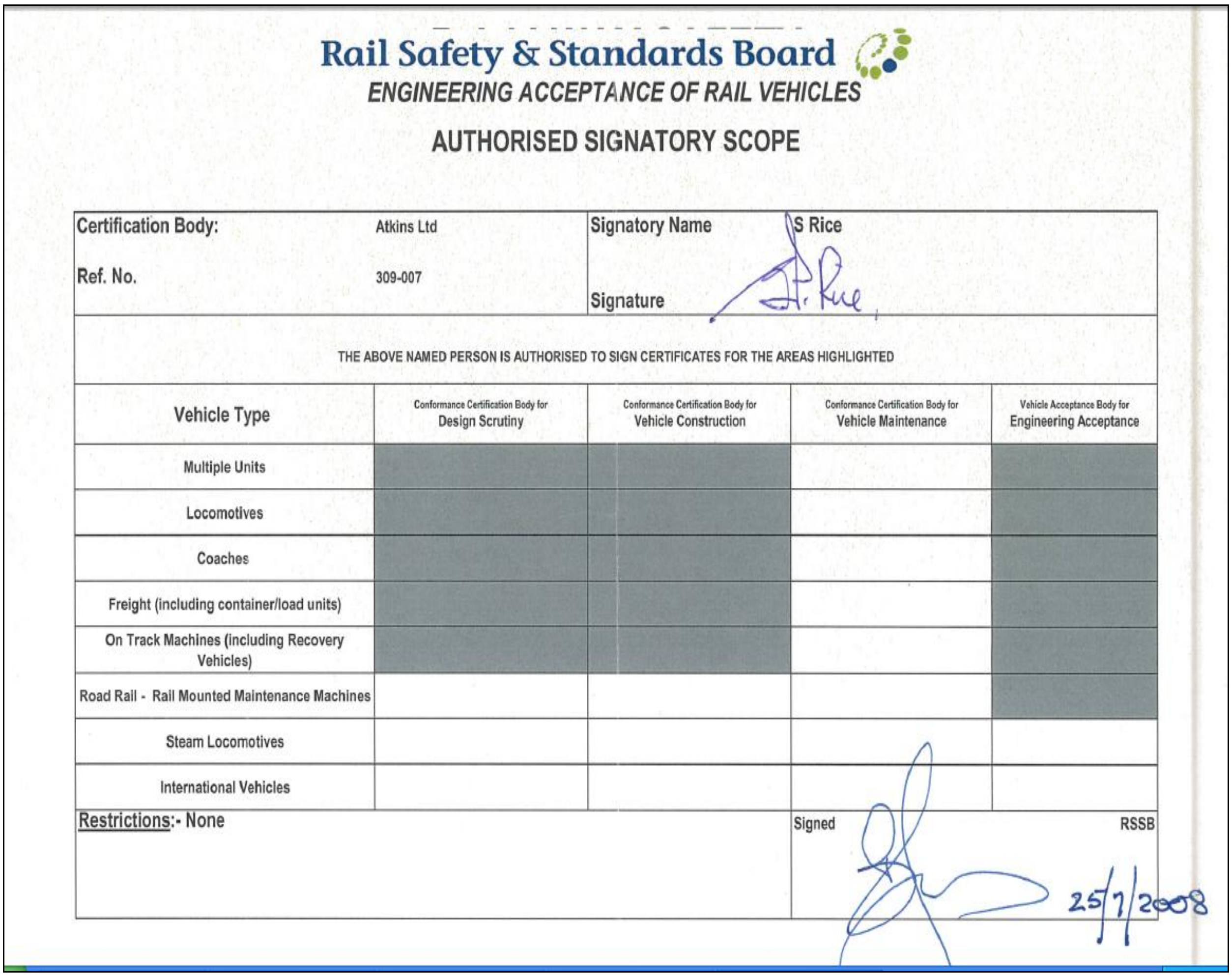
5. Clearances to UK or UIC (European standards) structure gauges and areas of concern

6. Wheel Profiles

7. Operating compatibility issues including electro-magnetic impact upon the signalling and electrification infrastructure.

8. Colour of the end of the vehicle (Yellow needed in UK)

9. Personnel access and egress



Rail Safety & Standards Board

ENGINEERING ACCEPTANCE OF RAIL VEHICLES

AUTHORISED SIGNATORY SCOPE

Certification Body:	Atkins Ltd	Signatory Name	S Rice
Ref. No.	309-007	Signature	

THE ABOVE NAMED PERSON IS AUTHORISED TO SIGN CERTIFICATES FOR THE AREAS HIGHLIGHTED

Vehicle Type	Conformance Certification Body for Design Scrutiny	Conformance Certification Body for Vehicle Construction	Conformance Certification Body for Vehicle Maintenance	Vehicle Acceptance Body for Engineering Acceptance
Multiple Units				
Locomotives				
Coaches				
Freight (including container/load units)				
On Track Machines (including Recovery Vehicles)				
Road Rail - Rail Mounted Maintenance Machines				
Steam Locomotives				
International Vehicles				

Restrictions:- None

Signed RSSB

25/7/2008

Figure 27: Engineering Acceptance Sample VAB Proforma (Source: RSSB)

3.5.3 Developments in UK Approval Processes

Following problems and complaints associated with complexity and timescales, there have been a number of current developments in the product and vehicle approval and acceptance processes. These have been largely addressed in many areas but particularly those concerning the use of self propelled rail maintenance machinery and new treatments or systems.

3.5.3.1 Vehicle Approval of On-track plant

Recently a review has been made of the parallel processes that involve Engineering Scrutiny (the VAB) and Product scrutiny (the client product approval process) and as the same technical experts are often used, it was suggested by Collinson (2011) that this could save 20% of the time and cost through a combined process. This is particularly relevant to on-track plant introduction both new and adaption. The Railvac type of plant falls into this category and proposals are in progress alongside the review of applicable Railway Group Standards. The role of the competent person under VAB for engineering acceptance is expected to remain. A key feature within the future strategy is the emphasis of safety; it was reported that between 1994 and 2009, 26% of all fatalities on Network Rail infrastructure involved on-track plant.

Figure 28: An overturned road rail machine 2011 (courtesy: Network Rail)

Over the next 4 years, Network Rail has initiated an "On Track Plant Safety Project" with 3 major work streams; machine design, roles and responsibilities and competence. The focus on machine design is related to the avoidance of risk and the message is that the future plant suppliers should be equipped with plant acceptance competencies.

3.5.3.2 Network Rail Product Acceptance Process 2011

Network Rail standard NR/L2/EBM/029 (Network Rail, 2011a) mandates the process for the acceptance of products for use on or as part of Network Rail infrastructure. This includes: new or modified products, materials, equipment, and systems ; Change of application; Road Rail Vehicles/attachments and Rail Mounted Maintenance Machines, On-Track Machines, road plant and Portable and Transportable Work Equipment that could affect or interact with the infrastructure. Network Rail has also developed a more sophisticated approach to product acceptance related to a set of criteria related to what is known as technology readiness. It is clear that best practice associated with experience over the last 10 years has informed the new process.

Technology Readiness Levels (TRL)

Programme Phase	TRL	Summary Description	Key Aspects
System validation	9	Technology "qualified" through successful service operations	Actual application of Technology in its final form under service operation conditions
	8	Actual Technology completed and qualified through test & demonstration	Technology proven to work in its final form and under expected conditions
	7	Technology prototype demonstration in an operational environment	Prototype near to, or at, planned operational system. A major step forward from TRL6
Technology validation	6	Technology model or prototype demonstration in a relevant environment	Representative model or prototype which is well beyond TRL 5 tested in a relevant environment
	5	Technology validation in relevant environment	The basic technological components are integrated with reasonably realistic supporting elements and tested in a simulated environment
	4	Technology validation in a laboratory environment	Basic technological components are integrated to establish they will work together. Low fidelity compared with the eventual system
Concept validation	3	Analytical & experimental critical function and/or characteristic proof of concept	Active research and development is initiated. Includes analytical & laboratory studies to physically validate analytical predictions of separate elements
	2	Technology concept formulated	Invention begins. Application is speculative, with no proof or detailed analysis to support the assumption
	1	Basic principles observed & reported	Scientific research begins to be translated into applied research & development

Table 2 Technology Readiness Levels (Courtesy Network Rail Ltd. 2011)

Network Rail has approved the use of Railvac and the Sersa Second Life timber treatment system in its latest policy document entitled NWR Track Asset Policy 2011 (Network Rail (2011b). The following quotation is taken from the document:

> *"Where it is necessary to reballast only (for the reasons described above) then vacuum reballasting has been successfully applied to both plain line and S&C. At present this work is carried out using RailVac machines imported from Sweden that are limited by their being constructed to a large Continental loading gauge (they cannot work in platforms or under some arched overbridges), but a machine is being constructed to the UK 'W6a' loading gauge. Vacuum reballasting will be key to delivering heavy refurbishment of S&C where it is desirable to carry out the reballasting without removing the track system, and is currently seen as the most cost effective option."* *[See Figure 17, page 41]*

> *"SERSA have developed a proprietary system called 'Second Life' which uses a pourable epoxy resin to locally restore the strength and shape of the timber in the baseplate bearing area and fixing holes. The process is applied in-situ and has been used successfully on the Continent and at trial sites in Britain to treat S&C bearers, particularly to restore track gauge. Modelling indicates that the cost of treating both baseplates on a sleeper is more than half the cost of installing a new sleeper, so it is a low value option for plain line."*

This new policy document for track is quite different from its predecessors and has been influenced in a significant way by the work carried out by the author and his delivery teams over the last 6 years. The typical approach in asset management in a railway infrastructure context was renewals and/or maintenance (Brown,1997) now there is a clear emphasis on refurbishment as a legitimate budgeted activity with clear specifications on the extent. The benefits have been predicted to save over 20% of investment costs within the UK, which is part of the efficiencies planned by Network Rail in the future (ORR, 2011). The new machine that specifically meets UK structure gauge from Sweden is testimony to a long term commitment to use the technology.

3.6 Analysis of the Influence of the Human Element

There is always a human element to the introduction and application of new technology in any field. It is therefore no surprise that in a traditional and longstanding area such as railway track engineering the speed of adoption is related to a myriad of complex interfaces and attitudes. In the context of rail, this can be categorised into the following areas:

<u>Negative Influences</u>

1. General Reluctance to change by individuals possibly at all levels
2. “Not invented here” syndrome by key players
3. Low risk taking approach by organisations and individuals
4. Commercial and financial biases, sometimes not always obvious
5. Insufficient strategic will to produce efficiencies
6. Poor knowledge of the overall context (often known as the “big picture”)
7. Perceived lack of direct experience in a specialised industry

<u>Positive Influences</u>

1. Exciting new ideas that inspire and motivate
2. Benefits obviously and quickly realisable
3. Innovators have a track record and depth of experience
4. Competence by innovators to persuade and inspire confidence
5. Enthusiasm of all parties
6. A team approach to solve complex problems
7. A team approach to deliver projects
8. A fair apportionment of risk and commercial reward

In these projects, the success in terms of introduction and delivery was related all of the positive aspects being realised, particularly the relationship of all the parties with a high element of personal trust and confidence. There can be little doubt that these psychological interfaces are crucial to what is colloquially known as a “can do” attitude. The leaders need to be fully aware of the influence and impact of the human element in the pursuit of innovation.

3.7 Review of successes in implementation of new technology

The success of the projects to introduce these new techniques in the UK is evidenced by two factors; the live use of equipment to solve challenging problems with UK rail infrastructure that could not have been achieved using conventional methods within predetermined time success cost parameters; and the adoption of national policies for such techniques by Network Rail as part of its agreement with the Office of Rail Regulation (ORR, 2011) for the next 5 year funding control period (CP5) from 2014-2019.

The use of equipment involving track and safety systems was able to be authorised through the Network Rail product acceptance process involving the professional engineering heads who were always involved in the first instance. This clearly helped to solve any problems early on to prevent delays sometimes caused by bureaucratic loops within formal organisations.

Any track borne machinery which was in essence classified as a “train” was subject to both the product acceptance process and VAB. It is important to note that the VAB process is outside of Network Rail’s jurisdiction being under the auspices of RSSB even though the “train” or machine was not working on live railway lines. Therefore it requires a great deal of project management to coordinate both approvals processes and this is where delays can occur.

A full programme of work for the Railvac machine was implemented in the UK within less than 12 months from the initial fact finding visit in Sweden. It is useful to identify the drivers for this fast track approach which meant that in real terms the risk was low overall because of a number of reasons:

1. The vehicle itself was designed to European standards and had a proven and documented record of working all over Europe.
2. The only major limiting factor was structure gauge which was carefully assessed by site surveys.
3. There was no physical effect to the track if used under careful supervision; the machine was limited to ballast removal and on-track movement.

The most important reflective aspect of the work carried out was the timescale from initial viewing to pilot use in the UK which was only 5 months. The technical VAB work commenced within weeks of seeing the machine in action to prepare the VAB body for their practical work on physically assessing the vehicle which was done in less than 4 weeks at the Serco Railtest plant in Derby UK.

The product assessment and use authorisation process was achieved very quickly mainly through close client involvement. The relevant Network Rail track engineers were involved in the process right from the first visit to Sweden in September 2004 and finding a suitable low risk first site. Clear and meticulous planning was essential and it obvious that that a critical path based and human factors project management approach was the key to success.

There are many challenges and difficulties in the pursuit of innovation especially in the railway industry where safety is paramount and most activities are in the public view. However, it is usually a balance between risk and human will, and in all cases there has to be an economic driver albeit a direct cost saving or a solution to a performance or time related issue. The key factors demonstrated in these projects generally relate to a simplification of appropriate technology and a people and team based approach to problem solving. There can no better endorsement of an idea than its incorporation into UK national policy. Figure 16 indicates the benefits of a good pressure distribution by ensuring ballast depths are sufficient and ballast beds remain uncontaminated (Liechberger, 1991)

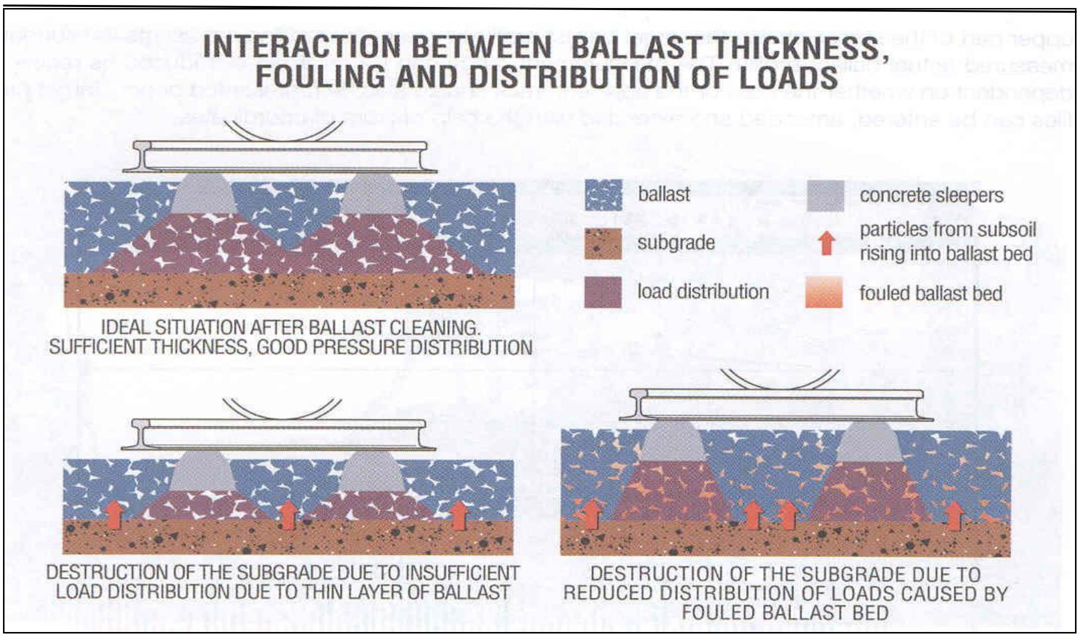


Figure 29: Schematic representation of the reduced bearing capacity of a contaminated ballast bed [courtesy – Network Rail Track Policy 2011 Bernard Litchberger]

4. CHAPTER FOUR PROJECT TWO

WEST COAST MAIN LINE JUNCTION REFURBISHMENT WORK

4.1 Introduction

The West Coast Main Line is the key South to North arterial railway route in the UK linking London with the cities of Birmingham Manchester Liverpool, Glasgow and Edinburgh (Scotland). The upgrade project was an integral part of the UK privatisation process and was linked with Virgin Trains investment in high speed tilting electric trains. The £10bn overall scope included major track remodelling and renewal to increase linespeed to 125 mph and reduce journeys times typically by 25%. For example, the key business concept was London to Manchester in 2 hours. The work commenced in 1998 and was due for completion in 2006.

The author was responsible for the £4 million element of the work that comprised the refurbishment of railway junctions and was appointed General Manager of Carillion Rail Ancillary Projects from 2004-2007. This group was set up to deliver innovative infrastructure maintenance and refurbishment projects from concept, through approvals leading to piloting and implementation. The works involved Network Rail RT21 contracts of managed by Carillion PLC. This was achieved by the utilisation of applied and adapted technology linked to specialist methods of working. The core achievement was technically driven life extension value engineering solutions to deliver linespeed profiles and the use of new innovative access technology.

4.2 Decision to Extend the Life of WCML Junctions.

A review of the whole strategy for the scope of the WCML upgrade project was carried out by the Network Rail WCML Project Team with the decision made to extend the life of key junctions rather than renew them.

It is a useful and appropriate reflective feature of successful new project scopes to identify the fundamental drivers for new techniques and innovative applications of technology particularly in the UK rail infrastructure industry. In 2002/3 the government regulator “Office of the Rail Regulator” and agency “Strategic Rail Authority” carried out a review of the cost profile of the West Coast Mainline Project and enforced the reduction from £13.0bn to £9.3bn through the negotiation of scope amendments. According to ORR (2003) the government made the specific demand that there was still an absolute requirement to achieve enhanced permissible speeds of up to 125mph by target dates to deliver the key features of the Virgin Trains Pendolino timetable.

