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Longer, faster and heavier freight trains – is this the solution for European Railways? Findings from a case study

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Abstract
The current research examines, applying qualitative research method and a case study, the notion of a ‘longer and/or faster and/or and heavier’ freight train in the European context. The case study is the trial of 1.5 km long Marathon freight train, funded by European Commission.

The current research finds that at this stage there is no commercial necessity of running a 1.5km long train. There are some technical and operational limitations to run such train which are less problematic, but the commercial necessity is a must and that will need sufficient traffic volume on a longer route (to justify extra time and cost incurred in marshalling yard and reasonable pre- and post-consolidated rail transport haul). The time required to form up/disperse such large formation could arguably be a major constraint.

The authors agree in principle with the ‘do more with less’ notion and the necessity of faster train concept. Also we are agreeing with the heavier train aspect. But, considering the current and future (more semi-finished and finished, containerized) cargo trend, it is more important that it is operated consistently, reliably, safe and commercially attractive relatively faster and possibly frequent services serving moderate distances (in line with EC White Paper target – around 300+ km). The operation of merging two (or more) short trains to form up to 750m long trains should be explored, in particular on the identified nine RFCs, to identify the potential and realistic opportunities for commercial deployment of ‘longer and/or faster and/or and heavier’ freight train.

Key words: rail freight; commercial case, operation; longer; heavier; faster; Europe

1. Introduction

In today’s competitive marketplace, reliability, cost competitiveness, time and demand responsiveness, are at the heart of freight transport service offerings, be they uni-modal (e.g. road) or multimodal (e.g. road-rail-road) (Islam et al. 2005; Kreutzberger 2008; Morlok & Spasovic 1994; Jackson, Matsika, et al. 2013). Other important criteria include flexibility, service availability at origin and destination,
tracking and tracing, through-transit security and working in partnership with transport and supply chain partners (Ballis & Golias 2004; Woxenius 2012; Yeo et al. 2008; Islam & Zunder 2013; den Boer et al. 2011). For many decades, rail played an important role in European freight transport but demand shift, caused by changes in production and consumption, has seen the share of rail freight in Europe decline rapidly since the 1970s. In more recent years, there has been an upward trend, or at least a stabilising of current share, in certain countries. Another important effect is the change of operational focus, from nationally based to pan-European services. (Section 4 is dedicated to detailed discussion of this aspect.) In this new scenario, there are multiple ways for rail freight transport to become more competitive, e.g. cost effective operation; capitalising on economies of scale; utilising more frequent services of lower volumes. Taking on board these criteria, the objective of this paper is to neutrally examine, by use of a case study, the respective merits of longer and/ heavier and/or faster freight train operations, and their viability in the European context.

Section 2 provides a discussion on the methodology applied for this research, followed by an introduction to the European rail freight context in Section 3 and a brief introduction to the case study – the Marathon freight train concept - in Section 4. After setting the context, Section 5 critically analyses the proposed case for longer and/ heavier and/or faster freight train operation. Section 6 summarises the research findings, with conclusions and recommendations set out in Section 7 and the implications for transport policy, in Section 8.

2. Methodology

The current research applies qualitative methods, including desktop research and discussion with the rail freight industry and shippers. The desktop research was concentrated on finding and critically reviewing publications on freight train length, speed and axle load, transhipment, marshalling etc. The publication source includes peer reviewed journal and conferences papers. The research also included online publications, publicly available research project deliverables, reports from organisations such as Community of European Railway and Infrastructure Companies (CER), Government bodies such as the Department for Transport (DfT), the European Commission, US Surface Transportation Board, the Association of American Railroads (AAR) and operating railroads in North America.

Nissen (1998) states that ‘Virtually all empirical social research involves comparison of some sort. Researchers compare cases to each other; ---- they compare cases to theoretically derived pure cases. -- Comparison provides a basis for making statements about empirical regularities and for evaluating and interpreting cases relative to substantive and theoretical criteria’ (p. 399). A case study can be defined as an empirical inquiry that investigates a contemporary phenomenon, in depth, and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin 2013; George & Bennett 2005; Islam & Eidhammer 2015). The current research
conduces a case study on the ‘longer and/or heavier and/or faster’ freight train concept and its commercial applicability in the European context. For the current research, a case study method was chosen to research and highlight the commercial needs and implications flowing from the adoption of the Marathon freight train model, set out in Section 4.

Islam and Eidhammer (2015) suggest that three phases can be identified within a case study research process. The first phase is the definition and design of the research, where the theoretical background is set out, including identification of relevant research questions and issues. For this paper the background information on European rail freight is provided in Section 3 and the case study (Marathon train concept) is discussed in Section 4. The second phase covers preparation, collection of relevant data and critical review. The second phase for this paper is set out in section 5. In the third and final phase, a summary of the findings from the analysis is made in section 6, followed by conclusions, recommendations and implications for European transport policy, in sections 7 and 8.

