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INNOTRACK

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Thematic Priority 6: Sustainable Development, Global Change and Ecosystems

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RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Glossary

Abbreviation/acronym	Description
AT	Alumino-Thermic
FB	Flash Butt
FFBW	Factory Flash Butt Welding
HIAB	Trade Name for a vehicle fitted with lifting crane
IM	Infrastructure Manager
LCC	Life Cycle Cost
LWR	Long Welded Rail
MFBW	Mobile Flash Butt Welding
S&C	Switches & Crossings

1. Executive Summary

Logistics is the management of the flow of goods and other resources between the point of origin and the point of consumption in order to meet the requirements of the user. It involves the effective integration of activities such as information flow, transportation, inventory, warehousing, and material-handling that together realise the value of time, space capacity utilisation resulting in a cost effective supply chain. Although the origin of logistics lie within military, the modern business world recognises the importance of effective logistics and has fully embraced the important principles through detailed analysis, discrete event modelling, and computer simulation of the various stages.

The importance of effective management of the supply chain and logistics for the maintenance of renewal is widely recognised and has driven the following three key developments that have made a step change difference in the optimisation of logistics of rail:

1. 120m long as-rolled rails
2. Rail delivery systems
3. Mobile solid phase flash butt welding process

Nevertheless, logistics of rails remains complex as it is affected by a very wide variety of factors such as the intended use of the rails (track renewal, track maintenance, S&C manufacture) and access to the location of use. Consequently, it was recognised that the development of a definitive directive for the logistics of rails should not be the prime objective of the Innotrack Project. Instead, critical analysis of the various factors influencing logistics of rail was considered to be more beneficial as it would enable a clearer adoption of the principles involved for the variety of circumstances encountered on different European networks. Several conclusions have been drawn from the analysis and the key aspects related to the financial impact of rail logistics are:

1. It has been concluded that logistics is an enabling technology for the introduction of innovations such as long length rails and mobile FB welding. Consequently the resulting benefits are already accounted for against the respective innovations.
2. The second area of financial impact should be covered by the contractual agreements between the rail supplier and IMs but availability of unit cost (Euro per tonne-km) could yield savings by comparison.
3. The final area of financial impact is likely to result from the choice made from the selection of logistic solutions discussed in Section 3. However, the optimum choice is not universally applicable to all networks and all circumstances and consequently it is not possible to derive a numerical first cost or LCC saving for each of the choices. Instead, the discussions presented in Section 3 could be converted into a “decision-tree” software programme to facilitate the choice of the optimum logistic solution. However, this was outside the scope of the current project.

2. Introduction

Logistics is the management of the flow of goods and other resources between the point of origin and the point of consumption in order to meet the requirements of the user. It involves the effective integration of activities such as information flow, transportation, inventory, warehousing, and material-handling that together realise the value of time, space capacity utilisation resulting in a cost effective supply chain. Although the origin of logistics lie within military, the modern business world recognises the importance of effective logistics and has fully embraced the important principles through detailed analysis, discrete event modelling, and computer simulation of the various stages.

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Nevertheless, logistics of rails remains complex as it is affected by a very wide variety of factors such as the intended use of the rails (track renewal, track maintenance, S&C manufacture) and access to the location of use. Furthermore, consideration of logistics of rails needs to be expanded to a wider perspective to include those aspects of renewal and maintenance that ensure optimum longevity of rail and the track as a system. Thus logistics of rails also needs to consider the influence of:

- Improved safety of track renewal and maintenance
- Improved quality of construction
- Reduced first time and life cycle costs of track renewal and maintenance

Achievement of the above targets requires a very significant technical input and these aspects, amongst other influencing factors, are discussed in this report.

3. Logistics of Rail – The Process

A schematic summary of the logistics of rails and associated activities is shown in Figure 1. Each of the 4 identified subsets are examined and discussed in more detail in the subsequent sections.

