F3—Fast Frequent Fulfilment—Industry–Academic Collaboration

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Abstract The rail freight sector has suffered a long-term decline in market share largely at the hands of road transport. Rail freight's product and service offers have proved to be inappropriate and irrelevant for freight and logistics markets underpinned by wholly different imperatives, requirements and demands compared to bulk low-value commodities. Rail has to re-calibrate its offer to the market in operational, commercial, technical and managerial terms. The paper sets out details of a UK-based study which is examining ways in which a rail/inter-modal offer could be developed and implemented to allow rail to participate in growing inter-urban freight and logistics traffic flows. The study described in the paper is a collaboration between industry, academia and specialist experts. The output if successful could potentially be delivered into other national rail/inter-modal domains.

Keywords Rail/inter-modal · Systems · Simulation · Operations
Terminals · Performance · Productivity · Asset management

1 Motivation

The motivation behind the study covered in this paper was to investigate and to demonstrate that the rail freight sector had to significantly adapt and adjust its current model of operation if it was to remain a competitive, attractive and ultimately profitable option within the European freight market. The study was designed to develop from a robust analysis of underpinning fundamental economic analysis of rail and competing modes linked to a more thorough understanding of the motivations and needs for shippers and cargo interests when making modal choices.

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The decline of rail freight has been reported, analysed and been the subject of numerous national and pan-national strategies, studies, reviews, analyses and projects. Despite all of these, the decline of rail as a relevant component in the freight market has continued to decline. The reasons for this were identified as complex and interactive and cover the entire spectrum of technical, engineering, operational, economic, commercial and management aspects. The study was aimed at determining what rail had to achieve in terms of its cost base to achieve parity in performance with road transport and to enhance its asset productivity. The latter was closely linked to the former. The study was aimed at using a rational process linking the economic assessment and outputs to guide the operational, technical and managerial aspects of a competitive rail freight offer. The focus was on the "softer" aspects rather than focusing on the development of a single technical solution and then seeking an application for this. The study was also focused on what the end-users of transport and logistics services actually wanted from service providers as a guide to the development of a credible rail alternative. In this, it used established market planning techniques and direct contact with service providers, 3PLs and aggregators, supermarkets and other sectors to develop a more complete understanding of the way in which rail's competition operated and how it had achieved an overwhelming market dominance in sectors requiring fast frequent fulfilment (F3) of cargo movements and deliveries.

The study was also focused on the performance of inter-modal terminals and related trucking activities for collection and delivery activities. The paramount focus was to determine if a rail/inter-modal service offer could be developed and what was required by way of hardware, software and operational methods to bring rail back into contention in an aggressive and cost-focused market. It was intended that the study should inform decisions on overall inter-modal system design including adaptations to existing technology and operational models as well as examining wholly new and innovative concepts.

The study team comprised a mix of academic, industry, research and consultancy personnel with previous experience in major national and international funded studies and projects. It demonstrated the need to adopt a multi-layered multi-skilled team to address and investigate the key issues which beset the rail freight sector. It also demonstrated the need to break out of the confines of railway thinking and logic and to really get to grips with the requirements and demands of the shippers and wider spread of cargo interests. The underpinning economics and market issues have to guide the railways' product and service offer response and not inflict a technical solution on a market already sceptical about rail's ability to perform adequately in a market segment which is underpinned by very different imperatives and pressures.

This study addressed freight issues set out in the RSSB's Rail Capability Delivery Plan 2017 Section 10—Flexible Freight. It proposed fundamental changes to the future competence and capability of rail freight. Freight transport activity within UK and elsewhere in Europe by rail had been completely outperformed by an aggressively innovative commercially driven road transport sector. Rail relied excessively on the movement of low-value bulk commodities and retained a very

limited capability in the burgeoning high-value, time-sensitive domestic logistics sector driven by wholly different requirements and imperatives.

The objectives of the study were as follows:

1. To identify and understand the requirements of the inter-urban freight and logistics market and related structures and systems and what performance expectations in relation to services, products, cost, reliability and response to disruption were required by any new option involving a rail/inter-modal component.
2. To develop a definitive cost model to allow the cost performance of orthodox rail, inter-modal rail and innovative rail options to be analysed and relevant KPIs produced. This was also intended to be used to investigate and model what rail would need to achieve to secure parity or near parity with inter-urban road freight services.
3. To develop operational models through simulation of train services including orthodox, inter-modal and innovative options to identify where performance could be enhanced in relation to speed and asset productivity and availability to make rail a more attractive and competitive option on merit. Minimum modal competitive distances were to be investigated to identify whether rail could breach lower competitive thresholds.
4. To develop through modelling and simulation existing terminal handling activities and sequences with a view to identifying means of making these more efficient and cost-effective. This also included road transport activities for inter-modal traffic and for palletised logistics.
5. To identify and rank options for further investigation and research in relation to the improvement of existing models of rail/inter-modal operation and to identify a rational base for the development of new rail-based options.
6. To specify performance requirements (commercial and operational) for a competitive rail/inter-modal service and supporting management and asset management systems.
7. To identify commercialisation and ongoing development options for radically innovative rail freight solutions able to compete fully on merit with road transport.