3. Background information on European rail freight transport

The European context is such that the present commercial market position of rail freight is complex, for many reasons, including the commercial and operational status of freight services, passenger versus freight priority and technical interoperability/compatibility issues. Despite the railway reform measures driven by the European Commission since the 1990s, rail’s market share has declined (European Commission 2014a) in the face of a dynamic, near universal, commercially aggressive and highly capable road freight sector (Community of European Railway and Infrastructure Companies 2013). The reforms, privatisation, acquisitions, merger and industry exit of rail freight (and passenger) companies have certainly shaken up the governance of the railway system in Europe, but these have not yet resulted in the positive modal shift from road to rail that was envisaged, endorsed and aspired to in the EC’s policy documents, such as 2001 Transport White Paper, the 2006 mid-term review of the 2001 White paper, and the 2011 Transport White Paper - where rail was targeted to secure a significant modal share gain by 2030 and 2050 (European Commission 2011; European Commission 2001; European Commission 2006). Rail’s inherent endowments of energy efficiency, speed, operation with economies of scale within a controlled sequenced and linear environment have still not been successfully converted to commercial gain. The recent trend in the rapid growth in inter-urban freight and containerised traffic, on an international and pan-European basis, has seen road freight become the dominant and preferred option for shippers and receivers, based around a mix of cost effectiveness, universal availability, responsiveness, competence and developing products and services quickly tailored and adapted to shippers’ requirements. This has come at the cost of increased traffic congestion, emissions, constrained access in cities, and fatalities and traffic related injuries and accidents, involving trucks at a disproportionate level.
The paper raises some questions to seek for ‘suitable’ or ‘appropriate’ answers for the evolving European rail freight context. Where cargo origins and destinations are densely populated and inter-urban distances relatively short, as in Europe, these conditions favour road transport, which is reflected in its dominant share of both in terms of tonne-km (moved) and tonnes (lifted) (European Commission 2014a; European Commission 2001; European Commission 2011). There has also been a shift of cargo typology, from the conversion and processing of raw materials that are industrial inputs, to semi-finished goods for assembly in factories and/or finished goods, for consumption. This is largely in response to the fact that over several decades a significant amount of manufacturing activity in Europe has moved to the East of Europe, or to other countries outside the EU, to seek cheaper industrial and labour inputs. Industries working increasingly under Lean or JIT (Just in Time) precepts require greater precision in transport services, in terms of delivery windows, routinely high levels of reliability, consistency, flexibility and availability on a 24/7 basis. All of these factors tend, at present, to favour road freight transport. The rail sector has not yet been able to develop a robust, cost effective, competitive and attractive alternative product or service offering to adequately address the high value, time sensitive market sector.

A key factor is that, in Europe, freight and passenger trains share the same, busy rail network, with freight usually assigned a lower priority by infrastructure managers (IMs) when allocating train-paths. Johnson (2012) reports that if the corridor between UK and Continental Europe could add one additional international freight train per day, the benefits (before corridor costs) could be circa £4 million per annum by 2020 (expressed in 2012 prices). To increase freight carrying capacity by rail, there is a world-wide trend towards increased axle loads (i.e. heavier) and train speed (Ferreira & Murray 1997). Recent studies such as (SPECTRUM Consortium 2013; SPECTRUM Consortium 2012) have identified that rail could potentially secure between 10% and 15% of Europe’s ‘low density, high value, time sensitive’ freight markets, currently moved by road, if it could offer appropriate products and services. This would represent a huge share gain, but requires a significant re-positioning of rail’s product and service offerings, including technologies, operations, planning and asset management techniques, for both infrastructure and rolling stock. Furthermore, it would have major implications for the management and development of infrastructure capacity, train scheduling, train sequencing and disruption response.

Six designated pan-European Rail Freight Corridors (RFCs): the Rhine–Alp Corridor; the North Sea-Mediterranean Corridor; the Atlantic Corridor; the Mediterranean Corridor; the Orient Corridor; and the Eastern Corridor) became operational in November 2013. Subsequently these six new corridors are complemented by three further RFCs (Scandinavia-Mediterranean; Baltic-Adriatic; and North Sea-Baltic) set to become operational by November 2015 (for details visit http://www.rne.eu/rail-freight-corridors-rfc.html). These corridors are expected to foster international freight transport and are intended to make rail more competitive. The IMs within these corridors will be required to cooperate across national borders, in order to improve service quality and reliability. On the RFCs, railway undertakings and applicants such as shippers,
freight forwarders and combined transport operators will be able to request pre-arranged cross-border train paths at a single contact point, instead of having to submit individual requests to several national IMs (Rail Net Europe 2014).

The rail operators (both passenger and freight) were originally government owned, nationalised organisations (Zunder et al. 2013; van der Horst & van der Lught 2009) and most of these incumbents are either still directly owned by government (IBM Global Business Services 2011) or run by government agencies, under some model of autonomy for commercial operations (e.g. French or German incumbent operators). Flowing from the EC's rail liberalisation efforts (e.g. Directives of 1991, three Railway Reform Packages and the Fourth Railway Package) (Community of European Railway and Infrastructure Companies 2013; Kallas 2013; European Commission 2014b), there are now private rail freight operators offering various block and shuttle train services on different routes (Woroniuk et al. 2013). Their position, as independent private entities, when taken together with that of foreign incumbents (i.e. incumbent national operator operating in another European country) represents a share of the total freight market of around 28% (in 2012) - much lower than that of national incumbent operators (see Figure 1). The foreign incumbents have increased their share, but the independent private operators' share has remained almost static over the same period (SCI/VERKEHR 2014). There are concerns that they maintain invisible links with the owning entity or organisation, IM, or national rail regulator. The latter is normally empowered and required to ensure impartiality in terms of access to the rail network. This suggests that the background measures governing European rail freight operations are far from being ‘free, fair and competitive’ - the required integral elements of a competitive market and the intentions of the reform measures. There are other major barriers for the new market entrant, such as economic (e.g. huge capital requirement); technical (e.g. transhipment capability); and skills and operational (e.g. capacity, demand and restrictive market information).

In addition, incumbent operators acquired some of the high-performing or prospective private operators. For example Rail4Chem, the then newly formed private operator formerly specialising in transporting chemical products, was bought by Veolia Cargo, which in turn was bought by Fret SNCF (the nationalised French incumbent freight operator) (Salehi et al. 2009). Although merger and acquisition are a part of competitive market, concerns arise when a private company is bought by an incumbent operator that was - and is in essence still - government owned and operated by a wholly owned government (or semi-government) company. This may be seen as a perverse outcome in the context of the European Rail freight market. A further perceived problematic aspect of European independent private and foreign incumbent operators competing with the national incumbent operators is that national IMs have favoured the national incumbent train operator, in ways both opaque and oblique, including priority path allocation, constraining infrastructure access for new entrants and inflated energy usage charges (Zunder et al. 2012; Railway Gazette 2013; Islam 2014). Various recent phases of reform, or attempts to improve the performance of the rail freight sector in France, including acquisitions, have not had a materially positive impact on the overall market share retained by SNCF, indicating the need for more fundamental reforms on issues such as asset productivity,
manpower/personnel and appropriately focused investment in attractive and competitive service and product offerings.

