The University of Nottingham

"The 7 Day Railway"

by

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Executive Summary

Network Rail, the not-for-dividend company formed by the government in 2002, owns and maintains the national railway infrastructure; essentially the tracks, signalling equipment and stations & structures. The company's main revenue stream is derived from selling "paths", in other words the routes and times for running trains by the passenger and freight train operators. The greatest obstacle to achieving growth and increasing revenue is the frequent blockages (known as "possessions" within the rail industry) to routes that are necessary to allow maintenance and renewal of the infrastructure. The most disruptive of these blockages takes place when a renewal of a switch & crossing (the part of the track that enables a train to change from one line to another, known as and referred to in this document as the "S&C") is needed.

The current installation time required for a standard S&C renewal is 54 hours. This engineering "possession" usually begins on a Friday night and must be completed in time to run first commuter services on Monday morning. Network Rail renews approximately 450 units of S&C every year and the disruption to weekend "paths" is significant and essentially offers only a 5 day railway to the train operators. The company has created a number of projects that it hopes will deliver the same level of service to the train and freight operating companies at weekends as it provides in midweek, hence the term "The 7 day railway" and the most significant of these projects and a key enabler of "The 7 day railway" is the Modular S&C project.

The ultimate objective for the Modular S&C project is to reduce the time of an S&C renewal installation from 54hrs to 8hrs. This will involve a significant culture change and competence for the existing installation staff and the introduction of "kaizen events" on conventional installation activities has already begun to deliver the improvements in time and quality that are required to meet the target of April 2011 for first 8hr installation. These improvements to approach and skills combined with delivery of a factory built S&C unit complete with all supplementary electrical and mechanical components that have been tested and commissioned prior to delivery for immediate use at the point of delivery, will form the factors needed for success.

This project will focus on one of the interim steps to achieving this 8 hour renewal. This will be done by reviewing two elements, firstly on the challenge of a contracting strategy to deliver a new engineering product and secondly on the ability of suppliers to manufacture and deliver an innovative S&C solution for the UK network. This management project will study, document and provide recommendations for both the contracting strategy and manufacturing processes using tools such as the service blueprint interwoven with the proven concept of value engineering.

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1. Introduction

1.1 Background

“Railways will run every day of year” This was the front page headline in The Times on Saturday 19th January 2008. The article stemmed from an interview with Ian Coucher, Chief Executive of Network Rail, who was outlining the demand for rail services to be available 365 days a year and the company’s commitment to find new ways to renew and maintain the infrastructure whilst maintaining routes for passenger and freight train services. Network Rail’s strategic business plan identifies a number of key initiatives that it hopes will deliver this commitment, as previously stated, the most significant of these is the Modular Switches & Crossings (S&C) Project.

The Modular S&C Project is part of a wider organisation within Network Rail, the Infrastructure Investment organisation. The diagram below (fig. 1.1) encapsulates the strategy within Network Rail’s Infrastructure Investment organisation that is intending to deliver the solutions needed to enable “the 7 day railway”. It depicts firstly the organisational change and associated behaviours that bring improvements to conventional renewal methods, followed closely by innovative solutions to radically alter the approach to S&C installation and other key works.

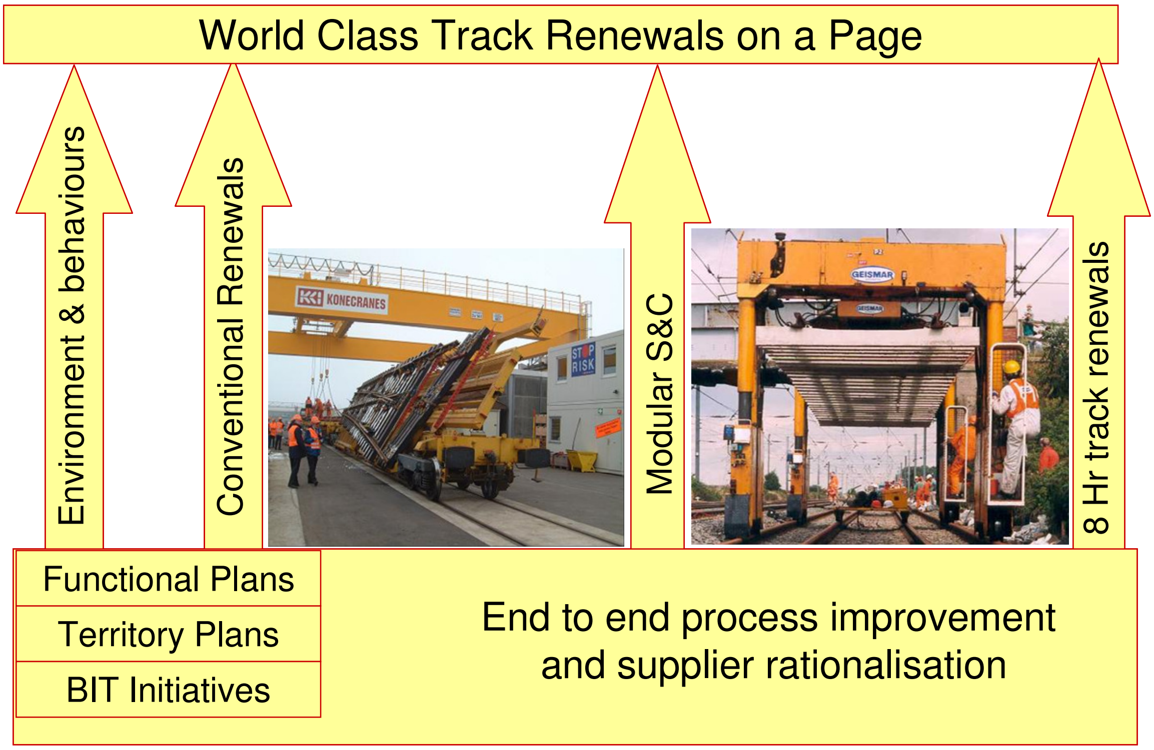

Figure 1.1 “World Class” track renewals on a page

The Modular S&C Project was created 18 months ago as a feasibility study. The key concept of this project centres on the lean manufacturing processes that are firmly established in the motor industry and an attempt will be made to transfer some of the methodologies to the manufacturing and installation needs of the railway in the UK. The current method of renewal involves the manufacture and assembly of a complete S&C unit, often hundreds of miles from the installation site, the purpose of which is to inspect and carry out quality checks. Following inspection and sign off it is then broken down into component pieces and transported by road or rail for re-assembly again at site. This has a number of disadvantages, in particular the often incumbent weather conditions and time constraints. Quality is affected at almost every site and remedial works to achieve minimum standard is common place.

The Modular S&C Project will attempt to reduce the time taken to renew the S&C unit from 54 hours to just 8 hours and will provide a warranted system to standards defined by Network Rail’s Track Engineering organisation. Renewals will then be able to be completed on any night of the week and will eliminate the lengthy blockages that exist today under current practices. This will require significant improvements in all the elements of S&C renewal from component supply, manufacture, delivery and installation capability.

The diagram below (fig 1.2) identifies the steps to how this can be achieved and outlines the high level incremental improvements to S&C installation. There are five key steps to enabling a "World Class" solution; each of these targets a specific improvement and the anticipated dates for implementation.

Figure 1.2 "54 to 8" The incremental steps from current installation times today to "World Class"

The first step of Early Deployment will focus mainly on planning and execution with limited scope on the supply chain outside of better packaging and pre-kitting of tools and equipment and perhaps some components. In parallel to this a fundamental review of the manufacturing process, assembly and delivery will take place, this will form the most significant change in the process. The concept is; that the S&C units, once assembled and tested at the factory (Fig 1.3), should be cut into a number of large sections that can be transported to site and simply re-joined, a process that will form the focus of this report.

This method of production and installation has never been attempted in the UK and will remove a number of "wastes" from the process, particularly the break up of the unit into component parts after testing to re-assemble once more on site whatever the conditions. Scope at this level will be restricted by railway site access, as these "S&C panels" will be delivered by road. Once this concept of delivering S&C in panel form has been proven, the next step will involve the use of special trains (Fig 1.4) which will remove the access restrictions and reduce installation time further. This combined with additional specialist plant and equipment and the intensive development of the highest performing installation teams will deliver the 8 hour solution.

Figure 1.3 Factory assembly

Figure 1.4 Delivery by specialist trains

It is important to understand the key constraint when installing S&C and why up until now the method has failed to see improvements in time and quality as far as records can reveal. There is a very straightforward explanation of this and it centres around one component of the S&C unit, the bearers. These are similar components to sleepers but bearers are used solely on S&C units and are usually much greater in length.

Whilst plain line renewals, the standard straight sections of track between the crossovers, have been improved with the introduction of modern machinery. The way in which S&C renewals are carried out on the UK Network has not changed since the commercial railways started in the late 1800's. This is solely due to the need for the above mentioned long bearers that stretch across the section at which the trains switch from one line to another; they are designed to provide support under the tracks as the train passes through the crossover or turnout. The diagrams below (figs 1.5 & 1.6) clearly identify these "long bearers" on turnout and crossover sections as well as the sleepers on the plain line sections. In addition, figure 1.6 shows indicates how the assembled S&C unit will be cut into the aforementioned panels that can be transported to site and then assembled as a modular unit.

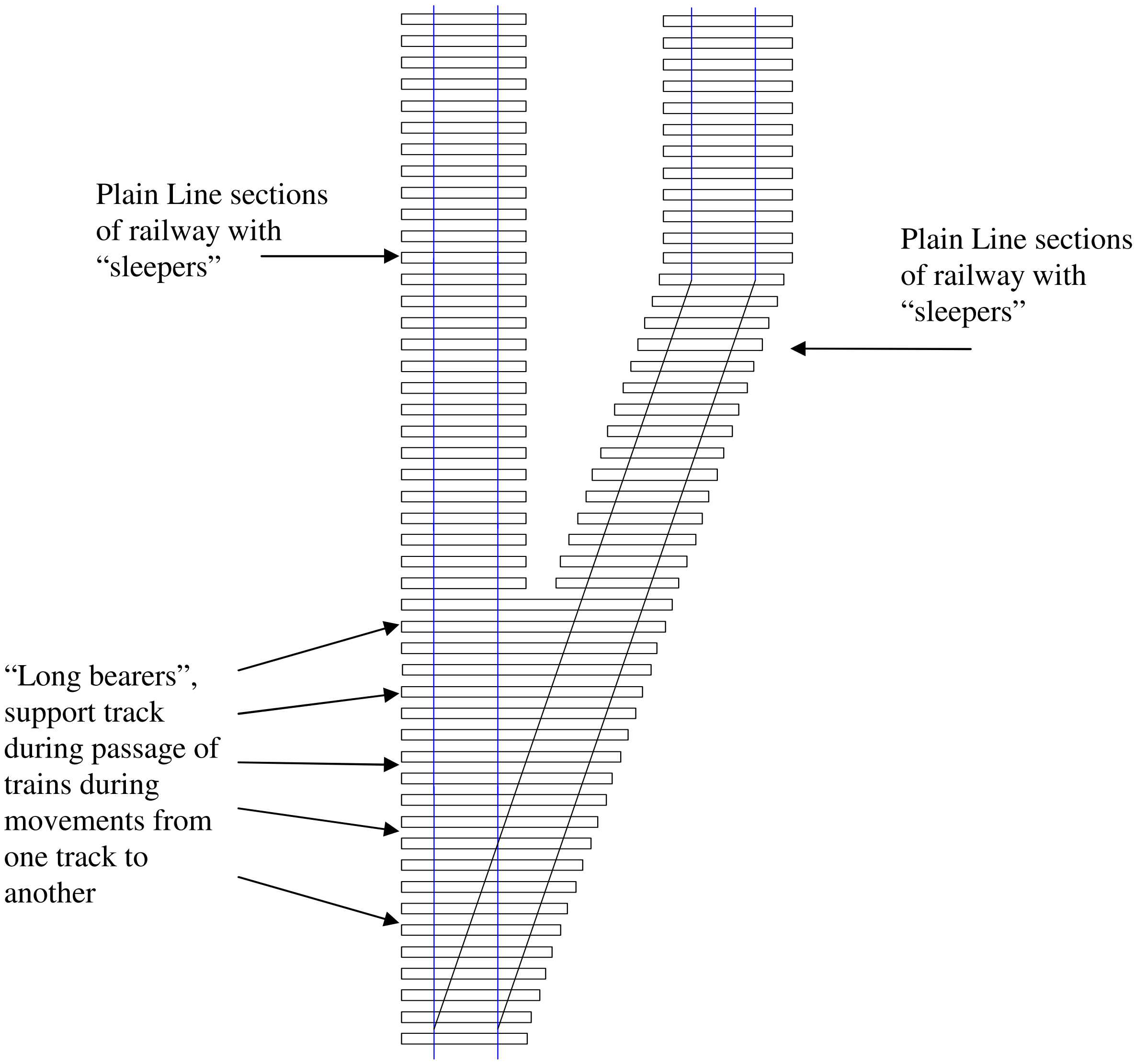

Fig.1.5 Typical S&C turnout track layout

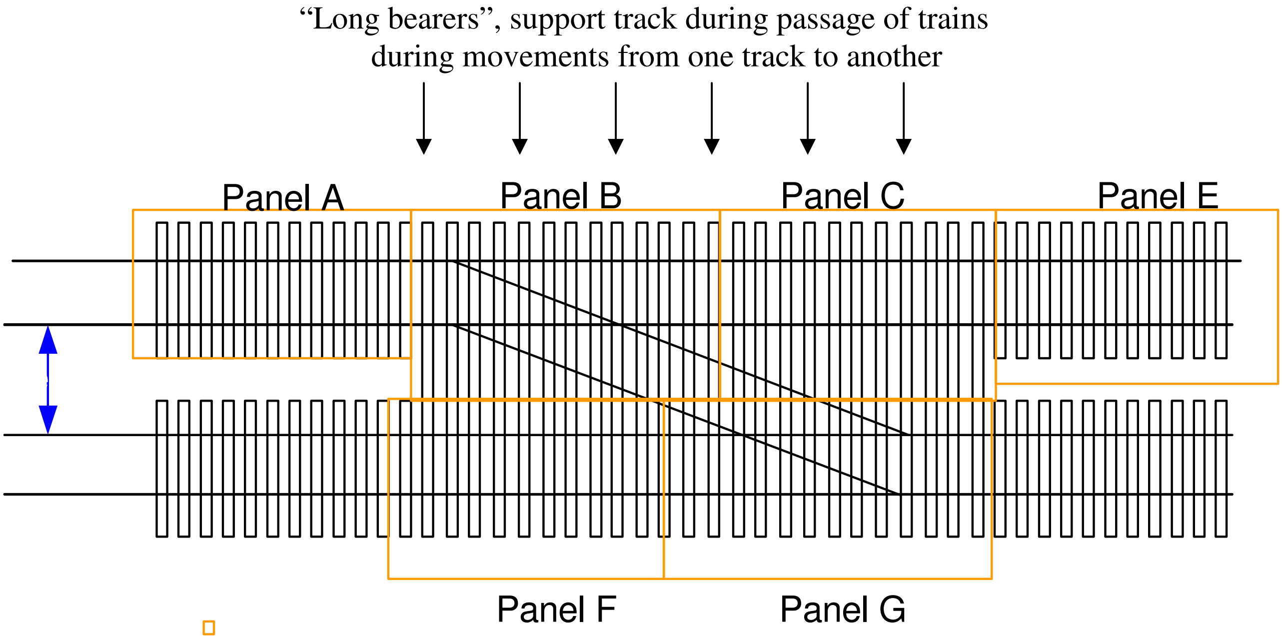

Fig 1.6 Typical S&C crossover track layout showing long bearers and "modular" panels

In recent years, European railway companies have succeeded with this concept of panel style installation; however, this has been achieved with the use of a flexible joint on the long bearer that has been cut (or cast in two pieces) which provides the stability in use as the train passes over that section. However, this is achieved mainly due to the wider gap between the tracks in Europe, this is not a feature of the UK railway infrastructure and a different engineering solution to the long bearers “problem” needed to be developed that would allow the modular installation of S&C.

There are two standard methods of installation of S&C in the UK. The first and by far the most crude and susceptible to error is termed “build in the hole”. In this method, the old railway section is cut into several parts and removed; the old ballast is then excavated. The ground is then prepared by laying a fresh layer of ballast and the new section is delivered in component form and assembled. Time constraints are a major factor in achieving quality standards. The second method is preferable and less affected by issues of time but is subject to individual site constraints. It involves building the S&C somewhere adjacent to the railway and lifting it as one piece into its final operating position, again quality issues can arise due to handling such a large section of railway infrastructure and the build environment not being appropriate to achieving tight tolerances in standards.

As part of the concept of delivering S&C units as panels as opposed to hundreds of components, it was decided that suppliers should then warrant these units as complete and ready packages that would be delivered and effectively unwrapped and installed as a ready-to-go unit. The installation methods were being tailored to adopt lean practices therefore it appeared logical to apply the same techniques with the supply chain. This has formed a significant part of the Modular S&C Project by focussing on the operations management of one of the key suppliers for S&C renewal, that of the S&C manufacture and assembly.

The principles of lean operations include cutting flow time and flow distance. As stated above, this research study will focus on the manufacture, assembly and delivery of S&C units. Emphasis will be placed on standardisation and the development of a “service blueprint”, a method first proposed by Shostack. This is similar to a process map but with the specific inclusion of the customer interaction. The aim is to identify points at which the service may fail and also where value may be added, this tool is also successful at representing the whole process from design to installation as a single operation, in the case of the Modular S&C programme, the customers here are the staff installing the finished unit. Similar approaches to S&C installation have already been implemented in some parts of Europe with mixed successes. The nature of their “newer” and often standard infrastructure lends itself to the “modular” approach, whilst in UK the older and mostly bespoke layouts present a much greater challenge. In “Thinking Beyond Lean” (Cusumano & Nobeoka, 1997), there is reference to Toyota and their “families of well integrated products that share design concepts as well as basic technologies”. This will be fundamental to achieve success, as the current environment sees every S&C installation as a bespoke design.