2 Current Practices

Current train technical, commercial and operating models were and remained wholly inappropriate and irrelevant to penetrate this market which works to very different imperatives and expectations. Shippers, forwarders, 3PL operators and hauliers engaged in inter-urban freight and logistics worked to imperatives and demands that have allowed them to dominate a market where rail previously had been a major player. Rail regrettably retained methods and practices that were

increasingly irrelevant and out of context to emergent patterns of logistics, spatial planning and commercial/industrial development. Rail had failed to develop an agility in terms of responsiveness to strategic market changes, the adoption of fast frequent reliable replenishment methods and a cost base linked to a much more intensive and intelligent use of its assets. Rail tended to favour, and still does, the use of larger and heavier trains. This followed railway "logic" as a means of spreading costs over a larger volume but failed to recognise other aspects of service such as frequency of replenishment, long load and discharge times, the capital invested in inventories and a lack of agility and responsiveness in the event of disruptions. High-volume retail and commerce have moved away from the model that rail seems incapable of abandoning largely on the basis of supply-side logic.

Rail had also failed to capitalise on its energy and environmental endowments to commercial success. Much triumphalism about these aspects was not reflected in market share growth or even a presence in some commodity and route sectors. In reality, rail has trailed the heavy automotive sector in relation to emissions compliance. This posed a problem for the rail freight sector in relation to the increased commercial competitiveness of modern fuel-efficient trucks. This also reflected the obsession within the rail sector for long-lived assets when in many cases these had become obsolescent and certainly not competitive or attractive when compared with the increasingly sophisticated products of the truck and trailer manufacturing sector. The whole investment cycle within the rail freight sector was five to six times as long as the trucking sector implying that it was possible for 30+-year-old rail equipment to compete with brand new road transport kit in front-line competition.

Asset productivity remained deplorably low with slow asset turn around times in terminals and yards. This in turn was reflected into rails alleged inability to compete on the basis of both time and cost over low and medium sector thresholds which immediately took it out of contention as a credible service provider for huge swathes of traffic in the <150 km range. Rail had generically failed to recognise seismic shifts in terms of the growing capability of the primary competing mode which capitalised on operational and commercial flexibility, responsiveness to market offers and constantly evolving logistics requirements.

Tesco was the most extensive current user of rail for distribution in Britain, operating on routes from Daventry to Scotland, the London area, South Wales and Leeds. These services operated transits to regional depots (RDCs) for direct delivery to store with some return collections from suppliers and returns of packaging and waste. The new concept the project sought to validate was intended to support and develop beyond this existing pattern which still employed long trains. Other major retailers are currently less committed to the use of rail on grounds of perceived unreliability, lack of flexibility and 24/7 availability and competent management (ref FTA On Track Report 2014). The freight operating companies leased complete trains to the aggregators to fill at their commercial risk. The FOCs were and remained very risk-averse as a consequence of their low profitability. Their current asset base, operational, technical and commercial model was not relevant or appropriate to service the demanding domestic logistics sector.

Rail retained its big train positioning which was appropriate for bulk low-value commodities but increasingly distant from logistics end-users requirements. Inter-modal, much beloved and supported by the EC, proved to be less relevant for domestic and international traffic in Europe where crossroad transport had already established a robust competitive edge and was not beset with traction and driver changes together with excessively complex operational procedures at border points. The complexities of power system variances, cross-border driver acceptance and the evolution of a common European signalling and train control mechanism just compounded the problems. Inter-modal traffic was also operated in large train formations on a conveyor belt basis between ports and major inland depots with the inevitable impact on train loading and discharge times.

Taken together rail had either been beaten from the market or effectively withdrew as it haemorrhaged traffic to the emergent competition. Despite this, there was a seeming reluctance to address the evident weaknesses in the whole product and service offer and to re-position the sector onto a more competitive and cost-effective basis as well as addressing the underpinning fundamental product and service issues. Rail relied excessively on bulk flows (coal) and when this was precipitately cutback (ref ORR freight Figs. 1, 2 and 3) rail's weaknesses were totally exposed. The model of operation for bulk traffics did not align with the requirements of the high-value time-sensitive inter-urban freight and logistics sector. If rail was to get anywhere close to the aspirations set out in the EU White Paper of 2011 in terms of modal split, then some fundamentally different approaches across the operational, technical, managerial and technical dimensions were required.