Figure 1 Change in market share of rail freight operators according to ownership

The non-geographical rail freight issues include terminal-to-terminal service operation (in the European context most of the time sensitive and high value cargoes need door-to-door service for collection and delivery), where goods are dependent on road transport for the “last-mile” component of a total transit. This can be seen as an inherent constraint to the commercial operation of rail (and other non-road) freight services. Offsetting this weakness requires a certain minimum threshold transport distance, using the prevailing technological, operational and management models, in order to be attractive to service users and to offset the cost of the pre- and end haulage and terminal lifting for unitised cargo. Although opinions are divided on this minimum transport haul (generally set above 300km), they have centred the idea of a ‘minimum break-even point’. However, there are examples of short haul rail services that were commercially operated, for both containerised and non-containerised (bulk) traffic markets, within the UK and the Netherlands, at distances of significantly less than 200km.

For the multimodal door-to-door transport of a container using maritime transport, Stopford (2002) suggests the following cost components: the ship (23%); container (18%); terminal (transshipment (21%); inland transport (25%) and other (13%). Similarly, the cost components of door-to-door multimodal service are: the line haul transport cost by rail; container cost; transhipment cost at terminals; road based pick-up and delivery cost (which can be punitive); and other (e.g. Freight Forwarder’s commission) costs. In the European context that cost has to match the direct, door-to-door transport cost by truck, which
reinforces the minimum or break-even threshold argument. Train competitiveness (long wagon life typically 40 years (Department for Transport 2011), meaning it was built with older technology) is also compromised by the retention of technology in front line service and this reinforces the fact that, in many cases, it is obsolete beyond acceptable and competitive limits. The average truck life is much shorter than rail assets and can be in the range of 5 to 7 years and include progressive technical changes, further eroding the attractiveness of the rail product and service offering (Berwick & Farooq 2003).

The existing operational model effectively sets its own limits as a means of securing modal shift, as the train operators focus on block trains. They have few service offerings for lower volume and intermittent cargo flows, which do not align with the preferred railway supply side position. (Jackson, Islam, et al. 2013a) identified that road transport can be cost effective and dominant for specific transport hauls of more than 600 km, in some specially defined routes in Europe, and that this is a major threat to rail. In a recent study conducted on the transport of Swedish grocery products, Krüger & Vierth (2015) found that rail freight service for similar distance is not suitable for time sensitive fresh fruit and vegetables. The examples of effective road transport - even for longer distance - indicate that much depends on the commercial and operational ability of rail freight operators to meet the requirements of the markets they serve (and, importantly, do not yet serve) before general conclusions can be drawn about competitive break-even distances. The authors are of the opinion that this is a major determinant in defining the demand and supply aspects of rail freight services in the European context, particularly containerised cargo flows, between ports and their hinterlands, and for international flows across borders, within the EU 28. Road transport retains a major share of this market and effectively sets the freight market benchmark for inland transport service quality and competitive pricing.

The EU aspires to a modal shift to rail (and waterways, if possible) from road, for distances over 300km transport haul, of 30% by 2030 and to 50% by 2050 considering three major policy objectives:

- Developing a **sustainable** transport system where rail freight plays an important role;
- Developing and implementing an **efficient** rail freight system that is attractive to its users;
- Developing a fully **competitive** rail freight system (European Commission 2001; European Commission 2011).

In line with these policy objectives, the EC sponsored research and demonstration projects, such as Marathon, SPECTRUM and RETRACK, to identify a range of technical and commercial options. The authors anticipate that an underlying problem in these aspirations is whether the changes achieved so far in the legislation and governance structure will result in a rail freight sector that is able to achieve the policy objectives on merit, or whether other interventions will be required. The next section is dedicated to an introduction to the case study - a brief introduction and description of the Marathon freight train concept.
4. A case study - Marathon freight train concept

The case study is the recently completed Marathon project: ‘Make RAil The HOpe for protecting Nature’ (http://www.marathon-project.eu), funded by the European Commission’s Seventh Framework Programme for research, technology and demonstration, under grant agreement no. 265647. The objectives of the Marathon project were ‘to improve the performance and appeal of rail freight services by the fast implementation of technologies, operations and business practices’ and ‘to reduce the cost of transport and increase capacity on the rail network’ (Marathon Consortium 2014b). The project adopted and applied the main theme that ‘deploying longer, faster, and heavier trains on the existing infrastructure’ was a possible model for application in the European rail freight market. As a method of lengthening the train formation, the project team merged two normal full-length trains, running in the same direction on a common section of route, with one of the two locomotives positioned in the middle of the new, longer formation, which would then operate as a larger combined unit. Remote control of the second locomotive by the driver of the lead unit saves the cost of a (second) driver. To increase the speed of the newly formed train, the project identified the need for improved coupling and braking systems, to cope with the complex dynamic properties of the longer train. From the outset the project also realised that ‘enhanced operation and traffic management is also a vital part of the project’. The project consortium worked on the notion that the longer, faster and heavier train ‘will provide extra capacity (i.e. more cargo volume with the same number of trains or the same cargo volume with fewer trains) along with estimated cost savings of up to 50% thus yielding an efficient operation’. The extra capacity, to be obtained at considerably lower cost, was envisaged to deliver a better service and a more sustainable, industrialised freight service (Marathon Consortium 2014a).