1.2 Scope

The scope of this programme can be seen in figure 1.7 below. This shows target delivery of modular S&C in the phases described above and the number of business units anticipated for production and delivery. These targets were submitted to the Office of the Rail Regulator (ORR), the organisation set up by the Government to regulate funding for the UK railway infrastructure, by Network Rail as part of its business plan for the financial control period that begins in 08/09. The company anticipates significant cost efficiencies with the advent of the “7 Day Railway”

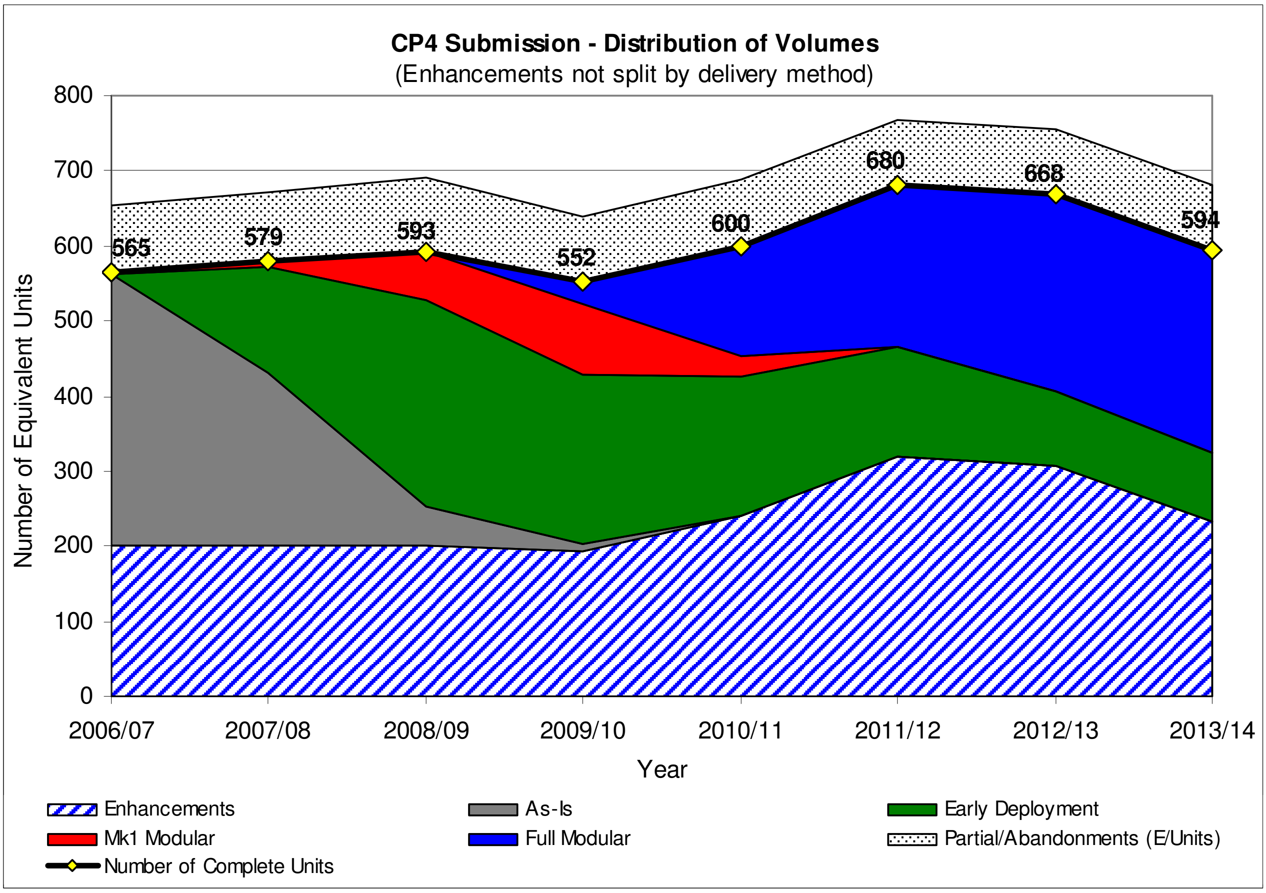

Fig 1.7 Phased delivery of S&C as modular

1.3 Objectives

The following objectives have been agreed following my appointment as project manager for the development and implementation on one of the interim steps to "World Class" installation of S&C. This interim step is named Mk1 Modular and will form the initial technical solution for "modular" installation of switches and crossings on the UK railway infrastructure.

The specific objectives are;

- Review the current process for the supply of switches and crossings and consider the challenge to developing a contracting strategy and recommendations that will enable a "world class" solution to manufacture and supply
- Evaluate the proposed production methods through trials of a technical solution for the implementation of modular installation of S&C, and in particular with the use of value engineering and service blueprinting as techniques to improve the processes involved.

2. Review of Literature

2.1 Introduction

The process required as part of the objectives of this study centres on the ability to determine the most appropriate method of supply for modular S&C, and furthermore methods used by current S&C manufacturers in producing and delivering S&C. The project is driven by a high level company strategy to change the way the railway infrastructure in the United Kingdom is made available for train operations.

The literature reviewed for this project therefore has focussed on the following areas; Contract Strategy, Lean Production/Project Management, and Operations Management, specifically lean manufacturing. The purpose of reviewing the literature was to establish industry norms and best practice, and if possible in a railway environment. The closest parallels that could be drawn from the literature found was mainly in the automotive industry with a number of projects with similar structure and delivery mechanisms as found in the railway industry, in particular the railway renewals projects such as the Modular S&C Project. As renewals in the railway industry are funded by the Office of the Rail Regulator (ORR), it was also considered appropriate to review guidelines for contracting strategy outlined in government literature.

2.2 Contracting Strategy

Identification of the right suppliers at the right time, with mutually agreed expectations can be extremely difficult due to the complexities of the market and the fact that most processes in manufacture rely on the human execution of these processes. One of the most elements of a successful commercial agreement is the clarity of expectations and specification accompanying the contract, stated James.E.Taylor, a senior executive of General Motors in 2000. He also added that most failures in execution can be traced back to unclear specification.

As an innovative development project, the Modular S&C project team need to consider carefully the specification to potential suppliers. For example, the existing supply base may have many years experience in producing conventional S&C units but no experience of producing modular units therefore the specification may involve the process for manufacture. Research shows that process requirements should be mentioned in specification, so as to check that the product can be produced in the manner required by the customer (Nellore, 2001). In addition to this, specifications may also include standards that are to be followed (Smith and Rhodes, 1992).

The ORR fund all railway projects and in the Government's guidelines for procurement and contracting the Office of Government Commerce (OGC) outlines the following high level requirements as a starting point for the client.

What clients need to be able to do:

- Be able to define clearly what they want
- Be aware of the market and negotiate deals that are justified on whole life value
- Know how the industry works, collecting market intelligence and regularly carrying out market research
- Know the major players, establish who regularly works well with whom and get to know the specialist suppliers
- Develop more effective arrangements to build up and share knowledge about the Performance of particular suppliers and the construction market generally, so that decisions about the appointment of suppliers are better informed.

Analysis for the contracting strategy will consider these key points. The following are excerpts from a case study of the Government's Environment Agency and shows how it has approached its engineering projects and the benefits achieved.

> *The Environment Agency's procurement strategy for engineering works has the following aims:*
>
> - *to deliver best value for money to the Agency*
> - *to be at the leading edge of technology, innovation and business best practice*
> - *to champion environmental best practice.*
>
> *The Agency has increased the value of its projects by combining similar projects or work within a region. It has also reduced the number of consultancy suppliers from forty-six to four.*
>
> *It has a national team responsible for the procurement and project management of capital projects to deliver new ways of working and to provide consistency in processes and relationships with suppliers.*
>
> *Suppliers should be better informed about the Agency's needs. Projects will be of higher value and for longer periods. This will allow suppliers to learn from one part of the work to the next and to agree targets for improvements to both cost and quality. Suppliers should make higher margins and cover both fair profits and overheads. They will have greater certainty of work, enabling them to invest some of the profits in development work.*
>
> *Fewer suppliers will be used, who will be able to develop a better understanding of the Agency's needs and to respond with more innovative solutions to those needs.*
>
> *Suppliers will receive a more consistent approach from a better informed and trained client. Suppliers' profitability on Agency work is now also linked to the achievement of the Agency's target.*

According to Liker (2004), Toyota have been rewarded time and time again for its serious investment in building a network of highly capable suppliers that are truly integrated into Toyota's extended lean enterprise. Most importantly however, Liker adds that Toyota's suppliers are integral to the just-in-time philosophy both when it's working smoothly and where there's a breakdown in the system, by working hand in hand with suppliers.

2.3 "Lean" Manufacturing

Lean production was introduced into the automotive industry over the last five decades, and studied in depth by Womack and his team in the 1990's. It is described by Shingo (1985) as "making items *when* they are required and in the *quantities* required, all as inexpensively as possible". The concept of "Lean Production" or "the Toyota way" is fundamentally about continuous improvement, sometimes referred to as "kaizen" and defines the basic approach that Toyota has to doing business. "When we talk about kaizen or continuous improvement, we are talking about the relentless, never-ending pursuit of eliminating waste in all of its forms" (Cunningham & Fiume, 2003).

Lean firstly focuses on identifying all source of waste in the process or workstream and then specifies what value means in terms of its products. Womack and Jones (1996) cite value as being defined by the customer and subsequently created by the producer. They go on to state that it is then necessary to identify the value stream, or actions that are necessary to deliver the successful engagement of the activities required to design, manage and schedule, and then produce the desired product. This is simply another step in indentifying or exposing waste, as a full analysis of the processes in terms of what the customer sees as "value" will serve to highlight activities which fall into the following categories;

- Those which create value
- Those which are unnecessary and non-adding value activities and are avoidable
- Those which are non-adding value activities but are unavoidable

The next step in lean operations is described as a series of flow and conversion activities (Koskela, 1992). Conversion activities are ones which are completed to add value to items or information being turned into a product**,** whereas flow activities, which can include such things as quality inspections and transportation of components to different locations and waiting, do not add value to the product (Dunlop & Smith, 2004). Increasing the efficiency of flow activities or reducing their unproductive time, therefore creates a “pull” method of working and “continuous flow”. This is the key methodology of lean manufacturing; making sure that production only takes place when it is necessary to complete upstream activities, rather than producing and storing large quantities of inventories as a buffer.

2.4 Operations Management

There are many interpretations of Total Quality Management (TQM). In BS.4778: Part 2 (1991) it is defined as: “a management philosophy embracing all activities through which the needs and expectations of the customer and the community, and the objectives of the organisation are satisfied in the most efficient and cost effective way by maximising the potential of all employees in a continuing drive for improvement” (i.e. TQM is both a philosophy and a set of guiding principles for managing operations).

Slack *et al* (2001) stress the need for the approach to cover all aspects of the organisation and every person within it and argue that one of the most powerful aspects to emerge from a TQM approach is the concept of the internal customer and supplier. Therefore, it is suggested that a TQM approach should be taken across all stages of the manufacture and supply. Robbins (2003) concurs, stating that the quality management is driven by the constant attainment of customer satisfaction through the continuous improvement of all organisational processes.

The stages of manufacture and supply could be referred to as the organisation’s order management cycle (OMC) (Shapiro *et al, 1992)* and it is often what determines the customer’s experience. They add that focussing on the OMC results in increased customer satisfaction, by keeping promises, and offers managers the greatest opportunity to improve overall operations.

The “service blueprint “ as outlined by Chase *et al* (2003) is an effective tool for mapping processes, highlighting touch points with the customer. An important part of process design is the concept called Poka Yoke, meaning “one way” “avoid mistakes”. This method of “fail-safeing” against potential product or activity failures assists in standardising the approach to delivering improved consistency. According to Bicheno (2004), the characteristics of a mistake-proofing device is that it undertakes 100% automatic inspection and either stops or warns of a defect, and that the aim of poka yoke is to design devices or processes that prevent mistakes becoming defects. However, these processes still need to be managed properly, Hardy (1990) stresses the need for the business management to appreciate the importance of getting the operations plan right and then pursue it with skill, effort and enthusiasm. Service blueprinting and poka yoke is fundamentally about prevention of errors which is a major factor in the railway industry where safety and regulatory demands are paramount and a “right first time” approach is crucial.

All operations need to have in place some form of performance measurement as a pre-requisite for improvement. Slack *et al* (2001) use quality, speed, dependability, flexibility and cost. Tangen (2005) states that a performance measure should fulfil more practicable measure requirements; for example, it should have an explicit purpose and be properly visualised for the right end user. This can be added to by considering the need for a “balanced scorecard” (Kaplan & Norton, 1992) ensuring that no one area of measure suffers at the expense of another.

3. Methodology

3.1 Concept

Lean

As stated previously, “Lean Thinking” is a concept that has its roots in the Toyota Production System. Whilst it has been around for some years the difficulty is invariably how to apply it in any given situation or industry. The first obstacle to overcome is the mindset that the railway “doesn’t make cars”. However, the parallels between car production (and indeed any engineered product) and the S&C renewals process are relatively aligned, as shown in the following table (fig 1.8):

Toyota Car Production	Modular S&C
Specification	Multi-Functional Requirement (MFR)
Design	Topographical survey, outline design & detailed design
Component Suppliers	S&C manufacturers
Assembly line	Installation & commissioning
Delivery to customer	Hand-back

Fig 1.8 Car industry vs. railway industry

The Modular S&C Programme has been established to implement the basic elements of ‘Lean’ within S&C renewals. This is being carried out in a series of steps:

The first step was to recognise that only a small fraction of the activities we carry out are actually adding value, the rest is waste. One of the key drivers in the Early Deployment and end to end process analysis has been the elimination of non-value-adding activities.

The second step has been to make dramatic changes in a short space of time through structured “Lessons Learned” and “Kaizen” or process improvement workshops. This helps to engage personnel and break down the "we have always done it this way" blockage to get things moving. (It also shows that the changes do not need to cost a lot of money to make.). This has been the essence of the first stage of the Modular S&C Project, Early Deployment, and has also helped accelerate the development of the Mk 1 Modular system. The aim is to build on these early successes, to sustain Early Deployment wins, and integrate them with an overall strategy to implement Lean across the whole Modular S&C process.

Issues uncovered during development have reinforced the need for a wide scale change is required across both Network Rail and the supply chain. These issues include:

- The need for an overall assurance system and
- The requirement for information to be produced on time, right first time
- The need for improved multidisciplinary team working
- The need to involve manufacturers, hauliers, installers and the maintainer

Value

According to SAVE (The Value Society), Value Analysis or Value Engineering was conceived in the early 1940s by Lawrence D. Miles while he was employed by General Electric (GE). At the time, GE were a major US defence contractor which was facing difficulties in securing materials needed to produce their products during World War II. Miles realized that if value and related innovation improvements could be systematically “managed,” then GE would have a competitive advantage in the marketplace. With that in mind Miles began to devise what he termed the function analysis concept, later termed value analysis.

The substance of this analysis centred on understanding the function of the component being manufactured. He questioned whether the design could be improved or if a different material or concept could achieve the function. This thinking is fundamental to modular S&C programme and will form an important part of the analysis of suppliers manufacturing processes.

3.2 Value Stream Mapping

Mapping the 'value stream' reveals how the process operates today. This may not be how it is supposed to operate, but it does provide a guide to actions needed to create the future state. Mapping acts as a consciousness raising exercise for all those involved and it provides a powerful diagnostic of how unsound the current process is. It reveals all the wasted time and effort in the process. From it we can quickly see which steps that are incapable of delivering quality on time, which are not available when needed (e.g. because they are broken), which are inflexible, and where the bottlenecks are. Knowing this we can use quality tools to analyse the root causes of variance, improve process availability and improve flexibility.

The first step is to recognise that only a small fraction of the steps that are carried out are actually adding value. The rest is waste. One of the key drivers in the reviewing the end to end process has been the elimination of non-value-adding activities. The following diagram (fig 1.9) outlines the key activities that occur in a typical renewal of S&C, from survey to hand back and close out. Note: As shown in figure 1.7 above, a number of S&C units are delivered and installed under what the company terms "enhancement schemes", these are managed by a separate organisation within Network Rail and excluded from this study which focuses only on like for like renewals.

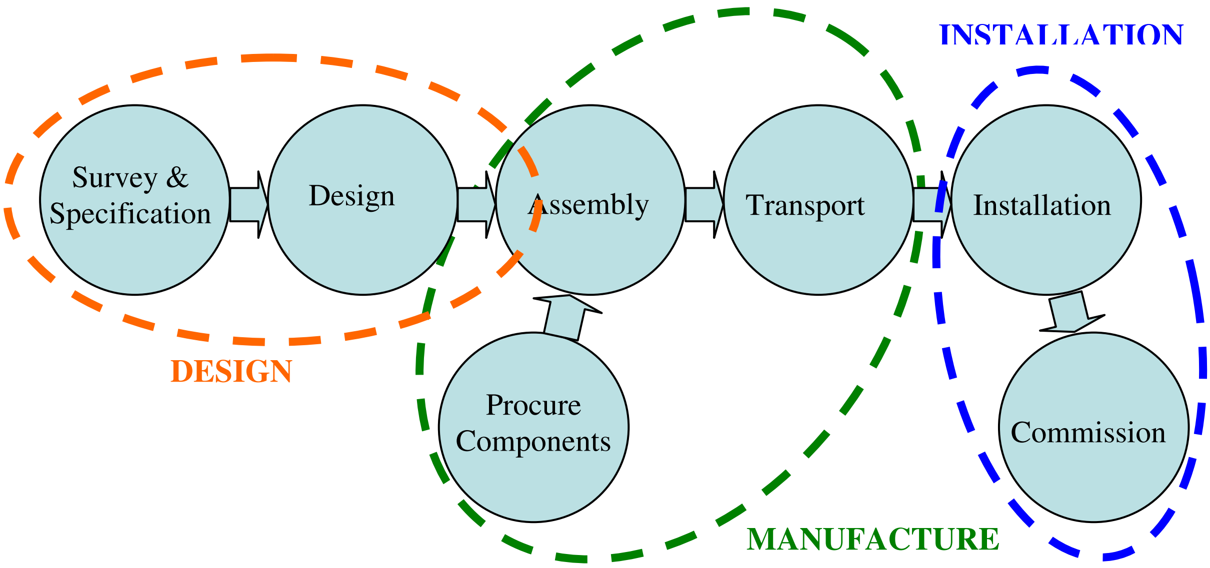

Figure 1.9 Key Functions in the S&C Value Stream

Survey/Design

Site Investigation: the survey work carried out in order to assess the physical condition of the work-site (e.g. condition of ballast, formation/soils, drainage, identification/location of buried services, etc.) to provide information to enable an appropriate Multi-Functional Requirement (MFR), or specification for design, to be drawn up. This work is currently carried out nationally by one contractor managed by the Infrastructure Investments, the Network Rail organisation that is responsible for projects that deliver national renewals of the S&C and plain line track renewals. Due to the highly specialised nature of this work, it is outsourced using contractual arrangements; it involves such work as the use of Ground Probing Radar, Automatic Ballast Sampling, digging of trial holes when necessary, etc.