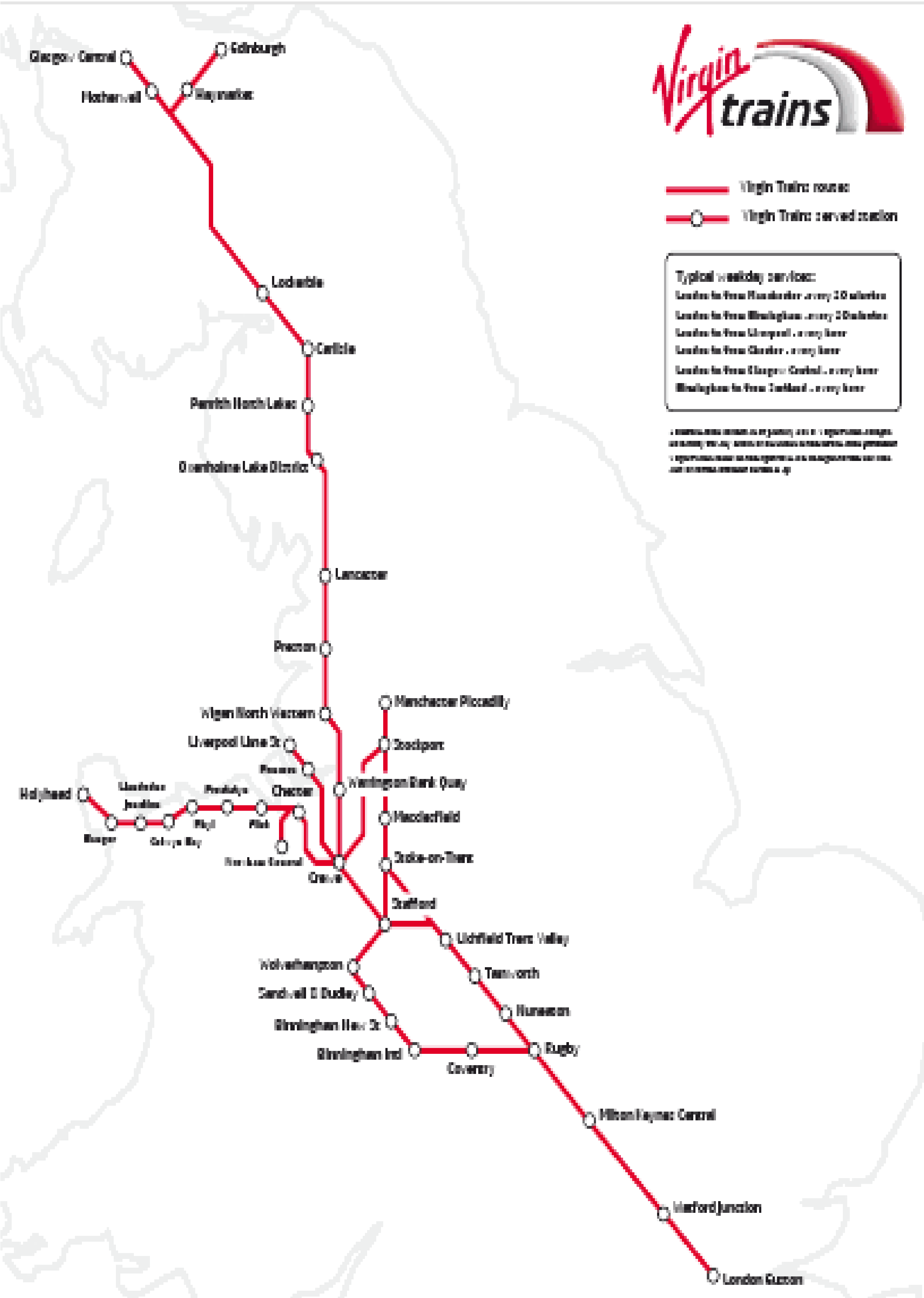


Figure 30: Route Map West Coast Main Line (courtesy: Virgin Trains Ltd.)

The project was carried out through a focussed programme of refurbishment rather than renewal delivering the new context of life extension. With timescales being challenging, it was essential to find and use new techniques that could be adopted quickly. This chapter identifies the successes, challenges and new processes and reflects upon alternatives and lessons learnt.

4.3 Junction Refurbishment Scheme Details

A comprehensive plan was devised in conjunction with the client to phase the work to maximise logistical flexibility and efficiency. The route has very different characteristics along its length but the northern sections are particularly curvy. The following section contains descriptions of the technical scope, specifications and locations for replacement of switch and crossing timbers and realignment work.

4.3.1 Location

This work was carried out in 3 phases that relate to the geography of the West Coast Main Line:

1. London Euston to Rugby 2003-2004
2. Rugby to Crewe 2004-2005
3. Crewe northwards 2005-2006
    - Crewe to Gretna Junction (Scottish border)
    - Branches to Liverpool and Manchester

Figure 31: West Coast Main Line Junction – Norton Bridge Staffordshire UK (Source: author)

4.3.2 Technical Scope for Enhanced Permissible Speed

The work involved the repair of track junctions instead of complete renewal. Mostly they comprised of 1970's and 1980's vertical switch and crossing layouts of 113A rail on hardwood timber bearers with a mixture of built up, welded, semi-welded and cast manganese crossing components. In most cases there were significant track geometry irregularities which were below the published Network Rail standard deviation specifications for current line speeds and also contributed to a low perception of passenger comfort.

This situation was a serious WCML project delivery issue because, although the track was theoretically within tolerances for existing rail traffic at current speeds, it was clearly unacceptable to consider the raising of the permissible line speeds without specific work to guarantee the integrity of the track structure albeit not by renewal but some form of refurbishment. The speeds were due to be increased on the basis of an allowable geometric profile but in some cases, there would be additional forces due to the concept of tilting trains. These trains, Virgin Pendolino Class 333, are able to travel at a higher speed around existing curves, because the tilt takes into account the shortfall in equivalent cant (super-elevation). In effect, the Pendolino train compensates for a lack of cant by tilting the body thus relieving the passenger of the effect. However, by definition and curving theory there is a greater cant deficiency of up to 150mm more than the normal allowable standard of 150mm (Network Rail, 2005) This exerts greater lateral and vertical forces upon the track usually on the high rail and there are obvious greater dynamic effects which are exacerbated by track irregularities and perturbations.

4.3.3 Technical Challenges involving Increased Speeds

The engineer's specifications would normally be satisfied through complete renewal of track junctions and a large amount of renewal had taken place during the early phases of the WCML modernisation and improvement project. The initial preliminary response to the demands of the Office of the Rail Regulator and the Strategic Rail Authority was to defer large multi million pound junction renewal schemes with a view that some form of refurbishment project could be created to deliver the enhanced speed profile within existing planning timescales and a limited budget. At this stage a challenge was put out to experienced organisations and the company GTRM Ltd., a joint venture between Tarmac/Carillion and Alstom PLC, who were the infrastructure maintenance contractor on the route responded and offered their services.

The agreed technical specification that was prepared to deliver these track geometry improvements was evolved through team discussions between Network Rail HQ track standards experts, local engineers and contractors from GTRM Ltd. In many respects, the interface between timber and ballast provides a stable structure without excessive production of fines. LePen and Powrie (2011) indicated through their testing at Southampton University that the concrete bearer ballast interface may have lower longer term performance. The agreed final specification involved whole-scale or targeted changing of hardwood timbers, realigning the vertical and horizontal geometry and some specific ironwork component renewal or replacement including welding and “fettling”. (A colloquial term related to an intrusive adjustment process with the objective of being the restoration of design track geometry.)

Figure 32: Access to WCML at Colwich Junction first use of ATWS (Source: Zollner UK Ltd.)

Having agreed a specification with input and output performance standards, the next major challenge was to formulate a planning schedule for delivery. This type of repair or refurbishment work can be carried out in two ways; complete shutdown (blockage) of the track or by a process of between trains working commonly used for minor maintenance work.

The key feature as to the delivery process was the obvious requirement that operational personnel would have to have guaranteed safety at all times whilst assuring absolute safety of trains. The overarching track theory is that the integrity of the structure of the track is not compromised during any repair activity that is carried out whilst trains are operating. It is by the application of a Network Rail Standard for Track Maintenance NR/RT103/2002 (Network Rail, 2002) that the work was planned. The standard allows for a timber to be missing or damaged as long as the timber on each side was sound and in good operating condition.

In actual fact, this is an extreme and limiting condition and subject to other aspects such as horizontal and vertical tolerances and not designed to allow for general application. It effectively, however, allowed for the authorisation of a framework through which a performance and safety validated method statement could be designed.

Figure 33: Changing Switch and Crossing timbers on the West Coast Main Line (Source: author)

4.3.4 Access Challenges

At the beginning of the first phase of work, advantage was taken of pre-booked possessions for the work albeit these would be at times of maximum labour usage such as at nights or weekends. This planning arrangement is colloquially known as “piggy-backing” on existing possessions. However, where locations for access were not already available, alternative arrangements were proposed.

A comprehensive method statement and risk assessment was carried out to deliver the work on a “between trains” basis during normal daylight weekday working hours. The system is well documented and evaluated through the Network Rail Rimini system (Network Rail Rule Book, 2011) and subsequently a “red zone” process was adopted. The main advantages were economic savings and delivery lead times associated with the following:

1. Competent and experienced manpower normally utilised at weekends was readily available during midweek daylight hours.
2. Red zone working had no impact on train running both in terms of delays due to speed restrictions or planned diversions. Also a major administrative savings through the avoidance of planning and publication in railway weekly operating notices.

3. Efficient delivery was possible through detailed planning to utilise resources to optimise productivity and avoid wastage and downtime.

4.4 Commercial Approach and Planning

Initially the work was procured through a negotiated variation of the WCML Infrastructure Maintenance Contract known as RT21. The mechanism was known as “cost plus” which related to the actual costs of the work being paid to the contractor with a 15% uplift for overheads and profit. The scope was based on a location by location basis where the client, Network Rail, and the expert from the maintenance contractor visited each location and following a review of track quality information and site surveys produced a plan.

4.4.1 First Phase of the works

Location	Timbers	Red Zone %	Point Ends	Estimate £k
Willesden	46	65	4	85
Harrow	36	96	3	92
Watford North	52	89	4	102
Watford South	42	94	4	75
Hemel Hempstead	56	93	3	80
Tring	65	96	4	120
Apsley	34	92	2	65
Bletchley	102	75	6	134
Wolverton	38	93	4	89
Rugby	32	89	2	43
TOTAL	**Phase One without ATWS** **Average cost per point end = £24.6 k**			**£885 k**

Table 3 WCML Project Heavy Maintenance Programme 2003/4 (Source: author)

4.4.2 Drivers for Innovation

Most contractual experts familiar with construction procurement will appreciate that this type of contractual arrangement is not particularly efficient as there few incentives from the contractor to reduce costs. However, in this case there were 3 factors which drove the search for innovation:

1. Red zone working is labour intensive as there is often a need to use a system of multiple manual lookouts to manually warn the approach of oncoming trains.
2. Red zone working is inherently inefficient in terms of allowable warning times and work stoppages which at busy times can cut down work by 40 minutes per hour as there is a need to be clear in both directions and sometimes on other adjacent diverging or converging routes.
3. The rules of working through the Network Rail standards process create locations which are "red zone prohibited". These are published in a hazard log and relate to poor sighting which may be due to line speed, curvature or fixed obstructions such as bridges, tunnels, viaducts, buildings, stations or track configuration in terms of junctions.

4.5 Application of Innovative Technology

For phase two of the project the use of Zollner's Autoprowa Automatic Train Warning System was considered as it would allow midweek work in red zones areas, especially at complex junction locations. The ATWS system is described in section 2.3.1 and has certain advantages that made it applicable to this project. Without the comprehensive use of the ATWS system, the 2000-2005 WCML route modernisation project and the ORR imposed cost savings would not have been realised from a technical perspective. Also, the project would not have been completed in time for the introduction of the new Virgin Trains timetable which was due to be introduced in September 2005. This new timetable relied upon the ability of the tilting trains firstly be allowed to tilt and secondly travel at enhanced permissible speeds.

The critical sections for this change were Euston to Crewe and Stockport where it was essential to reduce journey times; the key imperative was to reduce the journey time from Manchester to London below the 2 hour threshold. The Virgin business plan had linked this feature to the competitive edge between train and air travel.

4.6 Author's role as the General Manager Ancillary Projects

As it became widely known that the Network Rail infrastructure maintenance contracts were to be brought in-house in 2003/4, Carillion PLC formed a group called Carillion Rail Ancillary Projects in 2004 to offer services to Network Rail that encompassed a delivery unit that could further develop expertise in life extension from these works and invest in the application of innovative technology from other parts of Europe and the rest of the World. The author was appointed General Manager of the unit and was responsible for setting up the organisation, delivering existing commitments and developing new techniques and ideas for future expansion.

4.7 Later Phased Development using ATWS

This was the first challenge with a level of urgency to continue the WCML works now that the areas of relatively straightforward access that could be delivered were nearing completion. The normal protection process involved setting up lookouts who were competent trained trackmen who would be positioned where they could give adequate warning. The system is called Rimini and is carried out as follows:

1. Allocate the time needed (in seconds) for the work:
    i. Time to view a train and give warning
    ii. Time to acknowledge the advance lookout
    iii. Time to warn staff on site
    iv. Time to remove materials and small plant
    v. Time for site staff to move to a place of safety
    vi. Time to affirm that all is clear
    vii. Additional time for other exigencies
2. Calculate the distance the fastest train can travel in the time above.
3. Ensure that a sighting distance can be achieved and position lookouts.
4. Test the system before use to prove that it is a safe system.

It is usually necessary to protect staff and work in a minimum of two directions and in areas of curved track it may be that a number of 5-6 dedicated personnel are required. The above Rimini process was utilised successfully and it was still an economic solution to working although it was labour intensive. The ATWS system has had regular use in Germany but only for the purpose of warning staff that trains were about to pass by worksites. The challenge in the UK was to create a fail safe risk assured process to allow work to be done on open running track.

The early basic ATWS equipment consisted of a treadle fitted to the track with a locking facility and connected by a cable to a control unit near to the worksite. The treadle is a mechanical device that is a lever attached to a micro-switch; when a train wheel hits it a message is sent to the control unit. Another treadle is fitted at the other side of the worksite to give a message that the train has left the section. This is all controlled by the control unit from which are connected flashing orange lights and warning sirens. Following multiple trials, it was established that the system could protect works and staff given the level of warning associated with a clear assessment of time. The system has to be tested and is continuously fail-safe protected which means if anything goes wrong, a warning is automatically given. It was possible using a detailed qualitative risk assessment to compare these features with the human elements associated with a person watching for trains and "waving flags".

As indicated above under Rimini, this was the predetermined time in seconds needed to acknowledge the warning, clear materials and staff from the tracks and give assurances that all checks had been carried out. Once the system is in place there is only a need for a single lookout at the workplace so productivity is significantly enhanced. Also, a greater level of sophistication and accuracy is possible in this system.

The second phase of the work was carried out in areas where there was less flexibility and complex track layouts, notably at locations known as Norton Bridge and Colwich where diverging and converging traffic was involved.

4.7.1 Second Phase of the works

Location	Timbers	Red Zone %	Point Ends	Estimate £k
Kilsby	46	100	4	95
Nuneaton	36	95	3	92
Atherstone	56	98	4	102
Tamworth	38	100	4	75
Lichfield	45	92	3	80
Colwich	60	100	4	122
Norton Bridge	34	78	2	65
Stafford	86	89	6	134
Madeley	39	100	4	94
Crewe South	26	80	2	43
TOTAL	**Phase Two with ATWS** **Average cost per point end = £25 k**			**£902 k**

Table 4 WCML Project Heavy Maintenance Programme 2004/5 (Source: author)

The third (northern) phases of the work were not as critical as far as enhanced permissible speed was concerned because the route speed profile did not involve increasing speed through some of th junction areas only the plain line which had been subject to alternative treatment.

It was critical in these areas to deliver integrity and track quality and more specifically avoid or defer the potential of a temporary speed restriction (TSR) associated with track condition. The level and number of these TSR’s are a key feature of contract conditions in the privatised rail industry where a delay caused by effectively an asset management shortfall involves severe penalties usually in the region of £100 per minute.

The civil engineering industry would recognise these as liquidated damages and to put them into context, a 20mph speed restriction of only 100 metres on tracks over 100mph would delay every train by 3 minutes because of braking and acceleration profiles. Therefore with 40 trains a day on a busy route such as the WCML, such a restriction would attract £12,000 per day in damages.

4.7.2 Third phase of the works

Location	Timbers	Red Zone %	Point Ends	Estimate £k
Crewe North	46	70	6	85
Winsford	128	100	5	92
Hartford	120	100	4	102
Weaver Jn	170	85	8	150
Runcorn	150	75	6	134
Edge Hill	123	90	6	103
Longsight	170	55	8	145
Warrington	89	85	3	80
Wigan	134	85	4	120
Preston	76	65	2	65
Lancaster	142	90	6	134
Oxenholme	95	100	4	89
Grayrigg	28	100	2	35
Shap	54	100	4	64
Penrith	40	80	2	43
Carlisle South	102	75	6	123
Carlisle North	120	85	7	145
TOTAL	**Phase Three with ATWS Average cost per point end = £22.1k**			**£1709 k**

Table 5 WCML Project Heavy Maintenance Programme 2005/6 (Source: author)

There were some significant changes to scope in this latter phase mainly due to financial and whole life asset management concerns. In these cases only limited timber changing was carried out, which was considered by the author and his team as an uneconomic approach as the costs of site set-up were fixed and additional works only related to material and labour costs.

It will be interesting in 5 years time to review this decision which was made on the basis of the dates planned for complete renewals being achieved to programme. There could be a repeat of the problems of the Erewash Valley (see chapter 1) if a comprehensive asset management process is not fully instigated.

4.8 Learning Points and Best Practice Solutions

The main lessons learnt in this project were identified as the following:

1. Detailed method planning was essential to ensure and validate track integrity according to the maximum speed of trains passing the site

2. Clear advanced planning of real time arrangements for clearing materials and small plant from working areas during and after sitework shifts.

3. Validated approvals for the use of ATWS with detailed plans, testing, and commissioning arrangements to allow work in Red Zones (including prohibited areas) efficiently and safely without reliance on manual flag waving and intermediate lookouts.

4. Detailed risk assessment and comprehensive control measures to assure safety of personnel in the following areas:

    4.1. Pre-site surveys and planning

    4.2. Access and egress to railways and site locations

    4.3. Actual work site location

5. On site supervision and contingency intervention to place staff in positions of safety and clear any materials and plant which may be foul of open lines when trains are notified.

6. Emergency preparedness arrangement in place

    6.1. During working hours Monday – Friday between 0800-1600

    6.2. Outside these times robust on-call arrangements

7. Monitoring and checking procedures in between work shifts and the end of specific locations for period of maintenance to take account of settlement and integrity of components.

4.9 Summary Project Review

The life extension project was delivered on time and to budget which was a great achievement considering it was not originally considered a critical part of the original West Coast Main Line Upgrade Project. However, given that delivery of the overall project would be measured by the delivery of the Virgin Pendolino timetable and significantly reduced journey times, it soon became a fundamental part of the main project although its scope was relatively small. A clear output from this work was the need to maintain the track geometry on an ongoing basis to assure the track quality and passenger comfort levels involving the complexity of high speed train tilt mechanisms. Monaghan (2010) in his paper identified an innovative new track quality recording and analysis process that has been adopted across the whole route.

