# FINAL TECHNICAL REPORT
**Public**

**CONTRACT N° :** 1999- RD.10843

**PROJECT N° :** B99/99/SI2.101317-B66131122

**ACRONYM :** CrossRail

**TITLE :** Integrating local and regional rail, incl. cross-border aspects

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**REPORTING PERIOD :** FROM 01.01.2001 TO 30.04.2001

**PROJECT START DATE :** 01.01.2000 **DURATION :** 16 months

**Date of issue of this report :** 28.06.2001, version 1

**Project funded by the European Community under the 'Competitive and Sustainable Growth' Programme (1998-2002)**

# Document list

| Ver | Date | Prepared | Revised | Approved |
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# 1. Executive Publishable Summary

## 1.1 Objectives

The objectives of the CrossRail project are to:

- examine the integration of light and heavy rail networks
- define a European standard for tramtrain vehicles which will maximise market size and significantly reduce unit costs

The project is part of the Fifth Framework Programme, sub-programme area competitive and sustainable growth – key action sustainable mobility and intermodality. It thus has the broader objective of increasing mobility to stimulate economic growth in a way, which is environmentally sustainable.

## 1.2 Key findings

### 1.2.1 Analysis of Case Studies

A number of tramtrain schemes are under consideration across Europe. Yet despite high levels of interest only two schemes are currently in operation, whilst there is firm commitment to introduce a handful more (in Germany, France, the Netherlands and the UK). Analysis of case studies reveals many similarities between successful schemes; however, order numbers of vehicles tend to be low (typically 10 per scheme) with vehicles being custom built to fit specific infrastructure requirements.

### 1.2.2 User Benefits

Tramtrain schemes can bring unique benefits which have proved to be extremely attractive to people, generating higher usage of public transport systems and reducing car travel. In particular, they can deliver faster end-to-end journey times by reducing the need for travellers to interchange modes to reach their final destinations. Other benefits include improved accessibility, with more station stops and better frequency than equivalent heavy rail services. Finally, by maximising the use of existing heavy rail infrastructure the overall capital cost of schemes can be reduced.

The success of tramtrain schemes can be further helped by the use of related or "flanking" transport measures. These include integrated transport measures such as the provision of car parking at access stations and the co-ordination of bus services so that they feed into and out of tramtrain services. Also influential are city centre car parking policies, selective expansion of the road infrastructure and tariffs and road pricing measures.

### 1.2.3 Barriers to tramtrain introduction

Detailed examination of the case studies showed a clear hierarchy of factors. Without some basic enablers in place, the integration of light and heavy rail services cannot begin.

The first of these is a supportive political and organisational environment. Karlsruhe, Saarbrucken and other schemes in line for implementation benefit from the support of a single regional political body with responsibility for planning public transport provision within its area and access to funding to make capital investment in improving that provision and controlling flanking measures.

Secondly, the regulatory environment has to facilitate new initiatives. In particular, heavy rail infrastructure operators need to provide a positive environment for this kind of change.

Thirdly, there is a range of technical difficulties, which have to be solved. Whilst these can and do add additional costs into schemes, they can, however, usually be overcome.

Fourthly, standardising features of tramtrain design will bring benefits to both manufacturers and those putting schemes forward for development. Vehicle cost is a significant proportion of the overall cost (typically 15-20%).

Finally, it is clear from case studies that the types of barriers encountered when implementing a tramtrain project across national borders are no different from those which have to be solved in a purely domestic scheme. However, in a cross-border context these barriers become even greater and are thus harder to solve.

### 1.2.4 Market potential

The future sales of tramtrain vehicles largely depend upon the way barriers are solved in future. Based on this, scenarios have been built. The study has considered three scenarios – high, medium and low, making forecasts for each.

Market size for tramtrain vehicles is in the region of 7-60 vehicles per annum over the next 30 years, with a medium scenario of around 30 vehicles in average per year.

Compared to present and past tram and light rail vehicle sales (respectively 350 and 150 per year) it can be concluded that the number of sales is expected to be pretty low, even in the high scenario. It is therefore likely that the economies of scale will be limited and that tramtrains will be quite expensive in future.

The market of cross-border vehicles is a small niche market within the total tramtrain market. The number of sales will be very limited, so that within this niche market hardly any standardisation seems feasible, unless it is combined with the standardisation in the total market.

### 1.2.5 Functional Requirement specification

The CrossRail project has identified the most significant parameters for design, the majority of which are related to the need to interface with both urban and heavy rail infrastructures. It takes into account the UIC standards for heavy rail and the most recent findings of the MARIE project into the compatibility of future light rail systems. Original research has been undertaken to complement data from the case studies examined in the first stages of the project; the technical specifications of existing tramtrain rolling stock have been analysed, together with those of other tramtrain projects in France and Germany.

In addition to a vehicle specification, recommendations have been produced for criteria for designing new urban infrastructure. Using these at the initial design stage of any scheme would ensure a degree of standardisation and enable the use of a tramtrain based on the Crossrail specification. This would optimise the overall cost of projects, by taking full advantage of tramtrain rolling stock harmonisation across Europe.

# 2. Objectives of the Project

## 2.1 Background

One of the challenges facing us in the 21st century is the need to reconcile the individual's desire to travel with that for clean congestion-free environments. Over the last few decades the changes in population distribution, driven by different lifestyles and employment patterns have significantly altered the journeys that people make. This has been accompanied by an increasing dependence on the private car. The comfort and convenience of door-to-door travel, which the car can offer, has changed not only people's travel patterns, but also their expectations of the benefits, which a transport system should deliver. To compete, public transport must offer end-to-end journey times, which are not significantly worse than those, delivered by the car.

Public transport networks have struggled to keep up with these changes. Traditional heavy rail networks in particular lack the flexibility to respond to these new market needs. Trains are restricted to running on fixed infrastructure; the door-to-door travel opportunities they can provide are thus limited. In some cities, transport authorities have responded by opening new rail stations, serving new population centres, but the opportunities for doing this are restricted. Additional stations can significantly extend the journey times of existing passengers, whilst rail network capacity and rolling stock characteristics may prevent additional station stops in a route. Other measures taken have included the development of transport interchanges, where buses, trams, trains or all three come together, making transition between services as easy and comfortable as possible. Car parking facilities have also been provided at access points to the public transport network.

Better integration of public transport in urban areas can improve transport networks considerably. In particular, the linking of tram/light rail systems with conventional rail can help to deliver a transport network which more closely matches the needs and expectations of the modern traveller, reducing the need to change travel modes en route, delivering better accessibility and improving end to end journey times to become comparable with or even better than those offered by the private car.

This has led a number of cities to consider a new model of transport. Initially pioneered in Karlsruhe, Germany, the tramtrain concept uses a new type of vehicle (tramtrain), which can run on both light and heavy rail infrastructure, sharing the latter with traditional heavy rail vehicles. In order to achieve this, basic safety concerns had to be overcome. In particular, it is not practical to build tramtrains to the same crashworthiness as heavy rail trains (a cause of concern to safety authorities in some countries which has up to now kept tramtrains off some heavy rail networks); to avoid risk of collision damage, a solution of keeping trains apart through signalling has been developed.

## 2.2 The CrossRail Project

The CrossRail consortium is a group of leading European transport consultants. The project runs for 16 months under DG TREN (Contract No: 1999 – RD.10843). It is part funded by the EC with industry sponsors also providing financial support. The consultancy partners have also contributed 20% of the total cost. Review Groups represent the interests of the industry, UIC, UITP and other interested parties.

The CrossRail project is funded under the 5th Framework programme of the EC and aims to contribute to the objectives of the European Union by contributing to the reduction of the environmental impact of traffic and ensuring the use of existing infrastructure in the most efficient way. This will be achieved through the promotion of more environmentally friendly transport in urban areas, the reduction of road-traffic congestion and the improvement of the quality of city centres. The resulting improvement in accessibility will stimulate economic growth as well.