Topographical Survey: a full site survey (referenced to survey stations), including aspects such as the asset type and condition, signal sighting distances, overhead line infrastructure, type and condition of switch heating, existing telecoms type and condition, spare capacities, etc. It should also include a correlation to verify that the signalling drawings and records accurately reflect the actual on-site dimensional detail. This work is currently carried out by five external Design Houses (Arup, Atkins, Jacobs, Owen Williams and Scott Wilson) under contracts managed by Infrastructure Investments.

Outline Scheme Design: the creation of a high level (1:200) scheme drawing for the entire work site, (including Track, Signalling, Electrification & Plant, etc,). Satisfactory completion of this stage results in Network Rail giving 'Agreement in Principle' (AIP) to proceed with detailed design. This work is currently carried out by the same five Design Houses as above, managed by Infrastructure Investments.

Detailed Scheme Design: the creation of a detailed (1:100) scheme drawing of the entire work site. Satisfactory completion of this stage results in Network Rail giving 'Approval for Construction' (AFC). This work is currently carried out by the five Design Houses managed by Infrastructure Investments. It is normally done by the same Design House that produced the Outline Scheme Design.

Manufacture, Assembly, & Transport

S&C Component Supply: the procurement and manufacture of all materials (apart from rail which is supplied free-issue), component parts and sub-assemblies (e.g. rail switches) necessary for the subsequent assembly process. It includes castings, forgings, Point Operating Equipment (POE) and small components. There are currently three major S&C manufacturers (Balfour Beatty, Corus Cogifer and VAE (UK) under contract with Network Rail, managed by Network Rail's in house National Delivery Service (NDS) this is an organisation with Network Rail that was created to manage procurement of all systems and materials associated with renewals and maintenance.organisations.

S&C Layout Assembly: the assembly of component parts, sub-assemblies, bearers, etc. to create a complete and ready to install S&C layout, tested and ready to be commissioned. Note: this also includes the creation of 1:50 scale manufacturing drawings, from the Detailed Scheme Design drawings. Layouts are generally given a pre-delivery audit by Network Rail representatives. The manufacturers are as above, managed by the National Delivery Service (NDS).

Transport to site: the transport of the S&C layout to work site, either by road (currently over 75% of jobs) or rail haulage. Road haulage is sub-contracted by the S&C manufacturers and entirely managed by them; this is often under guidelines from the Department for Transport with regards to abnormal loads. Rail haulage is managed by NDS under their three engineering train contracts and is arranged under

<u>Installation & commissioning</u>

Enabling works: all the work that has to be carried out in advance of the preparation, core and follow-up engineering possessions that are used to install the S&C, including removal of cables and other obstacles from the 'keep out zone' around the S&C installation, slewing (designed lateral movement) of overhead power line equipment, completion of items found during the site investigation / topographical survey that should be addressed by Maintenance (e.g. drainage, vegetation clearance, replacement of damaged cable troughing), etc.

Installation: all the work-site activities, including the taking of the engineering possession and the overhead line electrical isolation, removal of existing S&C, excavation, laying bottom ballast, installation of new S&C, laying of top ballast, tamping, welding and stressing. The four installation contractors for track renewals are Amey Colas, Balfour Beatty, First Engineering and Jarvis. The contracts are managed by Infrastructure Investments.

Commissioning: signal testing and confirmation that the S&C and signalling systems meet their respective specifications and work in accordance with their design. Commissioning is carried out under the Installation contracts with the above.

Close-Out: the 'Hand-back' of responsibility for the S&C from the installer back to the operator and maintainer, and ensuring that the project is closed out in an orderly manner with updated asset management information, capitalised assets, settled contractual accounts and any contingencies and warranties put in place.

Figure 2.0 (Appendix 1) below shows the principal hand-offs between each function in the process.

S&C Track Renewals – E2E External Value Stream

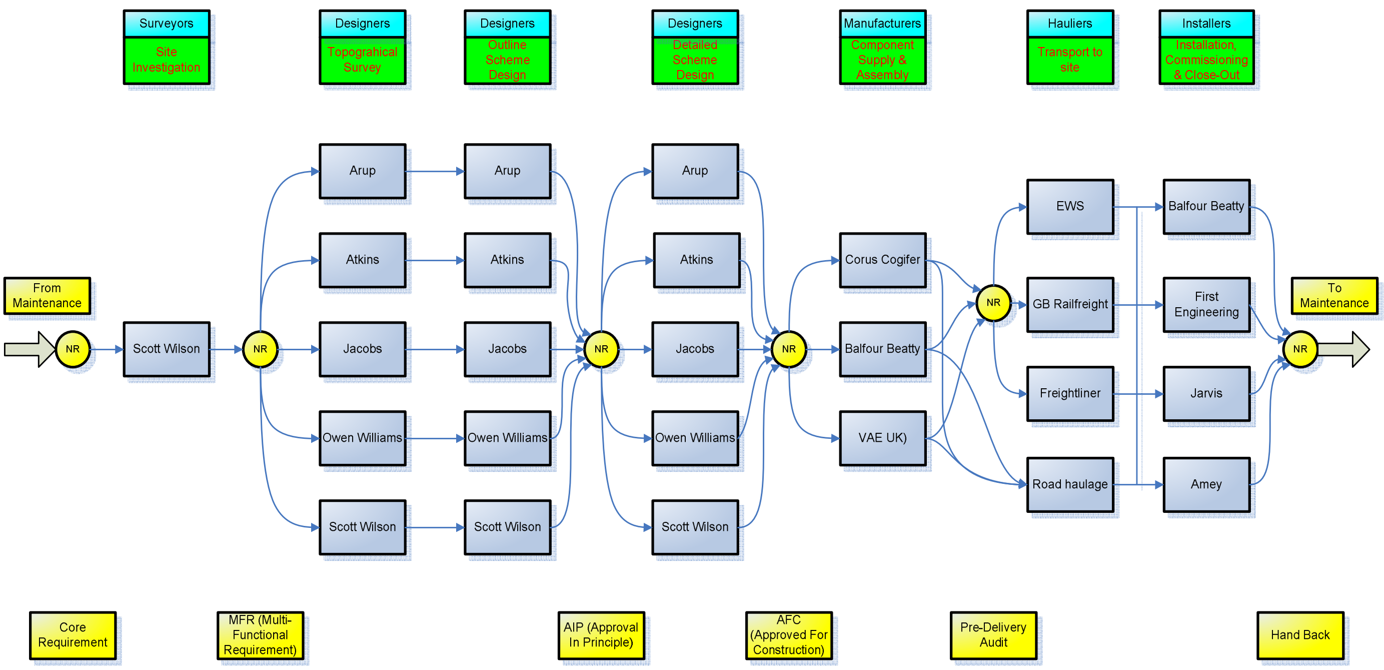

Figure 2.0 Steps of manufacture, assembly, delivery and installation

3.3 Market Analysis

In considering the anticipated change required by suppliers to produce modular S&C, it is important to establish the current market environment in which Network Rail is involved. Overall Network Rail is in a relatively strong position to maximise the benefits of competition in the S&C market. This is primarily because:

(a) Network Rail is the main buyer with significant expenditure

(b) It is easy to switch suppliers

(c) Network Rail's ability to procure directly from sub-contractors for components (backward integration)

(d) The abundance of supply within the market

However, there are also some significant barriers to overcome, mainly as a result of:

(a) Limited suppliers in the market due to barriers to entry e.g. start-up costs, experience, product acceptance; and,

(b) Suppliers awareness of criticality of components.

Therefore, in trying to determine this business environment in which Network Rail operates and the capacity for introducing change to improve supply, analysis must be completed on the industry suppliers for S&C. The “Five Forces Model” (fig 2.1) developed by Professor Michael Porter of Harvard Business School in 1980 provides one model that can identify the factors that can affect an organisation’s competitiveness. This can help a firm choose the appropriate strategy to enhance its opportunities (Sloman and Sutcliffe, 2004). This particularly important in the case of modular S&C where one supplier would be chosen to develop the new product as part of the interim step of Mk1 Modular.

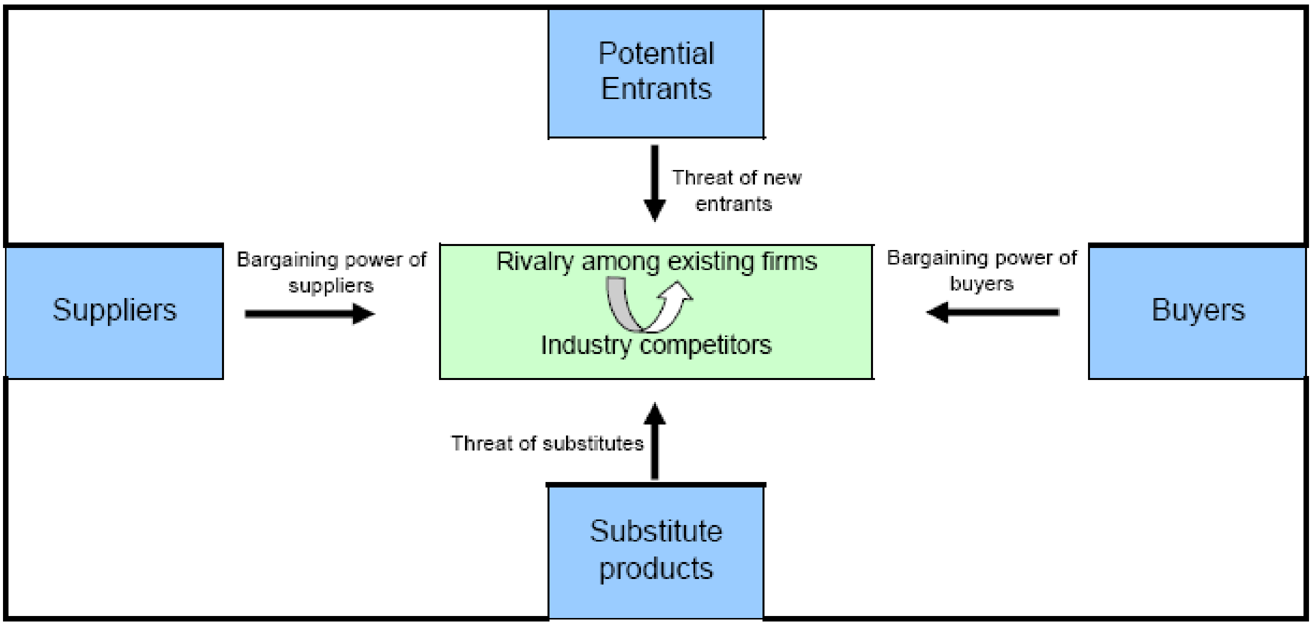

Figure 2.1 Porter's "Five Forces Model" 1980.

Analysis using Porter's "five forces" method revealed the following;

Industry Rivalry (Medium High)

The industry is mature and product demand is decreasing or stagnant.

The products supplied are very similar and Network Rail suffers little expense when changing suppliers. There are only three core suppliers in the market. However, of these three, two have the capability to significantly increase capacity. Network Rail must leverage these three suppliers against each other in order to optimise delivery performance (quality and timeliness).

Barriers to New Entrants (Medium High)

Some significant barriers to entry exist which include: expertise required to manufacture specialist products; high start-up cost; and product acceptance.

However, as products are manufactured to a standard technical specification, if new suppliers can achieve this they should be able to compete directly. Distribution channels may be difficult to access due to geographical constraints and current relationships between Suppliers and Network Rail current delivery teams.

Pressure from substitute products (High)

The introduction of Modular S&C into the UK may result in up to 75% of conventional S&C being renewed in modular format and provides a significant opportunity to substitute products.

However, these substitutes are likely to be provided to a large extent by the existing conventional S&C suppliers as processes for manufacture and assembly are relatively similar.

Power of Suppliers (Medium High)

There are a few suppliers in the market who have the capability of producing S&C products due to the specialised nature, product acceptance and high setup costs. However, where direct competition is available it is easy for Network Rail to switch between suppliers (assuming product acceptance has been achieved). The purchasing power of Network Rail for S&C is significant to all potential suppliers.

Power of the Buyer (Medium High)

Network Rail has useful purchasing power within the market as it is the primary UK buyer of S&C and there is sufficient supplier capacity to permit removal of existing suppliers. Network Rail should be able to use volume guarantees and other such mechanisms to maximise its leverage with S&C suppliers who are each competing for a share of the supply of similar products. Network Rail has a relatively low switching cost.

In terms of logistics for supply of S&C, the following diagram (fig 2.2) shows the locations for S&C installation for the last three years as well as the forecast for the coming year. Predictably, this shows a high concentration of units being installed in the London and Midlands and may be a contributing factor in selecting a supplier for modular S&C, this is due to the restrictions faced when arranging access to the railway for installation purposes.

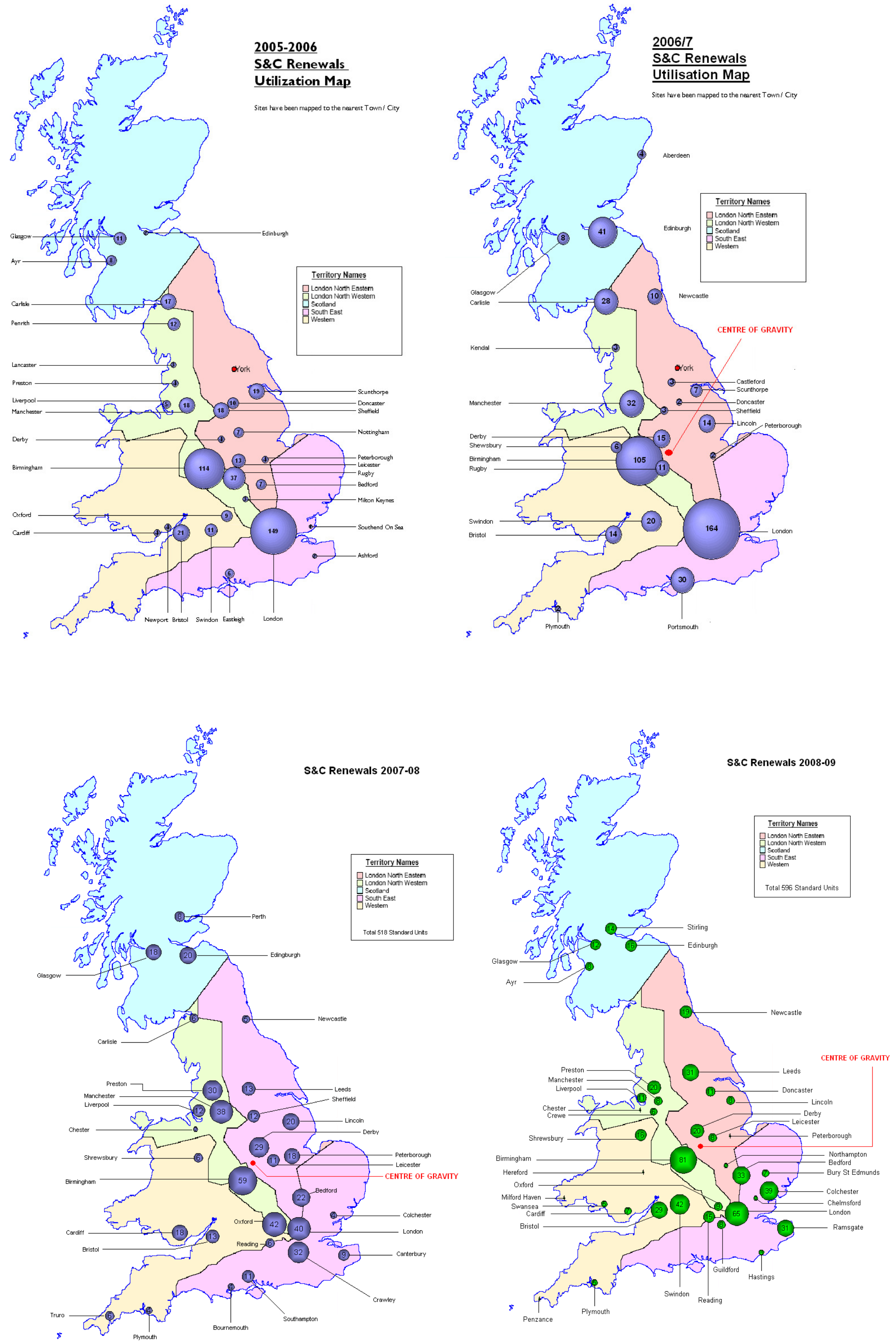

Figure 2.2 Maps of UK showing distribution of installed S&C

3.4 Current S&C Manufacture

Manufacturing has been the focus of quality-related attention ever since the industrial revolution. More has been written about manufacture than any other industrial subject, and yet problems abound. One reason is that many of the problems experienced in manufacture have their origins elsewhere, such as late definition of requirements (which are then subject to change), lack of feedback, etc. That is not to say that the manufacturers are fault free, observations of working practices highlight areas of concern immediately, but there is an obvious need to get away from the historical, adversarial relationships and blame culture that the industry has become accustomed to.

In considering the best strategy for the development of Modular S&C and in particular, the manufacture and supply of the modular style S&C panels, a strengths / weaknesses / opportunities / threats (SWOT) analysis was carried out for each of the following options:

1. Develop capabilities of external suppliers
2. Build and own a Network Rail assembly facility, but operated by a single supplier
3. Network Rail builds, owns and operates an assembly and manufacturing facility

SWOT analysis on these three options is as follows;

SWOT – Option 1 (develop capability of external suppliers)

Strengths	Weaknesses
- Retains competition - Understanding of existing processes - Established skill base - Reduced dependency on planning process - Existing plant and equipment (low investment)	- Perception of poor quality - Current culture thrives on 'fire-fighting' - Ability to adapt to new methods of manufacture
Opportunities	**Threats**
- Can start change now - New shell allows new start - Gives suppliers confidence to recruit to meet current demand - Challenges suppliers to raise their performance to meet track standards	- Need competitors to work together to optimise the assembly system - Requires suppliers to make capital investment

Figure 2.3 SWOT Analysis on Option 1

SWOT – Option 2 (NR owned assembly facility, operated by a single supplier)

Strengths	Weaknesses
- Network Rail control - Network Rail visibility	- Eliminates competition - Requires Network Rail capital investment (fixed overhead) - Understanding of existing manufacturing processes
Opportunities	**Threats**
- Change to contract - New shell allows new start - One facility, rather than three - Step change in culture	- May need to establish skill base - Dependency on planning process - Delay in starting change - Suppliers not confident to recruit to meet current demand - De-stabilise suppliers (maintenance & residual supply) - Time to validate processes and achieve quality

Figure 2.4 SWOT Analysis on Option 2

SWOT – Option 3 (assembly and manufacturing facility owned and operated by NR)

Strengths	Weaknesses
- Network Rail control - Network Rail visibility	- No known precedent anywhere in the world - Eliminates competition - Requires significant Network Rail capital investment (fixed overhead)
Opportunities	**Threats**
- Change to contract - New shell allows new start - One facility, rather than three - Step change in culture	- Will need to establish skill base - Dependency on town planning process - Delay in starting change - Some suppliers would exit market - De-stabilise suppliers (maintenance & residual supply) - Significant time to validate processes and achieve quality

Figure 2.5 SWOT Analysis on Option 3

The analysis above would suggest that developing the existing supplier base would offer the most realistic opportunity for success with modular S&C, the option of a Network Rail owned and operated facility would create a significant risk to the company. Although manufacturing was a core competence for the company under the old British Rail organisation, a step such as this for Network Rail may be too ambitious at this point and the timescales targeted for full implementation of the Modular Programme would bring additional difficulties. There have been clear instances where money has been invested in new buildings without the anticipated benefits being attained. The following case study illustrates the point.