The works were time and life limited as part of the measures to introduce a new high speed railway. Following on from the project is the ongoing need to consider a further phase of this activity as it was stated at the time that after 5 years problems could arise. The south portion of the West Coast Main Line is suffering from condition related problems at present (See Chapter Six; Gibb, 2013).

ATWS processes were developed in the UK as a part of this project and there were a number of specific achievements. The small local units were introduced widely across Network Rail. Following trials on this WCML project, the system was fitted with a unique sound actuation facility which adjusted the sounds of the warning sirens according to background noise levels. This has two benefits, firstly, to assure safety for the site staff and secondly, to avoid unnecessary noise pollution in built up areas.

The use of innovative access systems and smart non-disruptive planning processes complemented by a complex engineering and management framework have been recognised as making a significant contribution to knowledge.

5. CHAPTER FIVE PROJECT THREE

PILOTING OF NON-INTRUSIVE TECHNIQUES FOR SAFETY & PERFORMANCE

5.1 Introduction

This project covers the piloting and preliminary commissioning phase of the use of the life extension techniques in real situations to solve actual problems. The key features being the non-intrusive nature of the techniques identified during the initial research phase. A combination of these were employed including the Railvac vacuum reballasting train, “Second Life” timber resin injection and strengthening system and the heater restressing technique. Two case studies are presented; Wrawby Junction, Humberside, UK and Eurostar Junction (Ashford), Kent, UK.

5.2 CASE STUDY 1 Wrawby Junction Lincolnshire UK

5.2.1 Problems at Wrawby Junction

The junction was causing major problems mainly due to its condition and the severe contamination by coal spillage. A very severe speed restriction was in place of 20 mph which was causing train performance problems. However, it was becoming increasingly difficult to maintain the track even at this low speed and there were potential safety issues. The traditional repair would have involved major renewals causing major disruption and high cost. There was a need to find technically driven life extension value engineering solutions to deliver urgent improvements. The author’s team were consulted and recommended the use of new innovative vacuum machine and fastening repair technology. Contracts of £150k were awarded and managed by Carillion PLC.

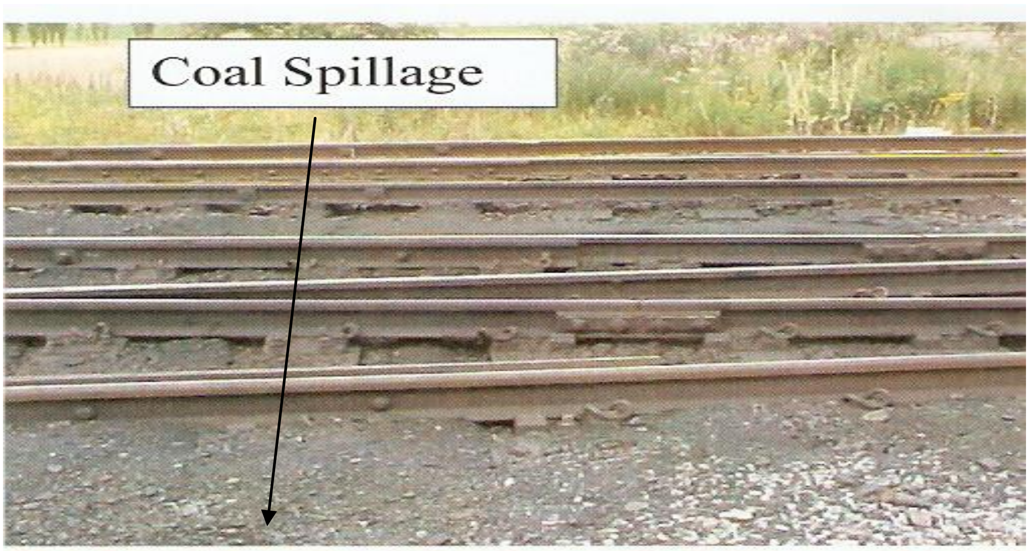


Figure 34: Wrawby Junction view of coal spillage 2005 (Source: author)

5.2.2 Background and Context

The railway system in the UK post-privatisation era was a challenging environment. The Railways Act 1994 created a matrix contractual framework which differed significantly from the previous vertically integrated British Railways Board model. Train companies contributed access charges to Network Rail related to the concept of a price per tonne-mile. This was a relatively simple system to introduce and on a national scale made sense and although there were many discussions regarding the true cost of freight, the industry in general worked together to formulate a progressive model. However, in the case of freight the system allowed freight companies to negotiate special and often urgent new business with their customers and use any route to maximise their revenue and profit. This case study relates to the track infrastructure challenges that occurred at Wrawby Junction, Barnetby, South Humberside in 2005.

Most informed sources (Wolmar,2005), including commentators and engineers indicated problems with uncontrolled freight access on UK rail infrastructure. The permanent way engineers within Network Rail and its suppliers attribute the rapidly deteriorating track condition at Wrawby Junction, Barnetby and other places to a sudden and unexpected increase in freight train tonnage across some railway junctions. However, contamination of the ballast structure, often known as ballast fouling can quickly exacerbate aged material with limited drainage according to Indraratna et al (2011).

The track condition at the junction was very poor with significant coal spillage being a major issue; a very restrictive speed restriction had been in place for some months and it was essential to undertake some palliative repair work urgently to maintain safety and improve performance. In 2005, there were a limited number of options available usually associated with selected replacement of components, partial or complete renewal.

The author was approached by the local engineers as they had heard of some of the new innovative techniques that were being developed and had been used elsewhere. The state of the art features expected were related to some key requirements of economy, efficiency and limitations of access and disruption to rail services during the works and fundamentally to fulfil an urgent need due to a deteriorating performance and safety situation. Site investigations were carried out using techniques used on renewal sites. Middleton et al (2005) describes the applications and particularly shallow geotechnical issues. The local technical team were instrumental in site investigation.

Figure 35: Spillage of coal choking the ballast and covering the track Wrawby Junction (Source: author)

5.2.3 The Location of Wrawby Junction

Wrawby Junction is located on the route between South Yorkshire and the East Coast of England, notably between the cities of Leeds and Sheffield and the docks at Immingham. It is a mixed traffic route with local and inter-urban passenger services and an equitable mixture of freight. The traffic levels have been reasonably static across all types and in common with the national trend there had been a steady reduction of overall train operation. This feature of current and future use had been the basis of informed regional asset management policies.

Figure 36: Location of Wrawby Junction Humberside UK (Source: www.streetmap.co.uk)

A major change in the source of supply of coal to power stations in South Yorkshire following the closure of many coal mines in the latter part of the 20th century was to import large amounts from Poland. This new traffic pattern added up to 20 fully loaded coal trains per weekday, each of around 2000 tonnes travelling in an east-west direction.

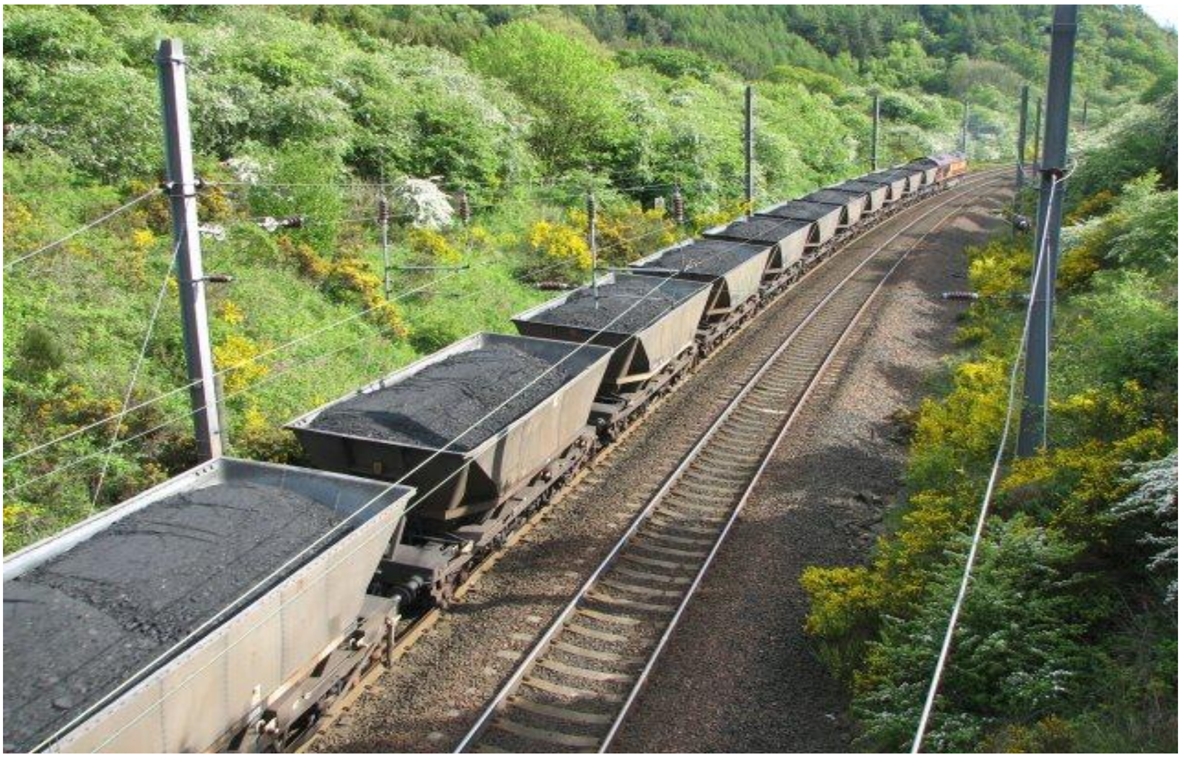


Figure 37: Typical fully loaded coal train en route from Immingham Docks to Leeds (Source: author)

It is significant that in the west-east direction a return journey of a similar number of unloaded trains also ran with loads around 500 tonnes. This feature has significant bearing on the problem and was exacerbated by the overloading of the coal wagons which caused coal spillage particularly at junctions.

5.2.4 The Track Condition

Wrawby junction is a traditional railway double junction which was constructed around 1880 and relayed in its current form in 1975. In railway terms, track is normally described as either “plain line” or “switches and crossings” (colloquially known as S&C) to identify the configuration and design or use. A double junction is where a two track railway diverges into two separate two track railways within a defined area. The track layout here incorporates two sets of switches, usually known as point-ends, and six crossings. It consists of vertical rails fastened to baseplates screwed into timber bearers. These are laid on a 300mm deep ballasted formation directly on a clay subgrade with open drainage.

Figure 38: Wrawby Junction Severe Contamination at a rail joint (Source: author)

The most obvious visual defect at the location was the vertical and horizontal alignment of the track known in the field as the line and level of the track. The company owning the infrastructure, Network Rail has mandatory standards for this aspect and this will have led to the imposition of a temporary speed restriction to maintain safety. Most derailments are caused by the wheels of a moving train losing contact with the rail and a slower speed will usually reduce this risk. The above is the simple explanation, however a full assessment of track condition identified the following defects:

1. Coal spillage up to and above rail level which alone is unacceptable because it hides the track components, preventing examination.
2. This coal will have blocked the drainage system by contaminating the ballast voids and blocking the pipework.
3. Loose and damaged fittings to ironwork and signalling equipment.
4. Damaged timbers with evidence of rotten areas, particularly where screws are loose or subject to movement
5. Gauge variations outside acceptable tolerance levels ("gauge" is the geometric distance between the running edges of the rails.)
6. Top variations in a static state and those particularly associated with the dynamic movement when trains pass over. ("top" is the vertical position in relation to design position.)
7. Line variations in a static state and those particularly associated with dynamic movement laterally as trains traverse the junction.
8. Twist and cross level variations in both static and dynamic modes, usually related to the fixed wheelbase of certain rail vehicles, normally 10 feet or 3 metres.

5.2.5 Technical Solutions

The Network Rail local maintenance delivery organisation, who were the client in this location, were looking for a solution that would satisfy a number of specific requirements. As already mentioned, minimal disruption was a major limitation especially regarding access to the site. In railway work, times when traffic was not affected was limited to night work at weekends. There was a pre-planned window for essential maintenance where only around 12 hours was available. In this timescale, any supplementary signalling disconnection or re-connection had to be included.

Also, the works had to produce some early results such as the raising of speed restrictions within a limited timescale to demonstrate to the ultimate client, i.e. the passenger and freight operating companies, that the solutions were designed to deliver benefits to them. This aspect of finding new and timely solutions to railway operating issues was a key issue in preventing any future claim for compensation that could be made either directly through the track access contract or by complaint to the legislative authority, in this case the Office of Rail Regulation, the UK government "watchdog" who are commissioned to oversee the industry.

There were two specific new innovative techniques proposed at this location. Firstly the use of the "Railvac" vacuum ballast removal machine and secondly the "second life system" for in-situ repairs and adjustments to the track timber system.

The "Railvac" machine is a rail-mounted, self- propelled, high capacity vacuum ballast removal facility; in effect a full scale rail vehicle around the size of a large locomotive. It is ideally suited for this solution as it could be stabled nearby and working within minutes.

Figure 39: Wrawby Junction; first use of Railvac in a coal spillage area. (Source: author)

The machine has a 250mm diameter tube with a tungsten tip connected to a hydraulic arm system with a remote control operating unit. The vacuum is a high power and with the hydraulic arm would be able to remove a variety of material with different levels of hardness and viscosity. The integral hopper which collects the material and has side discharge chutes for the disposal of the material that can be quickly utilised nearby.

The “Second Life System” is a technique that has been used in Germany and Switzerland for over 12 years. This process adopted is a European patented Swiss system where track is repaired in-situ using a resin and specially designed coil inserts. The track at Wrawby was reinstated to the original design horizontal alignment using pull and push tie bars once screws are removed. The system then involved drilling new holes which are usually elongations of existing holes and fitting new screws, held in place by stainless steel coils and the voids filled with specially designed resin. The resin gained suitable strength within 3 hours which was particularly relevant here as possession times were only 10 hours.

Figure 40: Second Life System Wrawby Junction 2005 (Source: author)

The system was used here to enable re-use of timbers which would otherwise have had to be replaced and the reinstatement of structural integrity complemented by the ballast replacement. This was achieved through the use of the specially adapted resin which is compatible with the flexible structure of hardwood timber and creates a homogenous final material that has an ability to accept loading as a composite material.

The figure above indicates the finished result and shows the temporary push and pull tie bars that are necessary to carry out the realignment process. The other major aspect to the repair work at the site included the traditional process of changing sleepers and timbers that were in a physical condition that was too poor in terms of decay and damage to be treated with Second Life System. The timbers are disconnected from the track leaving their baseplates in position and pulled through laterally. The replacement timbers were cut and treated as a pre-possession activity and then ready for insertion. Once in position the new timbers were jacked into position drilled and new screws fixed. To improve the integrity of the system, the opportunity was taken to replace the “pandrol” fastenings and any bolts and spacers in the track system.

The great advantage of combining this activity with Railvac ballast removal was the speed with which the activity could be completed especially where there is a need to create a pull through trough at one side of the track.

5.2.6 The Plan for Life Extension

The work was planned for 3 key weekend shifts with work being planned before, after and during these events. The programme of works was as follows:

1. Pre site investigation work to estimate depth of excavation and replacement ballast, assess condition of timbers.
2. Prepare ramps for and supervise delivery of Railvac machine in adjacent sidings; set up site cabins, security compounds, signage. Prepare access tracks across adjacent sidings, Dig final trial holes.
3. First key weekend shift – possession times - 2300 Saturday until 1200 Sunday. Excavate 60 metres of contaminated track and sub ballast, replace 30 decayed timbers; replace ballast and consolidate using tamping banks. Check and repair any other components and fixings to make good.
4. Midweek work between trains using “red zone working” to manually adjust and repair the track. (This needs special safety facilities to protect workers)
5. Second key weekend; as item 3 but on other adjacent track.
6. Third key weekend; same possession times; treat 80 baseplates with SLS system of resin injection.

5.2.7 The Output and Performance of the Works

This project was successfully delivered in 3 phased weekends with very few problems. In fact, the time taken to remove the direct coal spillage and contaminated ballast was around 80% less than the anticipated time. The spare time was spent removing coal spillage from adjacent areas of plain line on either side of the junction. The great advantage of being able to undertake this additional activity was that the full possession time could be used. The machine was working in an independent mode and could stop work almost immediately and return to its stabling point within the last hour of the agreed possession time. Significantly, there were no time overruns on any of the work, which is often unusual in railway civil engineering work as often there are many unpredictable elements, not least, the difficulty in accurately estimating the time required for extraction and track removal work.

The track was reinstated to design level and consolidated to prevent excessive vertical settlement following each of the activities and therefore, it was possible to maintain a 20/40 mph differential speed restriction; this allows passenger trains to travel at the higher speed, whilst freight trains travel at the lower speed. The key achievement here was the reinstatement of full linespeed of 60 miles per hour, which was done 2 weeks after completion. This will have achieved the main objective of train performance and have saved money and time for train companies. See the figure below, the key feature being the top and line achieved and the “maintainable” ballast profile.

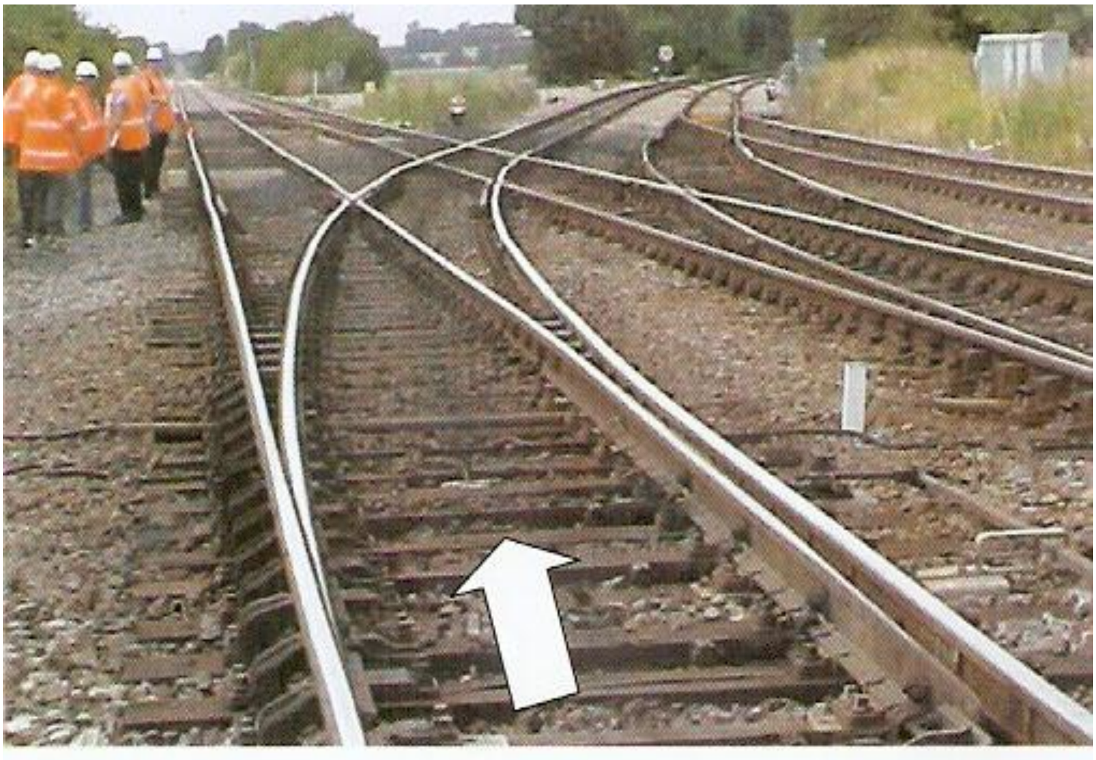


Figure 41: Completed junction life extension work at Wrawby Junction (Source: author)

One of the key review features that was remarked upon by visiting managers from both Network Rail and Carillion plc, the company the author was working for, was the clear induction and site briefing process for all workers, machine operators, technical staff and supplementary personnel. The time spent in producing and delivering briefing material was clearly worthwhile and had significant paybacks in terms of plan delivery.