## 2.3 Primary objectives

The objectives of the CrossRail project are to:

- examine the integration of light and heavy rail networks
- define a European standard for tramtrain vehicles which will maximise market size and significantly reduce unit costs

## 2.4 Secondary objectives

At the outset of the project the consortium further defined the objectives of the project as to:

- give an overview of recent European developments in tramtrain systems and vehicles
- identify barriers to tramtrain integration and recommend solutions
- identify barriers to tramtrain integration in cross-border locations and recommend solutions
- quantify the European market for a 3-system vehicle (and potential 2-system ones) and
- establish a Functional Requirements Specification for a universal modular 3-system vehicle.

# 3. Scientific and technical description of results

## 3.1 Background

The CrossRail project splits into four distinct phases and seven stages or Workpackages.

The first (identification) phase involved two stages or "Workpackages". Workpackage 1.1 involved the research, writing and analysis of 18 tramtrain case studies from around Europe. Workpackage 1.2 extended this work to review 21 cross-border systems between nation states.

The second (case study) phase developed these initial case studies further by drawing out the common themes and threads around them. Workpackage 1.4 concentrated on quantifying the user benefits of tramtrain systems for both travellers and operators.

The third (recommendation) phase contained two Workpackages, 1.3 and 1.5. These were originally conceived as separate studies, examining barriers to tramtrain integration in cross-border and domestic scenarios accordingly. However, initial work showed there was little difference between the two scenarios, and the decision was taken to combine the two. The subsequent study led to a series of recommendations based on technical experience and know-how developed during the implementation of tramtrain systems.

The final (specification) phase identified the market size for a European tramtrain system (Workpackage 2.1) and developed the Functional Requirement specification for tramtrain vehicles (Workpackage 2.2).

## 3.2 Workpackage 1.1 – Analysis of existing light rail / heavy rail integration

### 3.2.1 Objectives

The objective of this stage was to provide an overview of recent European development of tramtrain integration described with respect to transport system characteristics, customer services, organisational issues, and technical/operational issues. In drawing out common themes, it provided the basis for further research in subsequent Workpackages.

### 3.2.2 Methodology

Each partner collected data on existing and potential tramtrain projects across Europe. This was based on desk research, personal knowledge and original research on the projects concerned, including in-depth interviews with scheme promoters, local authorities and other interested parties.

To ensure consistency during the compilation of the case studies a questionnaire covering each of the generic headings was used for each. The questionnaire covered the following headings:

- Existing heavy/light rail network
- Rational for introducing/considering tramtrain solutions
- Integrated network layout i.e. extent of integration between each system
- Rolling stock characteristics for dual running
- Market demand (customer aspects)
- Operational and organisational aspects
- Financial and economic considerations
- Institutional aspects

Similarities and differences between projects were compared to identify technical and other issues for subsequent further research.

### *3.2.3* Summary of findings

The first stage of work concluded that integration between the tramways and railway networks can increase public transport use between suburban and city centres, without the need for transferring modes, whilst also delivering benefits in terms of reduced investment and operating costs compared with traditional heavy rail solutions. Not surprisingly, the concept has proved attractive to a number of city authorities and several schemes are in development for introduction in the next 5-10 years.

Infrastructure.

In most cases, tramtrains share infrastructure with urban trams and car traffic, plus regional trains and/or freight traffic. This is achieved by adapting the tramtrains around existing systems (for instance, when driving on street, tramtrains drive on sight, but on heavy rail, follow the existing rail signalling), not by building specific tramtrain infrastructure. This adaptability is unique to tramtrains, but means that certain infrastructure and technical constraints have to be overcome. These include differences between light and heavy rail networks such as platform heights, gauges and voltages on electrified sections. These elements and others were explored in more depth in Workpackage 1.5.

Safety

One of the main obstacles to introducing tramtrain running has been the need to persuade track authorities to allow than traditional heavy rail ones to share the track with light rail vehicles, which have lower crashworthiness standards. The solution developed has been to keep vehicles apart through signalling and protection systems. Other safety issues include safe passage of level crossings and safety on on-street sections.

Rolling stock

From the case studies, standard features were drawn that would be developed in the Functional Requirement Specification (Workpackage 2.2). Areas identified for further analysis in the section stage of the study were:

- Design of the front and of the rear of the vehicle
- Length, width and capacity
- Variable length of 29.5m to 37.5m according to local platform lengths
- Variable width from 2.55m to 2.65m
- Variable capacity: 200 places in a single train, with a 40% seat ratio
- Comfort, colours, internal design, seat widths
- Disabled criteria

Common elements could be:
- body structure
- traction
- electrical equipment
- bogies
- automatic coupling.

## 3.3 Workpackage 1.2 – Analysis of existing cross-border integration

### 3.3.1 Background
The objective of Workpackage 1.2 was to provide an overview of tramtrain within a cross-border context. In particular, any special cross-border characteristics were to be identified.

### 3.3.2 Methodology
All urbanised regions across Europe, which have proximity to national borders, were listed, producing a list of some 55 regions. The possibility of future LRT services in these areas was then examined. The total list was reduced to a shortlist of 21 by screening the regions against two specific criteria. Firstly, regions were ranked on a scale of 0 to 2 according to their local population size. Regions with populations of 200k and over were graded 2, with 100-200k as 1 and with fewer than 100k as 0. An LRT factor was then added; this screened the regions according to known or potential plans for introducing LRT operation in the future. This led to a short list of 21 locations; detailed case studies were then conducted into each. Literature searches were carried out, supplemented with original research, including in-depth interviews.

### 3.3.3 Summary of findings
Results concluded that in Europe, national borders represent huge hindrances for the integration of public light rail transport. Only one cross-border LRT project (Saarbrucken) has been realised in Europe to date, and only a handful of others are in an advanced planning stage. France and Germany are involved in most cases, reflecting the current stage of LRT development in these two countries. Few cases are expected to reach actual implementation stage in the near future.

## 3.4 Workpackage 1.4 – User Benefit Study

### 3.4.1 Background
With the case studies complete, the project moved into the second phase with this Workpackage. The objective of this phase was to investigate the user benefits of tramtrain schemes.

### 3.4.2 Methodology
A theoretical framework was established based on the value of time theory and the impact of transfers on benefits. In calculating the user benefits (defined as passengers travelling within the tramtrain system and the operators exploiting the system), the decision was taken to concentrate on two examples, Karlsruhe and Saarbrucken, due to the availability of data. Information on service characteristics and usage before and after development of tramtrain services was examined and conclusions drawn on key financial aspects of journey time savings. Using the whole range of case studies, further findings were made on the benefits of schemes, which will be of general use to those considering developments of this type.

### 3.4.3 Summary of findings
There is no simple methodological approach to the appraising of tramtrain schemes. The feasibility or otherwise of a tramtrain solution needs to be carefully evaluated against other existing and potential public transport solutions. The study found no evidence that existing transport planning appraisal frameworks as used by EC member states discriminate against tramtrain over more conventional transport solutions.

Tramtrain offers both operational and capital savings against a base case of an existing heavy rail operation. These savings alone may be sufficient to justify investment in a tramtrain solution, particularly against the backdrop that a subsidy from taxpayers is required to support most public transport systems.

**The Karlsruhe Experience**

Karlsruhe was the first European tramtrain system to be implemented and is therefore held up as a case study of best practice. It would, however, be naïve to expect that the experience of Karlsruhe can simply be replicated in other European cities.

The line S4 is the focus of the Karlsruhe case study (S4 was the first tramtrain route to be introduced). An important characteristic of Karlsruhe is the location of the main line railway station, some 2km outside the city centre. Prior to the introduction of tramtrain operations, rail passengers entering Karlsruhe had to change onto another mode (most commonly the city centre tramway) in order to reach Karlsruhe Marktplatz, the primary destination point. This transfer between modes at the main station meant that end-to-end journeys took longer. (Research shows that the perceived penalty incurred by modal interchange is perceived to be much higher than reality – see below).

By integrating the tram system with the train system, transfer penalties could be avoided and travel-time savings made. Rough calculations based on a number of assumptions indicate that the benefits from travel-time savings could be around 5m Euros per year, based on German values of time and valuations of avoiding transfers for users of the S4 route.

This is supported by the fact that the introduction of the S4 has led to an enormous increase in patronage. Interestingly, the system is busiest at weekends, when people go to the city centre for shopping and leisure or move to the surroundings of Karlsruhe.