To achieve the objective, the Marathon project team conducted two trials of 1.5km long trains across France, between Sibeling (Lyon) and Nimes – a transport haul of about 300 km - operated by Fret SNCF with support from other project partners. The trials received prior approval - normal procedure for path allocation - from the French National Safety Authority, EPSF. The first trial was run in January 2014, consisting of three (500m long) intermodal trains, en-route from Germany to Spain, with different types of wagon. The total train formation was 70 wagons and two Alstom Class BB 37000 electric locomotives. The second trial took place in April 2014, hauled by two Euro 4000 diesel electric locomotives. Weighing about 4020 tonnes gross, it was claimed as the longest freight train ever to run in Europe, comprising 72 wagons operating regular Kombiverkehr intermodal services between Germany and Spain. Both trials included some empty wagons to reach the target length of 1.5km.

From Figure 2, it appears that the operational cost per train mile of a longer train with the same number of locomotives is higher than for a shorter train, but the cost per pallet falls. This general economic calculation may have supported the Marathon train concept that uses the economies of scale (higher train capacity).
However, the solution (operation of longer trains) brings in new problems, discussed below.

Figure 2 Operational cost comparison for short versus long trains

![Cost Comparison Chart]

Source: Authors estimate, using orthodox cost calculation method for rail freight train operations

What is unclear is the amount of time required to identify and process the components of the trains to be merged, the time taken to complete the physical coupling and uncoupling of the train once the operation is completed, and the impact on other trains operating over the same route. The project consortium claims that the reduction in costs can be achieved by transporting more cargo with fewer resources. It is also unclear how and where the claimed 50% Marathon cost saving will accrue and how extra capacity will be delivered, against a base case of the more efficient use of maximum length/capacity using a single locomotive hauled train or trains. In summary, the Marathon project argued that the European rail network capacity could be increased by actions in three areas:

- Increasing train capacity by lengthening the trains where this is feasible and desirable;
- Increasing the operational speed of trains, so that traffic can possibly be moved utilising fewer trains and other assets;
- Enhancing train capacity by increasing net train payload weight - this could result from the use of lower tare weight rolling stock. This may be a less important parameter as cargo is increasingly governed by volume and not weight considerations.
To find out the suitability of deploying ‘longer, faster, and heavier trains’ on the existing infrastructure for the European rail freight sector, the following research questions or issues are crucial:

- Rail freight is one of the service options for customers; rail freight operators have to attract the consignment by offering the right services in Europe’s competitive market.
- To offer the right mix of products and services in a competitive market where the trucking industry is dominant, rail operators must consider a range of different operational options, including long versus short/medium sized trains; heavy versus light trains; faster versus slower trains; and frequent versus infrequent services – or indeed a combination of these - to satisfy a wide and diverse range of shipper and commodity requirements and commercial competitiveness.
- A key issue is, what can be done to increase rail’s capability to move more containers and other, non-containerised cargo, more efficiently and effectively and sustain a growing participation in these flows? In order to address this, the New Opera and Tiger Demonstration projects (NewOpera 2014) identified in detail the limitations at a number of key European mainland ports and other bottlenecks and proposed the “industrialisation” of train size and capability, including larger formation trains as an option to overcome these.
- Further questions for effective and efficient competitive rail freight services in the European context are: what is needed, appropriate or demanded and what is not needed, or is not applicable?

A further question to be raised is whether government owned and operated companies can match or out-perform the privately owned and operated trucking industry, in the European context. With the aforesaid background information and identified research questions and issues, the following section is dedicated to critically analysing the necessity for longer and/ heavier and/or faster freight train operations.

5. Discussion

The authors support the generic ‘do more with less’ notion and argue for the utilisation of rail assets (including rolling stock, infrastructure) and personnel in a much more intensive and cost effective way. Running two trains in a tandem formation is within operational practices, but can be constrained by the varying tractive capabilities of the locomotives deployed, for example: to start the train; accelerate; maintain speed in accordance with varying speed limits; control the train over undulating territory (meaning that a part of the train could be descending and the remainder climbing); and to brake the train, in normal and emergency situations. Modern AC electric motor locomotives (diesel electric or straight electric traction) are, by virtue of their inherent traction technology and power characteristics, able to exert much more starting and continuous tractive effort than earlier generations of DC motored locomotives. Such constraints will have an impact in terms of the scheduling and assignment of compatible traction
assets to any future Marathon type operations. Higher train speed inevitably implies higher energy or fuel consumption, increased track attrition, and therefore cost - which is largely attributable to the gross weight and unsprung weight of the locomotives and their deleterious impact.

The following sub-sections are dedicated to exploring the case for and against the deployment of longer and/or faster and/or heavier train concepts, in the European context.

### 5.1 Necessity for longer trains

It is asserted that ‘Longer freight trains can generate important economic benefits and productivity gains for rail freight’ (Community of European Railway and Infrastructure Companies 2014b). A similar assertion was also put forward for longer (and heavier) trucks (Nykänen & Liimatainen 2014; McKinnon 2005; Knight et al. 2008) and bigger or mega ships (Stopford 2002; Sys et al. 2008), for example, 18,000 TEUs container ships currently coming into operation, with even bigger vessels shortly being deployed into service. Bigger and heavier trucks and ships are used in response to market demand and operational need, completely commercially. An important aspect of this commercial response is that the mega ships can call at only selected, strategically and geographically important ports, that are well equipped with appropriate handling equipment such as large gantry cranes, operated by skilled operators. Among other things, the ports have to ensure a very short turn-around-time - say 22 hours in Rotterdam. These mega-ports are linked with feeder ports and feeder ships, together with road and rail links. To ensure a faster turn-around-time, some shipping lines apply a 'dedicated terminal policy' which has its own pros and cons (compared with 'public terminal policy'). For example, Stopford (2002) concludes that ‘Mega ships do not save much in costs'. Also Sys et al., (2008) found that optimal ship size depends on transport segment (deep-sea versus short-sea shipping), terminal type (transhipment terminals versus other terminals), trade route (East-West vs. North-South trades), and technology; and also that a ship optimal for one trade can be sub-optimal for another.