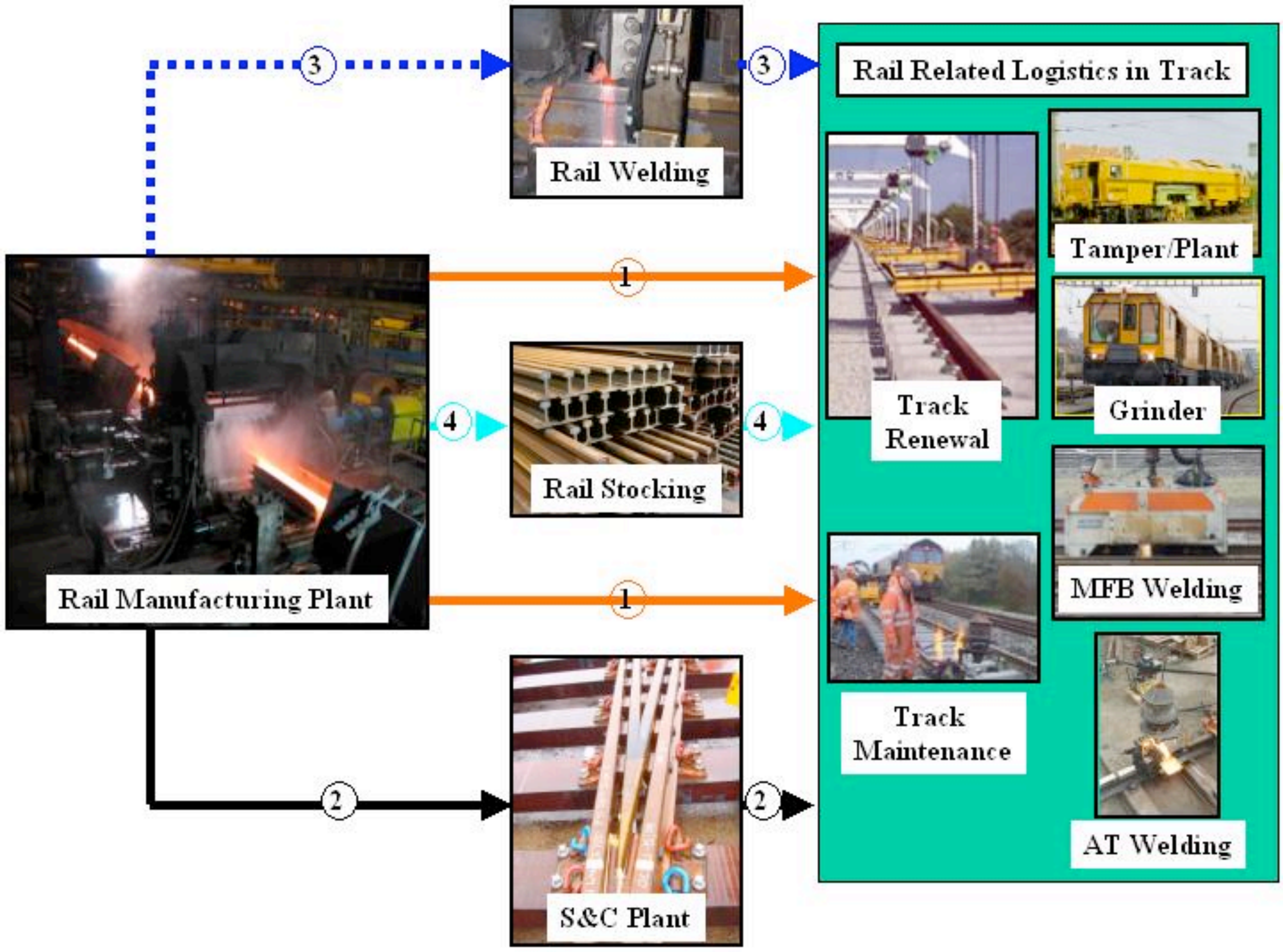


Figure 1 Various aspects of rail related logistics

Although a primary objective of logistics of rail is a reduction in initial and life cycle costs of track renewal and maintenance, which involves a number of different options and steps, it should be emphasized that optimisation of individual steps is not necessarily the optimum for the whole process.

It is apparent that Options 1, 3, and 4 in Figure 1 are different alternatives available for the supply of rails to track side; hence the need to examine their technical and logistical pros and cons. This is covered in Section 3.1 below.

In contrast, the manufacture of S&C requires the supply of rail lengths to specialist manufacturing plant for which the optimum logistics requirements are likely to be different to those of direct supply of rails to track side. However, one further aspect of logistics that needs to be considered in this case is the supply of the manufactured S&C unit to track side. This is covered in Section 3.2.

3.1 Rail Supply to Track Side

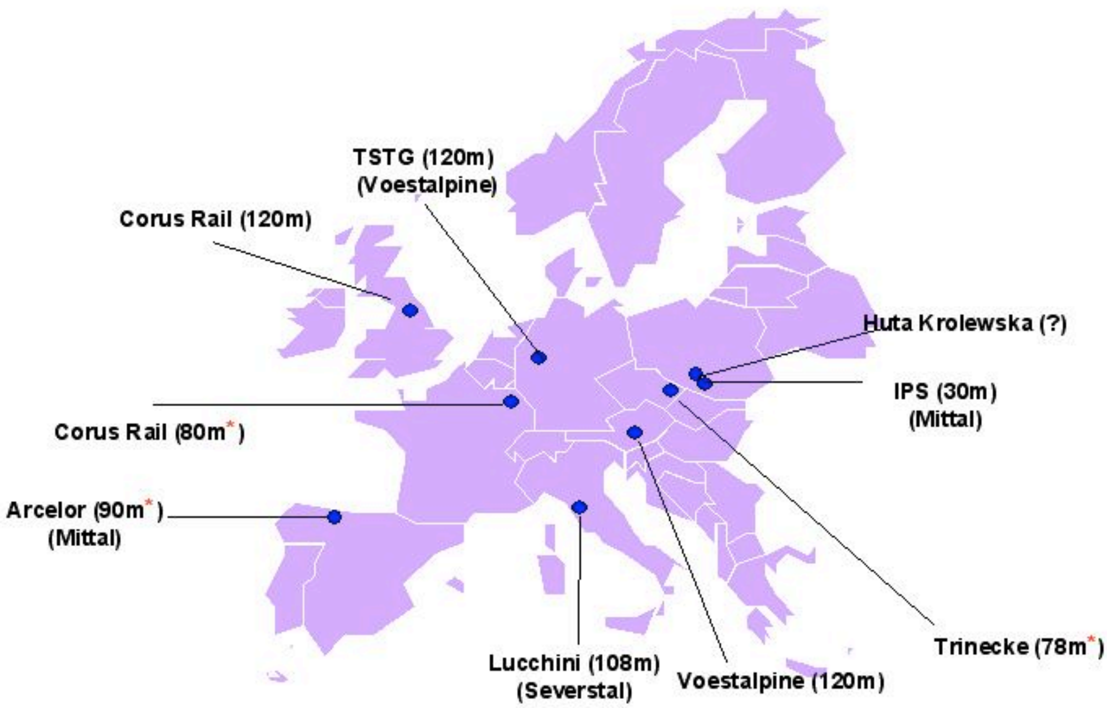
The total length of track within the EU 27 countries is approximately 300,000 km[1]. Assuming an annual replacement rate of just 2.5% of track, the length of rail requirement is 15,000 km per annum. However, a key requirement for the optimisation of logistics is the breakdown of the rail requirement by the intended use. Thus, as indicated in Figure 1, rail supply to track side serves the following 4 distinctly different usage operations for which the optimum rail logistics solutions also differ.

1. Full track renewal or new construction
2. Renewal – rail replacement only
3. Renewal of specialist track
4. Track maintenance – replacement of short lengths associated with defect removal

3.1.1 Full Track Renewal or New Construction

The very nature of the full track renewal or any new track construction process requires longer possession times and the delivery of many other materials and plants to the construction site. Hence there is a clear need for coordination of the flow of the various materials to and from the site. Furthermore, in support of the objective of minimising the LCC of track, the cost effectiveness of the logistics of rail supply needs to be balanced against the key technical desirables for longevity of the track.