One of the most exciting aspects is that a large proportion, up to 40%, of the passengers using the new tramtrain system were former car users. However, there are other important factors to consider in understanding the performance of the system, including:

- Increases in tram frequency leading to a reduction in generalised journey times
- Increases in comfort and
- Increase in accessibility (e.g. ticketing integration and more stops)
- Competitive environment e.g. rising congestion on competing road system
- The importance of other flanking measures such as not expanding road infrastructure

The table below shows the occupancy rate before and after the introduction of the S4 in Karlsruhe. The average number of seats per train has decreased following the introduction of tramtrain, but the frequency of the trains has doubled and the number of passengers almost tripled.

| *Occupancy rates on S4 Karlsruhe* | Before opening of S4 | | After opening of S4 | |
|---|---|---|---|---|
| | to Bretten | to Karlsruhe | to Bretten | to Karlsruhe |
| Number of passengers per day | 1082 | 1064 | 3707 | 2673 |
| Number of trains per day | 19 | 18 | 38 | 37 |
| Seats per train (average) | 485 | 485 | 200 | 200 |
| Occupancy rate | 12% | 12% | 49% | 36% |

There is anecdotal evidence to support the view that such benefits are not unique to Karlsruhe; other Germany light rail projects have reported increases in passenger volumes (VDV 2000).

**Benefits**
In general three types of benefits can be identified:

- Specific benefits to the tramtrain concept
- Benefits made possible by the tramtrain project
- Other benefits which could be achieved at any time

*Specific benefits.* The table below shows the different types of benefits which can arise as the result of a tramtrain scheme:

**Different benefits infrastructural change**

| Effect | Type of effect | To whom? |
|---|---|---|
| Direct | Operator benefits from exploitation | Operator |
| | Travel time savings | Passengers |
| | Comfort | Passengers |
| | Reliability | Passengers |
| Indirect | Labour market | Regional economy |
| | Housing market | Regional economy |
| | Reduction of emissions (noise, air) | External effects |

The most important effect of these benefits is an increase in the number of passengers using the tramtrain system and/or an increase in income for the operators.

*Benefits made possible by tramtrain.* These are benefits that are achieved due the opportunity given by the tramtrain project, but that are not specific to the tramtrain concept. Examples include:

- Re-designing a city centre at the same time as implementing a tramtrain system, for example, introducing a greater measure of 'pedestrianisation'
- Improvement of the local transport system, of which the tramtrain system is part

*Other benefits.* This category includes benefits that could be achieved at any time, and are not linked to the tramtrain system. Examples include:

- A reduction of the fares in public transport, which can lead to an increase in passengers

- Integration of tickets of different transport modes
- Flanking measures such as car parking and road pricing which have an effect on the number of passengers using the tramtrain system but are not necessarily linked to the tramtrain system.

The following factors were found to have an effect on costs and revenue:

- Track sharing. This enables investment costs in new infrastructure to be decreased and the capacity of the rail network to be optimised
- Service frequency. In Karlsruhe, the frequency of tramtrains was extended from 37 trains day just before the start of the tramtrain service, to 75 a day afterwards. In addition, the operation period was extended, enabling more frequent travel at nights and the weekend. Increased frequency led to higher operational costs – mainly depreciation, maintenance, labour and fuel costs
- Station spacing. Increasing the number of stations and thus accessibility can increase demand. In the Karlsruhe case the number of stops was increased from 8 to 36.
- Modal shift. The Karlsruhe experience showed a significant shift from road to tramtrain
- Traffic generation. A tramtrain system may increase passenger demand and generate more passengers.

Data available was not sufficient to quantify these factors in detail. However, the overall effect of these was positive in both the Karlsruhe and Saarbrucken cases.

Three important factors emerge:

**Avoidance of a transfer penalty.** This was confirmed as very important to passengers. Research has found that passengers perceive their travel time as higher than the actual travel time. Waiting time is considered negatively. Reducing the number of transfers also increases the reliability of an individual's public transport journey.

**Publicity.** In the case of Karlsruhe, public information about transport improved significantly at the introduction of the tramtrain services. The regular frequency of the tramtrain system made the timetables transparent, easy to present and easily understood. Plans for the whole public transportation system were designed so as to be easy to comprehend and were displayed both on stops and in the vehicles. The tramtrain system had a very good image amongst the public, which had a positive effect on other modalities of public transport (e.g. trains) as well.

**Other transport policy considerations.** In order to get the best out of tramtrain system other measures can be taken to improve its efficiency. These include:

- Park and ride
- Feeder buses, which modes complementing each other rather than competing
- Attractive and welcoming transport interchanges
- Car parking measures within the city centre
- Road pricing/tolling
- Selective expansion of "competing" road networks.

**Conclusions**
Many of the success factors of the Karlsruhe and Saarbrucken cases are present in other proposed tramtrain cases in Europe. In particular, the flexibility of light rail to serve new destinations and stations emerges as a key factor.
Success factors include:

- Improved network, serving more stations
- Direct access to people's destinations
- Shorter journey times (perceived)
- Better frequencies
- Better integration with other modes, including through ticketing
- Improved comfort
- Easily understood information and publicity.

Most of the cross-border schemes examined in Workpackages 1.2 are only at a very early stage of planning. Because of this, there is less detail on potential user benefits than in the domestic case studies featured in Workpackage 1.1. Nevertheless, some strong success factors to emerge and basically re-enforce the earlier findings on user benefits. In particular the greater flexibility of light rail particularly with regard to developing new routes and offering an improved network is the key.

## 3.5 Workpackage 1.3 & 1.5 – Recommendation on light rail / heavy rail integration (including cross-border)

### 3.5.1 Background
This phase of the project concentrated on identifying the barriers to integrating city centre networks (whether tram or light rail) with traditional heavy rail ones together with best practice for workable solutions. Early on in initial analysis it became clear that there was little difference between the barriers facing domestic and cross-border schemes. The decision was therefore taken to combine both into a single Workpackage.

### 3.5.2 Methodology
From the information contained in the case studies of Workpackages 1.1 and 1.2 it was possible to identify a list of the problems, which may be encountered in attempting to introduce tramtrain schemes. These problems or barriers logically fell into a number of classifications:

- Cultural/political (e.g. does a single authority have responsibility for planning the scheme
- Economic (e.g. how can funding problems be resolved)
- Technical (e.g. rail dimensions)
- Organisational (e.g. who operates the services)
- Operational (e.g. what are the implications for the operator)

Additional research into these areas covered published and Internet sources and more detailed analysis of the original case studies was also taken. This enabled solutions to each barrier to be put forward and tested against criteria of affordability and practicality. Where a number of alternatives emerged, these were ranked against the criteria to identify, where possible, an optimal solution.

In analysis it became clear that answers to problems often fall into different timescales. Thus there are several "quick fix" options to enable existing plans to be put into action; however, the optimal solution for future cases could be a much longer-term objective such as the harmonisation of standards on platform heights.

A separate desk study was made in the effect of directive 91/440/EEC and associated directives and into the interpretation and implementation of these by EC member states.

### 3.5.3 Summary of findings

Analysis clearly showed a hierarchy amongst the barriers to any prospective tramtrain scheme. In particular, there are certain barriers, which have to be resolved before any scheme can go ahead. Once these are removed, then others become more important. This hierarchy is outlined below:

- Political
- Legislative
- Safety
- Technical (infrastructure/rolling stock)

Although the problems facing a project may initially look insurmountable, in practice, analysis shows that there were only two reasons, which prevented case study schemes from going ahead. These were the lack of political support (and hence funding) and the inability to convince safety authorities that tramtrains can share track safely with heavy rail vehicles. Even here, solutions were found, providing there was sufficient demand (both local support and potential for usage) for a scheme, although it can take a number of years to resolve these problems.