For our current research, the relevant and very crucial question is whether there is enough real routine commercial demand for 1.5km long trains in Europe and whether the operation of such longer trains will indeed reduce cost and improve productivity. There will be implications of deploying the longer freight train on the network capacity, in terms of excessive train path consumption and occupancy and the potential impact of delay or failure on train sequencing. This is in particular crucial in some highly congested routes connecting major sea ports and hinterlands. The use of a very long train with embedded traction is arguably a technical, rather than a market led approach to the provision of large scale freight transport services. As such it is merely replicating and reinforcing existing supply side offers made by the rail sector to a diverse and increasingly sophisticated market, which has priorities and requirements that are not built primarily around the movement of containerised freight in very large formations. Many shippers
and receivers require continuous replenishment and receiving and not the arrival of cargo in large, infrequent blocks.

The location of consolidation points for larger trains is a further concern. The consolidation points for Marathon type trains will have to be selected so that the aggregation or disassembly activities can be accommodated without compromising active train running lines, or consuming excessive train paths, whilst these activities are undertaken. This may also imply that joining or separation points will be located on, or close to, a very busy multi-user network with the inevitable risk of disruption as train aggregation or disassembly is performed. Linked to this, the consolidation/separation time itself will be a further concern. The Marathon project suggested that an aggregation and disassembly time of 30 minutes is acceptable, if routinely delivered but, given the variability and volatility of industry practice, its realism must be questioned. Rail industry interests such as Novatrans (rail freight operator) and Combinant (Antwerp port based terminal operator) suggested that the average reliability of a freight train ranges from 75% to 85% when based around a 'one hour on-time limit', but falls dramatically to c50% if the window is shortened to 30 minutes (UIRR 2014). These are key arguments against the wider adoption of the longer train concept, so far unaddressed by the Marathon trials. The operation of a large train in a degraded situation (i.e. with only one locomotive operational), in transit, or at the assembly and disassembly phase, also needs to be addressed. The delay of one train section also has implications that the train is not able to reach the full planned Marathon formation, thereby complicating other train operations.

The location and time issues have implications for the planning and sequencing of the feeder and main trains, appropriately equipped traction, and the detailed train formation (loaded, part-loaded or empty), to minimise the risk of derailments due to excessive compressive or tensional forces once on the move. The consolidation service in a traditional marshalling yard is a time consuming process (Boysen, Fliedner, Jaehn, & Pesch, 2012). However, the ability to plan ahead and with effective sequencing may lead to a shorter transit time in a marshalling yard/sidings (Ballis & Golias 2004; Peetermans & Sondermann 2009). Also it must be ensured that the introduction of the longer train does not destabilise, or compromise, the operation of other train sequences operating around the large formation in normal or degraded operation. If this does occur, the delay attribution and cost should be directed to the root cause of the problem.

The inter-urban freight service sector in Europe is increasingly geared to unfailingly routine, reliable, door-to-door services. If there are regular and routine cargo flows, the aggregation of wagons (single wagons or groups of single wagons) may appear a credible and attractive option to shippers, particularly for a diverse mix of commodities and a wide spread of origins and destinations. This approach was researched, developed and commercially operated under the RETrack project (RETrack 2012; RETrack 2014), using single wagon load and wagon groups over a long haul pan-European route. Single wagon load freight has been in decline within Europe for a prolonged period, but the RETrack project was able to demonstrate that the model could be developed and successfully deployed (Woroniuk et al. 2013; RETrack 2012).
Research undertaken by the operators (e.g. (Bell & Roney 2011)) of very large single commodity trains (coal, sulphur, potash and containers) in Canada have highlighted a number of serious technical issues that constrain large train formation operations with embedded distributed power. These include longitudinal forces resulting from locomotive power application changes, train resistance forces, gradient, curve and rolling resistance and the acceleration and braking of the train, dynamic braking changes and intensity and the actual placement of the distributed power in a train formation. In North America, the use of traction at the head end, middle and rear of the trains is routine practice on various Class 1 railroads (AssociationofAmericanRailroads 2012; Chase 2014). Chase (2014) reports that the Class 1 railroads account for 94% of total freight rail revenue and haul large amounts of tonnage over long distances. This underlines the importance of routes that accommodate a routine higher flow of cargo. The relevant question is: which of the European rail routes carries, or will carry, such a high routine density of cargo that makes the adoption of the Marathon type model relevant or appropriate - and over what minimum sector length?

Maximum train lengths vary widely (see Table 1) among the European countries. Lochma (2012) suggested that: 'For conventional freight trains, train length may be increased to 750m on upgrades and new lines and to 1500m if economic and technical feasibility allows it'. At present it does not. The European Parliament adopted the Trans-European Transport Network (TEN-T) Guidelines in November 2013 and, in December 2013; the European Council approved it as new regulations to be enforced from January 2014. The TEN-T regulations stipulate that, by December 2030, the railway infrastructure of the core network must fulfil requirements such as: ‘Be fully compliant with the Technical Specification for Rail Infrastructure’ and ‘For freight lines: -- the possibility of running trains with a length of 740m’ (Community of European Railway and Infrastructure Companies 2014a).

<table>
<thead>
<tr>
<th>Train length</th>
<th>Countries</th>
</tr>
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<tbody>
<tr>
<td>835-850m</td>
<td>Germany</td>
</tr>
<tr>
<td>750m</td>
<td>Belgium, France, Poland, Sweden, Slovakia,</td>
</tr>
<tr>
<td>700m</td>
<td>Slovenia</td>
</tr>
<tr>
<td>550m</td>
<td>Italy</td>
</tr>
<tr>
<td>Less than 500m</td>
<td>Spain</td>
</tr>
</tbody>
</table>

Source: Data collected by authors from national infrastructure sources

The variation of maximum train length compromises the ability to operate through-trains at pan-European level, resulting in the operation of shorter train sections, or split trains, where lower length limits apply.