It is important to note that this kind of operation is taking place normally under adverse weather conditions, usually at night and at remote locations. The team responsible made a special effort to supply high quality welfare facilities for all the staff which included warm messing rooms, free and continuous hot drinks, drying facilities and adequate toilets.

5.2.8 Lessons Learnt and Best Practice

As in any worthwhile project there are lessons learnt and in the case of the Wrawby junction project, the following aspects were reviewed and improved upon in subsequent locations:

1. The ballast removal system by a vacuum method eliminated the need for signalling disconnections; as in all cases when track has been physically disturbed it was still necessary to test the signals, points and track circuits. An idea suggested was to design a process to do this remotely.

2. Safety briefings could have included greater detail of the timings of individual activities to further improve productivity and utilisation of manpower.

3. The contamination from coal could have been removed on very short midweek possession times prior to the work as it did add some level of uncertainty to removal rates.

4. A review of the sequencing of life extension activities may enhance further work to reduce rework and improve efficiency.

5.2.9 Review of Case Study

The success of the project and the applicability to other areas was a key feature. This was the first use of Railvac in a coal spillage area and worked very well; the machine proved that it can be used in a highly contaminated location with cohesive material that would normally have clogged other similar machinery. Also, with good planning, effective use can be made of minimal possession time.

Further investigatory work is planned to be carried out particularly in relation to site investigations to assess volumes of removed material. Also, another method of protecting the sub grade from immediate contamination was a suggestion. The use of Terram to create collection areas for future coal spillage was suggested, although trials and research will be needed to ensure integrity and prevent inspection difficulties.

5.3 CASE STUDY 2 - EUROSTAR WEST JUNCTION ASHFORD KENT UK

5.3.1 Problems at Ashford Station

Following discussions with senior engineers on the Southern Territory of Network Rail regarding the potential use of new innovative technology, a high profile track maintenance problem involving delays to Eurostar trains was identified. This had not been able to be rectified for some years without potential major disruption and cost. The author worked with the engineers to formulate technically driven formation solutions and geometric rectifications without disconnections to the track, signalling or electrification equipment and a contract for £400k was negotiated involving special possessions over Christmas Day and Boxing Day 2006. The author's role can be evidenced in Appendix 10.5 Method Statement for Ashford International Project.

5.3.2 Background and Context

The international stopping trains and high speed commuter services were diverted into the station via a medium to high speed connection line, Eurostar Junction, which was adapted into the existing infrastructure. There had been a track alignment fault in this location evident following construction which quickly resulted in a temporary speed restriction of 30 mph which was causing embarrassing delays.

5.3.3 Location of Ashford Station

Ashford International Station is located in Kent on the high speed line (HS1) from London to the Channel Tunnel portal at Folkestone serving international Eurostar trains travelling from London to Paris and Brussels. Full operation through the Channel Tunnel began in 1994 and included the building of the high speed line through to the outskirts of London. Any limitation to speed was challenged especially where the line had interfaces with the existing rail infrastructure according to Eurostar Group, (2005). Ashford was developed from a local station that provided commuter services to London and the surrounding areas. The rail system was enhanced in 2009 by the introduction of high speed commuter services using the high speed link. Through high speed services avoided the actual station on a dedicated route built to the original design parameters and is performing well.

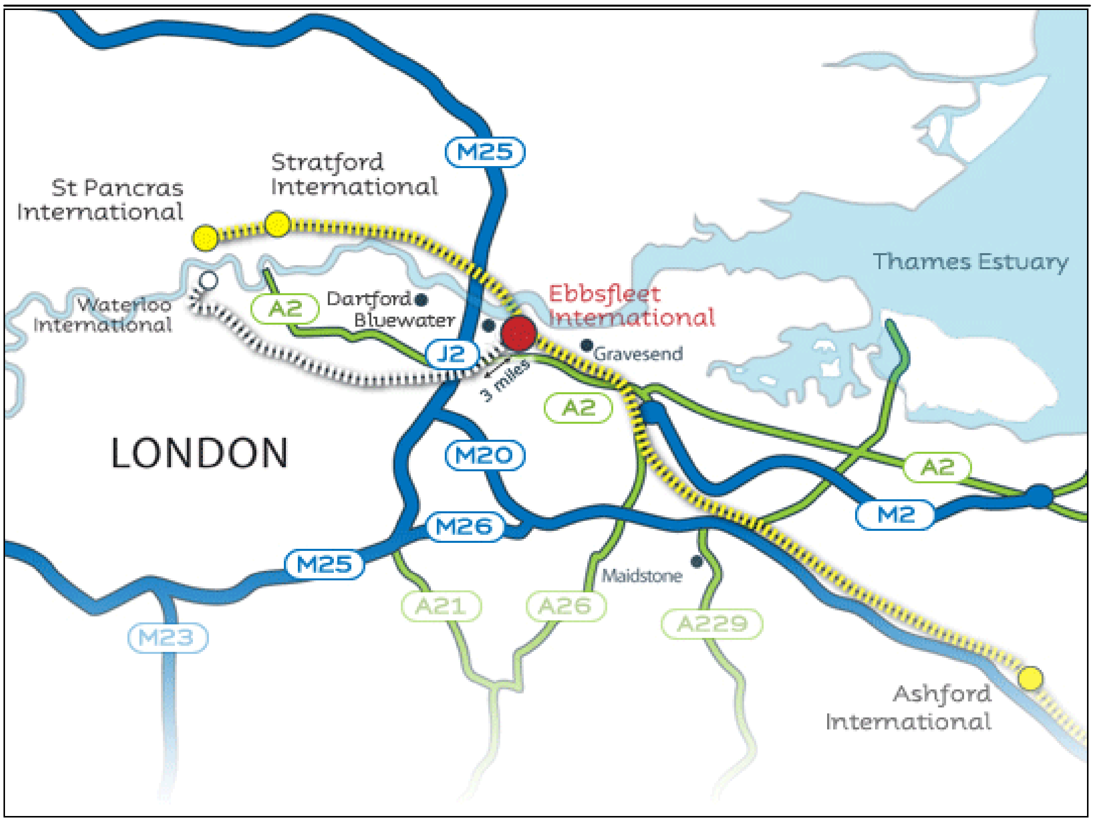


Figure 42: Location of HS1 and Ashford International Station (courtesy: Eurostar PLC)

5.3.4 Track condition and Problems

The challenge was the identification of solutions to long standing performance problems with a rail junction that was geometrically unacceptable following installation in 1998. Numerous attempts had been made to rectify the problem through normal maintenance, however even with regular palliative measures, it was not possible to remove the speed restriction. The local team contacted the author having been made aware that a solution could be applied using new technology. It was suggested that there were 3 major issues relating to this location:

1. Formation failure due to poor installation of drainage and geotechnical layers causing localised clay contamination and creation of wet beds.

2. Vertical alignment was incorrect due to the track being installed above its design level beyond normal acceptable tolerances.

3. Non-compliance of stress levels in the track, due to combination of poor installation and issues above.

5.3.5 Technical Solutions

A specification was required involving ballast and formation removal and vertical redesign. This was to be done without removing the track which was configured as a combination of plain line and switches and crossings and replacement with new ballast and installation of a geotextile. In addition, as a final precaution and stabilisation measure, the reinstatement of stress to the standard of 27 degrees Celsius level would be needed. Such a plan would have to be done with limited access and without disconnecting the signalling or third rail electrification system. As an added challenge, the work was to be carried out within the limitations of 25 kV overhead electrification and adjacent to platforms at Ashford Station. The Railvac machine appeared to be a workable option combined with the heater restressing system which had the potential to be able to work within constraints.

5.3.6 Plan of the Life Extension at Ashford West Junction

The location had limited access due to a complex train pattern involving intensive domestic and international rail services. It was evident that without major advance planning and disruption to services, Christmas Day and Boxing Day would be the only periods available where sufficient possession time of over 24 hours per line could be available.

Billing Item - Rates include Materials, Labour and Plant	**Unit**	**Rate £k**	**Quantity**	**Sub-total £k**
Railvac Machine	No of shifts	15	7	105.0
Heater Restressing Equipment including gas	No of shifts	3	4	12.0
Ballast replacement	Tonne	0.056	2000	11.2
Labour Cost (Christmas Triple Time)	No of shifts	0.03	270	81.0
Materials: Geotextiles, fastenings and other components and consumables	Various	-	-	32.0
Plant Hire 360 machines Dumpers and small plant	Various	-	-	90.0
Preliminaries, Site Set up and clearance	-	-	-	35.0
TOTAL Carillion Contract	**-**	**-**	**-**	**£320k**
Cost of Trains provided direct by Network Rail Southern Territory	1 Loco and hire of wagons per 10 hour shift	5.5	24	£132

Table 6: Ashford Track Repair Scheme Schedule of Works (Source: author)

The specification was agreed with the engineers and related to formation treatments, ballast replacement, consolidation of profiles and geometrical final tolerances. The final commissioning would also be the correct restressing level. The technical agreement was input related and the achievement of tolerances to the final geometry. Future liability for deterioration would be limited to a short period and related to immediate quality of the consolidation and dynamic settlement profiles.

There were a number of logistical challenges due to the confined location and the presence of railway electrification by the overhead and third rail systems. The site was very restricted and was rail-locked, in effect the whole working area was covered by a myriad of connecting rail lines. The access to the site was across a relief goods line. Some small items of plant and materials could be transported manually from a secure site compound on Network Rail land. Temporary ramps were needed to get road-rail vehicles to site. The majority of the bulk material such as ballast was loaded onto rail wagons and positioned.

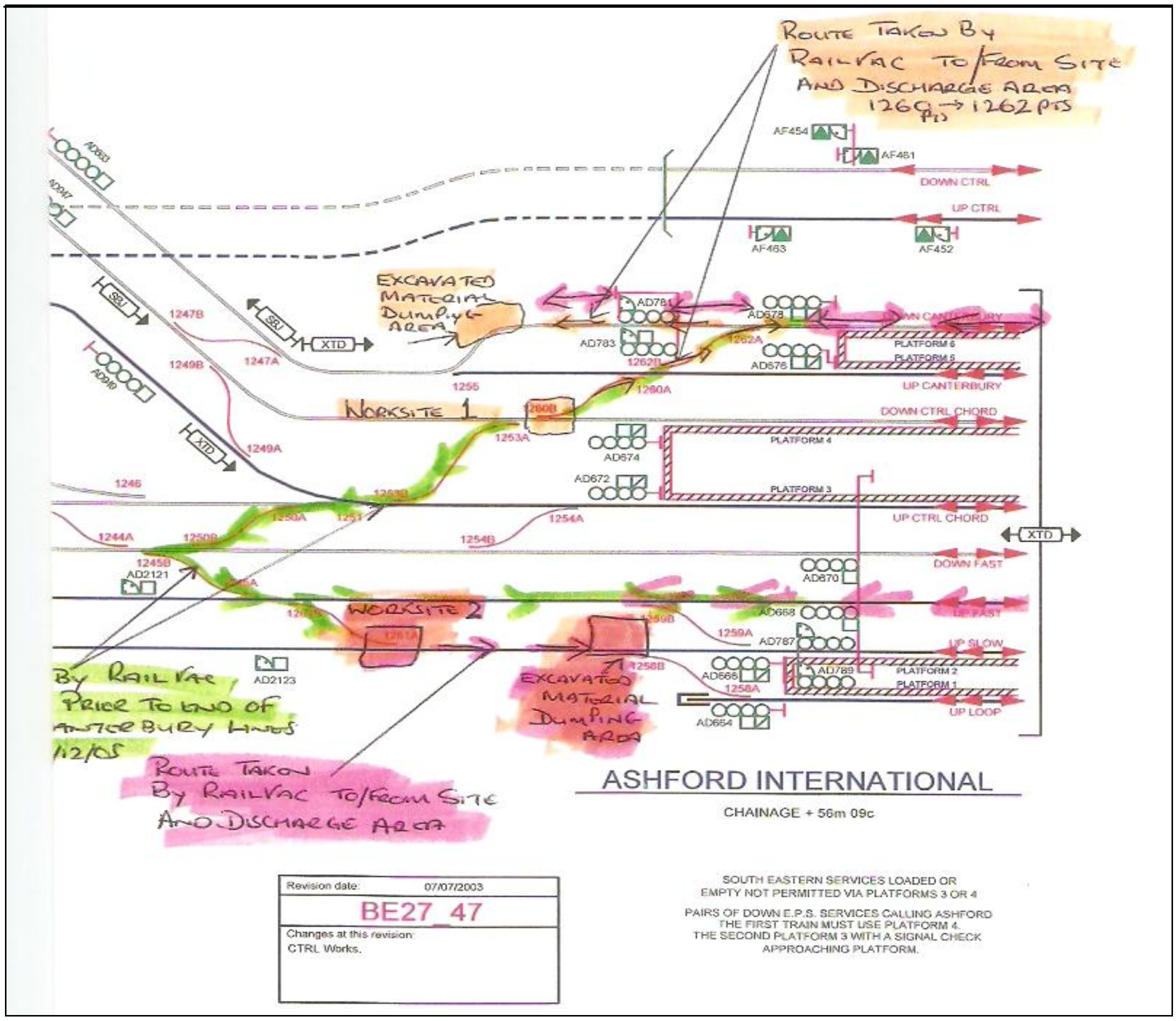


Figure 43: Working Site Diagram Layout at Ashford International Station (Source: author)

The overhead line electrification (25kV AC) was limiting in a vertical dimension to the normal 4.8 metres which was isolated. Equipment that could operate in close proximity to this system included 360 degree excavators and these were fitted with limiting devices. Isolations have to be managed carefully and this can lead to time delays due to the “permit to work” processes that are required at the beginning and end of every shift. The existence of the overhead equipment did not have any impact on the project.

The third rail 750V DC electrification system (see figure 43), did cause problems to the works, not only because of the similar isolation procedure, but because it was attached to the track at sleeper level and boarded in places. Significant advanced planning was needed to ensure the integrity of the equipment during the works and reinstatement to correct geometrical positions. The work was carried out over a four day period including Christmas Day and Boxing Day. The resources employed are shown in Table 6 and they were integrated with a complex engineering train pattern. An outline of the plan is shown in Table 7.

Activity Plan	**Days**	**Times**
Preliminaries: site set up, fix ramps, deliver materials, load trains, service plant, carry out surveys and mark-up TBM’s	20-24 December	0800-1600
Prepare for shut downs, take possessions, isolations permits, brief staff. Position first trains and plant, set up and prepare sites for commencement of Railvac work	24 December	1600-2400
Railvac work, adjust geometry to revised layout, replace ballast, consolidate and install geotextiles, repair track where necessary and align drainage arrangements.	25 December	0001-2400
Complete Railvac works, complete top ballast, tamp and line to final tolerances, restress track to 27 degrees using gas heaters	26 December	0001-2400
Final tamp and line to confirm whole design clear site and open lines for train running at reduced speed	27 December	0000-0900
Clear sites and follow up any track issues including checks of all trackside equipment	28-30 December	0800-1600
Follow up tamp and line to remove speed restriction during night time possession	30 December	0100-0500

Table 7. Ashford Track Repair Scheme Outline Plan

Figure 44: Use of Railvac in adjacent areas to ramp in new work (Source: Sersa-UK Ltd.)

5.3.7 Output and Performance of the works

This project was successfully delivered in the Christmas period with no reported problems. The materials trains employed to support the work were controlled well and added to the success of the delivery. Significantly, there were no time overruns on any of the work, which is often unusual in railway civil engineering work as often there are many unpredictable elements, not least, the difficulty in accurately estimating the time required for extraction work. The logistical issues of complex possession planning and electrical isolations were managed well.

The track was reinstated to design level and consolidated to prevent excessive vertical settlement following each of the activities and therefore, it was possible to open with a 20/40 mph differential speed restriction; this allows passenger trains to travel at the higher speed, whilst freight trains travel at the lower speed. The key achievement here was the reinstatement of full linespeed of 70 miles per hour, which was done 2 weeks after completion. This will have achieved the main objective of train performance and have saved money and time for train companies.

5.3.8 Lessons learnt and best practice

Specific areas that were learnt from the project included:

1. Planning had to be meticulous because of limited time and utilisation of Microsoft project with associated critical path analysis was essential to ensure on time delivery.
2. A clear and complex induction process for staff on various shifts and from a large number of multi discipline teams was needed.
3. The work was technically challenging from a geotechnical and geometric design aspect and required continuous monitoring from qualified engineers.
4. This was a new venture in that the Railvac machine activity had to be incorporated into a complex logistical working pattern with full size trains.
5. This was a unique experience in the use of Railvac to apply its innovative technology to the readjustment and repair of track without complete removal and complex earthworks.
6. Railvac use was extended from the normal avoidance of signalling equipment disconnection to working around third rail electrification equipment.

Figure 45: Completed Works at Ashford International Station (Source: author)

5.3.9 Review of Case Study

The success of the project and the applicability to other areas was a key feature. This was the first use of Railvac in a complex track area with two types of electrification. The train logistics worked very well; the machine proved that it was able to remove a variety of material and lower the track to achieve required design geometry. Also, with good planning, effective use can be made of minimal possession time.

The suggestions made from case study one regarding the use of the geotextile “Terram” were implemented and this added a further level of integrity to the life extension process. The track was moved vertically outside the Network Rail tolerances for not re-stresssing. The use of heater restressing to reinstate stress over the affected sections and equalise the forces over adjacent switches and crossings proved very successful and was an added bonus for the success of the whole scheme.