The rail sector could not rely on the increasing discomfiture of its primary competition as a way of regaining market share and long-term profitability. It cannot continue to operate in a cosy bubble of its own making in the belief that it offers a better service and has better environmental credentials.

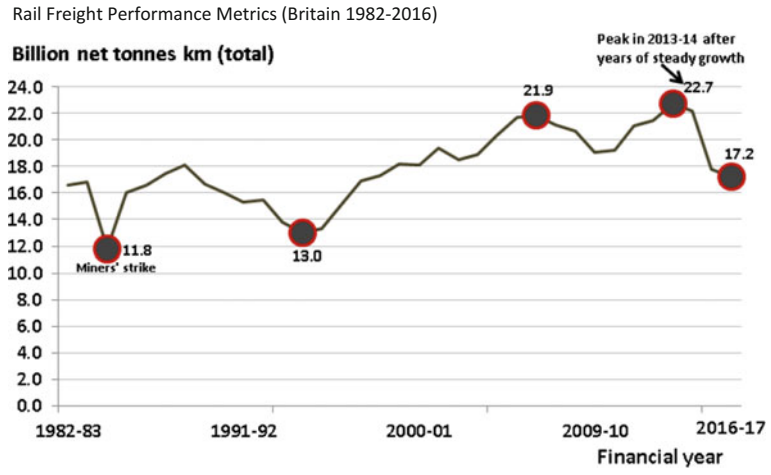

Fig. 1 UK rail freight time series 1982–2016 tonne/km

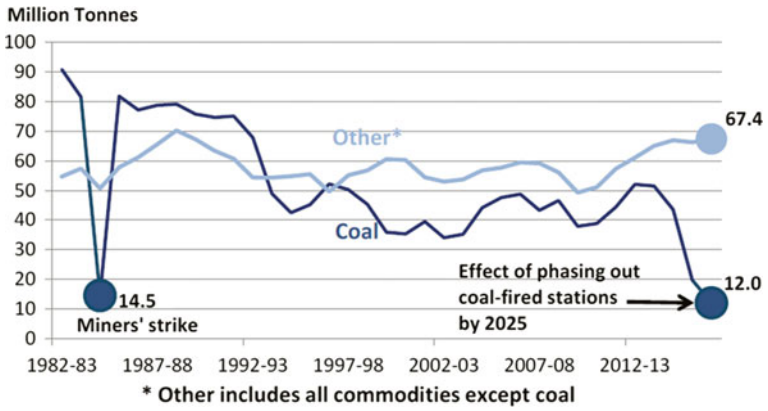

Fig. 2 UK rail freight 1982–2016 indicating the magnitude of the loss of coal traffic on originating tonnage performance

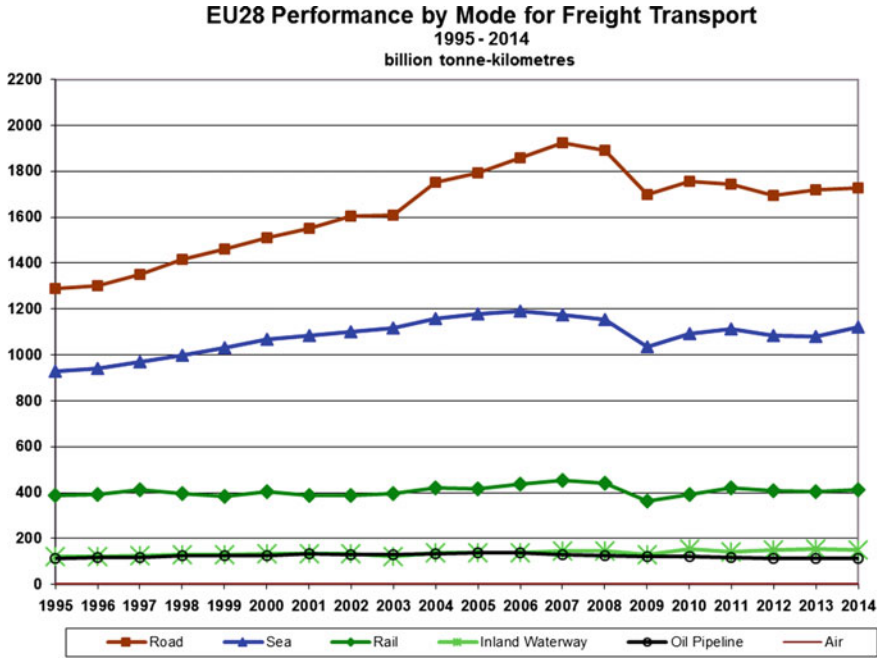

Fig. 3 EU freight traffic modal performance bn/tonne km 1995–2014

3 Case Study—New Solutions

A new project (F3—Fast frequent fulfilment) has been developed and is being funded within Britain to examine means of making a rail/inter-modal option attractive to shippers and wider cargo interests particularly in the high-value, time-sensitive inter-urban logistics arena. At present, rail/inter-modal has a very low share of this market segment for reasons outlined above. It would be possible to assume that rail cannot compete in this sector and that it has been effectively overtaken by more credible and attractive alternatives. Possibly but the alternative of developing, adapting and creating new solutions should not be dismissed. This is the basis upon which the F3 project was developed, proposed and for which funding has been secured.