The Royal Ordnance Main Battle Tank (MBT) factory outside Leeds was built in 1939. It was developed over the succeeding years, producing such famous MBTs as Centurion, Chieftain and Challenger. By the early 1980s it was a modern factory, equipped with large numbers of state of the art numerical control (NC) and computer numerical control (CNC) machine tools (largely funded by a massive order for MBT's for Iran, prior to the demise of the Shah), and won the Queen's Award for Exports on two occasions.

In 1986 the factory was bought by Vickers, who carried out a number of improvements, the most significant of which was the construction of a brand new manufacturing facility – all under one roof 540 metres long by 60 metres wide. Following a radical review of the make/buy policy, the business was moved into the new facility. Whilst manufacturing costs were reduced, the quality improvement was barely perceptible.

In 1995, following a number of quality improvement initiatives, Ingersoll Engineering consultants were brought in to implement a programme of lean manufacturing. The results were truly significant with quality improvements and tangible cost savings.

An exercise was completed to try to distinguish between what methods or approach are in place today and how it would need to be to achieve the ultimate success with the project, an 8 hour installation. There are a number of key changes required as the table below (fig. 2.6) shows, it makes the comparison with the current and possible future state and will provide a useful reference in trial implementations of the modular S&C unit production.

Current	**Modular**
Many different types of S&C	Standardisation of products ("kan-ban" systems with minimal stock top-up)
Customer preference requirements	Testing of the units before despatch
Items added to assembly in the field (in non-factory environment and less safe conditions	Pre-kitting of loose components for ease of installation
Limited testing of the units before despatch	Maximum testing of units before despatch
Limited protection of panels during delivery	Protection of panels prior to delivery
Limited pre-kitting of loose components for ease of installation	Topping up of installer minimum stocks for loose components by suppliers

Assurance process not managed by Network Rail	Self assurance with active feedback mechanism from downstream users (spc and data available on non-conformance) Remedy for non-conforming product and consequential loss
Non-conforming product delivered (but scale not known, could be high or low percentage)	Incentive for right first time and continuous improvement
Items removed before despatch and re-assembled in non-factory condition	Active feedback of cost of late information supply and impact (cost, delivery date and warranty)
Designs that cannot be made to tolerances	Pre-fabrication of as much as possible (e.g. points heaters, POE, foam protection) Designs that can be built (suppliers and designers working together)
Informal Supply Level Agreements	Formal Supply Level Agreements with clear KPI's
Poor relationships, lack of trust, lack of data	Excellent relationship and respect between parties – joint fixing of problems
Multiple points of contact with component suppliers	Components ordered on national basis to gain surety of supply, bulk discount, obsolescence management
Limited supplier development	Active supplier development
Poor assembly environment, limited assembly jigs and fixtures, limited handling equipment	Controlled assembly environment Use of jigs, fixtures, assembly jigs and purpose-built handling equipment
Re-creation of design drawings in 3D	One design model (no duplication)
CNC programmes tested on live components?	CNC programmes validated in CADDS, not on live components (e.g. Vericut CAD tool)
Limited rail connection	Rail-connected to reduce handling operations
Some sites in awkward logistical locations	Sited within M62, M11, M6, M4 envelope
450 units per annum	600 units per annum

Figure 2.6 S&C production (current vs. future)

4. Practical Application

4.1 Implementation of “Bearer Tie” solution

Background

The first stage of the Modular S&C programme required a technical solution to splitting the long bearers found in S&C installations. As stated earlier in this report, a solution had been established previously in Europe with immediate success in countries such as Holland, Germany and Switzerland. However, these European solutions involve a “flexible” joint at the centre of the bearer. This design succeeds on European infrastructure as the distance between adjacent tracks allows a certain tolerance for flexing. This type of joint would not suitable for the UK network of track as the proximity of one track to another would require that the characteristics of the bearer would need to remain the same in its split state as it had in its original form, in other words, a rigid system.

A development partner was contracted to produce designs for a UK type split bearer solution. The choice of contractor was intended to provide continuity from design through construction and delivery. This contractor was Balfour Beatty Rail Track Systems (BBRTS), the most centrally located of Network Rail’s S&C suppliers. Their main factory is in Sandiacre, near Nottingham, and following their acquisition of Edgar Allen’s, a rival S&C manufacturing business, they now also have a factory in Sheffield, and a cast-manganese-crossing foundry in Bathgate. This makes them the only UK supplier of cast crossings, capable of providing more than 98% of the geometries needed for S&C installation in the UK. These factories have an assembly areas dedicated exclusively to producing S&C layouts for the UK market, both sites are rail-connected which allows the option of loading assembled panels directly onto rail wagons for transportation to site. This is in addition to the standard method of delivery on road wagons.

Their layout yard for the Sheffield factory is currently on Network Rail leased land near Rotherham, they also assemble layouts for Scotland in Bathgate. In terms of capability, they claim to have a maximum combined capacity of around 600 renewals layouts per year, but around 450 is believed to be a more realistic steady-state figure. They have a high level of technical expertise "in-house" which Network Rail believed would lend itself to developing a solution for creating the "split bearers". Their cast iron foundry on the Sandiacre site also provides a large proportion of the components used by the other S&C manufacturers.

As part of the development of the split bearer solution for S&C installation, a strong emphasis was placed on BBTRS to improve the current production processes and in particular the principles of lean manufacture. A number of workshops were held with them to introduce the aims of the project. The diagram below (fig. 2.7) was presented to the BBTRS as the high level concept of what the trials would aim to achieve, removing as many activities from the worksite as possible and thus the critical path.

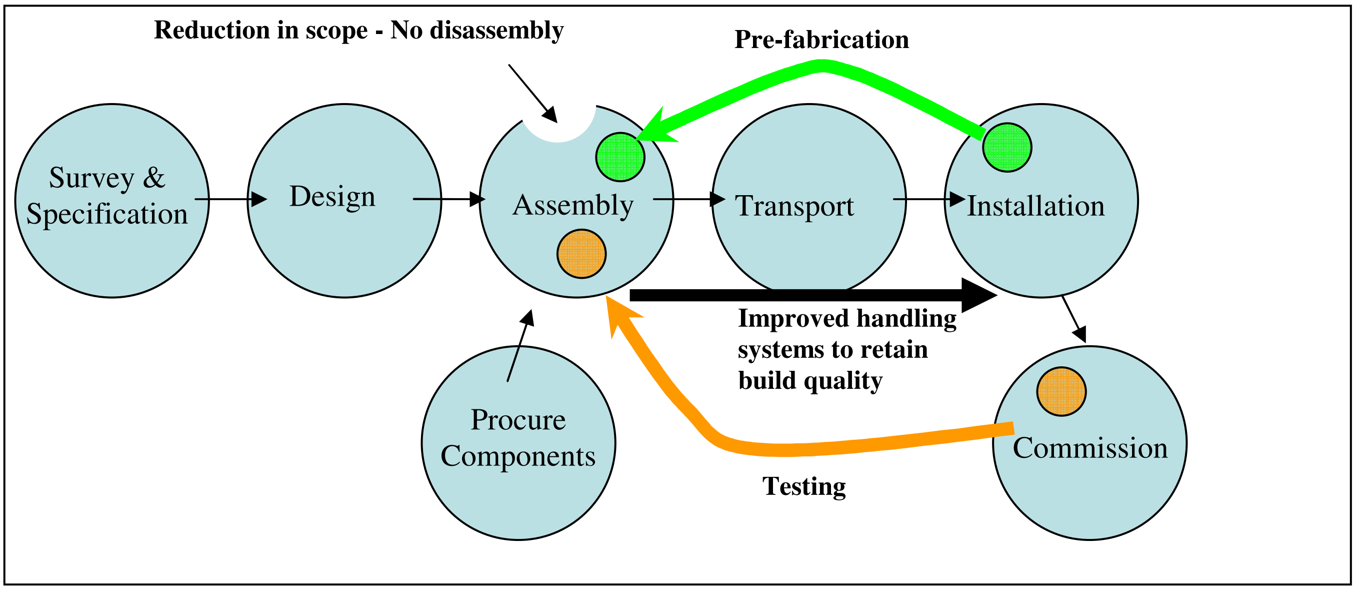

Figure 2.7 Applying lean to S&C manufacturing

4.2 Design & test of the new joint

A specification for the bearer joint was produced for BBTRS by Network Rail, they produced a drawing (appendix 2) and subsequent prototype version to this specification. The next step involved testing the joint, for this work Network Rail secured the services of Bodycote, recognised as a world leading testing company for the type of components that would be in use in the bearer tie solution. Bodycote provided a report that documented all test schedules conducted including rig test testing the joint over a million cycles. Following a review by Network Rail's Track Engineering organisation, the joint was approved for manufacture and testing.

The photograph below (fig. 2.8) shows the bearer joint and identifies its components, engineering at Network Rail request all reference to the product be labelled as the "Bearer Tie" as a clear indication to the product function. There are four individual components to the design; the U-shaped steel plate (called the "shroud") that provides the rigidity, a rubber pad that is placed between the concrete long bearer to provide protection against possible friction during passage of trains and the screws and washers that fix the system in place.

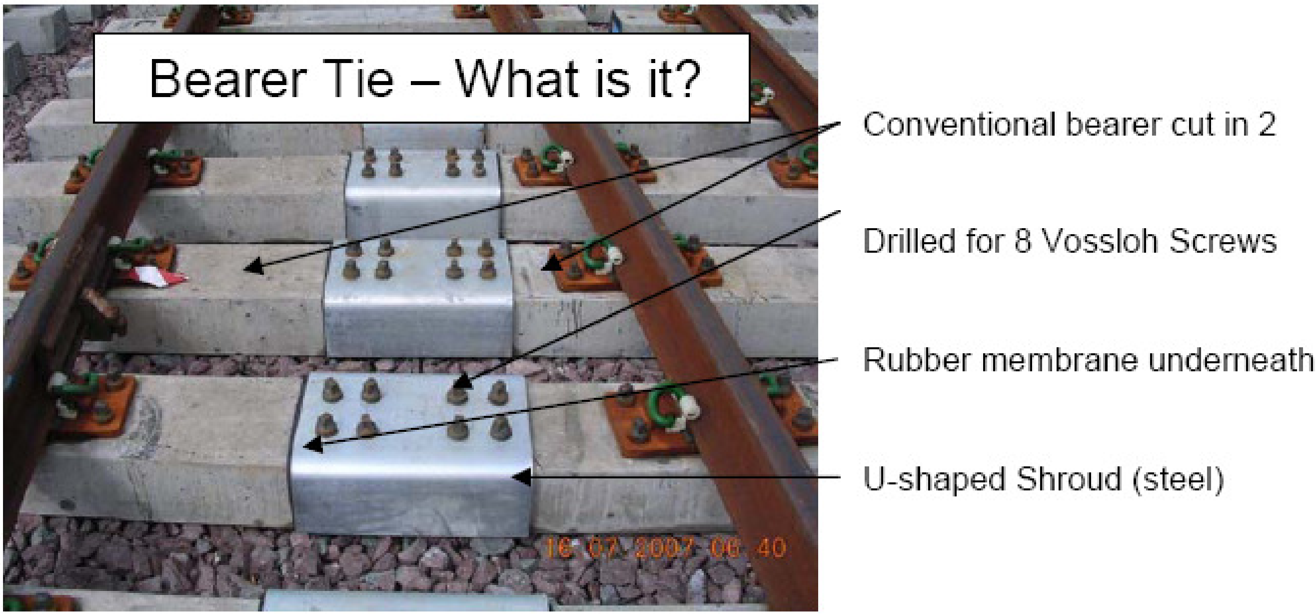

Figure 2.8 "The Bearer Tie"

4.3 Trial worksite selection

It was determined very quickly that not all renewal schemes would suit a “modular” installation. There would always be certain constraints in either the design or the characteristics of the location. The design would have to meet the scope of the programme that dictated specific S&C size, some S&C panels would simply be too large to transport even in modular form. Feasibility studies indicated that 75% of the annual renewals work bank would fit the scope which left location specific constraints such as access for road lorries delivering the S&C panels.

In line with typical flowchart concepts a “decision tree” (appendix 3 & 4) was developed. Presented as a two stage process, the first step (fig 2.9) determines whether the design is appropriate. The second step (fig 3.0) requires much more detail and is completed as part of the site survey. The first trial site was successfully identified using this simple method.

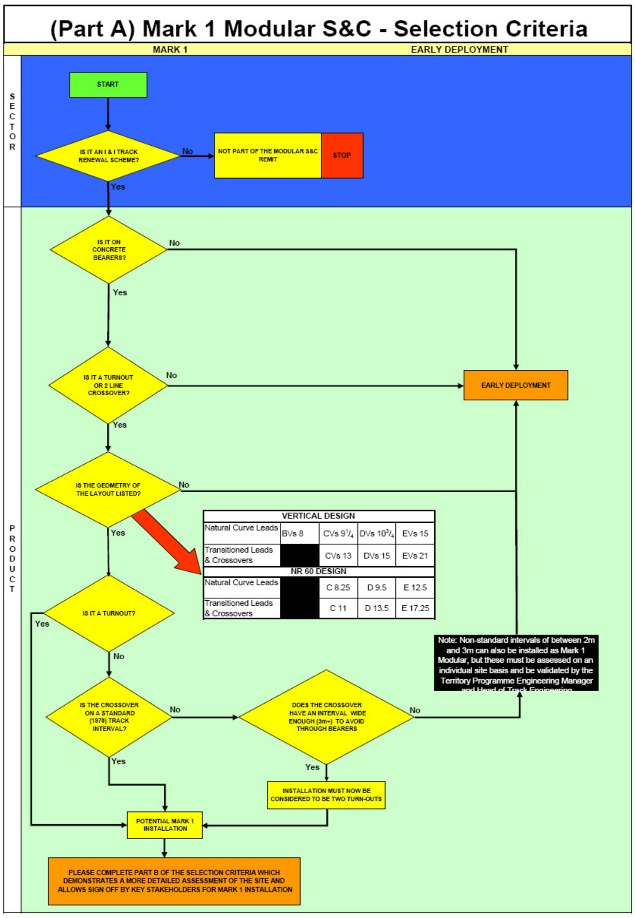

Figure 2.9 Scheme selection

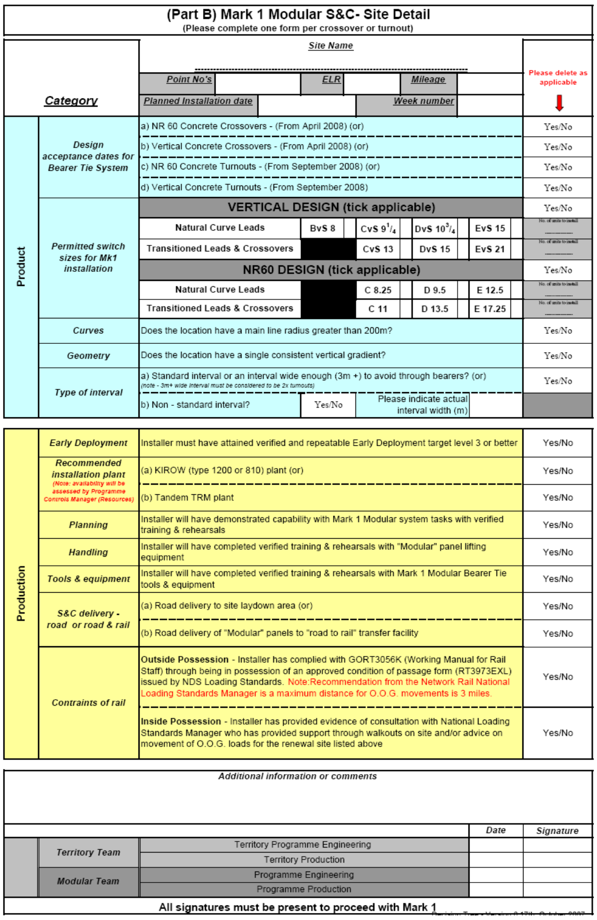

Figure 3.0 Production suitability

4.4 Trial Preparation

The location for the first trial was at Hunterston in East Kilbride, Scotland. The location was chosen using the decision tree and nature of rail traffic in this area provided an appropriate test of the bearer tie. There was a good mix of frequent passenger trains (relatively light in weight) and heavy goods trains which regularly used the crossing to access the nuclear power plant in this area, providing coal.

Several reviews were held with the S&C manufacturer prior to delivery, the main objective to understand the process for producing the unit. Following receipt of the approved manufacturing drawing, the key elements to production and their timescales are as follows;

1. Order the long lead items from outside suppliers (these are the long bearers and are produced by Cemex, a concrete manufacturer) at T – 12 weeks
2. Confirm all bill of materials and delivery dates from internal organisations at T- 12 weeks (All metal work such as cast crossings, rails, fastenings, clips, cable etc.)
3. Take delivery of all materials at T-7 weeks
4. Start S&C unit assembly at T-6 weeks
5. Complete S&C unit assembly at T-4 weeks
6. Client (Network Rail Local Delivery Unit) inspection of S&C at T-4 weeks
7. Cut the S&C unit in modular panels at T-3 weeks
8. Load the S&C panels onto lorries and deliver to site at T-1 week
9. Installation at T-0

The project team were satisfied with the overall approach of the supplier and their confidence to deliver. A weekly conference call was put in place to monitor progress from T-12 weeks. All activities went according to plan and the S&C unit was duly delivered to Hunterston for installation. The picture below (fig. 3.1) shows the first S&C panel being unloaded, this was the first occasion in the history of the UK rail network that an S&C unit had been built at a factory and delivered to site with all component parts assembled, albeit in panel form. The lifting beam is of key importance as zero deflection of the panel was stipulated by Network Rail’s engineering managers as a condition of the programme. This was successful.