The temporary speed restriction was removed after a few weeks and the line tested for track quality. Indications from a recent site visit (see figure 45) show an excellent finished product requiring little maintenance thereby achieving the client’s objectives.

6. CRITICAL REVIEW

6.1 Publication and Communication

There are limited comprehensive publications regarding Life Extension of Railway Track in the UK and worldwide including the use of innovative approaches. Research appears to be limited to investigative work relating to track asset life and modelling of deterioration profiles with the clear objective to optimise design and installation. The incorporation of techniques to extend existing asset life is often limited to a quick mention without any practical suggestions. The author published the first integrated paper on this subject and was awarded the Permanent Way Institution Silver Award in 2011 and 2012. (See Chapter 8) He then went on to publish other papers and present at International Conferences in London and Spain (See Chapter 7).

6.2 Contribution of the Author in the Subject

The author has developed this research study from previous work on Life Extension through his responsibilities in British Railways and Balfour Beatty as an experienced practitioner in the field in the UK. The roles he has undertaken since 2000 that have had a direct impact upon UK national policy for track include his appointments as Engineering Adviser in the Office of the Rail Regulator, General Manager of the Ancillary Projects Division of Carillion Rail and latterly at the University of Derby as a senior academic in Civil Engineering.

The key major contribution was his role in Carillion PLC where he formed a group called Carillion Rail Ancillary Projects in 2004 to offer services to Network Rail that encompassed a delivery unit that could further develop expertise in life extension from these works and invest in the application of innovative technology from other parts of Europe and the rest of the World. The author was appointed General Manager of the unit and was responsible for setting up the organisation, delivering existing commitments and developing new techniques and ideas for future expansion.

In his current role at the University of Derby the work carried out in the previous roles was consolidated from a consultancy angle and he actively monitored the development of techniques. The author also continued to influence and consult with senior engineers by liaising with Balfour Beatty's Consultant, David Ratledge who was working with the Office of Rail regulation from 2009 until 2012.

6.3 UK Safety Implications of Railway Track Life Extension

It was apparent, following the Hatfield accident in 2000 and other track related derailments and accidents throughout the early part of the decade (ORR, 2002), that asset condition was concern on the UK rail network. There were two particular concerns relating to the ability of the maintenance organisation to deliver a functional railway. Firstly, as assets are nearing the end of their life, it becomes more difficult to predict the performance especially when sudden dynamic forces are combined with weather and temperature. Secondly, this kind of maintenance work requires a high level of experience and dedication from trained engineering personnel. They are often working in remote locations and can be called out to make decisions and carry out work at all times of day and night. The HSE report from the Hatfield accident (Health & Safety Commission, 2002) noted that there were client and company pressures to avoid the imposition of temporary speed restrictions as train delays attracted financial penalties in the RT1A Maintenance Contract Regime.

The existing widely accepted asset management regime was to either renew or to maintain the track asset. The formulation of an “in-between” process of life extension is an important concept that has significant safety improvement implications for the future. The author’s role in developing and implementing this concept is a major contribution to knowledge in this specialist area and the safety of the UK rail system.

6.4 Asset Management involving Railway Track Life Extension

The incorporation of innovative techniques into the British rail industry has been a slow process during the last 15 years, due to the conflicting drivers of efficiency and safety alongside the major structural organisation changes following privatisation. Other industries have had similar challenges, especially manufacturing. Pham and Wang (1996) describe the problems as “Imperfect Maintenance” where corrective maintenance is a maintenance activity which may restore an item to a specified condition in case of failure. Later in the infrastructure lifetime, periodic works are executed to restore the infrastructure to a predefined quality level. Referring to the track as the main component of railway infrastructure, this work type includes corrections of geometry, partial exchange of used or faulty material. However, the corrections that were and are being made in many cases on the UK rail infrastructure network are not carried out homogenously, but partially with regard to one aspect of the structure. Andy Franklin, the industrial supervisor of this study, made this comment in relation to the replacement of just the rail or the ballast as there was clearly life left in the other parts of the asset.

Qualitative and quantitative risk assessments have been a key feature of the successful implementation of the new products including the use of PRINCE2 (OGC, 2009) to add a secure element to the planning process.

The author was aware of the difficulty in changing the mindset of many organisations involved in asset management and this is borne out by comments made by Wallsgrove (2007):

> *"The developing discipline of Asset Management has been recognised as a core capability for rail since at least the early 1990s – at least at some rail organisations. What I find curious is how slow others have been to adopt and exploit it, and why quite simple improvements remain untouched in major asset organisations. It was about 1999 when I was first aware of discussions about Asset Management in Network Rail's predecessor Railtrack, and not long after got talking to the people framing the London Underground PPP (Public Private Partnership) contract, where asset management good practice is a central feature. I cannot say everyone was keen. More conversations than I care to remember about "but we've always done asset management" or "it's just good engineering" – followed by no action to improve."*

Asset management and its complementary discipline of Life Cycle Costing (PA55, UIC (2010) have now been developed with tools that should support the optimisation of decisions on maintaining or renewing infrastructure assets. It is possible to model different maintenance and renewal options to provide decision makers with funding and output choices. Pham and Wang (1996) indicate that often simple renewal is no longer applicable, either due to technical limitations or for economic reasons and partial replacement is the only option when the track quality does not meet basic requirements or needs excessively high maintenance activity to remain operational.

6.5 Regulatory and National Policy Changes for UK Track Activity

It was of particular significance that the national policy was amended (Network Rail, 2011) to include the work carried out and pioneered by the author in the main areas of track intervention activity. Refurbishment became a "legitimate", budgeted and technically recognised track activity inside and outside of the rail industry. Network Rail and the UK government now recognise the economic advantages and this now embedded in the next five year control period for rail infrastructure financing 2014 -2019.

The practical applications of appropriate tools and techniques to deliver this concept are now in place and their robustness was proven by the work of the author over the last 15 years. Specifically, the following is stated by Network Rail in support of the author's work:

"Vacuum reballasting [Railvac] will be key to delivering heavy refurbishment of S&C where it is desirable to carry out the reballasting without removing the track system, and is currently seen as the most cost effective option."

"The [SERSA Second Life] process is applied in-situ and has been used successfully on the Continent and at trial sites in Britain to treat S&C bearers, particularly to restore track gauge.

The use of automatic track warning systems has developed more towards the individual small units than widespread track work under red zone working. Network Rail have purchased over 30 small units which are used on a regular basis. Frank Peters from Zollner –UK Ltd. indicated that following initial interest and utilisation, further developing use had appeared limited (Peters, 2013). The issue was due to be discussed at future UK national Rail Safety Conferences, a similar situation occurred in the past (Wheeler, 2004).

Figure 46: Railvac working at Derby UK 2012; author in picture with operator on right (Source: author)

There have been many comprehensive research activities to assess the integrity and condition of track ballast over the last thirty years. Recently De Bold et al (2011) developed a survey technique that involves frequency response function to assess the extent of fouling of ballast and built upon previous work to consider a "ballast fouling index". Other notable contributions to the knowledge of ballast deterioration profiles under loadings were developed by Aursudkiy (2007) and Middleton et al (2005) who both considered the range of ballast conditions that would necessitate a life extension intervention approach.

The key complementary tool to enable strategic planning is a decision support tool for optimising the maintenance and renewal balance particularly a system that would restore track infrastructure to predefined quality level by partial exchange of used or faulty material. Guler (2012) indicated the need for a geographical information and condition monitoring system that had the ability to provide a route based approach. The type of system suggested requires a comprehensive computer based modelling suite using high powered complex algorithmic parameters Guler (2013).

The issue of climate change and sustainability upon the planning and whole life modeling process is now becoming an area for consideration and is crucial to maintaining resilience in the service provided. This could be achieved in two ways; firstly by considering the impact in vulnerable locations by premature life extension or secondly providing stand by machinery to assist when problems occur. Doherty et al (2012) when discussing policies for Network Rail suggested that track irregularities need to be limited and life extension could be the "third way" to providing stability.

There is an urgent need to consider an extensive package of life extension works on the southern part of the West Coast Main Line between London Euston and Watford. The work that was done by the author and his team, effectively bought time and allowed the project for Virgin Trains new timetable to be delivered in 2005. However, when complete renewal of junctions was deferred for technical and economic reasons it was always the case that there would be some residual risk with an unknown timeframe. Gibb (2013) identified in his recent paper, the difficulties associated with a repair regime that would avoid costly temporary speed restrictions and contact has been made with the track owner to offer solutions from the perspective of life extension.

6.6 International Life Extension

Many countries in the world have been investigating techniques to extend track and component life. In France, a holistic approach similar to the UK has been adopted involving the development of component or elemental repairs and refurbishment. They have considered a maintenance policy including modelling and optimisation which aims to plan preventive or corrective actions in order to minimise the overall cost of interventions and in most cases maximise the lifetime of the system (Barros et al, 2002). According to presenters at IMPROVERAIL (2003) in general, the life of railway components can be divided into three characteristic phases: youth, middle age and old age. Each period of a component's life may be linked to a specific type of maintenance action, such as preventative maintenance to avoid premature degradation (Merrick et al, 2005), partial replacement of groups of components, additional strengthening work or additional components and finally complete renewal.

The strategy of life extension is obtaining support around the world. The overall concept appears to have been accepted as many countries have invested in high speed lines where asset management is a relatively straight forward principle based on experience. They have been able to follow a cyclic pattern and the degradation profiles have gone through a number of clear life cycles to facilitate accurate modelling. Countries that have been able to do this are Japan with the Bullet train now with 41 years in service and the French rail organisation SNCF who have experience of over 30 years with their TGV routes. However, it is the freight and secondary passenger railway routes of the world which face the greatest challenges. This is because of the differing age and technical profile of assets with potentially an unknown degradation profile.

The informed organisations including network Rail are trawling the globe for ideas to assist in this process and this fits in very well with the worldwide agenda coming out of Kyoto 1997 and Amsterdam 2010 regarding climate change and sustainability. Repair and refurbishment of track systems or individual components is a growth area and some recent developments have been reported.

In Berlin, Germany, a process for milling rails has been developed by Strabag Rail GmbH. The machine is a road rail facility that can be set up very quickly to carry out maintenance work. Rail milling consists of a process to re-profile worn rail heads by a single pass which involves “slicing” off rail pieces which could be up to 5mm wide and between 0.3 and 0.8mm from the surface. This compares with rail grinding using stones which require multiple passes and produces a high volume of sparks. Trials have taken place in the UK with the machine working in southern England with their UK partners, Bakerail Services Ltd.

Research into USA systems has indicated many examples of extending life of individual track components. There has been an upsurge of interest in developing life extension techniques for rail infrastructure in Northern Europe. This is reportedly due to the world wide recession and a greater worldwide consciousness of reuse and recycling of material rather than create new items. Hallisey (2003) has carried out work and patented a process for extending sleeper life (sleepers are called railroad ties in the USA) with an integral conduit. This consists of overwrapping with fibrous reinforcement containing a cured matrix associated with the fibres. The ties may be machined prior to overwrapping, and are preferably sawn along their length, and conduit inserted into channels machined therein prior to adhesively bonding the sawn portions together. The conduits may be used to provide signal and power cable passages with lessened likelihood of damage thereto.

Another organisation working out of the USA is the Willamette Valley Company from its offices in Eugene, Oregon. They have been developing repair mechanisms for timber and concrete sleepers. Murray (2013) describes the system SPIKEFAST® ET 75 CTR-100 which is specifically designed for wood-tie (sleeper) remediation and is a dual-component, non-foam polyurethane product that is designed to anchor spikes. The AAR (Association of American Railroads) in 2009 commissioned a comprehensive evaluation of all commercially available tie-plugging materials, including wood plugs and polymeric foams. The lateral test results were obtained by measuring the force needed to laterally deflect a cut spike head 0.2 inches, which simulates rail-gauge loss (i.e., widening between the rails). Due to using actual 20-year-old ties with wallowed-out spike holes and a wide range of tie integrity, a correspondingly wide range of analytical results were obtained. Therefore, all tests were conducted 20 to 50 times and the results were averaged. The data indicates that SpikeFast's lateral resistance was 20% higher than that of previously unspiked hardwood ties.

6.7 Summary of Conclusions

This detailed research study was carried out over a period of 11 years from 1996 to 2007 with further developments and analysis taking place between 2007 and 2012 with continued involvement of the author. There are a number of key achievements in this study:

1. The rapid application of appropriate new technology specifically to enable on site testing piloting and evaluation.

2. The lessons learnt regarding the approvals process for both product process and vehicle acceptance.

3. The use of the technology to solve a wide range of actual problems which has had a direct contribution towards the safety and performance of today’s railway infrastructure.

4. Asset management has been refined to cover a wide range of applications with formally applied matrices to guide implementation.

5. The decision by Network Rail to allow local engineers to adopt the new technology through a commercial framework where there was a clear business cases for its use compared with traditional methods. This led to an enhanced use of Railvac between 2008 and 2011.

6. The adoption of the techniques from the development of early research to the recent technological advances in UK national policy for the next 5 years of government rail policy through the Office of Rail Regulation.

7. However, it is usually a balance between risk and human will, and in all cases there has to be an economic driver albeit a direct cost saving or a solution to a performance or time related issue. The key factors demonstrated in these projects generally relate to a simplification of appropriate technology and a people and team based approach to problem solving.

8. The investment of £2 million into the building of a UK gauge Railvac machine which following trials in Derbyshire in March 2012 has now gone into full active service around the UK. Alongside the existing Swedish gauge machine, versatility of application is the key and they are able to undertake many types of work across a wide spectrum of infrastructure. Their scope now includes all aspects of track maintenance and renewal; track life extension works; drainage maintenance, rehabilitation and renewal; cable installation; enhancement works, such as improved route availability; and foundations for overhead line masts and signalling gantries.

Railvac Train II 18000/500 - 48 SD is a self-powered railway vehicle with two wagons rigid connected and used as one unit. The material wagon contains a hose-manipulator, filter chamber and a 45 m^3 spoil hopper and it is assembled on a standard freight wagon.

Figure 47: New version of Railvac UK Gauge in Derbyshire in 2012 under trials (Source: author)

9. Particularly Significant Developments with Major Impact upon Future Track Repairs

9.1. Eliminating un-necessary work such as ‘Track Out’ Reballasting and Repair

Much of the track engineering work undertaken currently requires that the track is taken out in order to facilitate reballasting works. The Railvac machine undertakes reballasting with the track left in-situ, improving production, efficiency and reducing potential damage to the asset and its premature renewal. Significant efficiency benefits are obtained for certain types of work, for example reballasting of switch and crossings under partial renewal works. Other of the systems such as SLS and heater restressing are equally non-intrusive.

9.2 Safety of Undertrack Buried Services and Cable Protection

During conventional track-out reballasting work, it is necessary to disconnect signalling and power cables, then reconnect and test them at the completion of the work. Railvac "track-in" reballasting avoids this as the cables are left connected. Benefits are cost efficiency, reduction in safety risk and lower track access requirements, supporting the industry's drive for increased efficiency and improved safety. Strikes of undertrack services by mechanical plant are a frequent occurrence in the UK. The Railvac equipment and its mode of operation provide minimal risk of damaging undertrack services proven by experience worldwide and in the UK. The figure below indicates this and emphasises the value of the process to carry out works with limited disruption and sensitivity.

Figure 48: Railvac excavating in a track area with complex buried cabling (Source: Railcare SE)

9.3 Improved Railway Availability: Reduced Track Access Requirements

Many traditional repair and renewal processes require track access periods for preparatory and follow-up work. Using the systems some not required such as the avoidance of stressing CWR after track out reballasting. There is also potential to use the process for specific structural works adjacent to the track. The ability to excavate short sections of ballast on top of under bridges for works such as waterproofing or patch repair provides the potential to undertake these types of works in short track access.

9.4 Excavation for pipe replacement and cable installation

The use of Railvac to excavate around existing drainage systems has major benefits in terms of sustainable replacement. In many cases digging conventionally by machine destroys the pipe and finishing needs to be done by hand (Additional comments from Andy Franklin). It is a very practical and efficient way of installing cables by using Railvac to create the trenches needed by vacuum extraction.

9.5 Reducing Costs for Route Availability Improvement

Track lowering under structures and in tunnels using conventional techniques involves track removal and reinstatement. Railvac enables this work to be undertaken without track removal. Benefits include reduced track access, greater efficiency and less safety risk.

7. RECOMMENDATIONS

This study and the work of the author has clearly made a significant difference to the UK rail infrastructure in a number of ways which are identified in the conclusions. However it is crucial to continue development in the pursuit of innovation and the application of new appropriate technology for ethical, economic, social and safety reasons.

There has been an increase in the worldwide contribution to this type of rail technology through improved communication. The author is pleased to have participated in the first international conference in Rail Development Technology Maintenance and Research held in Las Palmas, Spain in April 2012. Worldwide links have been established and it was pleasing to see representatives from Japan, USA, Brazil, India, Australia and many from all countries in Europe.

There a number of contributions made from the study which would be useful to identify and incorporate into other developments:

1. Simplify and choose appropriate technology to the point where risks from unknown ground conditions are minimised especially with relation to the impact upon the end product which running a safe, reliable and efficient railway.

2. Deliver a whole life extension solution within a given location from a menu of alternative options to optimise economic benefits related to track availability criteria.

3. Develop a cross functional technical team based approach that includes clients, regulators, customers and suppliers to accelerate the complex approvals process for the use of new technology and products. Work with partners who are looking towards the long term future.

4. Publicise widely the safety, sustainability and economic benefits within the UK industry and worldwide to promote further development.

5. Implement a UK national life extension strategy that involves the analysis of major railway route sections that are at risk of rapid deterioration which could lead to safety or train delay issues. In the sections above, mention is made of the south portion of the West Coast Main Line where work on this should start urgently. The proven techniques indicated throughout this thesis can support such a strategy by:

a. The purchase of another six UK Railvac machines by 2020 and develop technical advances to control excavation depth. A national management and planning process will be essential to optimise use.

b. Utilise more automatic track warning systems (ATWS) for use on both major work sites and individual maintenance activities. It may be clearly required to mandate a minimum level by the application of compulsory legislation to enforce use in a widespread manner.

c. Investigate economic ways of reducing the cost of second life system for use across the UK on a widespread basis. The cost benefit analyses indicate that a figure of £40 per switch and crossing timber could provide an economic process.

d. Promote the safety and sustainability benefits of the widespread introduction of heater restressing. This would reduce expensive thermit welding and provide system benefits across switches and crossing units throughout the UK.