The study will use modelling, simulation, analysis and to validate the benefits of an integrated near market system including innovative rail technologies, terminal and road elements, management systems and methods to fundamentally re-position rail freight's capability and commercial competitiveness based on both palletised and containerised traffic flows to service high-intensity cargo demand based on fast frequent fulfilment (F3).

Rail freight is viewed as part of a whole delivery system moving freight on end-to-end journeys. The core innovation is the integration of a short, fast freight train and to optimise movements through terminals, to improve loading and unloading trains and to drive down the cost of "final mile" road haulage. The outcome is predicted to make a step change in reducing domestic inter-modal freight end-to-end costs and to enhance its effectiveness.

Research on UK rail timetables, terminal operations and financial models indicates that a fundamentally different integrated approach is essential to facilitate any realistic future rail/inter-modal participation in traffic governed by demanding fast frequent fulfilment requirements. Rail has as a minimum, to match and outperform road-based systems on cost, productivity, service response, agility and availability (24/7 mandatory) and endow real quantifiable commercial advantages to shippers, owners and operators through the adoption of the new methods being proposed. It cannot position itself as a carrier of last resort.

Innovative train technologies and operational models are a major component to achieve the required changes. These technologies include rapid terminal handling and improved road fleet asset management to support the highly aggressive train productivity targets which are essential to underpin the economic case for this new model of operations. Linked cargo and resource planning and management systems are a central component of this initiative. The project is built around the simulation of very intensive short-train operations linked to terminal operations for the rapid loading and off-loading of containers, pallets and roll cages for onward delivery and collection. This phase will be linked to economic and commercial modelling to validate the simulation and test the concept in the face of operational changes and disruption. The project will also examine evolving requirements and not seek to merely replicate current practice. The emphasis is on high-value, time-sensitive

cargo, fast frequent fulfilment and to meet the demanding and evolving imperatives of shippers.

If this study is successful, a high-performance bidirectional validation train may be deployed to demonstrate to users and potential users that it can be technically, operationally and financially viable and become a routine integral part of complex national logistics systems. The emphasis is on high-value, time-sensitive cargo, fast frequent fulfilment and to meet the demanding and evolving imperatives of shippers.

The study addresses Flexible Freight (Section 10 of the Rail Capability Delivery Plan 2017). It is part of a process to drive down operational costs through a new, highly productive rail/inter-modal whole-system solution including optimising movement through terminals, improving train loading and unloading and taking cost out of "final mile" road haulage. To succeed, it has to be at a lower cost than equivalent all-road options. The analysis will cover end-to-end movements from major suppliers using palletised/roll cage commodities and inter-modal containers. It will be done on a connected systems basis to include road collection and delivery, terminal operations, rail transit and interfaces with users' IT systems. Delivery and return moves by road to/from stores from rail terminals are integral parts of the project. The project aimed to evaluate the full cost of using alternative modes of transport using a mix of available public sources, industry sources and material from government. A cost model has already been developed to evaluate the cost base of each mode of transport separately under an array of input variables which can be flexed. The key industry performance indicator is the annualised cost per pallet delivered. Informal pre-study modelling had indicated that rail solutions could be much more cost-effective if the assets deployed were used much more intensively under a disciplined and interventionist management regime. The "churn rate" of orthodox assets was increased and this demonstrated that a significant impact on the KPI was achievable by ensuring productivity was driven to much higher, but practical levels than under current practice.

Beyond this, the economic modelling had also encompassed the option of new short, fast self-propelled train concepts purpose designed, built and operated on a very intensive basis. This also showed great promise as a means of servicing traffic flows governed by the need to replenish inventories on a routinely reliable basis and not intermittent tsunami-type blocks.

A major component of the study will be to use simulation models based on real routes, timetables, enhanced train performance, infrastructure limitations, operational and commercial planning processes and end-user fulfilment requirements on a lower cost base. Two major national retail operators have already been contacted and agreed to share their data. 3PL operators are also involved. The outputs will include comparisons of end-to-end timings, delivery frequency and disruption response. In parallel, financial models will be used to validate the concept. The all-road delivery option is the cost and service benchmark to outperform using rail and inter-modal methods.