The table below outlines the most commonly encountered problems and suggests ways of resolving them:

| *Problem* | *Solution* | *Cost* | *Practicality* |
|---|---|---|---|
| **Political** | | | |
| No single authority to promote scheme | Establish new transport authority | medium | low |
| | Establish steering group | low | medium |
| | | | |
| Lack of political support | Minimise uncertainty about the project and increase the awareness of benefits (e.g. by lobbying, setting up an information desk) | medium | high |
| | Involve public at an early stage to create social acceptance e.g. by consulting interest groups | low | high |
| | Handle PR professionally | low-medium | high |
| | Create package deals, linking to town and city planning | low | high |
| | | | |
| Lack of support from residents | Information campaign, accurate and well-presented information widely available | medium | high |
| | Establish local information points and public displays | medium | high |
| | Professional PR campaign | low-medium | high |
| | Provide financial recompense for genuine disadvantage | medium-high | medium-high |
| | Look at alternatives to electric trams | high | medium |
| | Use existing heavy rail infrastructure where possible to reduce environmental impact and disruption | low | medium-high |
| | | | |
| Opposition from stakeholders | Bring together and involve in decision making process | low | high |
| | | | |
| Resistance from existing operators | Direct subsidy to compensate for loss of business | medium-high | high |
| | Reassurance based on other cases | low | high |
| | Allow for effects of planned schemes on revenue when third party contracts are let | low | high |
| | Involve in decision making early, especially in planning any engineering work | low | high |
| | Site visits, pilot studies | medium | high |
| | Accurate and timely information, feeling of involvement | low | high |
| | | | |
| National Transport policy planning cycles | Use existing processes e.g. regional transport plans | low | high |
| | Establish single planning authority (see above) | | |
| | Present professional and credible approach (see above) | | |

| ***Problem*** | ***Solution*** | ***Cost*** | ***Practicality*** |
|---|---|---|---|
| | | | |
| Constraints on public funding | Levy special taxes at national or local level to fund transport schemes | low | medium |
| | Private sector funding | low | medium |
| | External grants | low | medium-high |
| | Assessment criteria recognising true benefits of tramtrain schemes, including non-user benefits | low | high |
| | | | |
| Lack of mechanism to secure public funding | Private operator of service, recouping costs by user charges | low-medium | medium-high |
| | Privately run services subsidised by public purse | medium-high | medium-high |
| | Private investment recouped through leasing charges | low-medium | medium-high |
| | Public investment, private operator, where public funding is used for the capital costs of schemes with services subsequently provided by a private operator | low | low-medium |
| | | | |
| Cost of rolling stock | Bought by transport authority | high | high |
| | Build and lease agreement with manufacturer | high | high |
| | Owned by third party, leased by operator | high | medium |
| | Reduction of production costs through standardisation | medium | high |
| | | | |
| **Legislative** | | | |
| Lack of common approach across Europe | Common co-ordinated rules and standards | medium | high |
| | Speedy implementation of existing directives | medium | medium |
| Difficulty in gaining access to heavy rail infrastructure | Priority for tramtrains based on evaluation of user and non-user benefits | low | medium |
| Access charging regimes | Negotiate reduced rates for lighter vehicles | low | medium |
| | Common charging regime across Europe | medium | medium |
| Absence of common standards across Europe | Develop common rules and standards | medium | medium |
| | Sharing of CrossRail outputs | low | high |
| **Safety** | | | |
| No standard for acceptance of light rail vehicle onto heavy rail infrastructure | Develop standards | low | high |
| | Adopt risk assessment based approach | low | medium |
| Different safety systems | Trains and trams use their existing systems | low | high |
| | Tramtrains use both systems | medium | low |
| | New protection system installed to European standards on both networks | medium-high | high |
| **Technical** | | | |
| Platform heights incompatible | Adapt rolling stock – fit retractable steps or ramps | low-medium | medium - high |
| | Adapt rolling stock – variable floor heights | medium | low |

| ***Problem*** | ***Solution*** | ***Cost*** | ***Practicality*** |
|---|---|---|---|
| | Vehicles self-lowering | high | low-medium |
| | Adapt infrastructure - variable height platforms | medium | low |
| | Rebuild infrastructure | medium - high | high |
| | Develop European standards for the future | low | high |
| | | | |
| Light and heavy rail have different electrification systems | Adapt rolling stock – dual voltage vehicle | medium | high |
| | Use diesel rolling stock | medium | low |
| | | | |
| Gauge differences between networks | Adapt rolling stock – dual bogies | medium | low |
| | Adapt infrastructure – install extra rail | medium – high | medium – high |
| | Adapt infrastructure – rebuild tramway to match heavy rail | high | high |
| | Create European standards for gauge for the future | low | high |
| | | | |
| Network differences between track and wheel profiles | Adapt rolling stock – adapt wheel profile on tramtrain | low | medium |
| | Adapt infrastructure – upgrade tramway to match heavy rail | high | high |
| | Create European standard for tramway/light rail profiles to match heavy rail | low | high |
| | | | |
| Lack of track capacity | Alternative signalling solutions available (reduce block length; share blocks; moving blocks; four-aspect) | medium – high | low- high |
| | Install additional track | medium – high | medium – high |

The table illustrates how many technical problems have long term and short term solutions (e.g. gauge differences). One of the key things to be learned from this study is that long term planning can ultimately reduce significantly the costs of transport schemes, for instance, by ensuring that new tramways are built with future tramtrain integration in mind. Even if integration is not intended for a couple of decades, forward thinking of this kind will make it much easier for future generations to implement innovative transport schemes.

As demonstrated in table there are a number of instances in which different solutions can be applied to a problem. Often, the only practical (that is, affordable) short-term solution to incompatibility between light and heavy rail infrastructure lies in adapting the tramtrain vehicle to meet the characteristics of both networks. This can be the case in terms of adapting to different platform heights and rail profiles for instance. The result of this is that both networks and vehicles remain customised, with all of the cost implications that that entails. In the longer term, the development of Europe-wide standards which bring about compatibility between not only light and heavy rail systems but also cross-border networks will enhance and facilitate the introduction of new transport schemes.

Cross-border. It became clear at an early stage of the CrossRail project that with the possible exception of language and cultural differences, the barriers facing cross-border schemes are the same as for domestic ones. However, in cross-border situations these barriers tend to increase in size and solutions can become harder to find. Difficulties are often caused by differences in regulations and standards on either side of the border, but also results from the fact tat more people and organisations have to be involved in the decision making process. This often leads to the more subjective barriers becoming even greater, even if the problem itself is of no more magnitude than it would have been in a purely domestic scheme. In order to match the increasing and often politically increased need for cross-border mobility, systems must be developed which can respond to demand. The development of pan-European standards for heavy rail, light rail and tramtrain systems would assist greatly in the future integration of networks. Work should be undertaken to develop standards for the following:

- Platform height allowing heavy/light rail integration
- Track gauge allowing heavy/light rail operation and cross-border running
- Track profile allowing heavy/light rail operation and cross-border running
- Access for light rail vehicles onto heavy rail infrastructure

The handful of cross-border schemes, which have been completed, or are close to completion show a pragmatic approach. In general, countries concentrated on their domestic schemes first, sorting out the problems of tramtrain integration locally before adding in the dimension of cross-border running. This strategy has the benefit of ensuring that key decision makers (such as politicians) are not confronted with all problems and costs at the same time. A staged approach is therefore recommended.

## 3.6 Workpackage 2.1 – Rolling stock market study for tramtrain vehicles

### 3.6.1 Background

This phase concentrated on the rolling stock market for tramtrain systems and the future development of the market. Both supply and demand sides were analysed and forecasts made for future market size.

### 3.6.2 Methodology

Desk and field research was carried out to investigate potential market size. Interviews were held with representatives of European Rolling stock manufacturers (Alstom, Adtranz and Siemens) both to explore market opportunities and to clarify production processes and potential for economies of scale. The study began with an analysis of supply, then demand. Based on the outcome of these phases, three alternative demand scenarios were modelled to predict future market size.

### 3.6.3 Summary of findings

**Scenario One (low)**

Assumptions:

- No developments beyond existing known plans
- No implementation of EC directives on open track access, enabling heavy rail companies to maintain their current dominant market positions
- Lack of political motivation and funding
- No common European standards

Market quantification

The market for vehicles will remain limited. Only projects which already have well-developed plans for schemes will buy tramtrains in the future. Total market size over the next 28 years is in the region of 200 vehicles, an average of around 7 a year. No economies of scale achievable, prices stay at current rates.