Figure 3.1 Delivery of the first S&C panel

4.5 Installation

The installation of the complete unit was a major success, the pictures below (figs. 3.2 & 3.3) show one of the crossovers before and after installation. The original programme prior to the site being identified as a modular trial was to install two S&C crossovers and a single turnout over three weekends using the “build in the hole” technique, a total of 162 hours of possession time and major disruption to the rail network for both passenger trains and freight operators. By installing the S&C as “modular”, both crossovers and the turnout were completely installed and opened for traffic after only 54 hours, this was clearly a major success both in engineering accomplishment and in time saved.

Figure 3.2 Hunterston before

Figure 3.3 Hunterston after

There were a number of observations made however during the installation, most notable of these was that the smaller components of the bearer tie system were delivered in separate boxes, this lead to a number of problems. The screws for example were in bags of 50 and one of these bags were mislaid between transporting them from the delivery, delaying the installation team for over an hour whilst these were located. The washers were also in separate bags of 50 although fortunately these were all located and brought to the point of installation without incident. The most significant observation involved the bearer tie shroud plate. Once again these were packaged separately on a pallet and moved individually to the installation team upon request. However, these items have a weight of over 25kg and are therefore subject to a two person lift. This proved awkward and a number of stumbles and unsafe movements were noticed as they carried. These observations were formally captured and formed an important part of the lessons learned exercise that was carried out following the installation.

4.6 Inspection of installed S&C Unit

The Hunterston renewal site was inspected two weeks after installation. The inspection involved the removal of all the Bearer Tie plates (Shrouds). A number of split bearers revealed significant failure, these can be seen in the pictures below (fig. 3.4 & 3.5).

Figure 3.4 Cracked bearer

Figure 3.5 Broken bearer

There appeared to be two distinct failure modes. The first failure mode was that of cracking, as seen in figure 3.4. This appeared to stem from the inserts where the screws where positioned to hold the steel shroud in place. The second failure mode was that of concrete breakage as shown in figure 3.5, this was a failure of breakage and it was noted that the re-enforcement strand was closer to the end of the bearer than the drawings had stipulated.

Engineering Managers from Network Rail assessed the integrity of the crossing and passed it fit for traffic, the project team initiated an immediate investigation into the cause and a plan for removing the damaged bearers was created. The investigation was split into two categories. Firstly, a root cause analysis exercise was initiated within the project and included representatives from the S&C manufacturer and their supplier for bearers. A fishbone diagram (fig. 3.6) was created to analyse the problem. In Japan in the 1950s, Kaurou Ishikawa became one of the first to visually lay out the causes of a problem. His fishbone, or “Ishikawa Fishbone,” helped visually capture a problem’s possible causes and this technique ultimately, has become a standard in root cause analysis. The model starts with an identified problem and then attempts to establish possible causes by using separate categories that branch off like the bones of a fish. Its categories which typically include materials, methods, machines, measurement, environment and people can be modified to better match a particular issue.

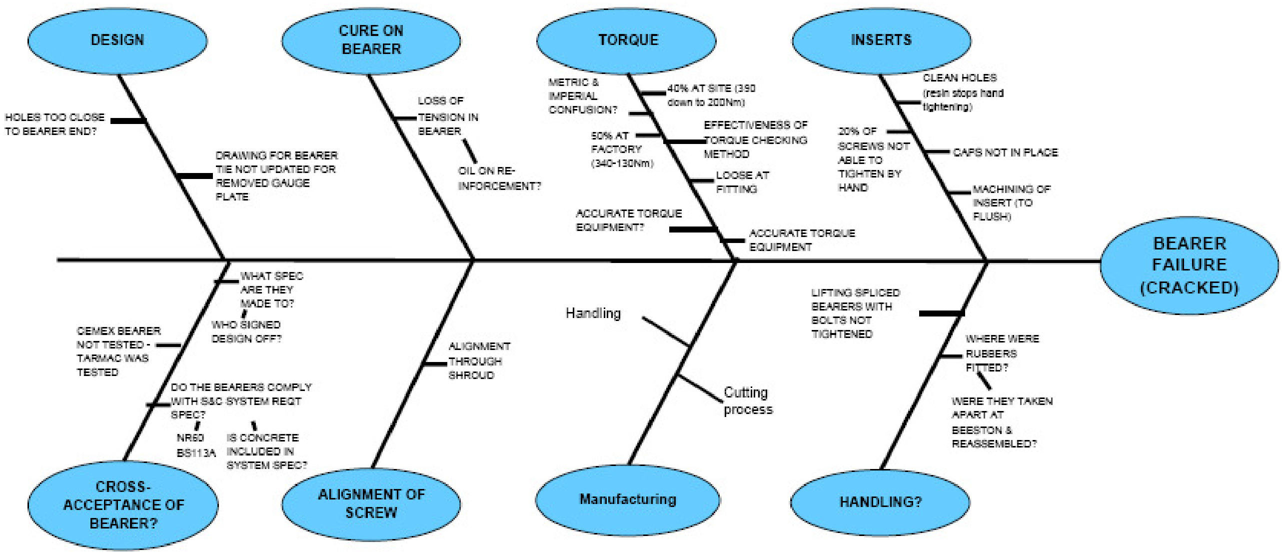

Figure 3.6 “Ishikawa Fishbone” of bearer failure

The analysis of the bearer failures quickly revealed some key elements that could have accounted for the failure. These mostly revealed failures to follow process at the manufacture and assembly points but more importantly, the condition of the bearers in terms of the quality of the inserts for the screws and the positioning of the re-enforcement for the concrete, gave cause for concern.

The second category of the investigation involved securing the services of a concrete specialist to professionally inspect and test the failed bearers; the company selected was Sandberg, a respected and well accredited specialist organisation. The remit to Sandberg was summarised as follows;

1. Initial Concrete Examination

a. Sections of the failed bearers to be sent to Sandberg laboratory for visual examination, core sampling for determination of strength and determination of mix proportions

b. Prepare sub-samples containing crack for microscopic examination to determine method of crack propagation (to be taken from samples supplied for 1. above).

2. Review all information on the delivery of the Hunterston concrete bearers

Carry out visit to CEMEX bearer manufacturing facility to determine the following relating to the failed bearers:

a. Relationship between CEMEX 'batch' number and bearer number.

b. Casting method for units.

c. Dates/ages at which critical operations were carried out and quality records associated with these operations.

d. The sequence of events at CEMEX in supplying the bearers

e. How are units handled at the works/ex-works

f. Any other pertinent factors.

3. Review of the Modular "System"

Obtain samples of Vossloh screws & Vossloh type screws, sockets and washers for laboratory testing. (Full assembly kit required including torque wrenches used during failures on site/works, splice plates, etc.)

4. Conduct a full review of the manufacturing and handling process at Cemex

Carry out inspection of test production of bearer/s at the Somercotes works; replicate as far as possible production timing and methods used for cracked bearers. Witness casting and production process to include:

a) Set up

b) Batching

c) Casting

d) Curing

e) Cube testing

f) Detensioning operation

g) Demoulding

h) Handling in the shop

i) Drilling operations

- Inserting dowels
- Grouting & dressing process

j) Handling between shops

k) Fitting installation operations for Splice Bearers

l) Handling after fittings applied

m) Storage

n) Handling after storage

o) Transportation and Loading

5. Destructive testing of damaged bearers from Hunterston

Testing of cracked bearer to total failure, to include tonnage, cycles etc. as undertaken in the Bodycote tests to establish projected failure in traffic following initial damage.

Sandberg agreed to a programme of 6 weeks in which to complete the work investigating the bearers and to provide a report on root cause findings. Network Rail arranged for the damaged bearers to be removed from the site at Hunterston and be shipped to their laboratory. A number of the tests that were conducted by Sandberg were witnessed by Modular S&C Project team members such as the strain gauging test as seen in the photographs below (fig. 3.7 & 3.8). This test is used to monitor the stresses and reactions of the concrete bearer when it is put under expected or exceptional loads, and from a variety of angles.

Figure 3.7 Strain gauging

Figure 3.8 Bearer testing during investigation

4.7 Results of the investigation

Sandberg completed the investigation into the damaged bearers within approximately 5 weeks. An excerpt from this report can be seen below (fig. 3.9 & 4.0) which outlines their findings.

plan positions of the holes other than with regard to the relative position of one hole to another.

The results of these tests are given in Appendix E to this report

4. RESULTS

The strains recorded in the cutting tests were all of insufficient magnitude to cause significant damage to normal strength concrete.

The strains recorded in some of the bolting tests were found to be significant and of sufficient magnitude to cause failure in concrete.

The strains recorded when re-bolting the cover plate to an already cracked bearer were extremely large, while the strains recorded during the bolting of the cover plate to an undamaged bearer were considered to be insignificant. This finding lead to the decision to test an uncracked bearer with a cover plate taken from a cracked bearer set up. The strains recorded during this test were found to be sufficient to cause failure.

The dimensional tests carried out by CEMEX (on the bearers returned from Eastriggs) show the tolerance for the placing of the Vossloh dowels have been exceeded for both the plan position and the verticality of the dowels (which we understand is specified as being 1° from the vertical).

The measurement of the holes in the cover plates (received by Sandberg at Washwood Heath on 5th February 2008) show that the formation of the holes varies from the requirements of Edgar Allen's drawing "NR60 'R' Type Intermediate Concrete Bearer Tie Unit" Drawing No. PD-05-0041 Rev4, which requires two of the holes to be 26mm diameter and the remaining 6No. holes to be 26mm x 32mm slotted holes. The cover plates received have 4No. 26mm nominal diameter holes and 4No. 26mm x 32mm slotted holes.

The dimensions of the holes in the cover plates were found to be within the $\pm$1mm tolerance given on the Edgar Allen drawing. However, the formation of the holes and slots were found to be irregular with lips remaining from where the holes have be punch formed and plan irregularities see Appendix F, Photographs 2, 3 and 4.

The shank diameter of the Vossloh type screws used in the assembly of the modular bearers was found to vary from 24.08mm-24.31mm (see dimensional results of Vossloh Screws in Appendix G to this report)..

5. CONCLUSIONS

The results of the tests undertaken where the concrete bearers were strain gauged showed that there was strain imposed in the bearers by the cutting operations and by lateral movement (such as would be caused by poor handling, tamping etc.) but that this strain would be insufficient to cause the bearers to crack in the absence of other factors.

The act of bolting the cover plate in place on the spliced joint was in certain circumstances found to impart sufficient microstrain into the bearers to cause structural damage.

Figure 3.9 Conclusions from Sandberg (concrete specialist)

The diameter of the screws fitted into a slightly undersize hole in the cover plate will reduce the amount of tolerance applicable to the location of the Vossloh dowels in the bearers. When slight variations in the location of the holes in the cover plates and non-verticality of the dowels is taken into consideration, we believe that this combination of errors and tolerances has caused the cracking found on site.

The dimensional inaccuracies identified in the locations of the Vossloh dowels in the bearers, the apparent non-conformance identified in the cover plates with regard to the round and slotted holes and the deformities identified in the holes themselves would appear to be combining to produce sufficient strain in the bearers to cause the cracking witnessed on site.

It must be noted that the testing undertaken by Sandberg has not been extensive in terms of the number of items tested and that therefore greater variations may exist than those reported here.

6. RECOMMENDATIONS

It is apparent that not all modular bearers crack.

The limited number that have cracked either during trial assembly at the S & C Suppliers yard or during installation would appear to have been caused by a combination of tolerance variations between the components and certain non-conformances identified in the dimensions of the bearers themselves.

There is no evidence to suggest that the principle of the modular bearer is defective. Indeed, the practical load testing carried out on undamaged bearers at CEMEX's Washwood Heath facility indicate that the bearers are able to accommodate high transverse bending loads applied beyond the joint position and that the amount of deflection that can be accommodated by the joint without causing a failure is in excess of 50mm.

We are not able to determine how inspections on the cover plates are currently undertaken as once manufactured, there is no datum from which dimensions can be measured. We would strongly recommend that the specifiers require a datum to be marked in the centre of the plate and that all relevant dimension are then referenced to this point.

Similarly, determining a set datum for the measurement of the bearer units should also be considered as currently there does not appear to be a consensus on how these units should be measured.

Finally, we note that the cover plates are required to be electro zinc plated but that the screw fittings are not. Some degradation of the galvanising should be expected where it is in contact with non-plated items.

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For Sandberg LLP

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11 February 2008

Figure 3.9 Recommendations from Sandberg (concrete specialist)

Following discussions and reviews of the Sandberg report, two clear conclusions were established. Firstly, the bearer tie system could be considered fit for purpose with the design successfully withstanding forces much greater that those that the S&C unit would be subjected to under normal conditions of use. Secondly, the component parts, as with any system, must be manufactured and assembled to tolerances identified in the specification and drawings.

The pictures below (fig. 4.1 & 4.2) are examples of where a manufacturer has not produced the product to specified designs and tolerances. In the case of this shroud plate, the specification says that the holes should be laser cut (these are clearly flame cut) and that the tolerance in size shall be 1mm (these hole shown is significantly out of tolerance).

Figure 4.1 Shroud plate out of specification

Figure 4.2 Shroud plate not cut to specification

The following photographs (fig 4.3 & 4.4) are of the bearers that were produced by Cemex for the Hunterston installation. The main problem with these bearers are the inserts that are created for the screws, as close inspection of these inserts reveals voiding around plastic insert and the poor alignment of the insert as it sits inside the bearer, there is also evidence of contamination within the insert and areas where surface repair has been made.

Figure 4.3 Quality problems with bearers

Figure 4.4 Voiding and alignment issues

The bearers found to be damaged at Hunterston clearly revealed that the re-enforcement strands that were introduced to the bearer tie design, were not positioned as required and that it was possible that this had contributed to the breakage as seen on the photograph (fig 3.5). However, discussions with Sandberg concluded that the only way to prove this would require destructive testing. A member of the Modular S&C Project team suggested that it would be useful if an x-ray could be done on the bearer but enquiries to both Cemex and Sandberg were inconclusive as both companies agreed that they had never heard of this being done before.

BBRTS were asked for their views and whilst they agreed they had never heard of this being done, they would be happy to ship the damaged bearer to their S&C foundry in Bathgate where they used an x-ray machine to conduct quality checks on cast-manganese crossings. X-rays were conducted on the damaged bearers and the photographs were sent back to Network Rail..

The results of the x-ray provided all the information required and can be seen clearly in the image below (fig. 4.5). The key points are; the re-enforcement strands are not straight and too close to the extremities of the bearer end where it is cut, secondly, it can be seen that the alignment of the insert is not straight and that there is uneven resin application.

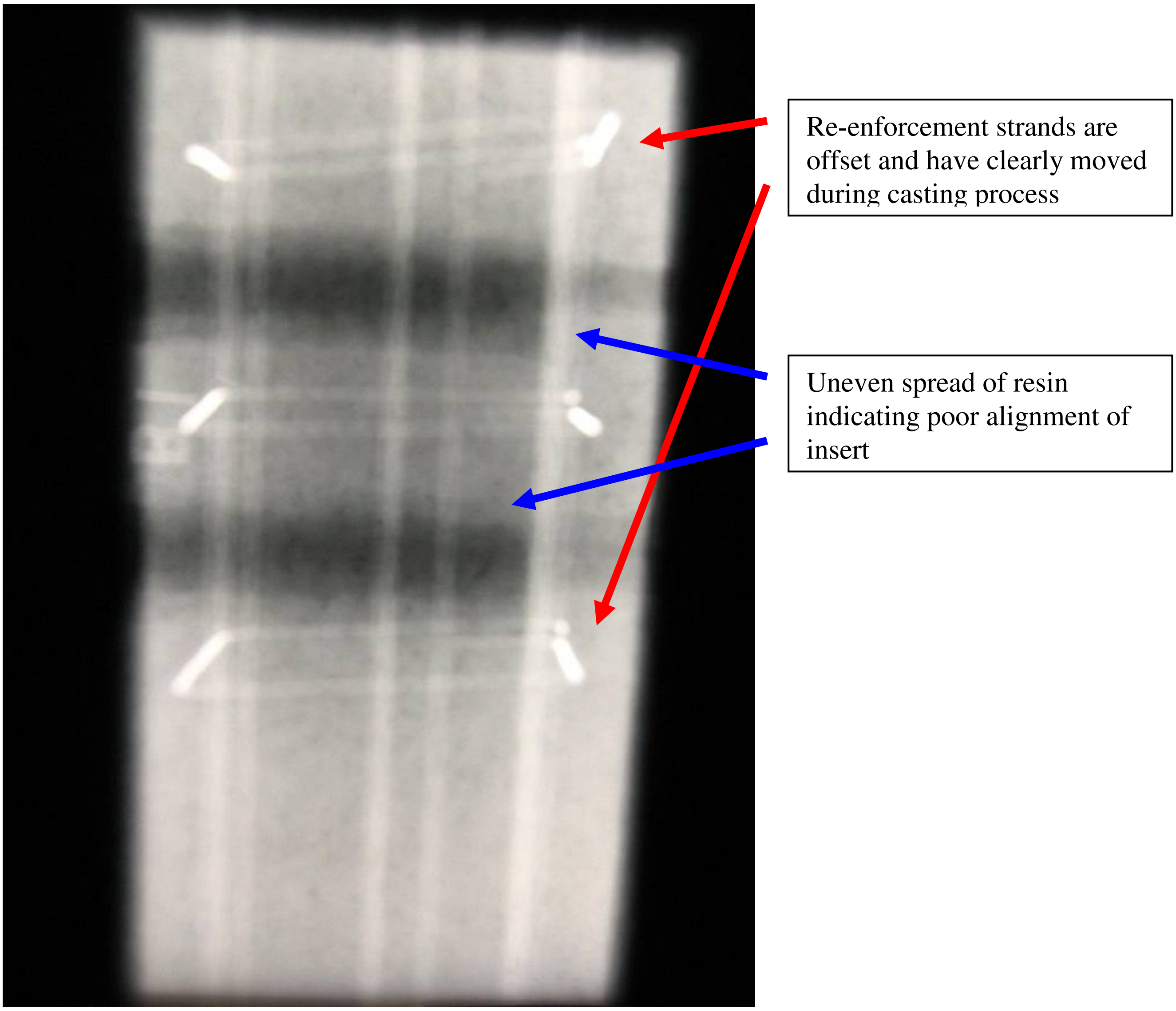


Figure 4.5 x-ray image of damaged bearer

The quality issues found with the bearers were presented discussed with the manufacturer. The bearers were procured by BBRTS from Cemex who are not a direct supplier Network Rail but they are an approved supplier of railway products. A request was made to visit the Cemex factory at Somercotes in North Derbyshire to witness the manufacturing process and to discuss proposals to improve the quality of the bearer production. Cemex agreed to this visit and were very open in their approach to solving the problems found at Hunterston.