If the results of the modelling and simulation are positive, a high-performance bidirectional short train will be deployed to validate the models and demonstrate its

potential to users of the system benefits. The introduction into service of a new logistics system using short, fast bidirectional trains as a core component could catalyse the development of new freight hubs and new routes. It will also reduce road congestion, save carbon emissions and generate export opportunities for the hardware and related train asset and cargo management systems into other rail domains.

There is a business opportunity to recapture freight for rail from road. But it needs to be done very differently. Over 90% of all freight (by volume) in UK is currently moved by road; rail's share following recent coal losses is ~5%. Rail now has a declining share of a growing market for transport services. This dominating road position results in a number of key issues including increased concern over increasing emissions and declining road vehicle asset productivity and congestion. Emissions, access and congestion problems are severe in city centres and will become more acute. This will lead to changes in logistics networks with large trucks increasingly excluded from local deliveries despite population growth in most major cities and changing patterns of retail fulfilment.

The use of short, fast bidirectional freight train formations operating as the trunk element of a frequent delivery service offers a more suitable fit than conventional trains to service an intensive model of demand and fulfilment required for palletised/logistics traffic and containers and be able to address some delivery distances below 100 miles.

4 Evaluation of New Solutions

Previous research supported by the EU as a proof of concept has underpinned ongoing technical and commercial research to refine and develop the short-train concept. There is no known similar state of the art concept in service aimed at the market sectors identified in this proposal. Research has shown that useable train paths 24/7 are available on the initially identified routes. The performance of the new concept trains would enable them to use these routes and be compatible with passenger services. The new train performance and size will also ease delays due to user induced change and network disruption. The financial partner has assembled comprehensive cost models of end-to-end modal systems This has indicated that a properly designed and intensively managed inter-modal system can deliver more competitive solutions for fast frequent fulfilment operations than either all-road or conventional rail solutions.

Enhanced terminal performance and integration with road delivery and collection services are a key component of the project. Cargo volume information will be gathered for analysis from two major supermarkets, a 3PL, and several other logistics users from different market segments. If the simulation work shows valid cost-effective benefits, the study will move into a short but full-scale validation phase.

The challenge is to produce credible models of proposed rail/inter-modal logistics operations, their supporting terminals and road services and the means of planning and managing transits and service levels. It is intended to use these models to confirm their financial and commercial basis, to identify where further improvements are required and to propose better and more cost-effective processes. If these investigations show a positive case then a series of validation operations will be set up to demonstrate to existing and potential users how such systems would work in practice and to provide confidence in the accuracy of the simulations.

The intended approach is to develop a linked series of operational and financial simulation models of the proposed fast frequent fulfilment inter-modal logistics system and its rival solutions, all-road and conventional rail services. These models will be used to demonstrate their effects on potential commercial service, environmental and economic outcomes. The study will provide a fully evidenced business case for TruckTrain Industries (TTI) to build and deploy the short, fast bidirectional freight train concept as a key integral part of an inter-modal system (Fig. 4). It will inform design requirements, configuration options and process changes needed at the point of inter-modal exchange (the area of greatest excess cost and delay) and elsewhere.

The study uses existing and new technologies in an innovative manner designed to make much more intensive use of the systems asset base. It is a disruptive challenge to prevailing constrained technical, operational and commercial methods used in the rail/inter-modal sector. A short validation trial service will be conducted to prove the accuracy of the modelling and simulation. Discrete elements of cargo-handling and inter-modal exchange will be live trialled to test process improvements.

Information and data will be gathered from major supermarkets, "small-lot logistics" and other identified potential categories, terminals, road hauliers' and

Fig. 4 TruckTrain® concept vehicle

users' IT systems. Timetable information will be used to establish train path availability patterns for a portfolio of routes and shipper's preferred movement times. End-to-end transit time will be compared. Potential scenarios flowing from customer induced changes and/or delays will be tested to assess response. Available terminals will be involved to include cargo handling for pallet and container flows, links to road services and asset management options. Economic modelling will use shipper, Network Rail and available industry data on capital and operating costs to confirm modal cost comparisons and to develop relevant KPIs (Annualised cost per pallet delivered by mode). The economic model will be derived from the EU Starfish project. Testing the model and the use of scenarios to identify where further refinement on operational, technical and asset utilisation may be needed will be undertaken.

The outcomes will be presented at two levels: a public document where operators' data has been protected and private documents for each partner to review and benchmark their own performance. It is anticipated that the operational benefit will be shown in and operational cost reductions and enhanced reliability. Major benefit is expected through productivity gains and closer integration of rail assets, terminals, road and cargo operations. It is intended to demonstrate that rail could be able to be used as a routine fully integrated component of existing complex and sophisticated logistics networks (shipper operated or 3PL) on merit.