**Scenario Two (medium)**

Assumptions:

- Development of schemes will be motivated by population growth and agglomeration in big cities
- General political will to attract users from cars
- More positive political/cultural attitude to tramtrain schemes
- Some harmonisation of legislation and standards

Market quantification

All projects identified for completion under low scenario will be completed, plus additional ones in the EU and Switzerland. Demand increases to around 800 vehicles over 28 years, that is, 29 per year.

**Scenario Three (high)**

Assumptions:

- All existing major barriers to tramtrain schemes removed
- Harmonisation of policies across Europe
- Standardised vehicle specifications, lower vehicle prices
- Sustained economic growth

Market Quantification
The high scenario assumes that in almost all cities that may introduce tramtrains, schemes are introduced. This gives around 67 schemes, with a total demand for 1675 vehicles over 28 years, average sales of around 60 vehicles per year.

**Conclusions**
Compared to present and past tram and Light Rail Vehicle sales (350 and 150 per annum respectively) it can be concluded that the number of sales of tramtrain vehicles is pretty low, even in the high scenario. It is likely, therefore, that economies of scale will be limited and that tramtrains will be quite expensive in the future. Total market predictions range from 7 per year to 60 per year. Most schemes will be entirely domestic, with a very small number of cross-border schemes possible.

A list of possible tramtrain schemes is given below, together with an indication of the scenarios in which they feature:

| Scenario | Phase | Country | City | Number of inhabitants (city proper) | Number of inhabitants (urban agglomeration) | Probability | Source |
|---|---|---|---|---|---|---|---|
| LOW | Existing | Germany | Karlsruhe | 277.011 | | 1 | 1994 |
| | | | Saarbrücken | 189.012 | | 1 | 1994 |
| | Near Future | | Bremen | 549.122 | | 1 | 1994 |
| | | France | Strasbourg | 252.274 | 388.466 | 1 | 1990 |
| | | | Valenciennes | -- | 337.000 | 1 | 1982 |
| | | UK | Sunderland | 297.226 | -- | 1 | 1994 |

| Scenario | Phase | Country | City | Number of inhabitants (city proper) | Number of inhabitants (urban agglomeration) | Probability | Source |
|---|---|---|---|---|---|---|---|
| MEDIUM | In discussion | Belgium | Antwerp | 470.349 | 669.125 | 0.75 | 1990 |
| | | | Brussels | 136.488 | 960.324 | 0.75 | 1991 |
| | | Germany | Aachen | 247.113 | -- | 0.75 | 1994 |
| | | | Kiel | 246.586 | -- | 0.75 | 1994 |
| | | | Frankfurt | 652.412 | -- | 0.75 | 1994 |
| | | | Bruinswick | | | 0.75 | |
| | | UK | Liverpool | 474.001 | -- | 0.75 | 1994 |
| | | | Manchester | 431.061 | -- | 0.75 | 1994 |
| | | Sweden | Göteborg | 444.553 | -- | 0.75 | 1994 |
| | | Denmark | Aarhus | -- | 277.477 | 0.75 | 1995 |
| | | France | Nantes | 244.514 | 495.229 | 0.75 | 1990 |
| | | | Grenoble | 150.815 | 404.837 | 0.75 | 1990 |
| | | | Orleans | 105.099 | 243.137 | 0.75 | 1990 |
| | | | Mulhouse | 108.358 | 223.878 | 0.75 | 1990 |
| | | | St. Etienne | 199.528 | 313.467 | 0.75 | 1990 |
| | | Greece | Patras | 153.344 | 170.452 | 0.75 | 1991 |
| | | Austria | Salzburg | 143.973 | 162.908 | 0.75 | 1991 |
| | | | Graz | 237.810 | 271.017 | 0.75 | 1991 |
| | | | Vienna | 1.560.471 | -- | 0.75 | 1992 |
| | | | St Polten-Krems | -- | -- | 0.75 | -- |
| | | Norway | Oslo | 473.454 | 758.949 | 0.75 | 1993 |
| | | | Stavanger-Sandnes | 101.403 | -- | 0.75 | 1993 |
| | In discussion non-EU | Switzerland | Geneva | 172.138 | 438.819 | 0.75 | 1994 |

| Scenario | Phase | Country | City | Number of inhabitants | | Probability | Source |
|---|---|---|---|---|---|---|---|
| | | | | (city proper) | (urban agglomeration) | | |
| HIGH | Early discussion | Luxemburg | Luxemburg | 76.446 | -- | 0.5 | 1994 |
| | | Switzerland | Zug | -- | -- | 0.5 | -- |
| | | Germany | Zwickau | 104.921 | -- | 0.5 | 1994 |
| | | | Kassel | 201.789 | -- | 0.5 | 1994 |
| | | | Bonn | 293.072 | -- | 0.5 | 1994 |
| | | | Braunschweig | 254.130 | -- | 0.5 | 1994 |
| | | | Nordhausen | -- | -- | 0.5 | -- |
| | | | Wiesbaden | 266.081 | -- | 0.5 | 1994 |
| | | The Netherlands | The Hague | 442.000 | 694.733 | 0.5 | 1994 |
| | | | Maastricht | 118.278 | 164.427 | 0.5 | 1994 |
| | | | Utrecht | 234.352 | 546.433 | 0.5 | 1994 |
| | | | Amsterdam | 723.163 | 1.100.764 | 0.5 | 1994 |
| | | France | Lyon | 415.479 | 1.262.342 | 0.5 | 1990 |
| | | | Paris | 2.152.329 | 9.319.367 | 0.5 | 1990 |
| | | United Kingdom | Bristol | 399.243 | -- | 0.5 | 1994 |
| | | Ireland | Dublin | | | 0.5 | |
| | | Greece | Thessaloniki | | | 0.5 | |
| | | Spain | Barcelona | 1.596.190 | -- | 0.5 | 1991 |
| | | | Madrid | 2.976.064 | -- | 0.5 | 1991 |
| | | | Valencia | 749.361 | -- | 0.5 | 1991 |
| | | Portugal | Lisboa | 663.394 | 2.561.225 | 0.5 | 1991 |
| | | | Porto | 302.467 | 1.174.461 | 0.5 | 1991 |
| | | Finland | Helsinki | 512.176 | -- | 0.5 | 1994 |
| | | Sweden | Stockholm | 703.627 | -- | 0.5 | 1994 |
| | | Italy | Genova | -- | 675.659 | 0.5 | 1991 |
| | | | Milano | -- | 1.371.008 | 0.5 | 1991 |
| | | | Napoli | -- | 1.054.601 | 0.5 | 1991 |
| | | | Palermo | -- | 697.162 | 0.5 | 1991 |
| | | | Roma | -- | 2.693.383 | 0.5 | 1991 |
| | | | Torino | -- | 961.916 | 0.5 | 1991 |
| | | | Trieste | -- | 229.216 | 0.5 | 1991 |

Source: http://www.un.org/Depts/unsd/demog/ctry.htm

## 3.7 Workpackage 2.2 - Functional Requirements for tramtrain vehicles

### 3.7.1 Background

This part of the project answered the objective of establishing a Functional Requirements Specification for a universal modular 3-system tramtrain vehicle, which can be used by European operators who want to implement a cross-border tramtrain project. This Functional Requirements Specification (FRS) shall also be applicable for 2-system vehicles for non cross-border or "national" cases. By harmonizing requirements, potential is opened up to achieve economies of scale; in particular design costs and unit prices may be reduced.

The Workpackage drew on the findings of 2.1, particularly with regard to production processes and costs, in order to identify possible areas of cost reduction.

As recommended in the Crossrail Recommendation report, the Functional Requirements Specification is based on a tramway specification. The specification draws on standardised elements of light rail/tramway vehicles, whilst taking into account the specific constraints of running on heavy rail networks.

Another option for obtaining price reductions is to facilitate common orders from different operators. By setting common functional requirements for European tramtrains, the present FRS also contributes to this objective. The FRS therefore takes into account common European infrastructure constraints as defined in the case studies of Workpackages 1.1 and 1.2.