At the factory in Somercotes, Cemex allowed an inspection of their manufacturing lines for producing concrete bearers for modular S&C. They described the high level steps in manufacture as follows;

1. The troughs that receive the concrete are prepared by running strands of steel re-enforcement cable the length of the trough which are stressed to produce strength in the concrete when set.
2. Concrete is poured into the troughs and left to set for a pre-determined period
3. Once set, the concrete is removed in sections required for each S&C unit, these are the long bearers.
4. The long bearers are then placed on a jig and 8 holes are drilled in the section that will become the “joint” for modular S&C
5. The bearers are then taken to the “glueing shed” were the inserts are added. This is done by hand by an “unskilled” operator using a jug, by pouring an unspecified amount of resin into the 8 holes and then placing the plastic insert into position.
6. The bearers are then transported to the S&C manufacturer’s layout yard.

According to Chase et al (2002), the purpose of value analysis or value engineering is to simplify products or processes. Its objective is to achieve the equivalent or better performance at a lower cost while maintaining all functional requirements defined by the customer. With consideration to this description there appeared to be a great opportunity to implement an immediate change to the modular bearer production process, even to the untrained eye. Traditionally, value engineering is conducted prior to production but as a development project there seemed no reason not to suggest changes to the production method put forward by the manufacturer.

Observations on the production of bearers were presented to Cemex. The most significant of these highlighted the point that a simple value analysis approach pointed to the need to cast the bearers with the inserts in place and thereby remove two thirds of the production process; specifically the drilling and glueing processes. This casting with components process was not alien to them as other small components are often cast into bearers such as baseplates for holding the track in place. This would provide tangible cost savings as value analysis is designed to do but more importantly, would likely to be an important factor in eliminating the quality issues that seemed to be caused by the process in place at that time.

Cemex explained that this idea had been explored but dismissed as initial tests had found that they could not get the inserts to remain in place as the concrete flowed through the troughing. This seemed plausible but it was requested that a working group be assembled to review this idea again. The remit for the working group not only required a solution to the casting of inserts but also required an answer to the re-enforcement movement as seen in the x-ray image (fig. 4.5).

Cemex responded positively to this request and seconded engineering resource from their factory in Washwood Heath in Birmingham. Four weeks after the initial meeting Cemex arranged a presentation of a solution to casting the inserts into the bearer. The photograph below (fig. 4.6) shows how they accomplished this.

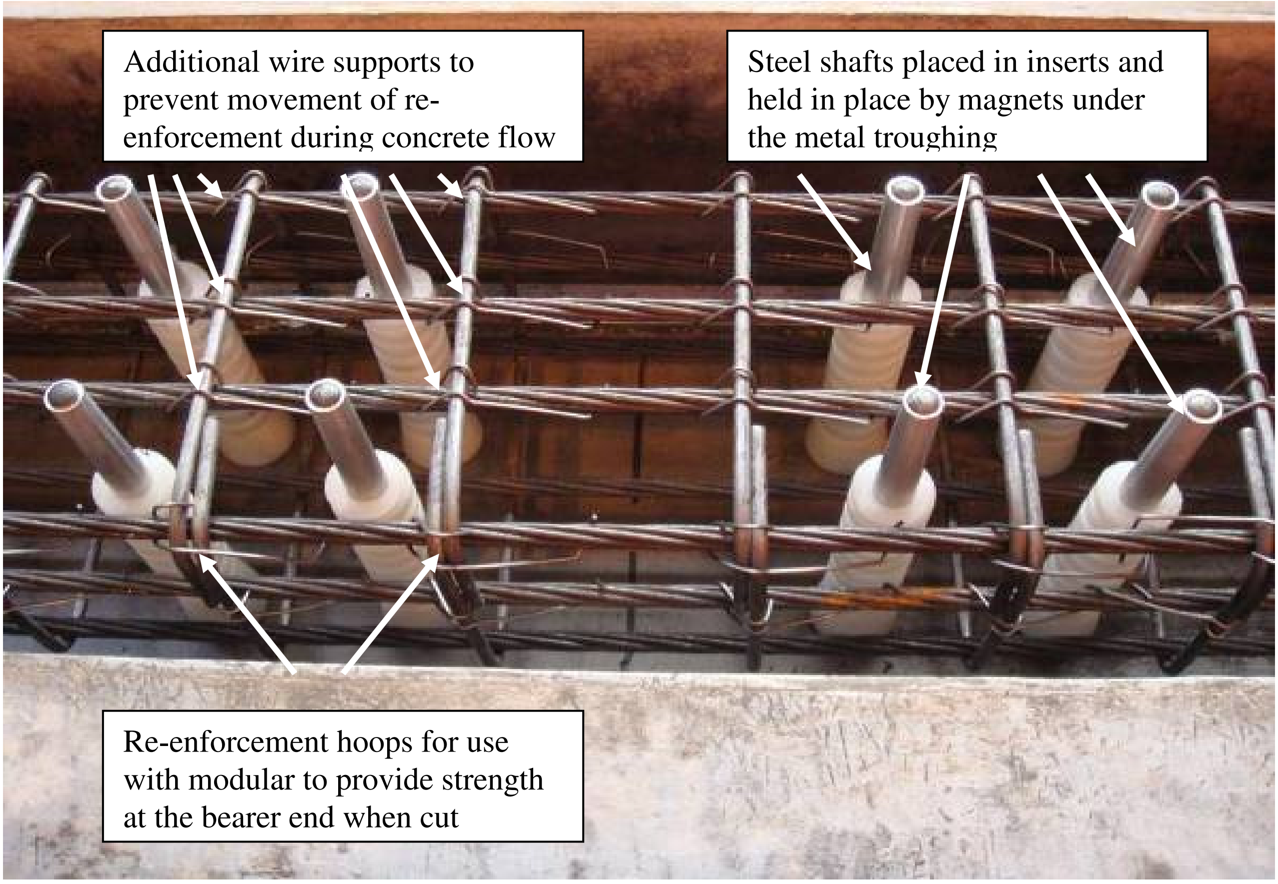


Figure 4.6 Cemex solution to casting inserts and maintaining re-enforcement integrity

The solution to the casting of inserts is simple but 100% effective. The base of the insert is cut off and a steel shaft with a flat flanged bottom (much like a valve from a combustion engine) is placed in the insert. The top of the steel shaft sits just high enough above the troughing level in order for it to be gently knocked out when the bearers have set and have been removed from the trough. The method used for getting the pins to hold the inserts in place inside the trough involves the use of high strength magnets, these are attached underneath the troughing and can remain in place permanently without affecting the casting of other concrete products. It can also be seen from the picture above the use of multiple wires around the re-enforcement hoops that prevent movement during concrete flow. To speed up the process and ensure accuracy when placing the inserts with pins in the troughing, again a simple solution was created, a steel jig (fig 4.7) that sits on top of the trough during set-up.

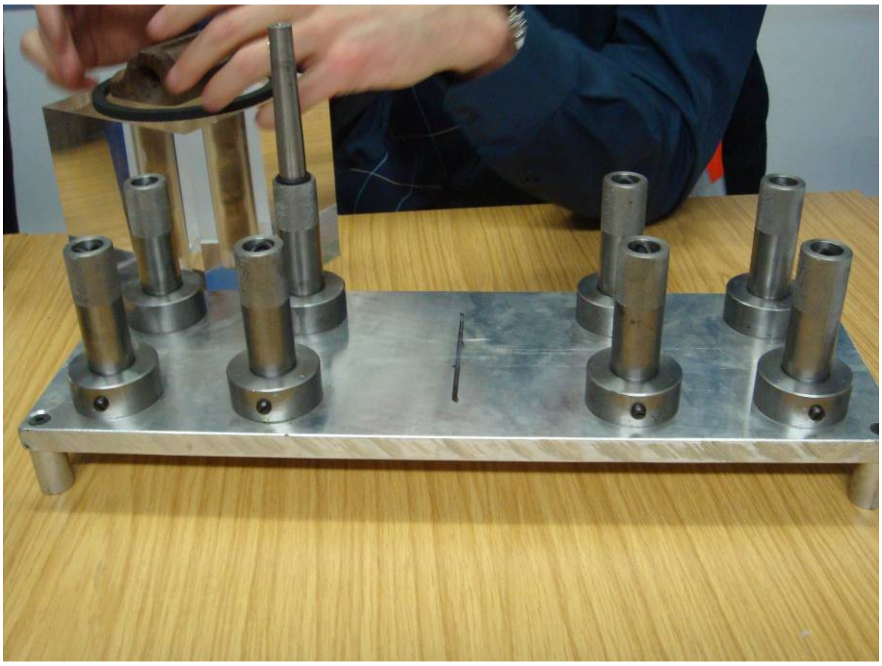


Figure 4.7 Cemex jig for insert placement

Cemex provided some examples of the modular bearers that had been produced using this new method. The significant improvement can be seen in the photograph below (fig. 4.8), this provides a good example of value analysis driving innovation to improve quality and reduce cost.

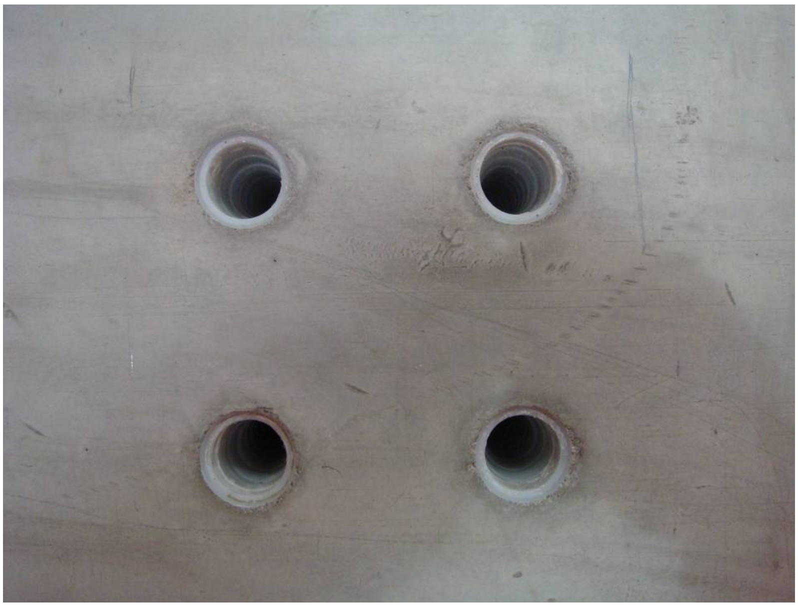


Figure 4.8 Cemex bearer cast with inserts

4.8 Second Trial

Following the failures uncovered in processes both in Network Rail and the supplier, a number of initiatives were implemented. For Network Rail, this centred on the inspection regime that was in place to ensure product conformity prior to despatch and the subsequent delivery of material at site. For the supplier, it was agreed that a service level agreement or service guarantee would be agreed for the supply of the next and future S&C units. This approach is not uncommon for the supply of most goods therefore it seemed like the most logical approach to dealing with problems associated with the first trial of modular S&C.

According to Hart (1998), most service guarantees don't really do the job, being limited in scope and difficult to use. Hart gives the excellent example of Lufthansa Airlines, who at that time had a guarantee that its customers would make ether connecting flights if there were no delays due to weather or air traffic control delays; unfortunately, these were the cause of 95% of all flights delays. With this kind of understanding of service guarantees, it is clear that any system implemented must be simple to use and enhance performance.

The steps or process for manufacture of modular S&C had already been described to the Modular S&C Project team, these are referred to above. However, this process had not been formally documented and the failure modes not understood. The project team also had a number of observations from the first trial that would significantly improve the product and service that was supplied to the S&C installation team.

A "service blueprint" was proposed to BBRTS that would firstly map out the steps in production and delivery and highlight the potential failure points with recommendations or "poka yoke" that would be instilled for prevention of product or service failure. The service blueprint would also be used to address any opportunities for value analysis, as a number of components that form the installed

S&C unit could be fitted at the point of assembly and remain in place effectively supplying at part tested and commissioned unit. The disassembly of the unit for despatch should consider removing the "waste" that is created by approach to product supply. Finally, the product must be warranted by means of a service guarantee that is agreed and upheld by the manufacturer, a checklist for supply of the next unit should be used to prove the warranted S&C unit.

The diagram below (fig. 4.9 & Appendix 6) depicts the high level service blueprint for the manufacture and supply of S&C units agreed with BBTRS.

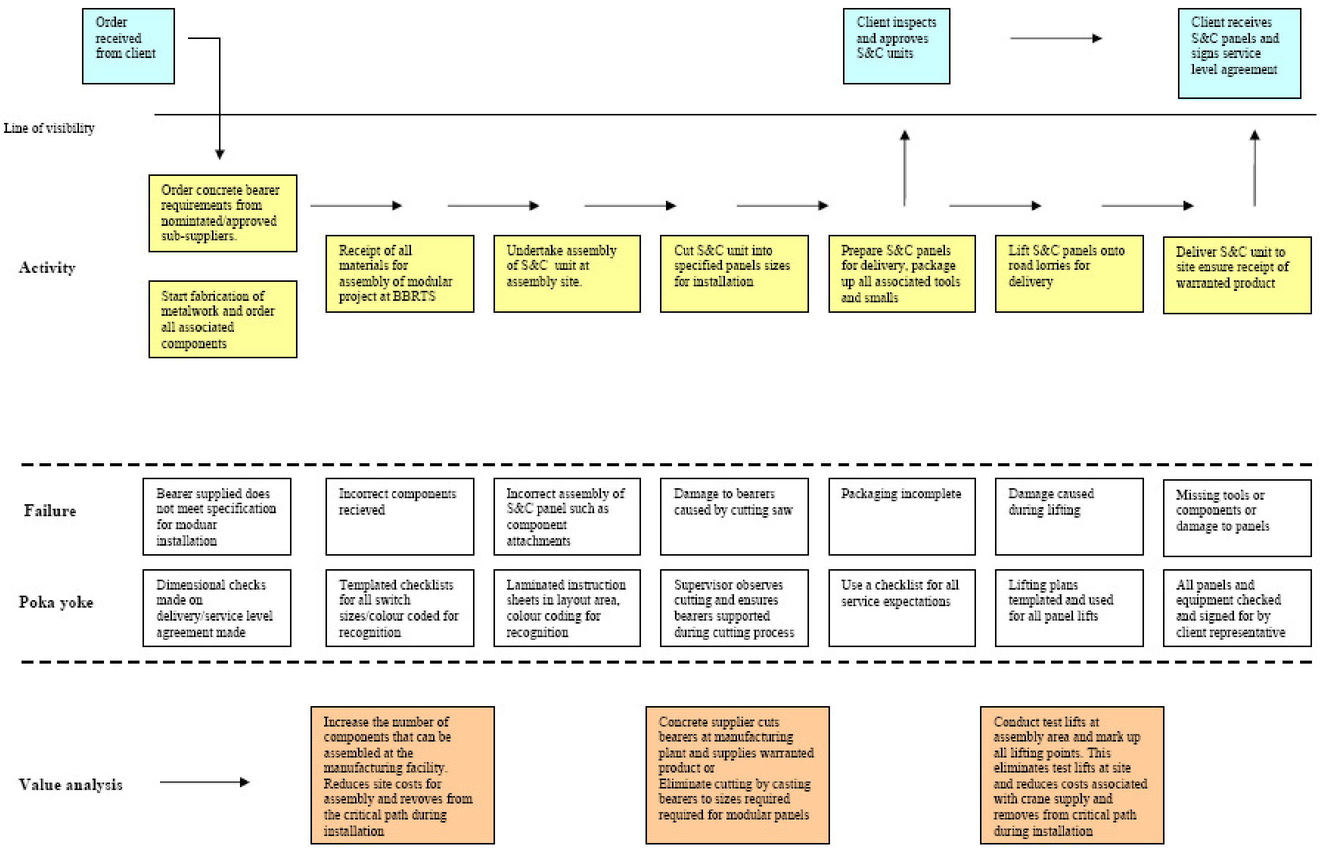


Figure 4.9 Service Blueprint for modular S&C production

As stated previously, there were a number of observations made during the first trial during installation involving not only areas for reducing cost but also factors of safety. These were raised with the manufacturer during lessons learned sessions and incorporated into the S&C unit "package". For example, at the first trial the shroud plates and their associated screws and washers were supplied separately from the panels and arrived in crates and pallets. When these items were needed during installation it required the use of lifting plant to transport them from the point of delivery to the point of installation and subsequently handled individually (and awkwardly) by the installation team to get them into position. In addition, a bag of screws was misplaced and delayed installation for over an hour whilst they where located.

The recommendation to BBTRS was that the shroud plates and screws be "banded" to the panels during assembly and delivered this way, allowing the installation teams to lift the shroud no more than a few feet and the screws being ready at hand. It was also suggested that a tool for handling the shroud be procured to improve the installation process further. These recommendations were accepted by BBTRS and the results can be seen in the photographs of the second trial further in this section.

As part of the mistake-proofing in the service blueprint for the manufacture of the S&C unit, a checklist (fig. 5.0 and Appendix 5) was produced and agreed as part of the service level agreement with BBTRS. This was designed to improve the inspection process and satisfy Network Rail that a "lean" S&C package would be delivered. That is to say that any assembly activities that are currently done on site are removed to the manufacturing facility and once assembled and tested, are protected and maintained in that state during transportation.