5 Impact

The opportunity is not a high growth market per se; transport, logistics and distribution are a mature but aggressively competitive cost-driven sector which can be expected to reflect overall national economic growth. The opportunity is based on the conversion of domestic transport, logistics and distribution from road to rail, where rail freight currently has a <5% share of tonnes lifted and a lower estimated revenue share (ref DfT Freight Statistics). National logistics sector volume and modal share data exist but in an unhelpfully compressed fashion. The full total monetary amount paid by major players to move their goods and products within Britain on an annualised basis is also opaque. There is a major structural weakness within Britain and Europe in relation to the accuracy, timeliness and relevance of existing statistical sources. Information time series is not consistent. There is no relevant published data on, for example, revenue market share within national and Europe wide freight markets to aid analysis and support investment projects.

The potential UK market size for a wholly new train system is estimated at mid-point 2660 new rail vehicles in linked sets to service the identified markets. This figure is derived from the 11.6 bn vehicle miles driven (DfT Stats 12 Jan 17) and 1.69 bn tonnes lifted. Unaddressable load sizes, journey lengths and industry sectors are excluded from the total journeys, resulting in a theoretically addressable market size of 26.6 bn tonne miles. The addressable element is assumed to be 25% or 6.6 bn tonne miles. This is a key assumption to be flexed and tested. Working on

a sector radius of 110 miles, 3.5 rotations per day and an average 18 tonnes per load over 360 operating days generates a need for 2660 vehicles. The cutover to a new position involving the integration of a rail/inter-modal component in domestic high-value, time-sensitive logistics networks will need to be carefully and skilfully planned and managed or risk failure.

All-road logistics faces issues increasingly concerned with congestion, access limitations and emissions in cities plus driver and fitter shortages. Attempts to improve economics by increasing vehicle/container size present their own challenges in city centres and non-motorway access. Rail is more constrained certainly in terms of height and variability of the loading gauge that precludes the use of the largest containers and semi-trailers on trains at present.

The study is to replace high-volume all-road operations by highly productive, well-controlled and intensively managed, environmentally friendly rail/inter-modal operations, together with lean terminals and short, predictable road collection and deliveries. Similar market conditions and constraints apply in North-West Europe, Scandinavia and other railway domains (China, North America) where this generic solution could also be successfully deployed. Global usage is estimated at seven times UK usage.

The study is planned to provide simulation evidence that the independently developed small, productive rail/inter-modal train concept can provide tangible benefits for shippers, 3PL operators and providers of rail, terminal and road services. The principal outcomes are focussed on reduced end-to-end fulfilment times and direct costs, higher levels of reliability of delivery, through transit security and securing substantial environmental benefits such as NO_x, particulates (PM_{10}) and land-take reductions. Productive rail and associated asset utilisation is mandated to be well in excess of prevailing norms to support the economic case for this solution.

The route to market involves demonstrating to major shippers, retailers and manufacturers that the integrated concept is a credible means of delivering fast frequent fulfilment and is fully competitive with all-road options on cost, service and product levels. Evidence will also need to be given to 3PLs so that they can integrate and operate a rail option profitably and successfully within their existing and planned logistics networks. The business case for users is founded on identifying and validating the benefits case arising from commercial operations. This project, if positive, is intended to be followed immediately by a live demonstration service of some 6 months duration carrying commercial freight. The demonstration service will provide the necessary proof required by both logistics users and financial backers to build and deploy into service the short, fast bidirectional freight trains operating a fast frequent fulfilment service. Analysis of the DfT statistics reveals a significantly wide market.

A certificated train operating company will operate and maintain the trains and provide a safety case. An after-sales support service (TruckTrain® Brokerage) to ensure high-intensity operations and maximise the capabilities of the rail assets at the time of deployment and subsequently as experience is gained is planned. TTB would gain (when fleets enter service) from levies on brokerage charges for multi-user cargoes and other support services. TruckTrain® as the originator of the

concept would benefit from build design royalties and possibly mileage levies. We foresee TruckTrains in use in UK by 2021.

Most freight train assets are hired from a leasing company/bank to rail freight (or passenger) operators. Train leasing companies will gain a net new additional source of income from fleet leasing and support. Train builders will gain income from new train building activities. The trains will probably be built by a UK or European train builder. Chinese rail equipment builders have also expressed interest in the concept. Network Rail will benefit from the movement of wholly new incremental traffic on its system with no additional investment. Major users could expect to consolidate their market position through better service, cost reductions and reliability gains. Terminals and road operators can expect to gain cost savings and market share through enhanced asset productivity.