### 3.7.2 Methodology

Results from previous study phases were used to identify the most significant parameters for tramtrain design. In addition, further in-depth original research was also undertaken into the case studies of the first two phases, collecting additional data on rolling stock and infrastructure interfaces. Extensive desk research into relevant studies was also undertaken whilst original field research within the rolling stock industry was also conducted. Existing European standards were also analysed. In the case of heavy rail, a number of UIC standards exist; within light rail, the harmonisation process still has some way to go. For the purposes of this phase, the draft outputs from the MARIE project (Mass Transit Rail Initiative for Europe) were therefore used as indicative values. Drivers of cost were also considered. The study also drew on the characteristics of existing vehicles from Karlsruhe and Saarbrucken and on the tenders recently issued by SNCF in France for Aulnay-Bondy line, and by Kassel transport authority in Germany.

### 3.7.3 Summary of output

Harmonization of tramtrain parameters will be of significant benefit for sites that do not have any urban network. Based on the detailed study of cost drivers and design parameters (see 3.7.2), the Crossrail project team has produced a detailed vehicle specification, which is designed to be used by authorities promoting new schemes as the base for tendering vehicle orders. The specification covers:

- Transport capacity
- Vehicle size
- Vehicle performances
- Ticket selling and validation
- Operation requirements
- Driving cab
- Accessibility
- On-board environment
- Passenger information systems
- Reliability, maintainability, availability
- Safety
- Functional interfaces

To maximise the benefits of a standard specification for vehicles standards for new tramtrain infrastructure are also recommended. This covers:

- Line characteristics
- Track characteristics
- Track gauge
- Gauge
- Platforms
- Power supply
- Electromagnetic compatibility
- Environmental issues

Details of both infrastructure and vehicle specifications can be found in the Workpackage Report 2.2; Functional Requirement Specification.

# 4. List of deliverables

As a research project, the deliverables take the form of reports.

The deliverables has all been delivered according to the agreed due-dates:

| | | |
|---|---|---|
| Deliverable 1 | Inception Report | March 2000 |
| Deliverable 2 | Identification Report | July 2000 |
| Deliverable 3 | Recommendation Report | January 2001 |
| Deliverable 4 | Rolling Stock Market Study | April 2001 |
| Deliverable 5 | Functional Requirement Specification | April 2001 |
| Deliverable 6 | Final Report | June 2001 |

All publishable deliverables will available on the CrossRail website (www.tramtrain.com) as soon as they are released by DG-TREN.

# 5. Comparison of planned activity with work accomplished

All work has been completed according to the agreed plans.

Due to the short project period (16 months from start to end) no mid-term evaluation report has been made. Therefore this Final Report is not the result of an iterative evaluation process.

# 6. Management and co-ordination aspects

## 6.1 Organisation of work

The CrossRail project is undertaken by a consortium of 8 partners; consultancy companies from 7 different European countries:

| CONSORTIUM OVERVIEW | | | |
|---|---|---|---|
| **Partner** | **Country** | **Business activity / Main Mission / Area of activity** | **RTD Role in project** |
| ScanRail Consult | DK | Railway and transport consultant services | Project Management & Co-ordination & Scientific and Technical Research WP-leader for WP 3.0 & 1.3 |
| Systra | F | Railway and Urban Transport Consulting and Engineering | Scientific and Technical Research WP-leader for WP 1.1 & 2.2 |
| TTK | D | Railway and Urban Transport Consulting and Engineering | Scientific and technical Research WP leader for WP 1.2 |
| NEI | NL | Economic research and consultant services | Economical and technical Research WP-leader for WP 1.4 & 2.1 |
| Halcrow | UK | Transportation Systems and Market Research | Economical and technical Research WP-leader for WP 1.5 |
| Trademco | GR | Consulting Research and Development within Technical & Economical Areas | Economical and technical Research |
| Transurb | B | Specialists in passenger and goods land transportation | Scientific and technical Research |
| DE-Consult | D | Railway and transport consultant services | Scientific and technical Research |

### 6.1.1 Steering Committee

A Steering Committee formed by representatives from all partners (in accordance with the EC Contract and the Consortium Agreement) is responsible for the technical management of the project, monitoring the progress and reviewing the deliverables.

### 6.1.2 Technical Advisory Group

A Technical Advisory Group is formed with representatives from the 3 sponsors ; Adtranz, Alstom and Siemens.

The Technical Advisory Group shall contribute with experience, knowledge and advice whenever required throughout the project. Special emphasis will be given to the following deliverables:

Deliverable 3: Recommendation Report
Deliverable 4: Rolling Stock Market Study Report
Deliverable 5: Functional Requirement Specification Report

The Technical Advisory Group will be invited to meetings with regular intervals by the CrossRail coordinator, who will chair the meetings.

### 6.1.3 User Group

A User Group will be formed with representatives from each of the selected Case Studies.

The User Group representatives will be generally informed by the co-ordinator about CrossRail in accordance with the dissemination plan. They will be invited to review the Identification Report and the Recommendation Report and they will be invited to two CrossRail Seminars.

## 6.2 Planning of work

### 6.2.1 Workpackages

The CrossRail project is planned as a framework of workpackages leading to the key milestones, mainly the deliverables (reports) and the public seminars. The activities in each workpackage is organised and managed by a workpackage leader across the participating companies.

### 6.2.2 Workpackage Leaders

For each work package the workpackage leader holds the responsibility for the work and tasks to be carried out according to the schedule and produce the results relevant as input for the other workpackages.

The WP-leaders are:

WP 1.1 Phillippe Carré, Systra
WP 1.2 Nils Jänig, TTK
WP 1.3 Jens Christian Jensen, SRC
WP 1.4 Sytze Rienstra, NEI
WP 1.5 Mark Jeffcott, Halcrow
WP 2.1 Sytze Rienstra, NEI
WP 2.2 Claude Deremy, Systra
WP 3.0 Hans-Ole Skovgaard/Djon Larsen, SRC

## 6.3 Co-ordination of work

### 6.3.1 Co-ordinator

ScanRail Consult is project co-ordinator of the CrossRail Consortium. The project co-ordinator is appointed and authorised by the DG-TREN and the Steering Committee.

The co-ordinator is overall responsible for the project's general compliance with the agreed contractual terms and for setting up appropriate and adequate systems within the consortium for communication internally and externally.

Originally Hans-Ole Skovgaard was appointed as co-ordinator, but (due to Hans-Ole's health-problems) Djon Larsen was proposed and accepted as co-ordinator, starting 01.08.2000.

### 6.3.2 Project Web, partners site

The undertaking of 'virtual' projects like this needs special means for distribution of information. Therefore a dedicated 'Partners-Website' is established on the Projekt-Web.
On the partners-web working dokuments are shared. Also the co-ordinator issues a monthly 'Bulletin' to the partners, giving a summary of activities and status for the last month, thus keeping everyone ajour across the workpackages.

### 6.3.3 Questionnaires

Since exchange of detailed information between partners are difficult because of the physical distances dedicated questionnaires are used by the workpackage leaders to collect specific input for the workpackage activities from all relevant partners.

### 6.3.4 Meetings

On top of the planned Steering Committee meetings, which are used to agree on plans, discuss the progress and evaluate results, a series of working-meetings – workshops - is held for different, specific purposes.

The total list of major meetings in the corsortium et al. is shown below.

| Venue | Date | Workshop | SC | TAG | Seminar |
|---|---|---|---|---|---|
| Karlsruhe | Feb.- 2000 | | 1 (Kick-Off) | | |
| Brussels | Mar.- 2000 | | 2 | | |
| Karlsruhe | May - 2000 | WP1.1&1.2 | | | |
| York | Jun.- 2000 | WP1.3&1.5 | 3 | 1 | |
| Copenhagen | Sep.- 2000 | WP1.3&1.5 | 4 | 2 | |
| Amsterdam | Oct.- 2000 | WP1.3&1.5 | | | |
| Manchester | Nov.- 2000 | WP1.3&1.5 | | | |
| Rotterdam | Dec.- 2000 | | 5 | 3 | 1 |
| Karlsruhe | Jan.- 2001 | WP2.2 | | | |
| Rotterdam | Feb.- 2001 | WP2.1 | | | |
| Athens | Mar.- 2001 | WP2.1&2.2 | 6 | | |
| Paris | Apr.- 2001 | | 7 (Closing) | 4 | 2 |

### 6.3.5 Undertaking of the work

Spirit

Generally the consortium has agreed to set a high level of ambition; we want to 'make a difference', and try to put added value into every report (within the limits given by the contracts).