S&C installers requirements from the Manufacturer

Date of installation ______ Location ______

Order No. ______ Points No. ______

SWITCHES

	YES	NO
SWITCHES TO BE DELIVERED AS A PANEL?	☐	☐
POINTS MACHINE ATTACHED THE PANEL FOR DELIVERY	☐	☐
POINTS OPERATING EQUIPMENT FITTED TO THE LAYOUT	☐	☐
MK1 LIFTING ATTACHMENT PLACED AND SECURED ONTO THE PANEL (TEST LIFTS COMPLETE AND ATTATCHMENT POINT MARKED)	☐	☐
LIFTING PLAN DOCUMENTATION PRODUCED AND ATTACHED TO PANEL (WEATHER-PROOFED)	☐	☐
POINTS HEATING INSTALLED AND SECURED ONTO THE SWITCH RAILS	☐	☐
SHROUDS BANDED TO BEARER	☐	☐
8No. WASHERS AND SCREWS PACKAGED AND BANDED ONTO EACH BEARER	☐	☐
INSTALLATION TOOLS PACKAGED WITH PANELS	☐	☐
RUBBER PADS BONDED TO SHROUDS	☐	☐
RUBBER PADS BONDED TO BEARER ENDS	☐	☐

CROSSING PANEL REQUIREMENTS

	YES	NO
FOAM TO PREVENT INGRESS OF BALLAST BETWEEN CHECK AND SUPPORTING RAILS AND IN FLANGEWAY OF CROSSIN(	☐	☐

SWITCH PANEL REQUIREMENTS

	YES	NO
FOAM TO PREVENT INGRESS OF BALLAST BETWEEN SWITCH AND STOCK RAIL!	☐	☐

JOINTS

	YES	NO
TEMPORARY BONDS FIXED AND TIED TO THE RELEVANT RAIL	☐	☐

REQUEST AND APPROVAL

REQUESTED BY (Contractor) ______ SIGNED ______ DATE ______

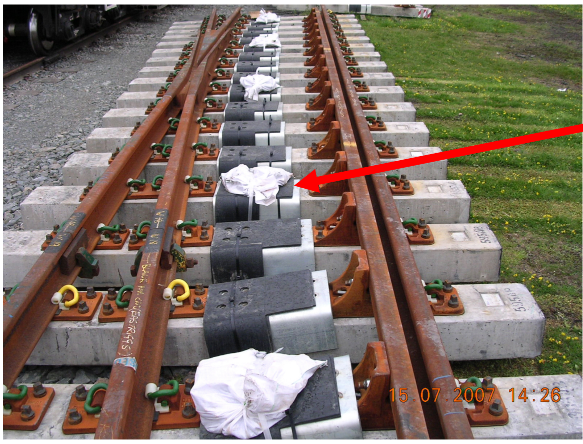
APPROVED BY (Network Rail) ______ SIGNED ______ DATE ______

Figure 5.0 Checklist for assembly and delivery

The process of documenting the assembly and delivery activities revealed a number of areas that could bring significant cost savings and efficiency, the application of value analysis in the service blueprint highlights these and will present clear opportunities for further recommendations.

4.9 Second Trial - Outcomes

The second installation of an S&C unit using bearer tie technology proved to be a major success. BBTRS incorporated all of the recommendations from the Modular S&C Project team and delivered a packaged S&C unit. The “pre-kitting” of the panels (fig 5.1) with the bearer tie components was a significant enhancement to the installation works and contributed greatly to the reduction in the overall installation time. A tool (fig 5.2) for lifting the shrouds was sourced and made manoeuvres increasingly easy.



Pre-kitting - shrouds and screws banded to the bearers in readiness for installation teams

Figure 5.1 Pre-kitting panels

Magnetic lifting tool for manoeuvring the shroud during installation

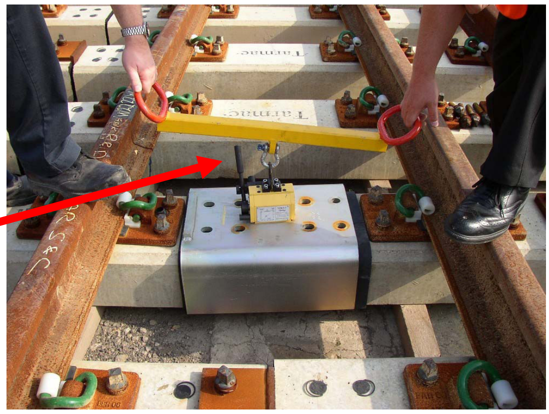


Figure 5.2 Magnetic lifter

The location of the second trial was March West in Cambridgeshire. The S&C unit here served a major freight depot that has strategic importance to Network Rail and the installation drew significant attention. Despite the added pressure on the installation team the old unit was removed and the modular unit installed and operational in 21 hours (fig 5.3 & 5.4). This was a reduction of 33 hours from the time allocated to the original conventional renewal.

The picture in figure 5.1 shows one of the modular S&C panels being transported by a crane from the delivery point which is a road access area approximately 200 metres further down the track. The rail crane is made by Kirow of Leipzeig in Germany; it is one of 8 of these types of cranes in use on the UK network which were commissioned due to their exceptional lifting capacity. The second picture shows the completed layout, the bearer tie clearly visible.

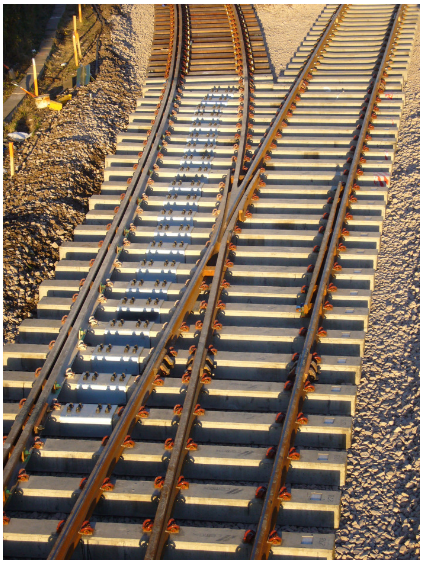


Figure 5.3 March West installation crane

Figure 5.4 Trial 2 installed

5. Conclusions

The Modular S&C programme has a clear objective; S&C renewal in 8 hours (or less). This is a key enabler of the aspirations for a seven day railway. There are interim steps to achieving this 8 hour renewal milestone and could be considered as a growth plan; growth in Network Rail's capabilities in managing suppliers, and producing contracting strategies that enhance the business. Parallel to this there needs to be growth in the capability of the manufacturing and installation suppliers in learning new skills and more importantly; new behaviours.

This study has considered Network Rail's opportunity to introduce a new product to the railway industry by reviewing the options in the industry for the supply of an innovative solution for S&C units and the subsequent trial production and installation of such a unit. However, reducing the time it takes to install S&C cannot be to the detriment of all other factors for as the trial installation revealed, there is little benefit in reducing the time if the quality is reduced and remedial work is required to put things right. Similarly, the solution for producing modular S&C units is of little use to the business if the cost of producing them exceeds the current unit rates. Engineers at Toyota have long worked under the edict that no new product will be approved unless; a) its cheaper to produce than the old one and; b) it removes the need to have the old product.

5.1 Contracting Strategy

The important issue facing Network Rail in deciding on how to manage supply of the key products for modular installation of S&C must be considered to be core competency. Up until 1995 the UK rail network was managed and operated by the state owned company, British Rail. This company possessed a wide spectrum of core competencies including manufacture, operations and civil & mechanical engineering, with little or no outsourcing required. This then became Railtrack and eventually Network Rail and with these changes came a significant reduction in core competencies. The core competencies today could be described as managing suppliers and core contracts and for this reason it would appear to be unsuited to attempt to return to manufacturing. However the way it which it manages the supply of S&C units will clearly impact on the anticipated success of the Modular S&C project and ultimately the success of the “7 Day Railway” strategy. It has been written that in order for a firm to profit from resources it must have advantageous access to the resources. This does not necessitate ownership of resources but does imply, in the absence of ownership, effective relationships being key to resource access (Nanda, 1996).

5.2 Manufacture of Modular S&C

Balfour Beatty Rail Track Systems were chosen as the supplier to assist in development and trial implementation of the bearer tie solution for Modular S&C. This was their core competency and they required little investment to create readiness for modular S&C production. They produced the designs and drawings for the bearer tie joint and Network Rail agreed with them pay for this and retain intellectual property rights for intended future rollout to the S&C manufacturing industry should the product prove successful.

The failures uncovered following the first trial were significant, with a lack of basic quality checks of components. This was a major concern to the project team and has implications for the industry overall and lead to discussions over the quality of conventional S&C units that were being supplied by BBTRS almost every weekend of the year. It became difficult to maintain focus on the needs of the project and reports to senior management in NDS requesting immediate audits of all S&C suppliers. It became apparent that the existence of quality assurance in terms of ISO9000 etc. does little to ensure quality at the factory gate. This supplier validation process is ongoing.

With respect to the manufacturing processes in place at BBTRS, the experiences of the first trial at Hunterston showed that preparation had been lacking in terms of documented procedures and the evidence found of quality problems with components demonstrated that there was no system or process to prevent it. Observations by the project team were taken on board and although the “lean manufacture and supply" ethos began to materialise following the lessons learned workshops there is still some way to go before BBTRS are considered competent in modular S&C supply. It is important to remember however, that the project is its early stages and although as mentioned above, concerns have been raised over supply of S&C in general, that competence and quality will increase quickly. The agreement with BBTRS to instil a service level agreement for supply will improve quality, but Network Rail must manage this closely in the future.

5.3 Review of Objectives

Objective	Completion
Review the current process for the supply of switches and crossings and consider the challenge to developing a contracting strategy and recommendations that will enable a "world class" solution to manufacture and supply	Supply of S&C reviewed and analysis conducted to establish Network Rail's options for contracting strategy. Recommendations made with reference to analysis and literature review.
Evaluate the proposed production methods through trials of a technical solution for the implementation of modular installation of S&C, and in particular with the use of value engineering and service blueprinting as techniques to improve the processes involved.	Supplier engaged to develop bearer tie solution for modular S&C Trial implementations conducted with analysis of production methods Recommendations made on improving manufacturing S&C units to improve quality and reduce cost

6. Recommendations

The following recommendations have been generated from the research, analysis and observations undertaken.

6.1 Recommendations for Supply of S&C

The analysis in this study supporting the options for contracting strategy provides evidence that the notion of a Network Rail wholly owned and operated facility creates a significant risk to the company and may have to be considered as a longer term strategy. This could be expected as the industry has never been responsible for large scale manufacture and it is difficult to find an example in any industry where the construction of a new factory in itself has brought about the step change in culture and quality that the rail industry requires to deliver modular S&C.

The end to end process for the specification, design, manufacture and installation of S&C is clear and as far as discussions can reveal, clearly understood by most of the organisations that are involved in execution of it. However despite this, the evidence available shows that dates for producing specifications are seldom met, designs (from 5 different suppliers) are invariably late and subject to change. This usually means that manufacturing drawings are not complete by the time needed to start manufacture but despite this, the S&C manufacturer presses on at risk, as the cost of failure is too great. Case studies of companies such as Toyota and Porsche show that quality is improved and cost reduced when open and collaborative relationships are conducted with suppliers rather than adversarial relationships. The current situation is that it would appear to be the lesser of two evils is preferred, in that a poor product installed and functioning perhaps at reduced speed for trains, is better than no product installed at all and a temporary railway closure imposed on the territory.

In consideration of the evidence and analysis of the process and value stream for S&C production, one recommendation to improve the future state could be described as shown in figure 5.5 (Appendix 7), this depicts a substantial reduction in variability in design and manufacture. The process has been rationalised to bring complete control of design and fewer suppliers of S&C.

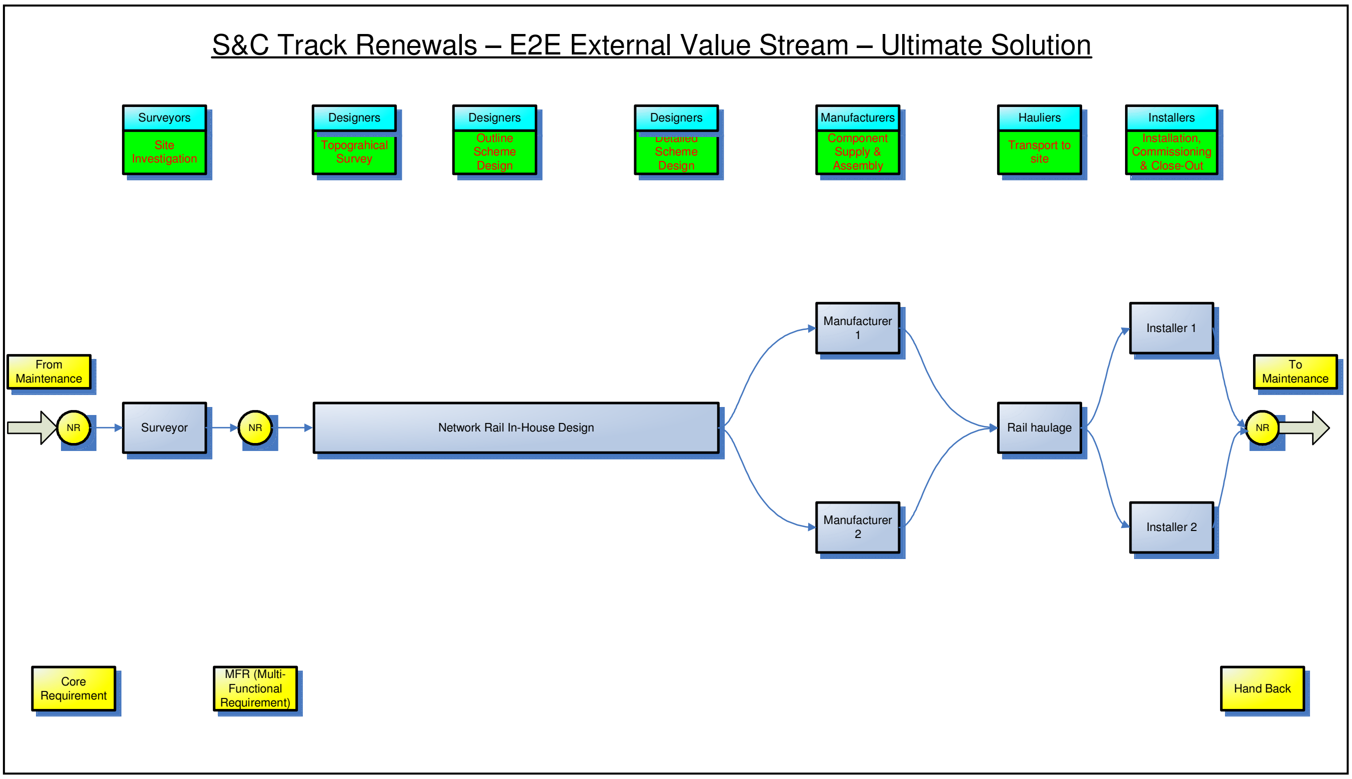


Figure 5.5 S&C supply rationalised

6.2 Manufacturing Recommendations

There is a clear demand for significant enhancement of our existing suppliers, recommendations for immediate improvements are the adoption of “World Class” manufacturing techniques, such as:

- Extensive use of jigs, fixtures & tooling
- Staff training in product and ‘customer critical features’
- Sweep, sort, straighten, systemise, sustain (5S’s)
- Lean – elimination of waste
- Continuous improvement culture
- Mistake proofing (Poka Yoke)
- Factual, data-based feedback (KPI’s)

Many of these changes could be delivered immediately as has been shown in part with the trials of the bearer tie units and since the units themselves are likely to be the same in concept as the ensuing steps for a “World Class” solution. The tendency is for organisations to look for the ‘quick wins’, but in this case there is clear need to provide the existing S&C manufacturers an opportunity to develop improved manufacturing processes in preparation for “World Class”. The analysis in this study indicates that Network Rail should encourage investment by its suppliers and provide a clear set of objectives and targets to be met through the interim steps of the Modular S&C programme. Lean production recommendations would include such requirements as;

- Covered assembly areas to improve assembly
- No dismantling of units prior to despatch – delivery in panel form only and thus removing re-assembly from the critical path at the worksite
- Maximising pre-fabrication in controlled conditions – reduces work line-side (fitting cables, point operating equipment, point heaters, etc)
- Maximising testing prior to factory exit – less commissioning on site

Recommendations for wider aims of this strategy should also include;

- Trying to ignite interest of other European suppliers
- Stipulating “World Class” manufacturing principles
- Giving full and timely specification of what the company wants
- Stipulating the specification / quality of units at the factory exit
- Defining the increased scope (prefabrication and testing) to minimise the need for activities that are currently carried out in less safe conditions on-site during installation
- Giving confidence for capital investment in facilities and tooling
- The implementation of KPI’s and formalised feedback