Breaks at aluminothermic welds account for well over a third of all rail breaks in most modern railways[2] although there is a belief that introduction of improved process control and better welder training has made modern AT welds more robust. Furthermore, particularly in higher speed lines, longitudinal geometry and the crown profile at AT welds is also considered to be a key cause of rail degradation as it can lead to the formation of squat type defects at the welds themselves or lead to higher dynamic forces following the weld that in turn can give rise to rolling contact fatigue and increased rate of degradation of track geometry. Hence there is a clear need to minimise the incorporation of AT welds through the use of longer length rails. The location of the major long rail manufacturers within the EU and the longest length produced is shown in Figure 2. It is apparent that 7 out of the 9 rail rolling mills have, or soon will be, capable of producing rail lengths in excess of 100m and rail length cannot be a discriminating factor. However, the rail mills are widely dispersed and, at least some, are remote from the major rail consuming areas. Although the distance between the point of manufacture and that of use has a significant bearing on the total cost of delivered rail, this can be addressed through the tender process by making sure that the rail price is inclusive of delivery to site. Hence, shorter delivery distances will be reflected in lower total cost of delivered rail.



* ≥100m capability under development

Figure 2 Rail Manufacturing Plants Within the EU

However, railways are long linear assets and although the availability of rails up to 120m long straight from the manufacturer has been a significant development, there remains a need for cost effective and technically robust technique for joining long hot rolled rails in track. The options available are discussed below.

<u>(a) >100m Hot Rolled Rails Welded Using AT Welds in Track:</u>

This option offers a reduction in the number of both AT and flash-butt welds compared to the use of up to 36m length rails that was considered the norm not many years ago. Although transportation of up to 120m long hot rolled rails is more expensive than shorter lengths of around 36m, they can be transported using standard flat wagons with several alternative discharge systems. However, as indicated earlier, the longevity and the robustness of profile of aluminothermic welds is widely questioned and although the use of up 120m long rails has reduced the number of such welds in track, the presence of an AT weld at 120m intervals remains the weak link in this option. Hence the option of constructing track with 108/120m as rolled lengths of rail joined together with AT welds is not the optimum choice for the construction of new track and is also unlikely to be the option of choice for the majority of long length full track renewals. Thus the alternative option available is to combine the benefits of long hot rolled lengths of rails (>100m) with the greater internal integrity of solid phase flash-butt welds. The adoption of this welding process leads to three further options for delivery of higher integrity welded lengths of rail to track.

(b) <u>Mobile FB welding (MFBW) of >100m rails delivered directly to renewal / rail replacement site</u>

This option uses a mobile flash butt welding (MFBW) plant to join >100m long hot rolled rail lengths into the length required at a new track construction or full renewal site. The closure weld can be made using either the MFBW unit or using an AT weld.

Again, the >100m rails can be delivered to site on standard flat bed wagons. The option has the advantages of reducing the number of AT welds in track compared to Option (a). However, site conditions necessitate more careful control of weld alignment and stripping to ensure the desirable level of longitudinal and transverse profiles around the weld. A further logistical restriction that needs to be considered is that a cost effective deployment of MFBW requires a minimum number of ~15 welds per shift.

Hence this option is suitable for full track renewal or rail replacement for all lengths of track where adequate possession time is made available and there are a sufficient number of welds for cost effective deployment of a MFBW unit.

(c) <u>Use of Mobile Factory FB Welding Unit at Location Close to Construction/Renewal Site</u>

This option is a slight variation on the use of MFBW with the added advantage that welding can be undertaken in more controlled environment to better support the rail lengths using roller tables. It should be noted that the larger number of welds made using a MFFBW unit make it more economical than similar number of AT welds or even MFBW made directly in track. It also offers the opportunity to form longer lengths of LWR that can then be joined in track using an AT closure weld. The plant facilities required to transfer the LWR needs to taken into account in the planning of logistics for this option. Furthermore, the use of this option is restricted by the availability of suitable locations close to the construction/renewal site and the availability of MFFBW plants that are not as readily available as standard MFBW units.

Hence this option is best suited for longer construction or renewal sites where a MFFBW unit can be located nearby.

(d) <u>Use of Factory FB Welding (FFBW) Unit</u>

This is a well established option in which hot rolled rail lengths can be welded into LWR strings. The move to the use of >100m hot rolled rail lengths reduces the number of welds and thereby contributes to a reduction in the installation costs and LCC of track renewal and maintenance.

Traditionally, all major railways have owned and operated welding plants although a few of the larger rail manufacturers have installed welding plants close to the rail rolling mill. The latter option involves internal transfer within the manufacturing plant followed by delivery of a standard length of LWR to the construction/renewal site.

Such factory FB welding plants are designed with the necessary processing stages and controls to ensure consistency of weld integrity. In particular, the use of semi-automatic profile grinding followed by laser alignment checks ensures that longitudinal profile is maintained within close tolerance. Furthermore, since in general, rails from individual rollings are used in the manufacture of LWR strings, they offer a closer match of dimensional tolerance to ensure better control of geometry around the weld.

Although dedicated LWR train units are required to transport such welded rails, good control of logistics ensures fuller payloads on such trains to deliver the necessary number of lengths to individual construction/renewal sites.

The choice of the length of the LWR string is governed by various factors including the longest lengths that could be transported through the network and the availability of a suitable LWR train unit. In the UK, 2 x 108m hot rolled rails are welded at a FFBW and the 216m LWR transported to site using specialised delivery trains owned by the Infrastructure Manager. In comparison, the longest LWR lengths in France and Germany are 400m and 300m respectively while 800m LWR strings are common in the Baltic States.

Thus this option is suitable for full track renewal or rail replacement for all lengths of track where MFBW or AT welding can be used to join the LWR strings into the lengths required for the sites with preference given to MFBW for longer sites.