Overall performance

All workpackage leaders and contributors has taken on their responsibility in a manner that has left no real problems about progress etc. to be solved by the co-ordinator.

Moreover the partners has show their motivation for the project by sending really competent ressources, which again has acted with great flexibility regarding extra workshops, late changes to improve the results and so on.

Finally the social environment has been very good – they have all been a pleasure to work with.

List of participants

The following list shows all the persons who have participated in formal project meetings, either as a part of the project organisation or speakers at the seminars:

| EC | Firm |
|---|---|
| Uwe Huismann | |
| Mari Varho | |
| | |
| **CrossRail Consortium (Steering Committee)** | |
| Philippe Carré | Systra |
| Sebastién Bodaine | Systra |
| Christian Brahimi | Systra |
| Claude Deremy | Systra |
| Frédéric Persat | Systra |
| Klaas Peel | NEI |
| Sytze Rienstra | NEI |
| Olga Teule | NEI |
| Corina Certan | NEI |
| Mark Brown | Halcrow |
| Mark Jeffcott | Halcrow |
| Nicky Forsdike | Halcrow |
| Adrian Grigg | Halcrow |
| Kostas Georgiou | Trademco |
| Emmanuel Dawans | Transurb |
| Michel Dehon | Transurb |
| Willi Tillieu | Transurb |
| Arnim Berger | DE-Consult |
| Axel Kühn | TTK |
| Nils Jänig | TTK |
| Johan van Ieperen | TTK |
| Henrik Sylvan | ScanRail Consult |
| Hans-Ole Skovgaard | ScanRail Consult |
| Djon Larsen | ScanRail Consult |
| Bjarke Wiese | ScanRail Consult |
| Karsten Jensen | ScanRail Consult |
| Kenneth Nielsen | ScanRail Consult |
| Lars K G Andersen | ScanRail Consult |
| Jens Olsen | ScanRail Consult |
| Jens Christian Jensen | ScanRail Consult |
| Solveig Lykke | ScanRail Consult |
| Inge Lauridsen | ScanRail Consult |
| | |
| **Technical Advisory Group (TAG)** | |
| René Tutzauer | Alstom |
| Sophie Le Lan | Alstom |
| Peter Gratzfeld | Adtranz |
| Peter Lutz | Siemens |
| Günther Dillig | Siemens |
| Rolf Schraut | Siemens |
| Werner Osterhus | Siemens |

| | |
|---|---|
| **User Group (Case representatives)** | |
| Ragnar Domstad | Västtrafik GO, Göteborg |
| Michael Glotz-Richter | Service Transport et Stationnement, Hansestadt Bremen |
| Gertrude Helm | Amt für Verkehrsanlagen, Stadt Aachen |
| Katrin Ulbort | Amt für Verkehrsanlagen, Stadt Aachen |
| Johan Vanhove | SNCB/NMBS Brussel |
| Thierry Duquenne | Service de la Politique des Déplacements, Ministère de la Région d Bruxelles-Capitale, Brussels |
| W Kluska | BPK Katowice, Poland (Transurb) |
| | |
| **Review Group** | |
| F Ciuffini | FS Divisione Infrastruttura |
| Jeroen Groenendijk | UITP |
| Lara Isasa | UNIFE |
| | |
| **Speakers (seminars)** | |
| Georg Drechsler | Bremen |
| Leo Haring | Randstadt Rail |
| Jean-Claude Degand | SNCF |
| André Pierre Boller | Strasbourg |
| Alain Groff | TTK |
| Ken MacKay | Sunderland Direct |
| Peter Wilkinson | Railway Inspectorate |
| Oliver Günther | EBA |
| Rolf Schraut | Siemens |
| Bernard Stumpf | Transdev |
| Trevor Griffin | AEA Technology |
| M Barbet | Sector |
| Johnny Restrup-Sørensen (meeting Copenhagen - site visit) | Oeresundsbro Konsortiet |

## 6.4 Exploitation and dissemination plans

The inclusion of technical partners Adtranz, Siemens and Alstom as sponsors of the project ensures the industrial exploitation of the project findings in particular, the terms of market analysis and the FRS.

During the cause of the project these following major dissemination actions has been made:

- Public Web
- A public Seminar (1) : "Recommendations on Tramtrain integration" was held in Rotterdam in December 2000 with about 65 participants.
- The coordinator gave a presentation of the CrossRail project at the UIC seminar "Shaping the Future of Rail IV" in January 2001 in Paris.
- A public Seminar (2) : "Standard Tramtrain Rolling Stock" was held in Paris in April 2001 with about 50 participants.

On top of that each partner exploits the results and competences obtained from CrossRail as part of their normal consultancy work and uses the project as a reference to win more jobs within this area. For specific details on this issue please refer to the Technical Implementation Plan (TIP) Part 2 (confidential) given by each partner.

Results could be further exploited however, by stimulating the creation of new tramtrain schemes or facilitating existing plans. All partners in CrossRail consortium aims to stimulate interest, debate and ultimately schemes, by using the knowledge gained for advising cities and regions on tramtrain integration as part of their normal consultancy work by presenting project details to local authorities, opinion formers, operators, Rail Authorities etc.

Also, in case further funding is provided they can upon request:

- Maintain the existing web site as a source of information on tramtrain
- Place articles in journals across Europe, publicising the project and its key findings
- Provide speakers at conferences to publicise the project and its findings

# 7. Results and Conclusions

## 7.1 Objectives

The objectives of the CrossRail project are to:

- examine the integration of light and heavy rail networks
- define a European standard for tramtrain vehicles which will maximise market size and significantly reduce unit costs

The project is part of the Fifth Framework Programme, sub-programme area competitive and sustainable growth – key action sustainable mobility and intermodality. It thus has the broader objective of increasing mobility to stimulate economic growth in a way, which is environmentally sustainable.

## 7.2 Project phases

The project was divided into the following stages:

i) The analysis of existing and proposed tramtrain schemes. Original research was undertaken into 18 schemes across Europe, and data gathered on infrastructure, rolling stock, operation and organisation of services, and financial and economic aspects. Similarities and differences between the schemes were identified and initial issues highlighted for further research in future stages of the project.

ii) Analysis of existing and proposed tramtrain schemes, which involve a national border crossing.

iii) Analysis of barriers to tramtrain integration in cross-border contexts and identification of solutions. Analysis of the 21 cross-border schemes was undertaken in order to identify which problems were common to all schemes (including purely domestic ones) and which were specific to the cross-border environment.

iv) Analysis of user benefits of tramtrain systems. A detailed study was made of the results of the Karlsruhe and Saabrucken systems. Benefits to both operators and the travelling public of introducing tramtrain systems were identified and financially quantified.

v) Analysis of barriers to tramtrain integration and identification of solutions. Detailed work was undertaken into the 39 case studies, which made up the first two phases of the project. Common themes were drawn out, relating to the difficulties of introducing schemes and best practice in solving them. Problems affecting vehicle design were specifically explored as background to the next stages of the study.

vi) Study of market potential. Detailed trend studies were undertaken into the light rail, tram and tramtrain rolling stock markets, and likely future demand for tramtrain vehicles was predicted.

vii) Development of a standardised Functional Requirements Specification. Based on the previous work stages, plus additional research, a vehicle specification designed to maximise both production efficiencies and the meeting of demand. In addition, a specification has also been drawn up for new tramtrain infrastructure to ensure maximum benefit from the vehicle specification.

## 7.3 Key findings

### 7.3.1 Analysis of Case Studies

Tramtrain integration is innovative, challenging traditional barriers between light and heavy rail, linking the two systems with a vehicle capable of running on both. This physical integration of two modes can also facilitate closer social and economic integration by bringing together communities split by national borders, or unlinked transport systems. Overcapacity on existing tracks may be used and new suburbs, which have grown as the result of spatial spread, may be served by high quality public transport. Integration is achieved by relaxing a key safety constraint (crashworthiness), counterbalanced by a technical (signalling) solution to maintain the basic safety integrity of the system. Analysis of case studies reveals many similarities between successful schemes; however, order numbers of vehicles tend to be low (typically 10 per scheme) with vehicles being custom built to fit specific infrastructure requirements.