8. PAPER PUBLICATIONS AND PRESENTATIONS FOR THESIS

February 2011

Permanent Way Institution Journal Volume 129 Part 1

"Life Extension of Railway Track Systems"

WINNER OF THE PWI SILVER AWARD FOR A PAPER IN 2011/12

Permanent Way Institution

The Board of the

Permanent Way Institution

certifies that the paper written by

Brian Counter

and published in the Institution's Journal for 2011
has won the

Institution Silver Award

The award was presented on
Saturday the 9th of June 2012,
at the Institution's Annual General Meeting in
Derby

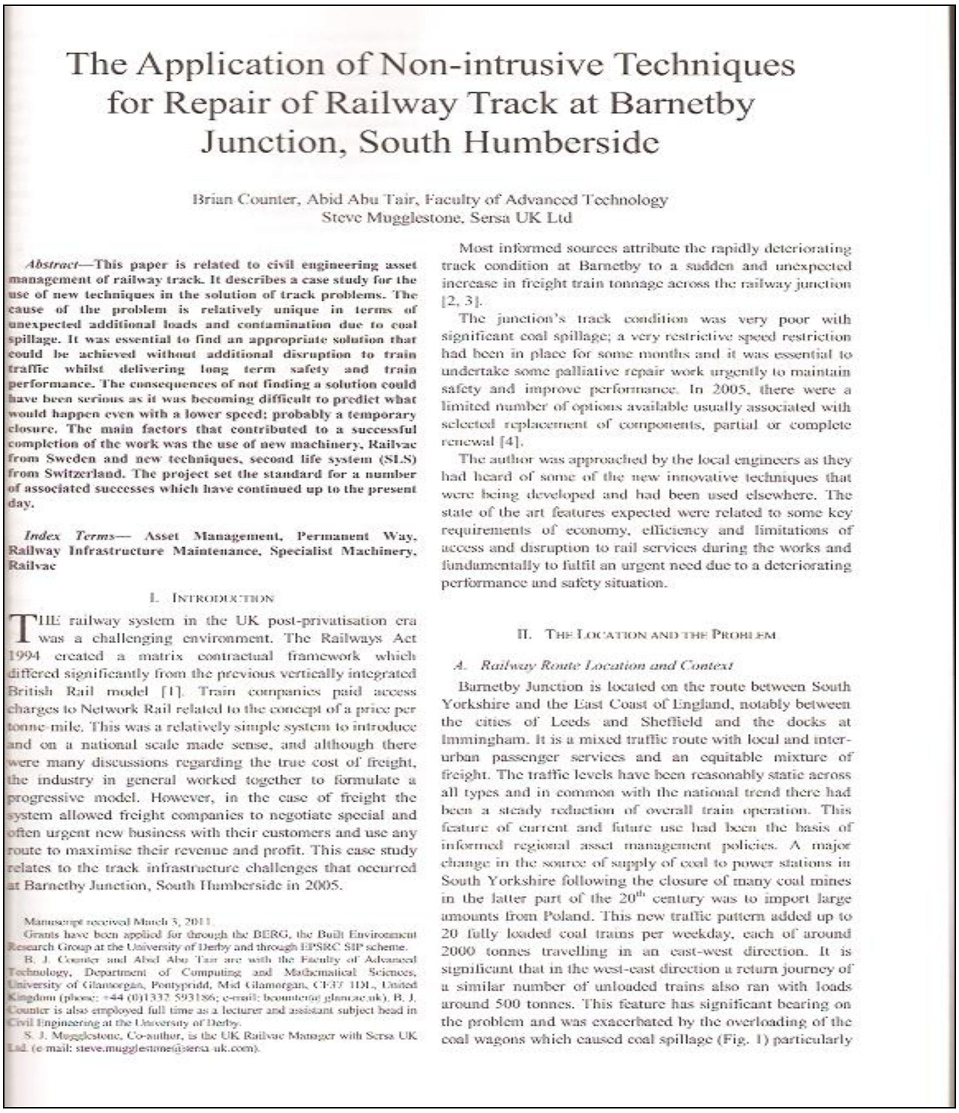
President

Chief Executive Officer

March 2011

University of Glamorgan Post-graduate Research Proceedings Case Study:

"The Application of Non-intrusive Techniques for Repair of Railway Track at Wrawby Junction, Barnetby, South Humberside" Post-graduate Research Proceedings March 2011 University of Glamorgan



The Application of Non-intrusive Techniques for Repair of Railway Track at Barnetby Junction, South Humberside

Brian Counter, Abid Abu Tair, Faculty of Advanced Technology
Steve Mugglestone, Sersa UK Ltd

Abstract—**This paper is related to civil engineering asset management of railway track. It describes a case study for the use of new techniques in the solution of track problems. The cause of the problem is relatively unique in terms of unexpected additional loads and contamination due to coal spillage. It was essential to find an appropriate solution that could be achieved without additional disruption to train traffic whilst delivering long term safety and train performance. The consequences of not finding a solution could have been serious as it was becoming difficult to predict what would happen even with a lower speed; probably a temporary closure. The main factors that contributed to a successful completion of the work was the use of new machinery, Railvac from Sweden and new techniques, second life system (SLS) from Switzerland. The project set the standard for a number of associated successes which have continued up to the present day.**

Index Terms— **Asset Management, Permanent Way, Railway Infrastructure Maintenance, Specialist Machinery, Railvac**

I. Introduction

THE railway system in the UK post-privatisation era was a challenging environment. The Railways Act 1994 created a matrix contractual framework which differed significantly from the previous vertically integrated British Rail model [1]. Train companies paid access charges to Network Rail related to the concept of a price per tonne-mile. This was a relatively simple system to introduce and on a national scale made sense, and although there were many discussions regarding the true cost of freight, the industry in general worked together to formulate a progressive model. However, in the case of freight the system allowed freight companies to negotiate special and often urgent new business with their customers and use any route to maximise their revenue and profit. This case study relates to the track infrastructure challenges that occurred at Barnetby Junction, South Humberside in 2005.

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Most informed sources attribute the rapidly deteriorating track condition at Barnetby to a sudden and unexpected increase in freight train tonnage across the railway junction [2, 3].

The junction's track condition was very poor with significant coal spillage; a very restrictive speed restriction had been in place for some months and it was essential to undertake some palliative repair work urgently to maintain safety and improve performance. In 2005, there were a limited number of options available usually associated with selected replacement of components, partial or complete renewal [4].

The author was approached by the local engineers as they had heard of some of the new innovative techniques that were being developed and had been used elsewhere. The state of the art features expected were related to some key requirements of economy, efficiency and limitations of access and disruption to rail services during the works and fundamentally to fulfil an urgent need due to a deteriorating performance and safety situation.

II. The Location and the Problem

A. Railway Route Location and Context

Barnetby Junction is located on the route between South Yorkshire and the East Coast of England, notably between the cities of Leeds and Sheffield and the docks at Immingham. It is a mixed traffic route with local and inter-urban passenger services and an equitable mixture of freight. The traffic levels have been reasonably static across all types and in common with the national trend there had been a steady reduction of overall train operation. This feature of current and future use had been the basis of informed regional asset management policies. A major change in the source of supply of coal to power stations in South Yorkshire following the closure of many coal mines in the latter part of the 20^{th} century was to import large amounts from Poland. This new traffic pattern added up to 20 fully loaded coal trains per weekday, each of around 2000 tonnes travelling in an east-west direction. It is significant that in the west-east direction a return journey of a similar number of unloaded trains also ran with loads around 500 tonnes. This feature has significant bearing on the problem and was exacerbated by the overloading of the coal wagons which caused coal spillage (Fig. 1) particularly

April 2011

AGM Presentation of PWI Paper *"Life Extension of Railway Track Systems"* Permanent Way Institution Journal Volume 129, Part 1, 2011

June 2011

Railway Engineering Conference, University of Westminster London Presentation and publication in proceedings June 2011 *"Life Extension of Railway Track Systems"*

Sept 2011

Presentation to Sheffield & Doncaster PWI Section *"Life Extension of Railway Track Systems"* Permanent Way Institution Journal Volume 129, Part 1, 2011.

March 2012

(Winner of the institution Silver Award in 2012)

"Heavy Rail Maintenance Machinery and System Innovations: The technical, procedural and human challenges of the introduction and piloting within the UK." Permanent Way Institution Journal Volume 130, Part 1, 2012.

Heavy Rail Maintenance Machinery and System Innovations:

The technical, procedural and human challenges of the introduction and piloting within the UK.

Authors: Counter, B., Abutair, A., Franklin, A., Tann, D.

Contents

Abstract

This paper is a reflective review of the experiences of introducing innovative rail track maintenance machinery and the challenges that were faced from all stakeholders. It explains the approval processes and procedures within the UK, describes examples of successful application of innovative technology and best practice. The technical assessments and problem solving is explored with ideas and recommendations for future systems. The whole rationale is proved by the adoption of the policies and techniques as a fundamental part of the UK's value for money strategy over the next five years. These have been endorsed by the UK Government's Office of Rail Regulation.

Keywords: *Railway track maintenance, machinery; approvals, vehicle acceptance body;*

1. Introduction

New techniques and innovative applications of technology are an essential feature of the continuing future development of the UK rail infrastructure industry. Throughout the last 20 years, introducing new machinery has appeared to become an increasingly difficult process. This was mainly due to the privatisation of UK railways which introduced a complex matrix of approvals and an enhanced reluctance by commercial organisations to take measured risks. This paper identifies successes, describes the key processes and reflects upon potential barriers and opportunities and concludes with a reflective review of the application of appropriate technology and management systems to deliver a strategically important scheme for a UK national rail project. The paper identifies the lessons learnt in the last 6 years and a review of the effectiveness of the current technical standards and procedures.

The paper will conclude with a reflective review of the application of appropriate technology and management systems to deliver UK government objectives for cost reduction in the long term. Recommendations are suggested for future streamlining of processes.

2. The background to the context of approval frameworks

The UK rail industry under the auspices of the British Railways Board (BRB) had centralised systems in place for approvals of rolling stock from its creation in 1962. There was a need to approve vehicle selection and specifications for trains built by private companies in the UK and abroad. The organisation for approval was at this time the BRB's in-house research organisation based in Derby. The areas covered included physical structure gauge, construction materials and structural design, traction and braking characteristics, wheel profiles, axle design, suspension systems, crashworthiness, and a whole host of operating compatibility issues including electro-magnetic impact upon the signalling and electrification infrastructure.

The full privatisation of the UK rail industry in the 1990's created a matrix of organisations that were in involved in approvals processes, these were known as Vehicle Acceptance Bodies (VAB) [1]. The relevant technical standards were originally managed by the newly created infrastructure owner Railtrack PLC who were the custodian of the standard setting process. In 2002, inquiries concluded following the Hatfield Rail Accident, that an independent authority known as Rail Safety and Standards Board (RSSB) should be created to oversee the process.

The current situation is that consultancy companies are licenced by RSSB [2] to carry out the vehicle approval and acceptance process for which they have contracts with train manufacturers and suppliers. This suite of approval processes applies equally to the builders of civil engineering on-track rail-mounted equipment whether it is allowed to move under normal traffic conditions, ie as a "train" or within lines temporarily closed for engineering works. (These are colloquially known as possessions or blocks in the UK.)

European systems are very similar and there has been a major involvement by member states of the European Economic Community to standardise these through open access and interoperability arrangements. However, there are special requirements within each state and each one retains the rights to specially approve especially with regards to electro-magnetic compatibility and operational safety requirements.

The principal and usually obvious barrier is the physical structure of the railway lines in the UK which are generally smaller in terms of bridge openings, tunnels and platforms. The use of new materials, technical equipment and technical processes has been controlled by the infrastructure owner on a consistent basis for a long time and this is known as the product approval process [3]. Usually, there is a system of testing, piloting and impact evaluation relating to quality safety and environmental considerations.

In summary, there are two distinctly different processes; vehicle acceptance and product acceptance; each having markedly different systems and timescales. Any innovations have to go through these processes and although there are clear standards to be complied with, my experience has been that timescales can vary enormously. The key issue is an overall commercial imperative that is either directly or time related to problem solving. Where a flexible risk-based approach has been adopted with personnel who can appreciate the holistic view and the urgency is accepted by all participants, rapid introduction and piloting can be achieved to deliver and adopt innovative new technology.

3. Preliminary visits to Sweden and Germany to view the systems

3.1 Visit to Sweden

In September 2004, a team from the UK including myself and a Network Rail engineer visited a working site in Umea, Sweden where the "Railvac" machine was working. This was a night shift and the work involved ballast removal in a switches and crossings location to facilitate replacement. It quickly became very clear that there was great potential in the UK, where geotechnical conditions were potentially more demanding. A number of other applications were observed including cable burying. The machine was a large self-propelled vehicle consisting of a 80 tonne storage and discharging tank with a powerful vacuum system. The innovation aspect identified was not only the power level but the hydraulic arm with a tungsten metallic cutter tube that had similarities to a powerful multi positioning excavator scoop.[4] This was the key distinguishing feature of the machine. The team had observed similar ballast extraction equipment in Europe but this feature not only had the power but a complex operational console that controlled not only the arm but the movement of the vehicle.

3.2 Visits to Germany and Switzerland

In late 2004 and 2005, a team from the UK visited a number of sites in Germany and Switzerland where they witnessed new innovations in track repair and maintenance invented by the Swiss company, Sersa. The process called "second life system" was applied to timber track layouts and involved the installation of stainless steel inserts and fast setting resin to reinstate structural integrity and lateral alignment.[5] The administrations in Europe were very keen to obtain systems to enhance the life of expensive track

April 2012

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Proceedings of the First International Conference on
Railway Technology: Research, Development and Maintenance,
J. Pombo, (Editor),
Civil-Comp Press, Stirlingshire, Scotland

Paper 54

Heavy Rail Maintenance Machinery and System Innovations: The Technical, Procedural and Human Challenges Posed by Their Introduction and Piloting within the United Kingdom

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Abstract

This paper is a reflective review of the experiences of introducing innovative rail track maintenance machinery and the challenges that were faced from all stakeholders. It explains the approval processes and procedures within the United Kingdom, describes examples of successful application of innovative technology and best practice. The technical assessments and problem solving is explored with ideas and recommendations for future systems. The whole rationale is proved by the adoption of the policies and techniques as a fundamental part of the United Kingdom's value for money strategy over the next five years. These have been endorsed by the United Kingdom Government's Office of Rail Regulation.

Keywords: railway track maintenance, machinery, approvals, vehicle acceptance body.

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10. APPENDICES

10.1. Heavy Maintenance Works Erewash Valley HMRI Involvement

Balfour Beatty

Brian Counter Regional Director
David Ratledge Engineering and Operations Manager

HM Railway Inspectorate

Phil Cable HM Inspector of Railways

3.3 An interview arranged with Chris Hall, HM Principal Inspector of Railways, was cancelled by Chris at short notice and could not be reinstated into the programme within the timescale of the review. The interview with Phil Cable was exceptional in that it was conducted over the telephone. All the other interviews were face-to-face.

3.4 The opportunity was taken to join staff from the Midlands Zone and Balfour Beatty on an inspection of the track, made partly on foot and partly by road/rail vehicle, between Pye Bridge Junction and Trowell Junction on the Erewash Valley Line (EVL). Together with Clive Wilding , Brian Counter and David Ratledge, Mike Noble who is the Balfour Beatty Project Engineer for Operation Erewash Valley also attended the inspection. Mike was able to give a presentation of the project plan and a detailed account of the progress with the remedial track work.

4. REVIEW TIMESCALE

4.1 The review was carried out over a period of two weeks commencing the 24th September, 1997.

5. RESPONSIBILITY FOR THE REVIEW

5.1 The review was conducted and this report prepared by Robert Brown, MBE, BSc, C.Eng, FICE, FCIT on behalf of WS Atkins Safety & Reliability.

5.2 Complete co-operation was extended to the author at all times by every member of the staff involved in the review, for which the author wishes to place on record his appreciation.

6. BACKGROUND

6.1 Before examining the causes of the failure in the management of the RT1A Contract for the EVL, it is necessary to give brief consideration to the events leading up to the state of the track which existed towards the end of 1996.

6.2 There can be no doubt that the EVL has suffered from under-investment for many years. During the time that the line was an integral part of the former LM Region, the available funds for track renewals tended to be concentrated, not unreasonably, on the

10.2 Hatfield Accident Rolling Contact Fatigue

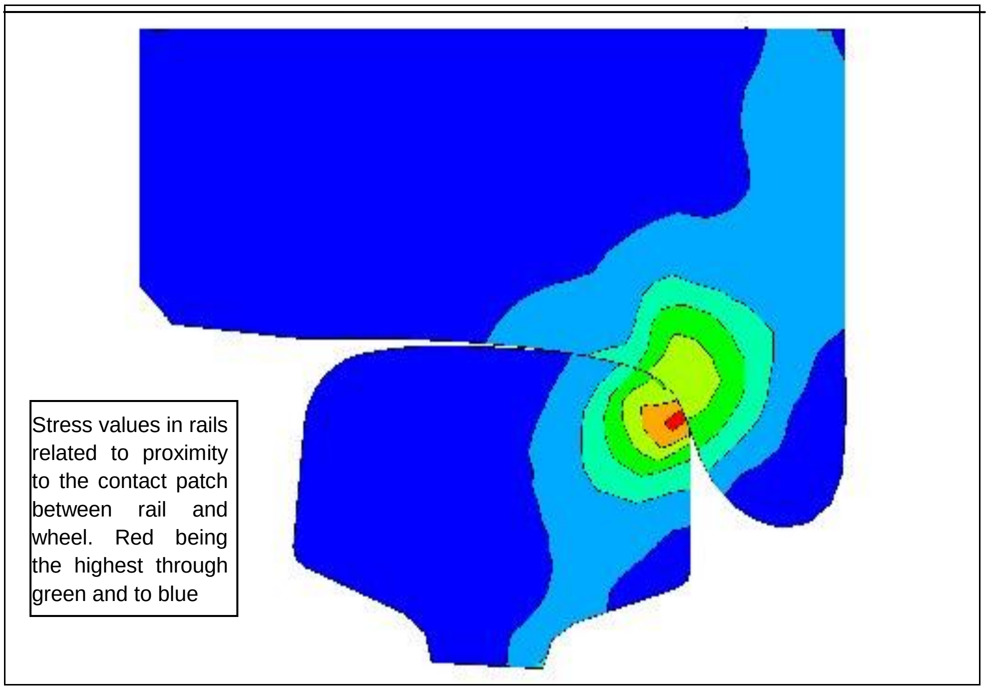


Diagram showing rail and wheel in contact and the stress distribution around the rail head. The key feature being the red area where rolling contact fatigue initiates cracking. Source: ORR 2002

Picture of railhead close to the Hatfield site where transverse fatigue cracking can be seen and the initiation of severe spalling. Source: ORR 2002

10.3 Carillion Rail

10.3.1 Railvac VAB Reports

AEA TECHNOLOGY RAIL

Rail Safety & Standards Board

CERTIFICATE OF
ENGINEERING ACCEPTANCE

This certificate formally records that the following vehicle(s) conform to the appropriate Mandatory Requirements as set out in Railway Group Standards.