3.1.2 Renewal - Rail Replacement Only

It is necessary to consider the logistics of rail for those sites that require only the replacement of rail rather than full track renewal. The work undertaken in Innotrack SP1 has demonstrated that railway networks are not a single linear asset but comprise of a multitude of curved and tangent track segments with different rates of rail degradation. Consequently the life span of rails in tight and moderate curves is shorter than those in tangent track. Furthermore, rail life curtailment because of the occurrence of rolling contact fatigue (RCF) in some curves has necessitated rail replacement at an early stage before ballast or sleeper life is exhausted. In contrast, rail life in tangent track is much longer and hence is likely to be a closer match to the life expected from sleepers and ballast. The segmentation exercise revealed that the length of many of the tighter and moderate curves lies in the range 200m to 600m. Hence, the options for rail logistics that need to be evaluated are:

(a) >100m Hot Rolled Rails Welded Using AT or Mobile FB Welds in Track

As discussed in respect of the new construction and full track renewal sites, although this option offers a reduction in the number of both AT or flash-butt welds compared to the use of up to 36m length rails, preference needs to be given to the use of solid phase welds delivered either by mobile or factory FB welding units. Consequently, the use of AT welds to join the long hot rolled lengths is not considered optimum for the renewal of rail in a large majority of curves. However, a further logistical consideration is access to some rail renewal sites – at times, access restrictions at some sites may not permit delivery of LWR strings and hence it may be necessary to deploy the longest hot rolled lengths that could be delivered and welded on site. In such circumstances, the use of MFBW or AT welding to join the rails will be dictated by factors such as economics of MFBW and the traffic density carried on the track.

(b) <u>Use of Factory FB Welding (FFBW) Unit</u>

The use of LWR strings manufactured using >100m long hot rolled rail lengths is considered to offer the optimum solution because:

1. It offers the longest available LWR string comprising high integrity factory FB welds.
2. Multiples of such LWR string can be used to span the full length of the rail renewal site
3. It reduces the time required to install the rails on site as significantly fewer site welds are required

The installation contractor of a recent installation in a UK network preferred the option of 216m LWR string compared to 2 x 108m hot rolled rail lengths welded in track using mobile FB welds.

Although the deployment of this option requires investment in LWR train units, such units are available in most major railway networks. A maintenance program of such train units is also essential to ensure that rails are not damaged in transit.

3.1.3 Delivery of Rail for Specialist Track

Supply of rail for the renewal of level crossings is an example of rail delivery for specialist track. Corrosion of rails from the salt treatment of the passing road is a major rail degradation mechanism at such locations. This is further exacerbated in third rail environments that promotes stray current corrosion. Consequently, there is a growing demand for the use of rails coated with corrosion protective coatings. Such rails are generally available in shorter lengths sufficient to span the width of crossings and need to be handled carefully.

The logistics solution to satisfy such requirements is a specialised rear steer flat beds complete with HIAB discharge facilities. This solution is employed for all remote locations or sites where there are no discharge facilities. Short length rails, up to 27m long, can also be delivered using standard flatbed trailers.

3.1.4 Delivery of Rail for Track Maintenance

The term “track maintenance” can have widely different scope in different railways. The logistics requirements discussed in this section are with respect to the delivery of shorter length rails as replacement of track with identified discrete defect. There is stipulation of a minimum distance of around 4.5m between two adjacent joints or welds in track in most railways and consequently removal of defects requires a length of rail generally ~9m long. There is an appreciably large proportion of rail supply that is required in shorter lengths as is apparent from over 20,000 defects taken out of a 32,000km network. However since defects could occur in any part of the network, the replacement short length rails are best stocked at discrete locations such as maintenance depots.

Hence, the most flexible logistical solution for the delivery of short length rails (up to 27m) is by road using flatbed trailers.

3.2 Delivery of Rail for S&C Manufacture

S&C are specialist track system components that are manufactured at supplier premises and generally require shorter length rails. Again, the most flexible logistical solution for satisfying the requirements of S&C manufacturers is by road using flatbed trailers. However, the innovation in logistics with respect to S&C units lies in the supply of the manufactured unit to site. The growth in passenger and freight traffic necessitates a reduction in the time window for maintenance and renewal and any temporary speed restriction following renewal and/or maintenance. In this context, there are initiatives in some railways for a modular construction approach to the installation of S&C. This system requires significant pre-assembly of the S&C units so as to minimise the assembly time required during the installation possession. A system to transport to a modular S&C is shown in Figure 3 below. This is a good example of the important role of logistics in introducing innovations to reduce the cost of track renewal and maintenance.

Figure 3 Transport of pre-assembled S&C panel – Network Rail modular S&C initiative[4]

3.3 Delivery of Rail to Stockholding Locations

Figure 4 below shows the location of the rail rolling mills and those of the major rail welding plants. It is apparent that there will be significant distances between the point of manufacture and the point of use for many railway network locations throughout Europe. Consequently consideration needs to be given to stockholding at strategic locations to permit shorter delivery time to the point of use. Clearly, the use of stockholding suffers from the disadvantages of double handling and deterioration of quality through corrosion when stored for long periods. Although these disadvantages could be overcome through careful handling and controlled stock rotation, it is essential to assess the balance of economic impact of stock holding and the savings from full payload deliveries at lower costs to the stockholding location. Some of the existing welding plants (e.g. Eastleigh in the UK network) may already be strategically located close to the area of greatest usage and hence serve as ideal stockholding locations for both LWR strings as well as long hot rolled lengths.

Figure 4 Location of rail rolling mills and rail welding plant within the EU. Not on the map: Kaipianinen Finland, Sannahed Sweden, Entrocamento Portugal and Schaerbeek Belgium

It should be noted that a survey undertaken by Innotrack SP5 indicated that the IMs carry a maximum of 10% of annual requirement in stock; the magnitude of this is governed by several factors including the distance from and the nature of the supply contract with the primary supplier and the magnitude of unplanned maintenance and renewal that is undertaken within the network.