The principal wider impacts within UK are those of reducing $CO_2/NO_x/PM_{10}$ emissions and road congestion on the strategic inter-urban road network. Road congestion has been variously estimated as a cost to the UK economy of between £6 and £27 bn annually. Vehicle miles have now surpassed their 2008 pre-recession peak. Freight trains only use 33% of the fuel per tonne mile of a large HGV and electrically powered trains break the excessive dependency of the transport sector on liquid hydrocarbon fuels. The new trains are designed to be faster and able to use a mix of energy inputs including electrification where this option is available.

There is a beneficial overlap into urban areas. The proposed terminal size needed for TruckTrains is smaller and simpler, allowing terminals to be much closer to city centres. The simple austere terminal concept may allow relevant but currently redundant rail links to be reactivated. The retrofitting of a simpler rail component into existing, new and planned logistics depots and terminals would also be feasible and cost-effective using the shorter trains and enhance the capability and value of such sites. That in turn enables the potential use of smaller, lighter road delivery vehicles using gas or electric propulsion for collection and delivery within the urban area, bypassing restrictions on HGV movement and reducing environmental impacts such as NO_x and particulates which arise from the use of large diesel-fuelled HGVs.

Road users will benefit from reduced inter-urban road congestion, which causes cost, delay and unreliability in moving finished goods into and from manufacturing sites and warehouses to retail locations. Estimated annual CO_2 savings are 642,000 tonnes, and lorry mile savings are 369 million miles (derived from the DfT statistics and subsequent market size calculations).

Network Rail will benefit from increased train mileage levels which earn additional track access charge income for no investment. TruckTrain's ability to accelerate, transit and brake with passenger train profiles means that better use can be made of the rail network even before the impact of large-scale digitization. Conventional freight trains cannot perform in such an intensive way. Each orthodox train can occupy up to three passenger train paths, and TruckTrain only needs one. TruckTrain is easier to re-sequence at junctions and to recover from delay as well as being more agile and able to use routes and lines denied to orthodox freight trains.

TruckTrain will work equally well in export markets where there is a developed and busy railway network, and the country is highly urbanised. Much of Western Europe is therefore addressable. Our business plan assumes that European sales will be three times the scale of UK sales, and sales to the rest of the world will be four times UK sales. Foreign sales could therefore reach £5.6 bn (2660 units × £300,000 × 7). TTI fees @ 8% should be £448M.

The study overall will be managed by TruckTrain® Industries in relation to work package integration, completion to time and quality, "red flag" issues and milestone reporting to UK. TruckTrain Industries will also provide financial management in accordance with Innovate UK requirements. Quality and budget reporting will also form part of TTI's project responsibility. The project is relatively uncomplicated and linear and lends itself to two-monthly progressions and reviews.

The study sequencing is designed to fit around and avoid peaks of activity in the retail and logistics industries, for whom the main event is the pre-Christmas surge. Relevant data will be sourced from major retailers shortly after project start and models developed during the Autumn (2017). After Christmas, the businesses which have provided the data will be shown initial outcomes, and the models adjusted and recalibrated. Simulations will then be run to test the robustness of the model to disruption through, e.g. asset failure. Final cost comparisons will be made between the three options of fast train, all-road and orthodox train using relevant KPIs.

During the middle phase of the study, a physical loading and unloading trial will potentially take place over several days to experiment with and prove different approaches for time and cost efficiency.

If the operational simulation and the cost model show a favourable outcome for the fast train option, the study will prepare for a validation train with the intention of running the demonstration in June 2018. Should the outcomes prove to be marginal this latter stage will not be progressed; instead study resources will be invested in further input cost reductions to terminal and road haulage costs.

Risk analysis needs to be broken down into risks which apply to the project already bid for in this application, and those which apply to the further TruckTrain concept development which builds and commercialises a short, fast fixed formation self-propelled bidirectional freight train.

The principal risks for this study lie in the area of data collection from the major logistics users, its content, format, time series and utility, and getting it early in the project. TruckTrain already has access to wide-ranging Tesco and Sainsbury's data from other studies. Some delays in modelling and simulation can be absorbed within the study timescale without penalty. Further, potential users outside the supermarket segment will be approached promptly at study start. The expert knowledge and input of a specialist retail logistics consultancy are expected to de-risk this aspect.

A further risk is that the range or quality of available paths for the new train services is not adequate or realistic. This has been tested by sample preliminary exploration of existing unoccupied slots, so is a reduced concern but remains to be validated in detail and for user acceptance.

The business case for the adoption of an innovative rail/inter-modal concept by the logistics sector has been scoped and looks potentially viable but it entails higher amounts of commercial and financial risk. The purpose of this study is to clarify and reduce these risks so that full-scale development can proceed and be funded commercially. The estimation of ultimate fleet size within the UK and other domains is encouraging, but will also need to be validated.