The maximum limits are set essentially by the length of passing loops, where a slower train can be held to allow higher priority trains to overtake. The (Marathon Consortium 2014b) proposed that a conventional bulk (cereal) train, between Morcenx (south-west France) and Antwerp (Belgium), could be coupled with two
other domestic conventional block trains, consisting of 22x15m long wagons, with a length of 350 meters and a gross weight of 1800 tons. This would result in a 700m long train - well within normal practice and therefore not well suited to the Marathon concept. If there is a demand for this type of operation, then this should be undertaken by rail freight operating companies, in response to identified commercial and operational need and without funding from the European Commission or national government.

5.2 Necessity for faster trains

Although their theoretical speed is much higher, European freight trains are generally operated at a much lower speed than inter-urban passenger trains and international trains in Europe (Community of European Railway and Infrastructure Companies 2013). They are slower to accelerate to the maximum speed set by the line gradient, curvature, weight limits, signalling system and the relative power of the available traction resources assigned to the train. Lower priority ‘drag’ trains operate at lower power to weight levels (~< 2.0 hp/tonne, compared to passenger trains ~8-10 hp/tonne) and consequently at lower speeds. This causes a major problem for the railway industry to accommodate more train traffic with differing performance capabilities, given the limited short-term prospect of incremental infrastructure capacity enhancements. Orthodox freight trains already consume excessive amounts of track capacity as a result of their constrained power: weight limits, so securing train paths that minimise the impact on following trains is a scheduling constraint and reduces their attractiveness to users. Marathon type trains are equally if not more constrained.

In a recent study of a rail freight (with an average of 29 trailers/train) service for a distance of about 600km, Krüger & Vierth (2015) found that 'average delay in the 90th percentile was around 2.5 hour and the 10% worst delays contributed to more than half of the total delays travelling south and almost two-thirds of the total delays travelling north’. The current dwell time of freight trains at a marshalling yard or yards (i.e. for classification or shunting) accounts for between 10% to 50% of total transit time in Europe (Ma & Guo 2014). This factor leads to an important issue of overall service reliability and puts pressure on train schedule maintenance (Ferreira & Murray 1997). Specifically affected is the reliability of transit time and speed, between the originating terminal/point and discharging terminal/point. Intermodal (containerised) freight trains are capable of running at 120 km/h, but discussions with the operational contacts in DB Schenker, GBRF and Fret SNCF suggest actual point to point speed averages in the range of 50-60 km/h, because of varying yard dwell times. Higher operating speeds for freight have been tried, but not sustained, as routine operating practice. For example, SNCF trialled a conventional freight train at speeds of up to 160 km/h in the Nord Region, but this led to much higher levels of track attrition, cargo damage due to poor vehicle riding and stability and excessive energy consumption to achieve and sustain the higher speed. Fast trains, for the movement of mail and other high priority cargo in trailers and containers, were operated under subsidy in the USA between 1968 and 1976, under the designation ‘Super C’; however,
these were eventually withdrawn due to the premium rates charged and the transfer of the US Mail contract to other operators (Bryant 1974).

What is essential is that freight trains can exploit their speed capability, where feasible, to minimise conflict and the imposition of delay on other traffic, as well as being able to outperform the road based competition on price and reliability. Higher speeds automatically imply higher energy consumption, increased track attrition and the need for reinforced braking. All of these will result in ultimately higher operational cost that raises the question of commercial justification. By implementing measures over a longer period, as guided in the TEN-T regulations that set a target of achieving freight train speeds of 120km/h by 2030 (Community of European Railway and Infrastructure Companies 2014a), these factors can be minimised, for example by the use of track friendly locomotive and wagon bogies, but there are limits to what can be achieved without a significant re-design of the complete train formation and method of operation.

Applying life cycle costing (LCC) and SWOT (strengths, weaknesses, opportunities and threats) methodologies, (Jackson, Matsika, et al. 2013; SPECTRUM Consortium 2013) explored a total of seven rail freight vehicle concepts: (A - Multi-Purpose Intermodal; B - Liner train - containers - Metro Cargo; C - Multi Purpose with Innovatrain horizontal transhipment technology, containers but no semi-trailer; D - Semi-Trailer with Kockums MegaSwing transhipment technology; E - Palletised cargo units; and F – Self-propelled options 1 and 2 – Self-propelled option 1 for containerised F(a), and option 2 for refrigerated and palletised cargo F(b)), all of which worked towards a rail freight service of fast, reliable and flexible trains - high-frequency services, working in hub-and-spoke networks and/or as multi-stop trains on longer routes, with links to urban rail networks and urban consolidation centres. Of the seven concepts, Concept C (containerised cargo with horizontal transhipment) found most favour, as it appears to have the cheapest cost per pallet per km, as well as claiming very positive logistics efficiency. Under this option, a railway siding can be turned into a transhipment point, requiring significantly reduced terminal investment cost (subsequently lower operating cost) - an important barrier for other types of transhipment options (Jackson, Matsika, et al. 2013; Jackson, Islam, et al. 2013b) - although the capital and operating cost of the truck-mounted transhipment technology appears to be very high. This may be a real constraint on wider application. The shippers’ requirements must be adequately reflected in service offerings. A study (Boysen 2012) warned that ‘Higher freight train speeds can result in significantly lower loading capacity and transport capacity per train and in a homogeneous traffic situation, even for the railway system as a whole.’ In reality the market may be indifferent to lower weight loading capacity, given the increase in lighter volume related cargo. Higher freight train speeds would imply the ability to exploit train paths akin to passenger train paths, in terms of acceleration, braking and line speed, and to minimise the impact on following trains. The authors argue for further study and development, with commercial demonstrations, for the use of faster freight trains with suitable, available and cost effective transhipment options, on both domestic and international services in Europe.
5.3 Necessity for heavier trains