3.4 Transport by Sea Vessel

Rail transportation can also be executed using sea vessels, where appropriate. This type of transportation is beneficial for larger tonnages to be shipped to the same final destination over long-distances. The salient points of note in undertaking this mode of transportation of rails are:

1. Rails need to be transported under deck to protect them from saline corrosion. On deck transportation of rails is not recommended
2. Careful stacking plan, even under deck, is required to prevent corrosion damage from “sweating of rails”
3. Availability of suitable vessels restricts the rail lengths that can be transported in this manner to a maximum of 80m, although more commonly to 60m.
4. The loading and unloading systems need to be carefully engineered to prevent distortion and permanent bending of the long length rails.
5. The pre loading and post unloading stocking conditions need to be assessed carefully to prevent corrosion damage

4. Financial Impact of Choice for Logistics of Rail

The preceding sections have demonstrated the technical merits of the use of longer lengths of hot rolled rails and solid phase flash butt welding to join such rails. It has also been shown that railway operations are complex and the "one size fits all" approach is not pragmatic. The innovation required from logistic operations related to rail was to enable the deployment of the specific innovations. In this context, rail logistics has developed the systems to deliver up to 120m long hot rolled rails on standards flat bed wagons and the delivery of up to 400m long welded strings on specialist LWR trains. Mechanisms to hold the rails in position during transit, to maximise the payloads, and to assure a safe discharge have also been delivered. Equally, innovation has been introduced in the transport of pre-assembled S&C panels to facilitate rapid installation of modular units. It is, therefore, apparent that the key financial impact comes from logistics of rail acting as the enabler for the introduction of rail innovations that are key to the realisation of LCC savings in track renewal and maintenance.

The second area of financial impact lies within the contractual agreements between the rail supplier and IMs and although availability of unit cost (Euro per tonne-km) may yield savings by comparison, it was not feasible because of commercial confidentiality. More detailed consideration of the contribution of logistics and the contractual interfaces are presented earlier deliverables from the project[5-6].

The final area of financial impact is likely to result from the choice made from the selection of logistic solutions discussed in Section 3. However, the optimum choice is not universally applicable to all networks and all circumstances and consequently it is not possible to derive a numerical first cost or LCC saving for each of the choices. Instead, the discussions presented in Section 3 could be converted into a "decision-tree" software programme to facilitate the choice of the optimum logistic solution. However, this was outside the scope of the current project.

5. Summary and Conclusions

The importance of effective management of the supply chain and logistics for the maintenance of renewal is widely recognised and has driven the following three key developments that have made a step change difference in the optimisation of logistics of rail:

1. 120m long as-rolled rails
2. Rail delivery systems
3. Mobile solid phase flash butt welding process

Nevertheless, logistics of rails remains complex as it is affected by a very wide variety of factors such as the intended use of rail (track renewal, track maintenance, S&C manufacture) and access to the location of use. Consequently, it was recognised that the development of a definitive directive for the logistics of rail should not be the prime objective of the Innotrack project. Instead, critical analysis of the various factors influencing logistics of rail was considered to be more beneficial as it would enable a clearer adoption of the principles involved for the variety of circumstances encountered on different European networks. This approach could also be translated into a “decision –tree” software to facilitate the choice of the optimum logistic solution. The key conclusions from the analysis of the different influencing factors undertaken are:

1. The supply of rails to track side needs to be examined with respect to its intend use and the associated resources available.
    a. Thus, for new track construction and full track renewals, for which longer possession periods are available, the use of long hot rolled rail lengths welded using solid phase welding is recommended. However, the choice of solid phase welding technique (mobile FB welding, mobile factory FB welding, or factory FB welding) is governed by the cost of the three welding options, and the availability of standard flatbed wagons or LWR train units.
    b. For rail renewal projects in curves of lengths that are simple multiples of the maximum length of LWR available, the use of LWR strings delivered using specialist trains is considered the most desirable option as it minimises the installation time. The LWR string should be made from >100m hot rolled lengths of rail. This option was the preferred solution for a contractor in the UK. However, use of on-site mobile FB welding of >100m hot rolled rails is also acceptable provided the quoted costs are equally or more favourable.
    c. It has been confirmed that up to 120m long hot rolled rails can be transported using standard flatbed wagons while specialist LWR train units are required to transport up to 400m long LWR strings (Baltic states can transport up to 800m LWR strings). However, it has been noted that the maximum length of LWR strings that can be transported in various EU network ranges between 144m and 400m.
    d. For rails for specialist track, such as the use of corrosion protection coated rails for installation in level crossings, the use of shorter length and a HIAB equipped delivery vehicle has been recommended.

   e. The difference in the scope of rail “maintenance” in different networks has been acknowledged but for the defined scope of defect removal by replacing a short length, the use of road flatbed trailers to deliver up to 27m long rails is considered optimum.

2. The supply of rails to S&C manufacturers is also best undertaken by road using flat bed trailers. However, the innovation in logistics of S&C has been in the use of inclined wagons to transport pre-assembled S&C panels to facilitate significantly more rapid and accurate installation.
3. Three distinct areas of financial impact of rail logistics have been examined.
   a. It has been concluded that logistics is an enabling technology for the introduction of innovations such as long length rails and mobile FB welding. Consequently the resulting benefits are already accounted for against the respective innovations.
   b. The second area of financial impact arises from the distance between the site of rail manufacturing and its use. This aspect should be covered by the contractual agreements between the rail supplier and IMs but availability of unit cost (Euro per tonne-km) could yield savings by comparison.
   c. The final area of financial impact is likely to result from the choice made from the selection of logistic solutions discussed in Section 3. However, the optimum choice is not universally applicable to all networks and all circumstances and consequently it is not possible to derive a numerical first cost or LCC saving for each of the choices. Instead, the discussions presented in Section 3 could be converted into a “decision-tree” software programme to facilitate the choice of the optimum logistic solution. However, this was outside the scope of the current project.