Current conventional freight operators have been sceptical largely because they are locked into existing operational, technical and commercial models of activity which have led directly to rail's weakened market share and minimal presence in the growing high-value, time-sensitive inter-urban logistics sector taken by road haulage. Rail in the UK and Europe does not yet have relevant products, systems or service capabilities allowing rail to compete adequately with road-based systems. Retention of the existing orthodoxy seriously constrains rail's abilities. Developing a wholly new market led credible concept and allied technologies and systems is a high-cost option within the rail sector and needs external funding support to move through further development and deployment.

Other sources of funding are not available. Early stage venture capitalists and angels have been approached and feedback obtained that the investment case was too early. UK Rail FOCs suffer from low single-digit profit margins and are unable or unwilling to invest in innovation. Universities are supportive and conduct engineering design research but are not allowed to fund early stage businesses. Consequently, external funding is necessary to aid the development of the train and allied fast frequent fulfilment concept so that it becomes investable. It is expected that the study will provide quality information which will allow the support of future users to be gained. This in turn will give private funders the confidence to invest in the next stages of the development of the concept.

Public funding allows a collaborative project of critical mass to be assembled to undertake properly the necessary R&D. The effect is to accelerate the TruckTrain project and give greater credibility in the eyes of the major potential users which are being asked to contribute data and scarce management time.

The total cost of this study is Euro 206,000. The project combines expert consultancy knowledge, academic input and practical trials in a cost-effective mix which moves the TruckTrain Project a longway forwards to commercial exploitation. It would be unwise to reduce costs further without impacting project outcomes.

The validation train which will involve hiring and crewing a 10 wagon trains and locomotives for 3 days of operations and attendant lifting and short-haul road delivery costs has been budgeted at £31,712. This exercise, although expensive, is the minimum essential to validate the modelling and simulation exercises. The train loading and unloading trial are expected to cost £14,700. This is expected to validate cost saving assumptions and generate further cost-saving ideas.

The TruckTrain partners will invest to cover the balance of costs not covered by grant funding.

The SCALA group was invited to collaborate but insisted on being a subcontractor. Their input is expected to be invaluable and greatly shorten the time taken to identify and approach suitable users of the F3 Service.

The rail industry generally has shown no interest in systematically developing its end-customer service levels or significantly improving its productivity and lowering its cost base to service the logistics sector. This project is based on prima facie evidence that it would be to customers' and operators' benefit to adopt a more flexible, cost-effective and productive approach to this demanding business segment.

The UK mid-point sales forecast is for 2660 TruckTrain vehicles, with forecast export sales seven times greater.

Existing publications by the academic/economic partner have shown that there are likely to be significant economic benefits from the short-train approach, compared to both conventional rail and all-road solutions. The key purpose of the project is to substantiate these findings.

The environmental gains from a shift from all-road transits would be significant in terms of emissions reduction, lowered fuel usage and land-take near terminals. At full fleet size of 2660 units, carbon emissions savings are 641,698 tonnes per annum, and lorry mile savings could be 369,000,000 per annum.

6 Conclusions and Next Steps

The F3 study is designed to validate a series of key parameters that will inform the development of a concept or concepts designed to make rail freight a more competitive and thereby attractive option in the movement of high-value, time-sensitive cargo between cities and towns. It is aimed at developing a definitive position on comparative modal economic performance to inform the operational, technical and asset management aspects of any new product or service offer into the market. It will have as a minimum to match the performance of the best of road transport and to anticipate further performance enhancements to maintain competitiveness. This implies challenging a lot of orthodoxy and accepted practice within the rail sector. If this is not undertaken, then the risk is that rail will remain largely marginalised as a player within the freight sector.

The study looked in depth at the end-users requirements as a major guide to the development of a new rail/inter-modal concept. These requirements drive the whole concept development process and cannot be ignored or assume a technical concept that does not recognise them will work or be accepted. This is a key conclusion and points up a major strategic weakness within the generic rail freight domain. Compared to the commercial aviation and heavy automotive sectors, rail does not have a coherent or established product development process to support investment in new commercial and operational initiatives. It has retained a primary focus on engineering and technical issues and by comparison neglected the "softer" commercial and business issues which should have had priority.

The study encapsulated aspects that probed into the terminal operations, organisation of activities and related commercial and planning systems. The option to integrate these into a seamless operation yet allowing different company or organisation-based IT to work within a common envelope was explored and linked to other projects (re Freight Arranger®). The flow and response to information on train schedules, arrival times, train formations, container positions and priorities and links to the final road-based delivery activity were also a focus for the project. Rail had a high on-time arrival profile but the benefits of this were identified as being lost within the state of almost permanent chaos and change within inter-modal terminals. Delays imposed on deliveries by terminal and road transport-related issues needed to be separated from the rail element and addressed to allow an inter-modal option to be competitive and attractive to shippers as an alternative to the present all-road option.

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