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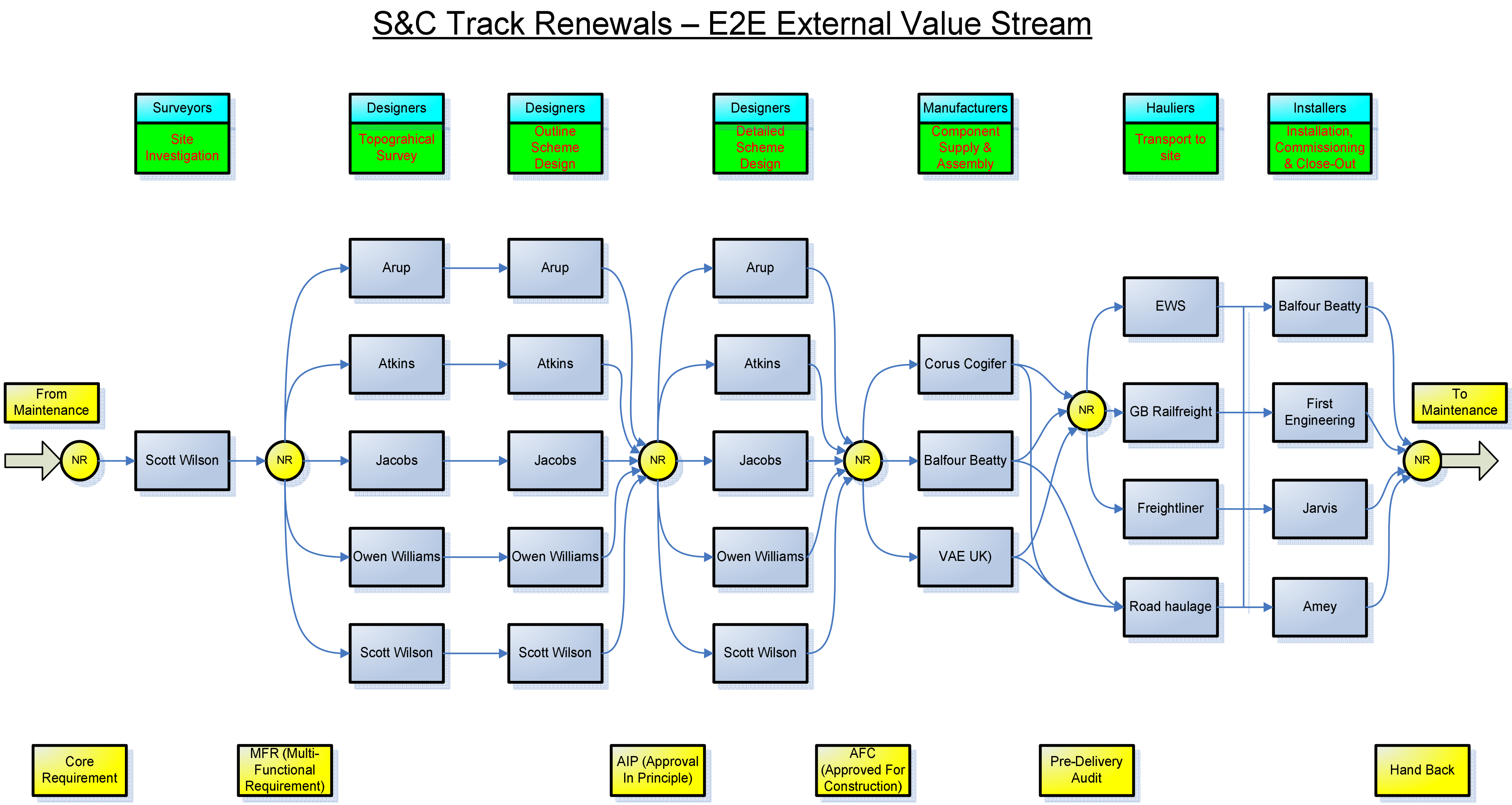
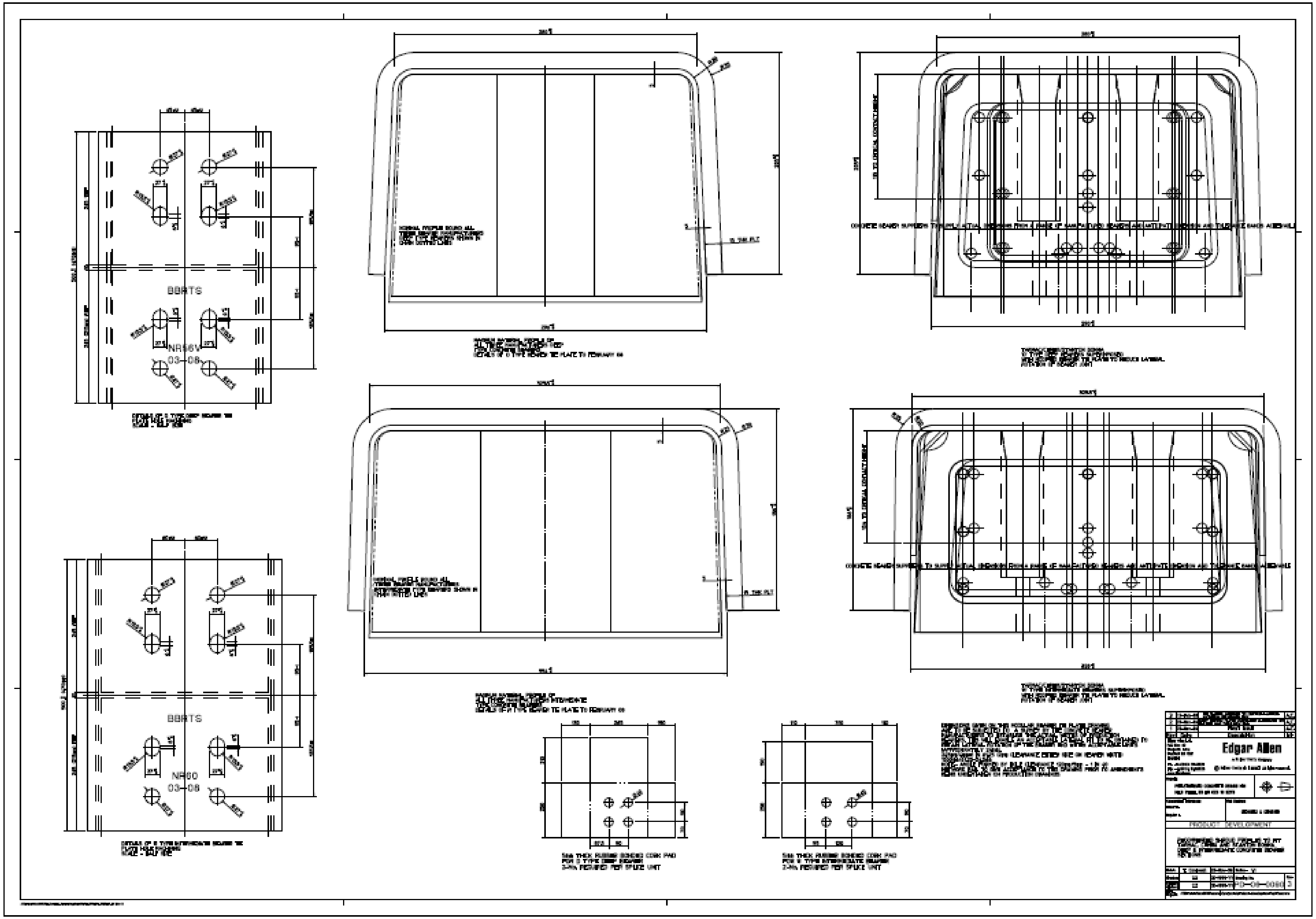
9. Appendices

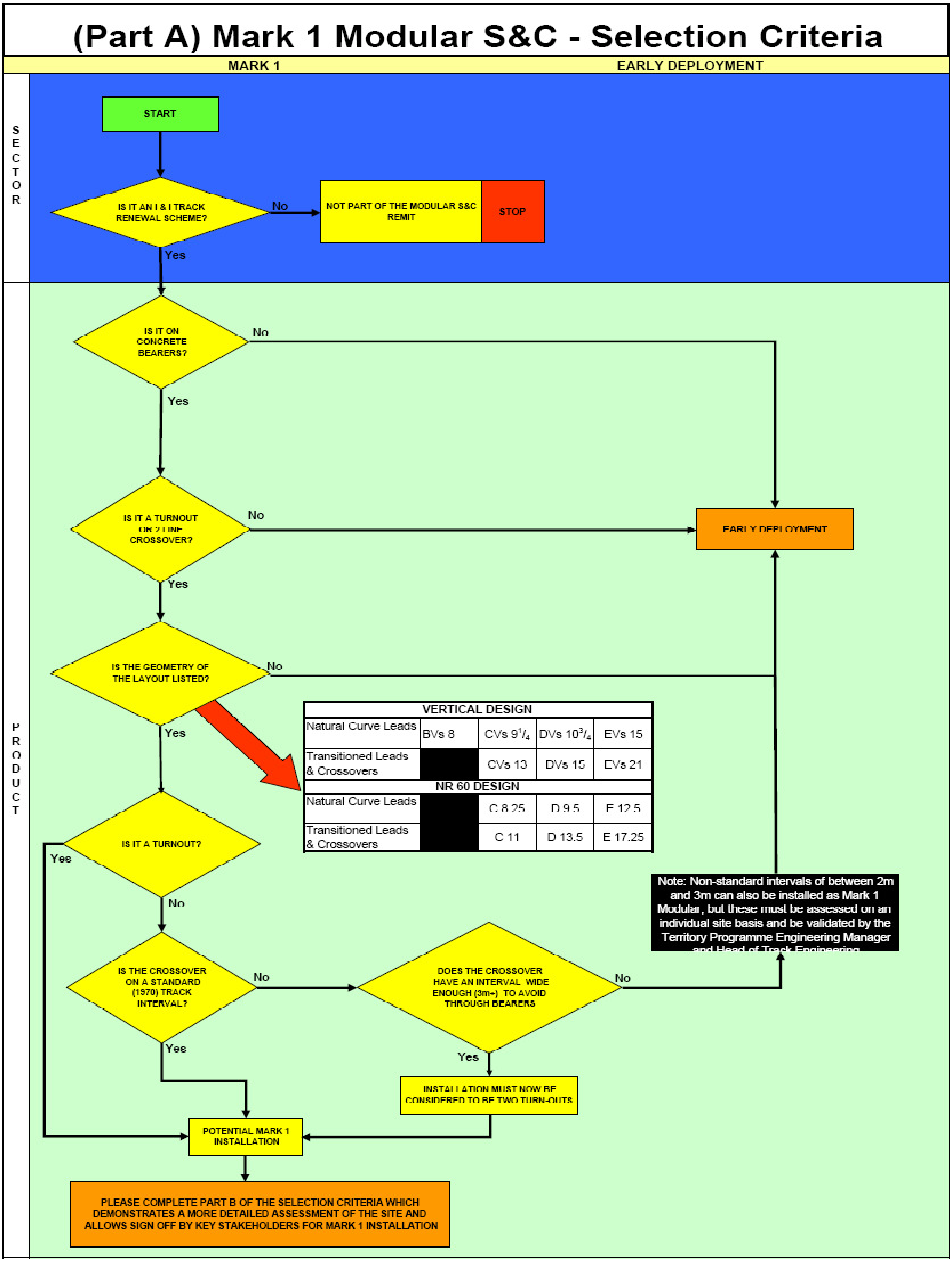
Appendix 1 – S&C renewals current



Appendix 2 – Drawing for the Split Bearer Solution



Appendix 3 – Modular Decision Tree (Part A)



Appendix 4 – Modular Decision Tree (Part B)

(Part B) Mark 1 Modular S&C- Site Detail
(Please complete one form per crossover or turnout)

Category		Site Name						Please delete as applicable ⬇
		Point No's		ELR		Mileage		
		Planned Installation date				Week number		
Product	Design acceptance dates for Bearer Tie System	a) NR 60 Concrete Crossovers - (From April 2008) (or)						Yes/No
		b) Vertical Concrete Crossovers - (From April 2008) (or)						Yes/No
		c) NR 60 Concrete Turnouts - (From September 2008) (or)						Yes/No
		d) Vertical Concrete Turnouts - (From September 2008)						Yes/No
	Permitted switch sizes for Mk1 installation	**VERTICAL DESIGN (tick applicable)**						Yes/No
		Natural Curve Leads	BvS 8	CvS $9^1/_4$	DvS $10^3/_4$	EvS 15		No. of units to install ....
		Transitioned Leads & Crossovers		CvS 13	DvS 15	EvS 21		No. of units to install ....
		NR60 DESIGN (tick applicable)						Yes/No
		Natural Curve Leads		C 8.25	D 9.5	E 12.5		No. of units to install ....
		Transitioned Leads & Crossovers		C 11	D 13.5	E 17.25		No. of units to install ....
	Curves	Does the location have a main line radius greater than 200m?						Yes/No
	Geometry	Does the location have a single consistent vertical gradient?						Yes/No
	Type of interval	a) Standard interval or an interval wide enough (3m +) to avoid through bearers? (or) *(note - 3m+ wide interval must be considered to be 2x turnouts)*						Yes/No
		b) Non - standard interval?	Yes/No	Please indicate actual interval width (m)				
Production	Early Deployment	Installer must have attained verified and repeatable Early Deployment target level 3 or better						Yes/No
	Recommended installation plant *(Note: availability will be assessed by Programme Controls Manager (Resources))*	(a) KIROW (type 1200 or 810) plant (or)						Yes/No
		(b) Tandem TRM plant						Yes/No
	Planning	Installer will have demonstrated capability with Mark 1 Modular system tasks with verified training & rehearsals						Yes/No
	Handling	Installer will have completed verified training & rehearsals with "Modular" panel lifting equipment						Yes/No
	Tools & equipment	Installer will have completed verified training & rehearsals with Mark 1 Modular Bearer Tie tools & equipment						Yes/No
	S&C delivery - road or road & rail	(a) Road delivery to site laydown area (or)						Yes/No
		(b) Road delivery of "Modular" panels to "road to rail" transfer facility						Yes/No
	Contraints of rail	**Outside Possession** - Installer has complied with GORT3056K (Working Manual for Rail Staff) through being in possession of an approved condition of passage form (RT3973EXL) issued by NDS Loading Standards. Note:Recommendation from the Network Rail National Loading Standards Manager is a maximum distance for O.O.G. movements is 3 miles.						Yes/No
		Inside Possession - Installer has provided evidence of consultation with National Loading Standards Manager who has provided support through walkouts on site and/or advice on movement of O.O.G. loads for the renewal site listed above						Yes/No

Additional information or comments

			Date	Signature
	Territory Team	Territory Programme Engineering		
		Territory Production		
	Modular Team	Programme Engineering		
		Programme Production		

All signatures must be present to proceed with Mark 1

Decision Tree Version 0 17th October 2007

Appendix 5 – Manufacturers Checklist

S&C installers requirements from the Manufacturer

Date of installation		Location	
Order No.		Points No.	

SWITCHES

	YES	NO
SWITCHES TO BE DELIVERED AS A PANEL?		
POINTS MACHINE ATTACHED THE PANEL FOR DELIVERY		
POINTS OPERATING EQUIPMENT FITTED TO THE LAYOUT		
MK1 LIFTING ATTACHMENT PLACED AND SECURED ONTO THE PANEL (TEST LIFTS COMPLETE AND ATTATCHMENT POINT MARKED)		
LIFTING PLAN DOCUMENTATION PRODUCED AND ATTACHED TO PANEL (WEATHER-PROOFED)		
POINTS HEATING INSTALLED AND SECURED ONTO THE SWITCH RAILS		
SHROUDS BANDED TO BEARER		
8No. WASHERS AND SCREWS PACKAGED AND BANDED ONTO EACH BEARER		
INSTALLATION TOOLS PACKAGED WITH PANELS		
RUBBER PADS BONDED TO SHROUDS		
RUBBER PADS BONDED TO BEARER ENDS		

CROSSING PANEL REQUIREMENTS

	YES	NO
FOAM TO PREVENT INGRESS OF BALLAST BETWEEN CHECK AND SUPPORTING RAILS AND IN FLANGEWAY OF CROSSIN(		

SWITCH PANEL REQUIREMENTS

	YES	NO
FOAM TO PREVENT INGRESS OF BALLAST BETWEEN SWITCH AND STOCK RAIL!		

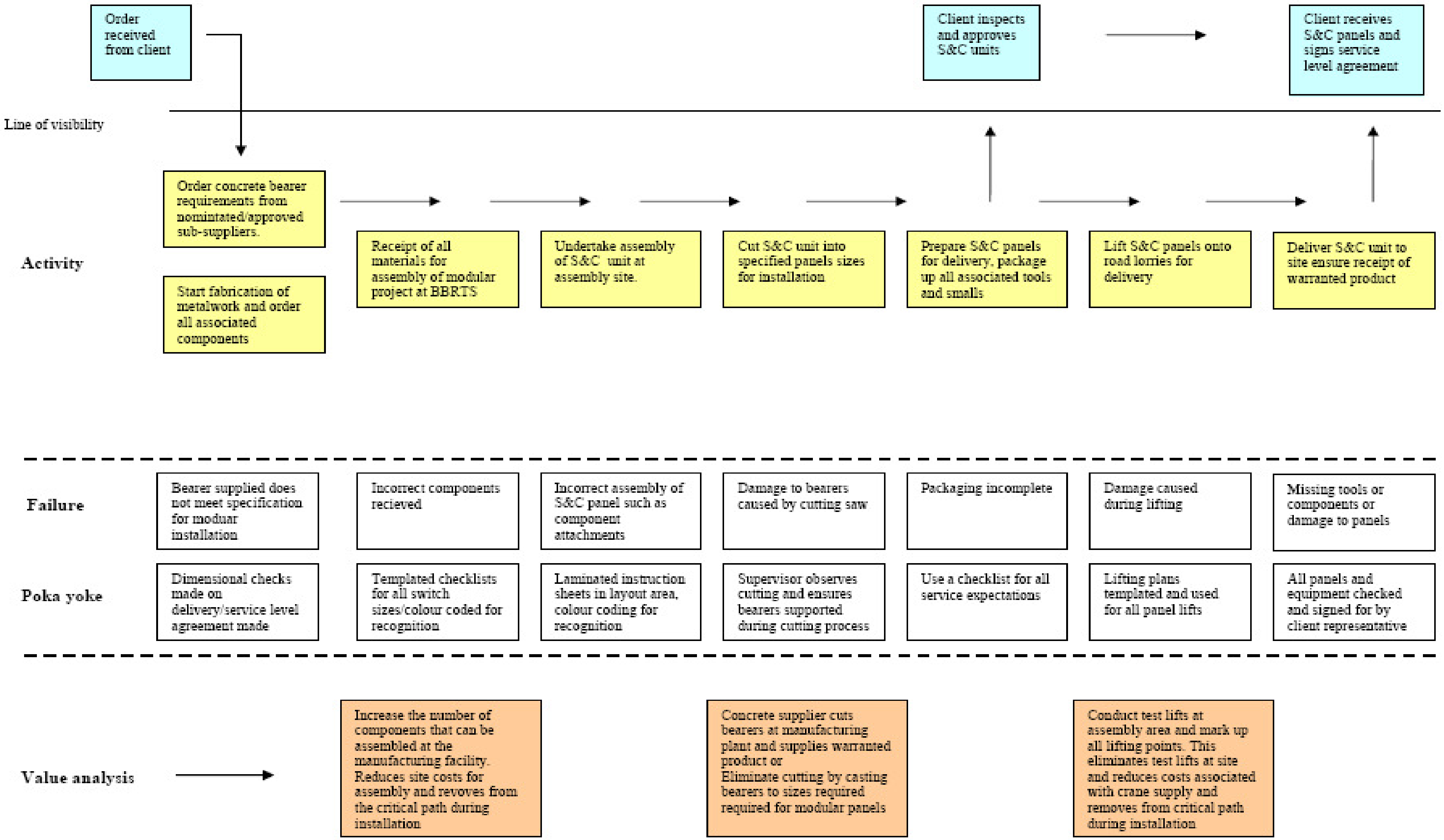
JOINTS

	YES	NO
TEMPORARY BONDS FIXED AND TIED TO THE RELEVANT RAIL		

REQUEST AND APPROVAL

REQUESTED BY (Contractor)		SIGNED		DATE	
APPROVED BY (Network Rail)		SIGNED		DATE	

Appendix 6 – Service Blueprint for S&C Manufacture



Appendix 7 – S&C Value Stream Future State

S&C Track Renewals – E2E External Value Stream – Ultimate Solution