6. References

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3. Innotrack Deliverable D1.2.5 – Track Segmentation; Lead Partner Corus
4. Geoff South – Network Rail HQ Track Engineering "Presentation to the Railway Industry Association – 2nd July 2009"
5. INNOTRACK deliverable D5.1.5 – Final Report on Existing States-of-the-Art for Construction, Maintenance and Renewal Activities and Assessment of Logistic Constraints
6. INNOTRACK deliverable D5.1.6 – Final Report on conduct of interfaces between contractors and infrastructure managers

Appendix

Main influencing variables on the logistic chain of delivering rails

Listing and description, assessment of costs and possible benefits; examples

A1) Rail length

The rail length is a very important parameter concerning the logistics of rails. The longer the rail produced in the rail mill the less weldings are required in track. This leads to decreased efforts concerning logistics during the installation processes of rails in track as well as during operation because every welding represents a point of inhomogeneity with a significantly increased probability of failure and subsequent traffic disruptions and repair needs.

For manufacturers the change-over to the production of long rails is connected with huge investments into the production line as well as into the finishing line. Generally all logistic processes of the rail rolling mill are affected. Nevertheless a general trend towards a production of rails longer than 60m can be observed all over Europe in the recent past as the benefit of a reduction of weldings in tracks is obvious.

There is also another process which had to be adapted to long rails: transportation. Also for transportation of this innovation several solutions have been developed in the past and special tie-down devices are available now. Nowadays transportation of long rails is possible on ordinary (standard) flat bed railway cars almost without any restriction. Tight curves do not represent a problem neither do the gradients of track. In addition transportation of long rails has even taken place on railway-ferryboats.

It is pointed to the fact that not the long rail alone (although itself an innovation) represents the objective regarding logistics but the possibilities and the potential regarding economic items obtainable by the *use* of long rails.

Nevertheless, taking into consideration that the majority of rail deficiencies (detected with ultrasonic devices) and roughly 50 percent of all rail breaks occur in weldings the reduction of weldings by introducing long rails should be achieved. The potential to be tapped can be described with the following figures: Compared to short rails of 30 meters length the number of required weldings is reduced by 75% and with even 60m long rails this percentage remains at 50% if 120m rails provide the basis for the comparison.

A2) Rail welding

Modern track systems can be characterized as being continuous guideways. In the past rail joints were replaced by rail weldings (with the exception of very tight curves due to danger of lateral track buckling) and this trend nowadays can also be noticed for switches as the majority of newly delivered high speed switches are equipped with moveable frogs.

For standard track several methods for rail welding have been available since the 1920s and also recently developments have been carried out and new processes have been invented. Rail weldings played an important role during the Innotrack project too and new processes such as the narrow HAZ process of Corus have been elaborated and tested. Simplistically two different methods for rail welding are available (aluminothermic weldings and flash-butt-weldings) which are executed in track with special equipment or mobile welding machines and also in special welding plants in case of flash-butt-weldings. For details concerning these methods it is referred to the respective deliverables of the Innotrack project as well as to general railway-related literature.

As discussed above, there are different possible approaches in order to achieve CWR (continuously-welded-rail) tracks. It can easily be seen that rail weldings can be executed in track only, and as a combination of welding in welding plants and in-track welding. In this case rails with lengths up to 400 meters (in some cases even more) are produced by welding short or long rails. This long rail is then transported to the site and the remaining weldings are performed in track using both aluminothermic welding and/or flash-butt-welding processes.

The cost of one **rail welding** amounts to **200 up to 500 € per welding**, strongly depending on the boundary condition but independent from the respective method in principle.

A3) Transportation

The transportation of rails represents the only unavoidable part of the logistic chain of delivering rails from the rolling mill to the construction site. The development of just-in-time (JIT) transportation of rails, which is the standard type of transportation in many other fields of application (automotive industry), has become a newly developed alternative to conventional rail transportation and allows a minimization of (unnecessary) manipulation actions as well as stock keeping and provides extraordinary advantages regarding logistic costs.

All different modes of transportation (from lorry to vessel) have already been highlighted in the first report on logistics of rails (Deliverable D5.5.1) and therefore this chapter will concentrate on the most important transportation mode, railway transportation. Generally a differentiation can be made between two types of railway transportation of rails: “interrupted transport” and “direct transport”, see Figure A1.

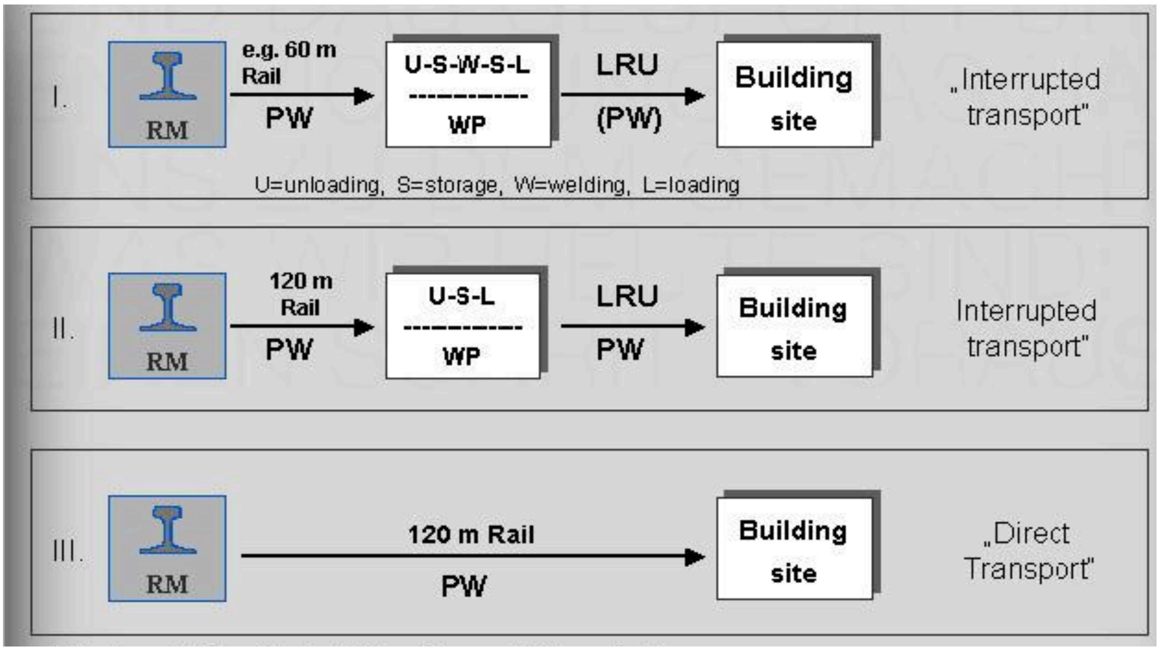
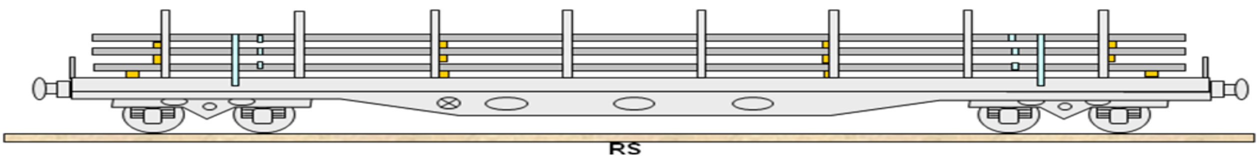