The rail vehicle axle load varies in Europe, ranging from 17 – 25 tonnes. The TEN-T regulations stipulate that, by December 2030, the railway infrastructure of the core network must fulfil the requirement: ‘For freight lines: at least 22.5t axle load’. The gross weight of standard bulk wagons varies, but is typically between 83 tonnes (25 tonnes of tare (empty wagon) weight and 58 tonnes of payload) and 105 tonnes (28/30 tonnes of tare weight), for some bulk cargo (Marathon Consortium 2014b). Compared to other European countries, axle loads are generally higher in the UK, Sweden and Norway. Special wagons with an axle load already of 30 tonnes are routinely deployed in Sweden and Norway, for the movement of iron ore, and use only head-end traction, i.e. no distributed or embedded traction. In a study (Boysen 2012) suggested that higher axle load results in fewer wagons being needed to carry a given payload tonnage, but does not necessarily contribute to higher transportation capacity per train, or for the railway system as a whole, unless other components are adjusted, such as locomotive power.

Increasingly, the higher weight aspect of freight operation is of a lower importance in the European context, as low density high value and time sensitive cargoes are on the rise. Toubol & Castagnetti (2014) suggest that future European trade evolution can be characterised by a growing volume of containerised imports of finished goods from the Far East, while exporting more specialised, technologically advanced products, agricultural products, foodstuffs and services. The ISO dimensioned containers typically weigh in the range of 4-5 tonnes empty (specialist units such as refrigerated units weigh more) and up to the ~35 tonne gross mark, when fully and correctly loaded. The increasing need for cargo volume - particularly for containerised cargo, swap bodies and trailers, rather than the previous norm of higher weight raw materials for heavy industry - indicates that cargo weight per se is not the primary issue. The use of lighter wagons, with a reduced tare weight, could offer a solution. However, the introduction of lighter wagons raises the issue of possible derailment, resulting from excessive buffing or compression forces, particularly of lightly loaded or empty freight wagons. Equally, issues arise from the braking of a multi-section train, particularly over undulating terrain.

Advanced rail vehicle design has helped by reducing the tare weight of bulk freight cars (e.g. use of aluminium body). The North American railroads have been able to increase the payload per unit length of train, through a combination of technical enhancements and operating practice. The axle load of 30 tonnes in the US railroads is near universal on the Class 1 lines. The North American railroads have also been able to take advantage of the much more generous loading gauge, which is much more constrained in Europe. Extensive modifications have been made to the US rail infrastructure to allow the operation of double stack container trains, which is not feasible in Europe, for the movement of ISO dimensioned containers and European swap bodies of 48’- 53’ in length. The ability to operate twin stack trains has effectively allowed the railroads to double the payload per unit length
of train - a significant productivity gain and competitive commercial edge for railroads able to deploy this type of technology. Various railcar configurations have been developed to allow the transport of containers with varying sizes to be carried at speed, with embedded power. In principle the authors agree with the main theme of increasing train weight, in particular net cargo weight (meaning higher cargo carrying capacity), and the European rail freight industry will have to find relevant and effective solutions, as in the US - though these may not necessarily be the same.

6. Summary

The current research examined the notion of a longer, faster, and heavier train concept, by using a case study tested in France with two trial trains between Sibelor (Lyon) and Nimes, under the Marathon project. The question is whether 1.5 km long Marathon trains are a valid option for further development, or whether it is likely to be confined to very specific niche of commercial traffic and geographical application. The authors acknowledge the routine commercial operation of 1.5km (and longer) trains in North America, where the technical, operational and commercial perspectives and context are totally different. In the European context, many technical and operational constraints will continue to exist, given the short transport hauls and the busy networks used by both passenger and freight, making it essential to tailor solutions to that environment rather than imposing an essentially technically led option such as Marathon, rather than market led solutions, as has occurred in the trucking and shipping sectors. There are some serious technical, operational and commercial limitations and the Marathon concept is not a panacea. The location of aggregation or disassembly activities is a major concern in relation to infrastructure management, and train scheduling is an important art in finding appropriate arrival and departure times to and from each station/terminal/yard (Abid & Khan 2015). The time required for aggregation and/or disassembly of such large formations is arguably even more of a constraint to their routine deployment and acceptance due to, among others, the variable reliability of arriving and departing trains (although the Marathon project suggests only half an hour will be required). Coping with disruption or failure with a train of this size could be a serious operating headache that cannot be lightly dismissed. The Marathon concept implies the potential accommodation of different train operating practices for different customer requirements of inter-modal, bulk and conventional cargo. Large formations may cause compression and tension within the train and also bring technical and operational issues, linked to the placement of light, heavy and empty freight wagons.

Overcoming the technical and operational constraints is less problematic, but the commercial viability of longer trains (application of economies of scale) will routinely need sufficient traffic on a longer route (with a marshalling yard or similar facility and reasonable pre- and post- consolidated rail transport haul) to justify the application of this concept. The need to add empty wagons during the actual Marathon trials indicates the concern over the availability of regular, revenue-paying traffic. The authors do not lightly or summarily dismiss the
Marathon concept, but are concerned that it is being presented as a panacea to cope with the predicted growth (i.e. modal shift set by the EC White Paper 2011) of primarily container traffic, particularly traffic moving to European hinterlands through major sea ports. The current study raises concern whether the support for this initiative will be sustained, in a free and open market for rail services, and whether the above considerations could preclude the wider application of the concept. Competing for track space with dense streams of passenger traffic is another major concern.