NAME OF CERTIFICATION BODY
AEA Technology Rail

ACCREDITATION CODE
ER

Vehicle Type & Class: Railvac Unit
Vehicle Number(s): 31-74-390 0080-1

Vehicle Operator: Carillion Rail
Vehicle Owner: Railcare AB

Authorised By: B K Wilkinson

Issue Date: 03 November 2005

See page 2 for Mandatory Requirements against which compliance has been confirmed

Expiry Date: 02 December 2005
(Where applicable due to special limitations)

Certification Body Official Stamp

AEA TECHNOLOGY RAIL Vehicle Acceptance Body

Special Limitations:
See Special Limitations section on following pages

Reason for Issue, including Scope of Work:
The scope of this certificate is for the acceptance of the Railvac ballast extraction vacuum machine for short-term operation.

The expiry date is applied from 05/179/TNC.

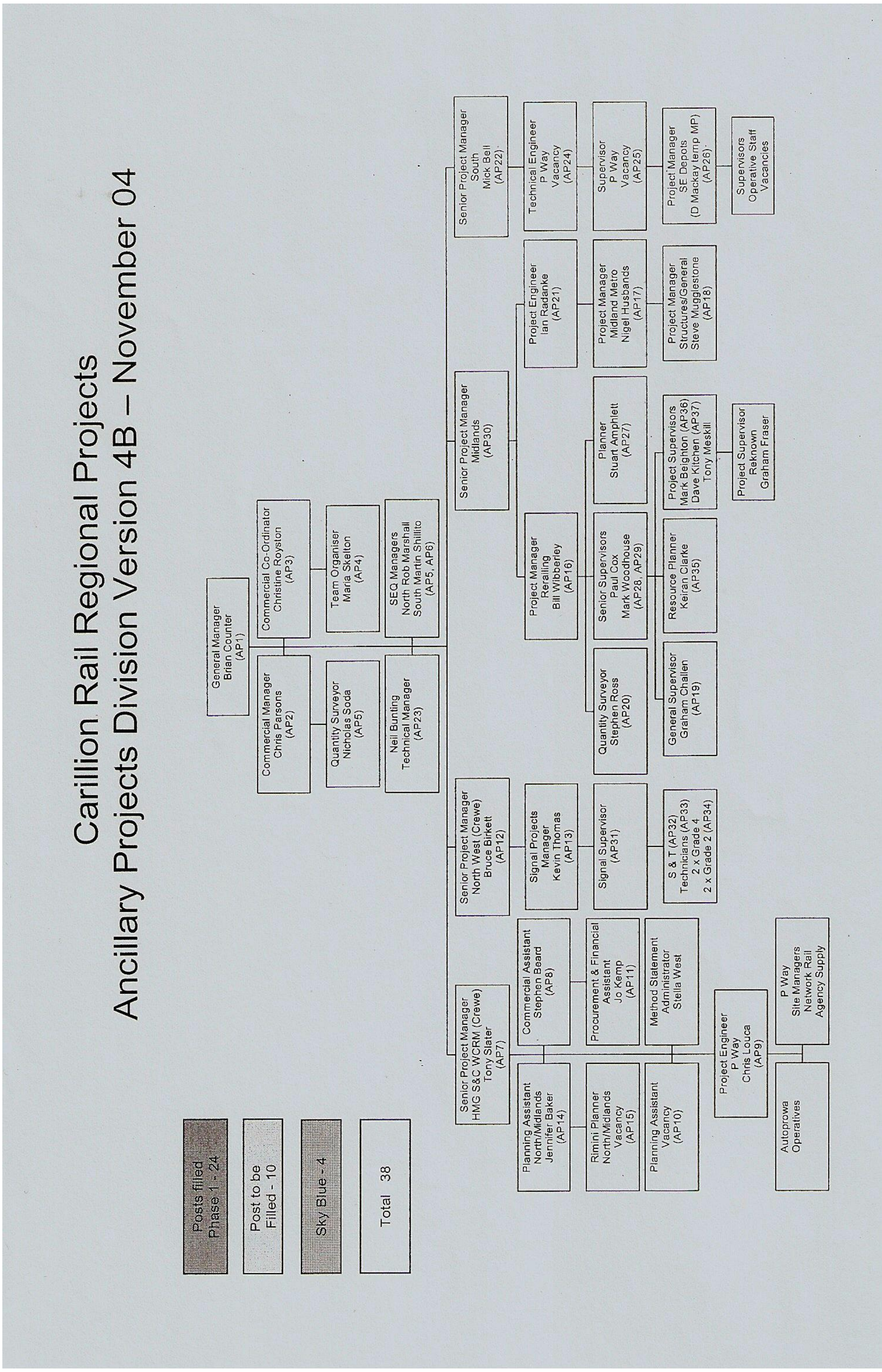
Certificate No:
ER/0745/05

Page 1 of 3

AEAT/RAIL/F/F046(e) Issue C00

Customer - Train Operator Copy

10.3.2 Organisational Chart Carillion Rail Ancillary Projects Group



10.4 Site Investigation Foxhall Junction Didcot

Prepared by Andy Franklin, Professional Head of Civil Engineering,
Carillion Rail Newport, 18-12-2004

Background

This report describes a visit made to see the potential vacuum reballasting site at Foxhall Junction at Didcot on 16-12-04 in the company of Tony Hopkins, PWE Didcot for Network Rail.

Objectives

I set myself the following principal objectives based on the project remit. These were to:

1. Look for a location at which the Railvac machine could be on and off tracked assuming delivery by road
2. Inspect the site for any clearance problems that would arise from the use of a machine built to a UIC loading gauge
3. See if the site were suitable for vacuum reballasting and particularly to look at:
   3.1. the nature of the material to be removed
   3.2. a location for disposing of the spoil
   3.3. a location to stockpile ballast

Foxhall Junction - The site and some history

Foxhall Junction is located on the Great Western mainline (MLN1) from London to Bristol and lies half a mile west of Didcot station at 53m55ch. It forms the junction between the main and relief lines, the Didcot West Curve (DWC) and the Didcot Power Station Sidings (DPS) and Milton Siding serving the Milton Industrial Estate. See Site Diagrams.

At the east end of the site are 4 lines. From north to south these are the Up Goods Loop (reversible), the Relief Line (reversible) and the Up and Down Mains. Line speed over the Up Goods Loop is 25mph, on the Relief line is 50mph and on the Mains is 125mph.

When Didcot Power Station was built the rail connection faced east as the coal traffic came from the Midlands via Oxford and the Didcot West Curve. Now however nearly all the coal is imported at Avonmouth Docks and comes up the main line from the west. At Milton Junction loaded trains cross to the Up Goods Loop and stop beyond SB935 signal, the loco runs round via the Relief Line and the train is hauled into the Power Station for unloading. Empty trains also perform the same manoeuvre on the Up Good Loop prior to dispatch west such that all trains to and from the Power Station cross the junction twice.

Other traffic that uses the West Curve are automotive parts from the Midlands to Swindon, 'Binliner' trains of rubbish from the west of England en route to the Bedfordshire old claypits and some stone traffic.

The sites proposed for reballasting are on the:

1. Up Goods Line between 53m45ch and 53m61ch and include a trap point, a fixed 1 in 7½ diamond and 2 turnouts
2. Relief line between 53m60ch and 53m66ch and includes 2 turnouts.

There is now work proposed on the Main Lines.
All the S&C is of vertical design on hardwood timbers and is in reasonable condition however the ballast conditions are very poor. Pollution with coal dust has inhibited prevented drainage and despite remedial works the formation has now failed, clay is pumping up in many places and the site is a 'super red' for top. There are also problems with twist and cyclic top.
The PWE has become increasingly frustrated with the deferment of this item and the resource he is having to put into the site to keep it running. It does not respond to tamping.

Items Arising for Further Consideration

1.	On and Off Tracking the Railvac Machine The Railvac machine will have to be delivered by road and there is a suitable site for transferring it from road to rail in the siding serving Milton Industrial Estate. The site is within the yard of a road haulage contractor (Cannon) and is used by the Great Western Society when moving railway locomotives by road. The track is set in a paved concrete area and would seem to be ideal for this purpose (see Pictures 1 and 2) Action required: 1. Inspect the yard to ascertain it suitability in conjunction with the chosen road haulage contractor. 2. Approach Cannon's re the use of the yard.
2.	Clearance to the Infrastructure The structures affected by this work are: 1. the signal gantry at 53m47ch 2. signal SB944 3. Didcot Bypass overbridge at 53m66ch 4. signal SB942 at 53m76ch 5. the signal gantry at 54m03ch 6. Foxhall Farm overbridge at 0m15ch on the West Curve. Of these only I believe only the last is a potential problem and needs to be checked (see picture 3). Action required: 1. Decide who will check clearances 2. Check the clearances to Foxhall Farm overbridge
3.	Nature of Material to be Removed The site is polluted with coal dust, is very wet and the formation has failed with wet clay pumping up in many locations. Even where it was not intended to reballast (remember the job has been planned with conventional traxcavating in mind) there is coal spillage to clear up and there is a need to discuss how drainage could be improved (there is currently none) see Pictures 4, 5, 6 and 7). This material is soft and wet and will make a mess when it is removed. I would suggest it would also be 'special waste'. I think this job will probably best be considered a palliative as I believe what is really needed for the long term is a clay dig and blanket. Action required: 1. Check if the material will become special waste and if so where it needs to be taken 2. Review the need for some formation treatment e.g. a geotextile membrane
4.	Location for the disposal of the spoil The most likely location would be in the yard adjacent to the Up West Curve at about 0m19ch (see Pictures 8 and 9).

	The site has good road access but would need to have the track decked out to provide access for a digger and to prevent pollution of the ballast. **Action required:** 1. Obtain permission to use this site (it is Network Rail land) 2. Decide who provided the decking on the West Curve 3. Decide who provides the plant and haulage to dispose of the spoil
5.	Location for the provision of a stockpile of ballast There are two possible locations. At the same site as for the disposal of the spoil adjacent to the West Curve which has the potential for confliction of moves or in the vee of the junction at Foxhall at 53m48ch see Picture 10). **Action Required:** 1. The method of working will determine the best location 2. Obtain permission to use one of the sites
6.	**Possessions** There are a series of blockades coming up in weeks 42 to 50. These are the regular winter long weekend blocks between Didcot and Swindon for track renewals work. Carillion is doing Steventon S&C (loop connections) and Amey SECO are active in the blockaded. There are there are other opportunities: 1. on part of the site on weeknights (there is traffic using the West Curve by night but this could possible be rerouted) 2. on Saturday daytimes and Sunday nights when there is no coal traffic to the powerstation and little other freight **3.** on the 2-weekly 9 hour Saturday night maintenance block of the station area. This is Didcot North, Moreton Cutting, Foxhall Junction inclusive but does not cover the mains for the full period. **Action required:** 1. Decide who is to book the possessions 2. Decide who is to carry out possession management 3. Decide who is to be site manager
6.	Technical issues There will be a need to produce a design scheme and provide technical support. Tony would like to provide this himself. **Action required:** 1. Decide who is to provide technical support for design and implementation.
7.	S&C Tamping and other plant The will be a need for an S&C tamper and depending on how the work plan is evolved road rail excavators, road rail dumpers etc. Action required:

	1. Decide who will procure and supervise the other plant
8.	Safety Case Issues The proposed Railvac machine has no safety case or product approval to operate in the UK. The machine owners Railcare will have to operate it but at present they do not have a UK Contractors Assurance Case and will need to get some operators passed in UK PTS. **Action required:** 1. Evaluate what safety documentation is needed 2. Decide if the Railvac is going to operate under the Carillion Safety case 3. Prepare the safety management documentation 4. Arrange for Railcare staff to be PTS trained 5. Arrange for a UK COSS to be trained as a Machine Controller for the Railvac
9.	**Other issues** Before Network Rail commits to this they are going to need a plan and price for the work. I believe we need to get someone over form Railcare to work with our Project Engineer and Network Rail's Engineers to prepare a detailed work scope (once they understand the machine capability) and an estimate of cost. **Action required:** 1. Appoint a Project Engineer from Carillion 2. Arrange for a site visit and planning meeting with someone from Railcare 3. Put together a detailed indicative plan and develop an estimate of cost

10.5 Method Statement for Ashford International Project

Document	Method Statement – Re-Ballasting/Re-Stressing Works at Ashford International Station
Document No.	RPAP022/AK/GEN/MS/01
Version No.	01
Date	14/12/05
Page	1 of 29

carillion

CARILLION RAIL

METHOD STATEMENT

Rail Vacuum Works

Client : Network Rail

Project : Ashford Kent

Authorisation

	Name	Signature	Date
Prepared By	S Mugglestone Carillion Ancillary Projects		23/12/05
Checked By	D Kelly Carillion Ancillary Projects	P.P.	23/12/05.
Authorised By	B Counter Carillion Ancillary Projects		23/12/05
Accepted By	P Fleming Network Rail		

10.6 Network Rail Policies for Track work 2011

This appendix contains excerpts from the published document that identifies the strategic national policies for track activity for the next 30 years. The document was produced in conjunction with industrial and supplier involvement. A number of explicit policies were developed directly from the work carried out by the author and his teams during the period 2004 to 2012. Specific relevant policy areas are highlighted in this appendix. The full document is available on ***www.networkrail.co.uk***

Refurbishment

Definition of levels of Refurbishment Network Rail 2011

Refurbishment is proposed as an alternative to full renewal in the CP5 policy where it enables lower whole life cost management of the track. Renewal is complete replacement of the track system, setting the track to the start of its lifecycle. Refurbishment is partial replacement of the track system, re-setting the track to earlier in its lifecycle. Two generic levels of refurbishment have been developed and modelled, medium and heavy:

- Medium refurbishment, which does not include full ballast replacement, is designed to deliver a 20% extension to service life 'good' or 'satisfactory' track geometry quality.
- Heavy refurbishment, which does include full ballast replacement, is designed to deliver a 50% extension to service life 'good' track geometry quality

Key aspects of refurbishment and the rationale behind them are as follows:

- Refurbishment is an alternative to renewal that extends the life of the asset without completely renewing it. Refer to Asset Policy Section 6 – Intervention Options for a full discussion on the types of refurbishment to be considered.
- In the second stage of the assessment a proportion of the renewals in each route criticality set will be assigned for refurbishment instead of renewal. In this case, the criteria for initial identification will be very similar, but additional criteria are required in the second stage to determine whether the track is suitable for refurbishment instead.

Therefore, the new procedure is:

1. Identify renewals, after the revised renewal budget has been applied.
2. Identify track that is suitable for refurbishment. This will exclude track that is to be renewed in that year, as well as track that is unsuitable for refurbishment, either because the track type is not suitable for the refurbishment option or because refurbishment will not improve the track sufficiently (i.e. it will still require renewal in the next year so refurbishment will not be cost-effective).
3. Prioritise refurbishment for that location and solution.

Scenario 1. Expected traffic increase, current asset information

This is an evolution of the policy currently being applied in CP4. The renewal mix (i.e. high output work, complete renewals with traxcavation with and without formation treatment, steel sleeper relay, rail renewal) was originally set at similar relative proportions to those planned for the last three years of CP4 for each Criticality Band, with no refurbishments.

Once the optimal renewal rates had been identified, some of these renewals were re-allocated to heavy and medium refurbishments, where there would be sufficient confidence that the refurbishment could deliver the required 50% (for heavy) and 20% (for medium) extension of service life.

Most of the refurbishments were targeted on the lower Criticality Bands, where there is better track access to carry out remedial actions to mitigate any performance issue that might arise. This means that steel sleeper relay would be virtually eliminated in CP5, because the track that it is most suitable for (low category, timber jointed track with moderate ballast condition) is also likely to be suitable for refurbishment work.

The renewal and refurbishment volumes were then re-calibrated to meet the condition targets. This meant there was a slight increase in some of the renewal and refurbishment volumes, but nevertheless the final costs were significantly lower than the original renewal costs without refurbishment.

Heavy maintenance (tamping, stoneblowing and rail profile grinding) was adjusted to account for the amount of renewal and refurbishment work. Where very heavy renewals have been applied in Criticality Band 1, resulting, as expected, in a large improvement in ballast condition, the requirements for stoneblowing have decreased, because there is much less track in poor / satisfactory condition.

In lower Criticality Bands, stoneblowing has been increased at the expense of tamping, because the medium refurbishment is expected remove the risk of the stoneblower breaking the sleepers, and stoneblowing is likely to be a more effective treatment for much of the track than tamping.

What will be done / improved?	How will this be done?	What are the benefits?	How will the intervention regime change?
Refurbishment will be specified as an alternative to complete renewal.	Modelled refurbishment volumes will be included in the consistently derived starting point for the development of the RAMPs. Asset information, decision support tools and site inspection will be used to confirm appropriate refurbishment volumes in the RAMPs and to develop site specific specifications.	Lower whole life cost. Lower CP5 cost to meet the required outputs. Exploits the residual service life in the track system components.	More refurbishment and less complete renewal.
Reballasting of plain line and S&C to extend the service life of the whole track system.	A reballasting programme at approx 2/3 life cycle will be developed. The work will be included in the RAMPs. Reballasting process and plant requirements will be developed with supply chain partners.	Lower whole life cost. Lower CP5 cost to meet the required outputs. Exploits the residual service life in the plain line and S&C track system components.	More reballasting and less complete renewal. Lower volumes of plain line and S&C renewal possible in later control periods.
Improved gauge and alignment on timber S&C layouts.	A re-gauging programme of timber S&C layouts will be developed. The work will be included in the RAMPs. Training and development to improve competency in the specification and delivery of S&C refurbishment.	Timely refurbishment will extend timber S&C system service life. Lower whole life costs. Will reduce subsequent maintenance costs, improve performance and reduce safety risk.	More re-gauging of S&C. Reduced reactive maintenance and replacement of components.

What will be done / improved?	How will this be done?	What are the benefits?	How will the intervention regime change?
Refurbishment of jointed timber plain line track on low criticality routes.	A programme of resleepering, joint treatment and gauge restoration on jointed timber track on low criticality routes will be developed. The work will be included in the RAMPs.	Timely refurbishment will extend the service life of jointed timber plain line track. Lower whole life costs.	More resleepering and joint treatment. Less complete renewal.
Refurbishment of concrete sleepers with un-maintainable obsolete fastenings.	Techniques to refurbish common obsolete fastenings are being developed. The work will be included in the RAMPs.	On many sites, the sleepers are in good condition apart from the un-maintainable obsolete fastenings. Replacement of the fastenings exploits the residual service life in the sleepers. Lower whole life costs. Lower CP5 costs as refurbishment replaces more expensive renewal.	More refurbishment of fastenings. Less complete renewal.
Sustain performance on a route section pending enhancements or high output renewal campaigns.	Refurbish individual sites instead of renewal pending future significant works such as enhancements or high output campaigns.	Lower whole life costs. Lower CP5 costs as refurbishment replaces more expensive renewal. Lower subsequent renewal costs from more efficient delivery.	More refurbishment. More efficient renewals.
Improved 'refurbish or renew' decision making.	Develop a standard process to identify, specify and deliver effective refurbishment that achieves the required outputs. Develop a financial model that indicates whether refurbishment is likely to achieve lower whole life cost than renewal.	Reduced whole life cost of track asset management. More consistent process with greater assurance and visibility.	More refurbishment and less complete renewal.