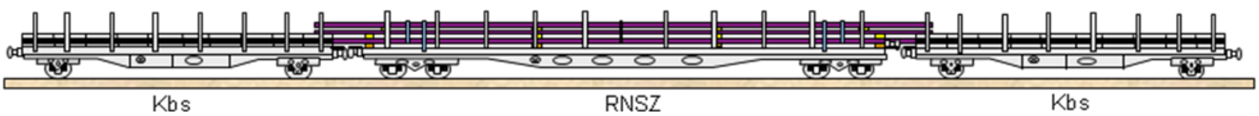
Figure A1: Transportation modes

Transportation can take place using standard flatbed cars for short rails. For long rails special long-rail-units (LRU) come into operation as well as several connected standard flat cars. On the following page examples are given:

<u>Example 1:</u>
Transportation of short rails with standard flatbed cars

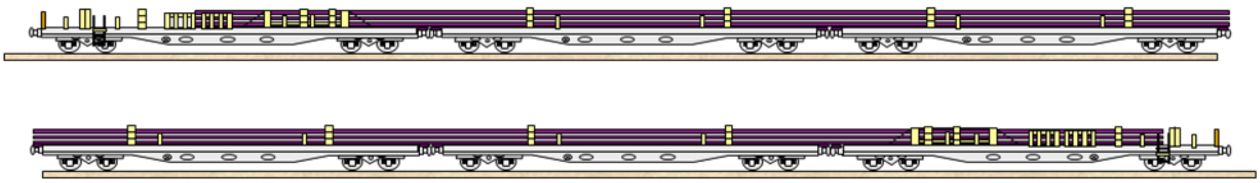


<u>Example 2:</u>
Transportation of short rails with standard flat cars (with trailers)



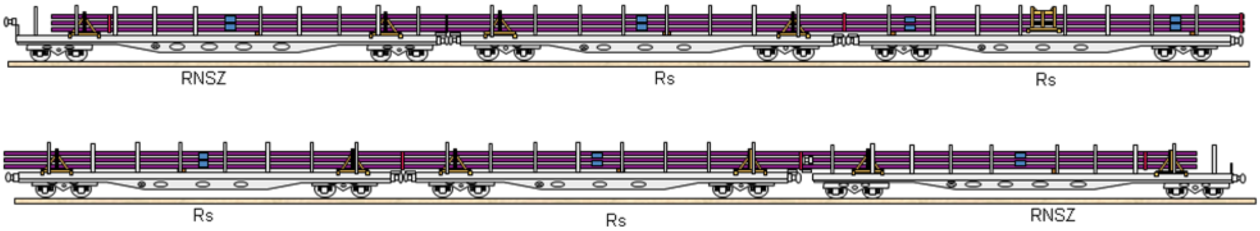
Example 3:

Transportation of long rails with special long-rail-unit



Example 4:

Transportation of long rails with standard flatbed cars



Optimizing the logistics of transportation is a challenging task as there exist several parameters, which have an influence on the logistics and the transportation charges. Moreover these parameters show considerable differences within Europe too. On the one hand minimum loads per freight car are mandatory in many European countries, which have to be paid in any case, even with lower loads per wagon. On the other hand a big scatter of the transportation rates themselves can be observed not only between the different networks but also within a distinctive network taking into consideration different distances between the starting point of transportation (rolling mill or welding plant) and the respective site in track. The fixed amount (independent of distance) to be paid any time together with the freight rate per kilometre may lead to the following example, where the transportation of rails over a distance of ***450 km*** could cost ***60€/tonne*** (e.g.).[1]

Based on this unsophisticated illustration, which – nevertheless – represents a very realistic example out of the total amount of different rail transportation processes, it can be assessed that

- taking into consideration logistic processes and logistic related costs <u>direct transportation</u> should be <u>favoured</u> whenever possible *and that*
- interrupted transportation which, may be necessary in distinctive cases (such as unplanned repairs), leads to significantly higher costs.

[1] The cargo rates given in these two examples are based on common railway transportation activities (typical loads around 200 tons and typical distances). Some deviations will occur over Europe especially when uncommon boundary conditions are applied and this will lead to different numerical values. Note also that the interrupted transport leads to increased distances to be covered in most cases.

Only by changing the transportation mode from interrupted to direct just-in-time (JIT) transportation **savings of up to 25 to 30%**of the overall transportation costs can be achieved, also taking into consideration shorter distances usually to be covered with direct transportation.

It is also pointed to the fact that in case of just-in-time transportation to the site achieving these savings can be achieved without any required activity of the railways apart from changing the final destination of delivery.

A4 Manipulation

The manipulation of rails is one cost-driver concerning logistic-related monetary efforts, which is unavoidable when rail delivery is carried out following the interrupted transportation mode. At the same time rail manipulation is the only part of the delivery-chain of rails which can be eliminated without replacement for rail installation in track (investment and renewal).