The authors agree with the necessity for faster train operation (rather than theoretical concept), which is supported by studies in the SPECTRUM project, as well as by the TEN-T Regulations. Very high speed is not critical; what matters is the ability to routinely operate consistently reliable, safe and commercially attractive services, that are relatively faster and can be operated more frequently during both peak and off-peak periods with a similar speed to regular passenger trains, that will fulfil shipper’s needs on a sustained basis. Considering the current and future cargo typology trend, the authors advocate that - as explored in the SPECTRUM study - European customers will need fast, frequent and reliable freight trains - possibly available 24/7 – to serve moderate distances (around 300+ km, in line with the EC White Paper target) with higher scheduled speeds and higher levels of frequency, punctuality and reliability. The summary findings of the research are presented in Table 2.

Table 2. The ‘likely impact’ of the faster, longer and heavier freight trains, compared to current European freight trains

<table>
<thead>
<tr>
<th>Impact on</th>
<th>Faster and longer train</th>
<th>Faster and heavier train</th>
<th>Longer and heavier train</th>
<th>Faster, longer and heavier train</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal efficiency and performance</td>
<td>Lower</td>
<td>Lower</td>
<td>Lower</td>
<td>Lower</td>
</tr>
<tr>
<td>Disruption response</td>
<td>Lower</td>
<td>Lower</td>
<td>Lower</td>
<td>Lower</td>
</tr>
<tr>
<td>Certainty of train operational planning and control</td>
<td>Lower</td>
<td>Lower</td>
<td>Lower</td>
<td>Lower</td>
</tr>
<tr>
<td>Threshold between assembly/disassembly points</td>
<td>Higher</td>
<td>Higher</td>
<td>Higher</td>
<td>Higher</td>
</tr>
<tr>
<td>Time of assembly/disassembly</td>
<td>Higher</td>
<td>Higher</td>
<td>Higher</td>
<td>Higher</td>
</tr>
<tr>
<td>Reliability of arrival and/ departure in terminal</td>
<td>Higher</td>
<td>Neutral</td>
<td>Lower</td>
<td>Lower</td>
</tr>
<tr>
<td>Wear and tear of track</td>
<td>Higher</td>
<td>Higher</td>
<td>Higher</td>
<td>Higher</td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>Higher</td>
<td>Higher</td>
<td>Higher</td>
<td>Higher</td>
</tr>
<tr>
<td>Commercial viability</td>
<td>Unproven</td>
<td>Unproven</td>
<td>Unproven</td>
<td>Unproven</td>
</tr>
</tbody>
</table>

Source: Authors’ estimates
7. Conclusions and recommendations

The authors agree that, at a generic level, much more needs to be done with less in the European rail freight sector, by raising productivity, improving asset management and lowering costs to make rail a more attractive, commercially competitive option. In the global competitive market, shippers and consignees require a freight transport and logistics service that offers reliable, consistent and precise movement and storage of goods and, in a market like Europe, such requirements have become even more crucial. In line with the TEN-T regulation that stipulates ‘running trains with a length of 740m’ (Community of European Railway and Infrastructure Companies 2014a), the authors conclude that the 1.5km long train concept is essentially unrealistic and a distraction for widespread application in the European context. Future project funding by the European Commission should be more in line with the TEN-T regulations that target improvements in different technical and operational aspects, e.g. axle load of 22.5 tonnes and routine speeds of 120km/h Europe wide, in particular on the nine RFCs (Rail Net Europe 2014). That the operation of longer or shorter trains should be a market driven option is also argued by CER (Community of European Railway and Infrastructure Companies 2014c). The more intensive use of scheduled, routinely reliable and faster 740m long trains (Europe-wide by 2030) under a much more pro-active, commercial-minded and interventionist operational management regime (as used in the RETRACK project), could potentially raise network capacity and rail’s market share. This implies not only an enhanced rail operational capability, but also port and inland terminal operations, as well as more effective synchronisation of pre- and end road haulage. The line haul is only one component of the overall cargo transit.

8. Implications for European transport policy

The Marathon type 1.5 km long freight train concept is, in the authors’ view, a distraction rather than a commercial solution, in the European context. The freight train length should be market driven (i.e. bottom up approach) rather than a top down approach and European transport policy should be as consistent as possible about a maximum common length train. In terms of heavy (i.e. axle load) freight trains, European rail networks (in particular RFCs) should be developed, with a freight train operational capability of 22.5t axle load, across Europe. In terms of speed, a freight train should be able to operate routinely and safely at 120-130 km/h, for a more pragmatic and robust option. To match such axle load and speed requirements, the rolling stock will have to be developed (e.g. braking systems). Train size is only one in a basket of commercial solutions, including terminal performance and efficiency, disruption response, train and operations planning, energy efficiency issues, asset management and productivity that need to be addressed in an integrated manner. There is no unique single option for train size and, in a dynamically evolving and highly competitive market (where road haulage is the main competitor), it would be a serious mistake to assume a ‘one size fits all’ model, particularly if the solution involves a very large train formation aimed at supporting the rail sector’s supply side position. The case for longer, faster and heavier trains as envisaged in the Marathon project has been developed
on the basis that it will yield advantages by operating trains on an “industrialised” scale. In reality, the case for such long trains overlooks the impact on the time and track capacity required to form up, operate and break down a much longer train with embedded power, and the consequences of delay or disruption involving a very large train in transit - not only on the Marathon train itself, but also on all other trains, including passenger services, operating in close proximity. It also overlooks some of the real technical risks in operating such large formations.

The economics of operating very large train are not yet fully visible or available for scrutiny, but appear to focus on the generalities of the economies of scale argument, which is not appropriate or relevant to servicing the aggressively competitive high value, time sensitive freight transport sector in Europe. The move to a more widely available model of more efficiently operated trains, up to 740m overall in length, that are fully integrated within the context of the existing infrastructure and other services operating, potentially offers a more positive and easily adopted option, with greater flexibility.

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