### 7.3.2 User Benefits

Tramtrain schemes can bring unique benefits which have proved to be extremely attractive to people, generating higher usage of public transport systems and reducing car travel. In particular, they can deliver faster end-to-end journey times by reducing the need for travellers to interchange modes to reach their final destinations. As a result, not only the actual travel time may be reduced but also the perceived travel time may be reduced even more. Analysis places the benefits of this for the Karlsruhe scheme in the region of 5 million Euros per annum. Other benefits include improved accessibility, with more station stops and better frequency than equivalent heavy rail services. The latter is achieved through lower operating costs of tramtrain in relation to heavy rail (around 50% lower). Finally, by maximising the use of existing heavy rail infrastructure the overall capital cost of schemes can be reduced.

The success of tramtrain schemes can be further helped by the use of related or "flanking" transport measures. These include integrated transport measures such as the provision of car parking at access stations and the co-ordination of bus services so that they feed into and out of tramtrain services. Also influential are city centre car parking policies, selective expansion of the road infrastructure and tariffs and road pricing measures.

The cases studied also demonstrated the importance of softer measures, not traditionally measured by transport economists. These include the perception and image held by people with regard to tramtrain schemes. Trams are perceived as better quality than urban rail or bus in many European cities and as such have been particularly successful in attracting people away from the private car.

With so many benefits to offer, it is not surprising that a number of tramtrain schemes are under consideration across Europe. Yet despite high levels of interest only two schemes are currently in operation, whilst there is firm commitment to introduce a handful more (in Germany, France, the Netherlands and the UK).

### 7.3.3 Barriers to tramtrain introduction

Detailed examination of the case studies showed a commonality amongst the problems facing tramtrain schemes. A clear hierarchy of factors emerges. Without some basic enablers in place, the integration of light and heavy rail services cannot begin.

The first of these is a supportive political and organisational environment. Karlsruhe, Saarbrucken and other schemes in line for implementation benefit from the support of a single regional political body with responsibility for planning public transport provision within its area and access to funding to make capital investment in improving that provision and controlling flanking measures.

Secondly, the regulatory environment has to facilitate new initiatives. In particular, heavy rail infrastructure operators need to provide a positive environment for this kind of change.

Thirdly, there is a range of technical difficulties, which have to be solved. Whilst these can and do add additional costs into schemes, they can, however, usually be overcome. Taking a longer-term view and adopting European-wide standards for new light rail schemes would make future integration with heavy rail easier and bring down the costs of that integration.

Fourthly, standardising features of tramtrain design will bring benefits to both manufacturers and those putting schemes forward for development. Vehicle cost is a significant proportion of the overall cost (typically 15-20%). Adapting vehicle design is one way of overcoming some of the infrastructure features, which can stand in the way of schemes, being cheaper in the short term than adapting the infrastructure itself. Having a standard design way of solving these issues will make the planning stages easier, whilst standardising infrastructure in the longer term should bring additional benefits in terms of standardising vehicle design.

Finally, it is clear from case studies that the types of barriers encountered when implementing a tramtrain project across national borders are no different from those which have to be solved in a purely domestic scheme. However, in a cross-border context these barriers become even greater and are thus harder to solve.

### 7.3.4 Market potential

The future sales of tramtrain vehicles largely depend upon the way barriers are solved in future. Based on this, scenarios have been built. The study has considered three scenarios – high, medium and low, making forecasts for each.

In the high scenario it is assumed that all barriers would be solved, so that the circumstances for tramtrain schemes become optimal. A quantification of this scenario indicates that the average number of sales may be 60 per year up to 2030. The amounts may of course vary per year. In this scenario many functional requirements are more or less standardised, so that some economies of scale can be achieved and the price can be lowered to some extent.

In the low scenario, circumstances are much less favourable, resulting in a demand averaging 7 vehicles per year. In practice this number is achieved by quite large orders in some years and zero-sales in other years.

The medium scenario – being a less extreme scenario – results in an average number of 29 vehicles per year.

Compared to present and past tram and light rail vehicle sales (respectively 350 and 150 per year) it can be concluded that the number of sales is expected to be pretty low, even in the high scenario. It is therefore likely that the economies of scale will be limited and that tramtrains will be quite expensive in future.

The market of cross-border vehicles is a small niche market within the total tramtrain market. The number of sales will be very limited, so that within this niche market hardly any standardisation seems feasible, unless it is combined with the standardisation in the total market.

### 7.3.5 Functional Requirement specification

Harmonisation of tramtrain vehicle requirements has potential benefits for manufacturers and scheme promoters alike in bringing about economies of scale. The CrossRail project has identified the most significant parameters for design, the majority of which are related to the need to interface with both urban and heavy rail infrastructures. It takes into account the UIC standards for heavy rail and the most recent findings of the MARIE project into the compatibility of future light rail systems. Original research has been undertaken to complement data from the case studies examined in the first stages of the project; the technical specifications of existing tramtrain rolling stock have been analysed, together with those of other tramtrain projects in France and Germany. In addition, an extensive study has been made of applicable European and International standards.

The objective of this phase is to provide a specification that can be used in most European countries. A complete overview of infrastructure constraints on heavy rail and urban networks has therefore been performed. Key parameters considered are power supply, track gauge, boarding access, capacity and length, vehicle gauge, catenary height, loading parameters, crashworthiness and traction performances.

In addition to a vehicle specification, recommendations have been produced for criteria for designing new urban infrastructure. Using these at the initial design stage of any scheme would ensure a degree of standardisation and enable the use of a tramtrain based on the Crossrail specification. This would optimise the overall cost of projects, by taking full advantage of tramtrain rolling stock harmonisation across Europe.

## 7.4 Results and conclusion

The principal project **results** are:

- Study of current developments in tramtrain in Europe
- The identification and quantification of the user benefits attributable to the introduction of tramtrain schemes
- The identification of key barriers to the introduction of schemes
- Recommendations for solving the barriers that may occur when implementing tramtrain systems
- Evaluation of tramtrain in the cross-border context
- Market projections for tramtrain vehicles
- Development of a Functional Requirement Specification for a universal modular 3-system tramtrain vehicle, also applicable to 2-system vehicles
- Recommendations for new urban infrastructure

The objectives of the project have therefore been delivered.

The principal project **conclusions** are:

- The development of tramtrain systems can offer significant user and non-user benefits and, when used in harmony with other measures, achieve a substantial modal shift
- Principal barriers are lack of political and therefore, financial, support, rather than any technical issues
- There is little difference between cross-border and domestic schemes, except that although problems tend to be the same in both, the magnitude is greater in the former
- Market size for tramtrain vehicles is in the region of 7-60 vehicles per annum over the next 30 years, with a medium scenario of around 30 vehicles in average per year.
- Standardisation of design is currently hampered by need to produce rolling stock in short runs, adapted to specific infrastructural requirements; whilst the Functional Requirements Specification produced by the project should facilitate the placing of common orders by different operators (hence reducing production and purchase costs) – harmonisation of infrastructure standards in the future could further benefit development of new schemes and avoid the need for costly adaptations of rolling stock design

# 8. Acknowledgements

The CrossRail consortium wishes to thank the following people and organisations for their extraordinary contributions to the success of the project:

- Siemens, Alstom and Adtranz for being sponsors of 30% of the budget for the project.
- Case study representatives for taking the time to answer the detailed questionaires.
- SNCF (Jean-Claude Degand) for speaking on the Seminar 1 with such short notice, and for contributing so actively to the arrangement and funding of the seminar 2.
- All external speakers at the seminars (please refer to the list in section 6.3.5) for al the preparations it must have taken to make such great presentations.

# 9. References

For references to further information about tramtrain and related subjects please refer to the project web: www.tramtrain.com, where links and adresses are given to CrossRail partners, sources of information used in the reports, speakers and their presentations etc.