The manipulation of rails - mostly carried out in welding plants - requires human resources for the operation of the machines, associated maintenance activities and all actions which are connected to railway shops. The movement of rails is especially expensive, as this must be done manually when people remain in the danger area (which is the case when clamping actions are carried out (e.g.)). There is also machinery for rail manipulation required, which becomes more complex[2] the longer the rails. This item is also connected with the demands of stock keeping in terms of land requirements.

The cost of **manipulation and associated stock keeping only** can be assessed with **30 to 70 €/to**. As a matter of course the cost depends to a great extent on the local specifics. For a better understanding, these figures must be related to the costs of the manipulated track element, the rails. It has also to be taken into consideration that manipulation has become an unnecessary action due to the development of just in time transportation of rails to the site for rail installation.

However rail manipulation is still unavoidable for repair work shops where short rails have to be stored and manipulated in order to have them ready whenever needed in track (e.g. replacement of rails after a rail breakage)[3]. An example for this approach can already be found in Europe, where all rails that are used within new investment or planned renewal are delivered directly to the site and just short lengths are stored (and manipulated) in railway shops for unplanned maintenance only. There are several benefits connected with this proceeding: Generally a direct transportation is carried out from rolling mill to the site, no additional manipulation (and storage) efforts are required for all planned actions and all efforts related to unplanned maintenance (manipulation, storage etc.) are minimized also due to small sized facilities.

[2] Complex in terms of more devices required. The manipulation itself does not change when longer rails have to be handled.

[3] A second example for necessary stock keeping are insulated joints.

A5 Stock Keeping

Stock keeping has become an increasingly sensitive issue during the last period of time and stock keeping is always connected with logistical and monetary efforts. For stock keeping the respective plants and associated areas with appropriate railroad connections are required as well as human resources for the operational management and handling. On the other hand there are the stored goods, the rails, which always represent tied capital.

The cost of **stock keeping and** the associated and required **manipulation** of rails can be quoted with **30 to 70 €/to**. It has to be pointed to the fact that these efforts do not represent any value added and thus should be minimized if possible. Therefore a new approach towards logistics of rails (use of long rails, direct just-in-time transportation etc.) will be able to make a significant contribution to the minimization of logistic-related costs.

A6 Selected examples

Below three different examples are given in order to evaluate the benefits of improving the logistic chain of the delivery of rails. The examples also provide a frame for economic assessments. An explicit execution of calculations was not carried out within this deliverable, as there will be different input data for each individual railway in Europe.

Nevertheless the calculations may be carried out using the figures mentioned in this report and summarized in table 1. This can be done in order to get a *quick impression* of how big the advantages of optimized logistics of rails are[4], but also when detailed data concerning logistics for a distinctive example are not available.

<table>
<tr><th>action</th><th colspan="2">description</th><th>Cost</th></tr>
<tr><td>welding</td><td colspan="2">all types of weldings</td><td>200 to 500 €
per welding</td></tr>
<tr><td>manipulation stock keeping</td><td colspan="2"></td><td>30 to 70 €/to</td></tr>
<tr><td rowspan="3">transportation</td><td>Direct</td><td>from mill to site
(700 km, example given)</td><td>~75 €/to</td></tr>
<tr><td rowspan="2">Interrupted</td><td>part 1
(450km, example given)</td><td>~60 €/to</td></tr>
<tr><td>Part 2
(250km, example given)</td><td>~50€/to</td></tr>
</table>

Table 1: Possible input data for the examples given below

[4] Overall savings of roughly 40 to 50% are calculated with the input data of table 1.

Please note that the cargo rates for transportation differ significantly all over Europe and that this becomes more complex when international transportation is carried out. The values given in table 1 represent realistic values which – as a matter of course – depend on a distinct example only and are given in order to allow a quick execution of the calculations given below so that impressions, of how big the benefits of direct transportation may be are, are facilitated.

The information below is valid for typical European sites (rail renewal) which can be described as follows:

Site length: 1 400m
Rail length: 2 880m

(2 880m = 24 rails with length of 120m)
(2 880m = 48 rails with length of 60m)
(2 880m = 96 rails with length of 30m)

(2 880m = 22 weldings with 120m-rails)
(2 880m = 46 weldings with 60m-rails)
(2 880m = 94 weldings with 30m-rails)

Rail profile: 60E1 or similar
Total weight: 173to

<u>*Example 1:*</u>

Case 1:	***direct transportation***		
	transportation cost (from mill to site)	_______€/to * _______to =	__________€
		Sum Case 1	__________**€**
Case 2:	***interrupted transportation***		
	transportation cost (from mill to storage)	_______€/to * _______to =	__________€
	manipulation stock keeping	_______€/to * _______to =	__________€
	transportation cost (from storage to site)	_______€/to * _______to =	__________€
		Sum Case 2	__________**€**

Example 2:

Case 1:	***direct transportation 120m rails***		
	transportation cost (from mill to site)	_______€/to * _______to =	__________€
	Welding	_______€/w * _______w =	__________€
		Sum Case 1	__________**€**
Case 2:	***interrupted transportation 60m rails***		
	transportation cost (from mill to storage)	_______€/to * _______to =	__________€
	Welding	_______€/w * _______w =	__________€
	manipulation stock keeping	_______€/to * _______to =	__________€
	transportation cost (from storage to site)	_______€/to * _______to =	__________€
		Sum Case 2	__________**€**

Example 3:

Case 1:	***direct transportation 120m rails***		
	transportation cost (from mill to site)	_______€/to * _______to =	__________€
	Welding	_______€/w * _______w =	__________€
		Sum Case 1	__________**€**
Case 2:	***interrupted transportation 30m rails***		
	transportation cost (from mill to storage)	_______€/to * _______to =	__________€
	Welding	_______€/w * _______w =	__________€
	manipulation stock keeping	_______€/to * _______to =	__________€
	transportation cost (from storage to site)	_______€/to * _______to =	__________€
		Sum Case 2	__________**€**