What will be done / improved?	How will this be done?	What are the benefits?	How will the intervention regime change?
Use recycles, refurbished S&C units in lower category lines	At renewal of S&C in higher criticality band the materials will be recovered and refurbished where appropriate Develop an enhanced 'end-to-end' process for the management of materials	Lower initial cost Environmental benefit by reusing materials Availably of serviceable components for older designs of S&C	Better recovery of materials form renewal site Increase in the use of serviceable material
Refurbishment of concrete sleepers with un-maintainable obsolete fastenings.	Techniques to refurbish common obsolete fastenings are being developed. The work will be included in the RAMPs.	On many sites, the sleepers are in good condition apart from the un-maintainable obsolete fastenings. Replacement of the fastenings exploits the residual service life in the sleepers. Lower whole life costs. Lower CP5 costs as refurbishment replaces more expensive renewal.	More refurbishment of fastenings. Less complete renewal.
Develop and implement reballasting techniques for S&C and plain line heavy refurbishment	In consultation / partnership with the supply chain.	Ability to deliver the reballasting element of heavy refurbishment across many more individual sites than at present (Some with limited access) Flexible approach that can be used in a wide variety of situations Complements exiting renewal equipment	More reballasting as part of heavy refurbishment

Policy Statements for S&C

10	Refurbishment	Refurbishment may be considered at any point during the life cycle of the track, where it offers an effective whole life cost solution to one or more of the following: 1. achieve the desired service life of the track system, or 2. extend the service life of the track system, or 3. reduce the volume or cost of maintenance to the track system, or 4. improve the performance of the track or infrastructure system The target volume of refurbishment to be included in the route asset management plan for each SRS shall be determined by modelling. The modelling rules shall be designed to produce volumes that support achievement of the policy objectives. Refurbishment shall be classed as either Medium or Heavy and shall be output driven with the objective of delivering specific improvements. All track proposed for refurbishment shall be inspected and the work scoped for delivery against the intended outputs. Medium refurbishment does not involve full ballast replacement and shall be specified to deliver: a 20% extension to service life; track geometry standard deviations that are at least in the NR/L2/TRK/001/C01 'satisfactory' band for track quality track suitable to be maintained by stoneblowing; elimination of site specific maintenance problems; a 10% reduction in maintenance input (for example stoneblowing, resleepering, rail adjusting, defect removal and repairs); removal of the site from the 'at risk of TSR' register; a 50% reduction in Mean Time Between Service Affecting Failure (MTBSAF) for S&C. Heavy refurbishment involves full ballast replacement and shall be specified to deliver: a 50% extension to service life; track geometry standard deviations that are at least in the NR/L2/TRK/001/C01 'good' band for track quality track suitable to be maintained by tamping or stoneblowing ; elimination of site specific maintenance problems; a 30% reduction in maintenance input (for example tamping, resleepering, rail adjusting, defect removal and repairs); removal of the site from the 'at risk of TSR' register plain line CWR sites suitable for the application of extended basic visual track inspection interval using NR/L2/TRK/001/A01 process A Mean Time Between Service Affecting Failure (MTBSAF) at a level equivalent to track renewal work for S&C. A Refurbishment Handbook will be produced to give advice on the range of treatments available.
72	Reballasting	S&C that is otherwise serviceable but that sits on poor ballast shall be considered for heavy refurbishment including reballasting, preferably in situ e.g. by undercutting or vacuum extraction

S&C heavy refurbishment								
Gauge	**Alignment**	**Timbers**	**Ironwork**	**Ballast/ Formation. Drainage**	**IRJs**	**Points Operation Equipment**	**E&P/ Signalling**	**Service Outputs**
Installation standard Tolerances +/- 2mm (NR/L2/TRK/001/C01 and D01) (allows gauge transitions)	Alignment design to achieve SDs in the 'Good' band for track category	Replace with new or re-gauge and refasten baseplates to alignment and gauge.	Weld repair /profile grind or minor replacement with serviceable materials if available or new. Renew bolts and fastenings as necessary Fit weldable leg end crossings suited to track category Consider conversion to shallow depth switches	Renew or clean ballast. Create drainage fall on excavated/ cut surface and ensure drainage path for water to exit the ballast box.	Renew and/or eliminate. Relocate away from switch heels, crossing legs and switch from t joints where possible 4 or 6-hole glued units as standard	Renew POE (clamp locks / point motors). Renew stretcher bars. Install roller baseplates.	Refurbish points heating. Cable management Improve cable management to make track fully OTM maintainable	Service life +50% SDs in the 'Good' band for track category Track can be maintained by tamping or stoneblowing Site specific maintenance problems addressed. Performance: MTBSAFs at renewals levels. (6 ½ years MTBSAF) Maintenance input reduced (tamping/ defect removal/ repairs) by 30%. Site removed from the 'at risk of TSR' register
Possible delivery mechanisms								
SERSA second life system or similar. Use 'gauge setting bars' to ensure tolerances.	Requires survey, design and installation	SERSA second life system or similar. Use 'gauge setting bars' to ensure tolerances.		ABC /undercutting machine or Rail Vac to excavate or clean as required. Remove / clean ballast houlders. Refurbish drains as required.				Note: need to undertake a study/ analysis of maintenance benefits after Christmas. Also need to resource estimate Heavy refurbishment and compare with renewal unit rates.

S&C medium refurbishment								
Maintenance standard Tolerances For track category (NR/L2/TRK/001/C01)	Alignment design to achieve SDs in the 'Satisfactory' band for track category	Patch replace with new timbers or 'pull through' and re-gauge.	Weld repair /profile grind. Renew bolts and fastenings as necessary Fit weldable leg end crossings suited to track category	Spot re-ballasting. Localised clearance of shoulder to ensure drainage path for water to exit the ballast box.	Renew on condition. Relocate away form switch heels, crossing legs and switch from t joints where possible 4 or 6-hole glued units as standard	Service POE? (clamp locks/ point motors). Renew stretcher bars on condition. Install roller baseplates if performance is driver.	Service points heating. Improve cable management to make track fully OTM maintainable	Service life +20% SDs in the 'Satisfactory' band for track category Track can be maintained by stoneblowing Site specific maintenance problems addressed. Performance: MTBSAFs 50% better (3 years MTBSAF?) Maintenance input reduced (tamping/ defect removal/ repairs) by 10%. Site removed from the 'at risk of TSR' register
Possible delivery mechanisms								
Coils / 'Spike fast' type epoxy treatment	Localised geometry correction	Coils/ 'Spike fast' type epoxy treatment		In bearer dig, rail vac or similar vacuum excavation. Localised clearance of ballast shoulders. Refurbish drains as required.				Note: need to undertake a study/ analysis of maintenance benefits after Christmas. Also need to resource estimate Medium refurbishment.

10.7 Benefits of Railvac – Detailed Further Opportunities

There are 2 current UK Railvac machines (The new UK gauge and the Swedish gauge) are versatile and able to undertake many types of work across a wide spectrum of infrastructure. Their scope now includes:

1. Track maintenance and renewal;
2. Track life extension works;
3. Drainage maintenance, rehabilitation and renewal;
4. Cable installation;
5. Enhancement works, such as improved route availability;
6. Foundations for overhead line masts and signalling gantries.

10.7.1 Eliminating un-necessary work such as 'Track Out' Reballasting

Much of the track engineering work undertaken currently requires that the track is taken out in order to facilitate reballasting works. Railvac undertakes reballasting with the track left in-situ, improving production, efficiency and reducing potential damage to the asset and/or premature renewal. Significant efficiency benefits are obtained for certain types of work, for example reballasting of switch and crossings under partial renewal works.

10.7.2 Undertrack Services and Cable "Friendly"

During conventional track-out reballasting work, it is necessary to disconnect signalling / power cables, then reconnect and test them at the completion of the work. Railvac track-in reballasting avoids this as the cables are left connected. Benefits are cost efficiency, reduction in safety risk and lower track access requirements, supporting the industry's drive for increased efficiency and improved safety. Strikes of undertrack services by mechanical plant are a frequent occurrence in the UK. The Railvac equipment and its mode of operation provide minimal risk of damaging undertrack services proven by experience worldwide and in the UK. Benefits realised are no disruption to production, lower safety risk and costs.

10.7.3 Replacing only life expired assets

The Railvac is an ideal piece of equipment to support Network Rail's drainage improvement strategy. It can be used in conjunction with pipe surveys and drain jetting equipment. When localised failures are identified it can be used to excavate a short section of trench, enabling the damaged section to be replaced. The benefits are that Railvac fits within the existing strategy and will allow significant efficiency within drainage operations. Additionally, drain refurbishment can be added to the possible solutions for drainage improvement providing the potential for even more efficiency, i.e. the savings obtained between having to install a new drain versus that of being able to refurbish an existing drain.

In addition Railvac provides a high output and efficient techniques for the changing of concrete sleepers. This would provide Network Rail with an efficient system for this operation allowing full or partial changing of these components.

10.7.4 Improved availability: Reduces Track Access Requirements

For many of the work activities that the Railvac can carry out, it is proven as a more productive process then current methodologies, e.g. wet spot removal. Hence, it requires less track access to produce the same output. Additionally, for many of these processes other track access periods, for preparatory and follow-up work, are not required. An example of this is the avoidance of stressing CWR after track out reballasting. Benefits are a reduced number of track access periods required supporting additional capacity requirements for the network. There is also potential to use the process for specific structural works adjacent to the track. The ability to excavate short sections of ballast on top of under bridges for works such as waterproofing or patch repair provides the potential to undertake these types of works in short track access periods. Potential benefits are efficiency, productivity and reduced lengths of track access.

10.7.5 Reduced risk: Improves Safety

The avoidance of not having to remove the track improves the safety risk profile of the works, i.e. reduction in number of (excavating) machines on site and elimination of lifting operations. Additionally, far less equipment is used with lower numbers of staff. Benefits are cost efficiency and far lower safety risk.

10.7.6 Efficient Delivery Benefits

Experience from both worldwide and in Britain has demonstrated significant efficiency benefits across a wide range of work applications. Specific examples include 40% improvements in switch and crossing reballasting and maintenance wet spotting processes. Experience has also shown that when the Railvac equipment is introduced it provides a stimulus for innovation and more applications for its use are developed. So far some 45 applications have been identified, each of which provides benefits in terms of efficiency, safety, production or performance.

Its versatility and potential are indicated in the following other applications:

10.7.6 Improve Drainage Works

Versatility of operation is a major benefit within these operations enabling the following works to be undertaken by one machine, including drain trench excavation, catch pit cleaning, cross drain excavation, replacement of filter around over pipe runs; and excavation for pipe replacement. The latter two applications are not undertaken in Britain because of methodology problems that the Railvac can overcome. – digging conventionally by machine destroys the pipe and finishing needs to be done by hand – Andy Franklin notes. The Railvac is therefore an ideal piece of equipment within Network Rail's drainage improvement strategy to support pipe surveys and drain jetting equipment. The benefits are that Railvac enables further drainage activities (not currently undertaken in the UK) to be undertaken thus providing opportunity for significant efficiency within drainage operations.

10.7.7 More efficient Cable Installation Techniques

It is a very practical and efficient way of installing cables by using Railvac to create the trenches needed by vacuum extraction. The cables are often buried in high risk areas to prevent vandalism and the potential high cost of disruption.

10.7.8 Improved Reballasting of Track for Partial Renewal and Maintenance

Use of Railvac eliminates the need to take the track out for reballasting. Significant and proven efficiency benefits have been realised both worldwide and in Britain. These have been realised on works such as switch and crossing renewal and wet-spot eradication where efficiency benefits of more than 40% over traditional methods are commonly realised. Significant efficiency benefits are therefore very realisable if the equipment is fully integrated into Network Rail operations. Significant amounts of partial track renewals are programmed to be undertaken throughout CP4. The Railvac's ability to reballast track productively and efficiently provides additional scope for engineers to specify this for life extension works. The potential to target the 'root cause' of the problem (the ballast and formation) as well as the 'effect' (poor track conditions) provides Network Rail with a better engineered, but more efficient solution to significant amounts of partial renewal works. Currently some 40,000 wet spots are removed each year from Network Rail's infrastructure. These are removed either manually or by mechanical excavators. Railvac has a proven record worldwide of undertaking this activity more efficiently and trials and modelling in Britain suggests that an efficiency of 40% on current practices is possible.

10.7.9 Reducing Costs for Route Availability Improvement

Track lowering under structures and in tunnels using conventional techniques involves track removal and reinstatement. Railvac enables this work to be undertaken without track removal. Benefits include reduced track access, greater efficiency and less safety risk.

10.8 Statement from Industrial Supervisor Andy Franklin Network Rail

Introduction

This is an important piece of work; it is both timely and relevant to today's railway civil engineers and infrastructure managers as I shall discuss further.

This is also an unusual work as few, if any, engineers whose working life has been involved with the day-to-day maintenance and renewal of the track system have set out to record their experience let alone develop their studies into PhD which makes it all the more valuable.

Indeed the published work that has come out of the development of this thesis and the presentations made to Permanent Way Institution sections and international conferences are already in themselves valuable additions to railway engineering literature and discussion.

Context

As a contemporary of Brian's, I have lived through the same changing railway environment from the days of the nationalised British Rail and years of slow, managed decline and rationalisation of the assets, through privatisation and the era of contract maintenance and on into the current world where the industry is facing the happy challenge of ever increasing demand and the engineering challenges this brings. At the same time we are more 'regulated' and controlled by the Government than ever British Rail was and facing the challenge of demonstrating that we can deliver value to the taxpayer and our direct customers.

In this thesis Brian sets the track engineering in the broad context of the political, economic and social drivers that have produced this change and this is valuable in demonstrating that what, from an engineering view, once seemed a reasonable way of working is no longer acceptable to our wider stakeholders.

Asset management approach

In the preparation of Control Period 5 (CP5) Network Rail has further developed the asset management approach started in CP4. A key part of this for track was to measure 'asset life' in terms of Equated Million Gross Tons (EMGT) and not in years. Once this view is taken then defaulting to the 'renew' option no longer stands up to scrutiny as the 'life' bought with new assets on more lightly used lines cannot be financially justified and the concept of 'refurbishment' to restore the capability of the track system has come to the fore. Brian also demonstrates that refurbishment is a cost effective method of restoring the performance of an aging asset (for example removing temporary speed restrictions) either as a permanent solution or as in palliative measure pending more major works.

This is an approach that Brian recognised before many in the industry and this paper clearly demonstrates the value of the work done to the extent that the particular examples of using the 'RailVac' and 'Second Life System' are specifically included in the Network Rail CP5 'Track Asset Policy'.

On the Wales Route where I work there are many miles of rural, lightly used, predominantly jointed track that will be sustained by a policy of refurbishment with renewal being an exception arising only when major components (such as the rail) is worn out or when a new level of performance (for example higher line speeds) are needed.

Similarly on our secondary routes single component replacement (typically the ballast or rail) is becoming the norm with a view to maximising the life of the individual track components.

Innovation

Brian demonstrates that innovation is not all about new technology (in railway civil engineering terms 'big yellow machines') it is as much about imagination, ideas, processes and above all people. In this paper we see new ideas combined with old concepts and brought together as effective work systems that delivered what was needed.

It is only in recent years that those within the British railway industry truly embraced the idea that others beyond our shores may have good ways of doing things and to go out and look for ideas that can provide solutions to problems at home. This is of course the beginning of the story and Brian brings to life the issues around 'importing' process and equipment into the 'risk averse' railway community. The issues exposed are a threat to innovation on the UK railway network which needs to be addressed.

In the paper however Brian demonstrates that with the right will and by a structured approach demonstrating the benefits in a way that all stakeholders can understand that the process can be relatively painless.

Conclusion

This is a valuable piece of work that can be developed by Brian and other as the practice of asset management in railway infrastructure grows.

Andy Franklin

Route Asset Manager [Track]

Wales Route

Network Rail Infrastructure Ltd

Newport 4th June 2013

11. GLOSSARY OF TERMS USED IN THIS DOCUMENT

TERMINOLOGY	**EXPLANATION**
ATWS	Automatic Track Warning System
Autoprova	Zollner patented ATWS
Baseplate	Metallic support between sleeper and rail
Blockage	Closure of railway line for engineering work
Bearer	Support for switches and crossings timber/concrete
Bull head	Type of rail section used in early railways
Chair	Metallic support between sleeper and rail
CP4 CP5	Regulatory Control Period 4 or 5
Cross level	The difference in vertical height between rails
Crossings	Rail configuration where lines cross
Double Junction	Rail divergence involving two lines
Flat Bottom	Type of rail section with flat surface at base
Gauge (track)	Distance between rails (UK normally 1435mm)
Gauge (structure)	The physical outline of a train or rail vehicle
Green Zones	Safe location without trains running
HMRI	Her Majesty's Railway Inspectorate
Key	Wood or metal wedge to fit rail to a chair
Long Timber	A supporting timber parallel to a rail
Lookouts	Persons employed to observe and warn staff
Network Rail Ltd.	Owner of UK Rail Infrastructure 2003 onwards
ORR	Office of Rail Regulation
Points and point ends	Tapered rails that move to allow trains to cross

GLOSSARY OF TERMS USED IN THIS DOCUMENT (continued)

Permanent Way	Railway Track involving rails and supports
Plain Line	Basic Track without any switches or crossings
PWI	Permanent Way Institution
Possession	Closure of railway line for engineering work
Rail	Metal usually steel that train wheels run along
Rail joints	Bolted or welded connections between rails
Railtrack PLC	Owner UK Rail Infrastructure 1994 – 2003
Red Zones	Open line requiring protection for staff
Rimini	Risk assessment for persons access to track
Road Rail	Machines that operate on railways and roads
RSSB	Rail Safety and Standards Board
RT1A RT21	Rail contract types used post - privatisation
Sleeper	Support for rails; timber, concrete or steel
Switches	Tapered rails that move to allow trains to cross
SRA	Strategic Rail Authority UK Government Agency
S&C	Switches and crossings
Tamping	Process to consolidate ballast under track
Timber	Support for switches and crossings (bearer)
Turnout	Track form that diverges from
Thermit	Process for welding alumina-thermic
Track work	Track including rails, sleepers, fastenings
Twist	Fault in track usually vertical and longitudinal
VAB	Vehicle Acceptance Body
Wet Spots	Areas where ballast has deteriorated into paste
WCML	West Coast Main Line