Expansion of the Sheffield tram-train network

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This paper will explore why the Northern Powerhouse Rail programme is considering an expansion to the existing Sheffield tram-train network, highlighting the benefits and challenges of tram-train systems and the future potential of tram-train in the UK.

INTRODUCTION

Northern Powerhouse Rail is a transformational rail investment programme aiming to promote economic growth across the North of England by providing faster and more frequent services between major cities and economic centres across the North. This paper will discuss the consideration of extending the current Sheffield tram-train network, why this is being considered for Northern Powerhouse Rail and outline some of the challenges and work being undertaken to overcome these.

Operational analysis work concluded that the heavy rail network north of Sheffield Station is constrained, due to a mix of train service types and destinations (local, regional and long distance), and to accommodate additional trains would require significant infrastructure works. As part of delivering transformation, Northern Powerhouse Rail is considering the expansion of the existing Sheffield tram-train network, beyond its current terminus in Rotherham, to improve connectivity and capacity elsewhere in the region. This paper will outline the benefits identified and challenges experienced as part of work to assess the feasibility of expansion of the existing tram-train network, including how these challenges have been overcome and how this knowledge and experience might be used in the future to tackle some of the biggest issues facing the UK rail industry.

WHAT IS TRAM-TRAIN?

Tram-trains are light rail tram vehicles adapted to run on heavy rail lines, allowing them to transition between operating as a tram within a city centre, and as a train on the existing heavy rail network. These adaptations give them the benefits of both rail systems; the increased flexibility of a tram, such as the tighter working radius of as small as 25m, and the higher speeds achievable by a heavy rail vehicle. Tram-train vehicles are therefore capable of not only serving passengers within in a city region but also serving passengers between cities and towns.

Tram-train systems are more frequently being considered as a cost-effective means to tackle the industry challenge of increasing capacity on the network, particularly in typically more congested urban areas. By utilising the existing intra-city road network in city or town centres, as well as the existing heavy rail lines, tram-train networks can improve transport connections between cities and/or towns, thus minimising the infrastructure impacts, disruption and cost implications of bringing a heavy rail line or station into a city or town centre. Furthermore, enabling greater local connectivity and capacity through tram-train networks can also open up capacity on heavy rail lines for longer distance services.

Although tram-train projects are not new concepts globally, they are novel for the UK with Sheffield being the first and only tram-train system in the country to date having opened for service in 2018. Tram-train is an innovative solution in the UK to improve network capacity across a large area – an issue that has previously been solved by development of separate light and heavy rail networks. There are many ways in which tram-train vehicles operate differently from trains once they are using the heavy rail network. For example, tram-train vehicles have much higher acceleration and deceleration rates than heavy rail trains, making it feasible for more stops. Furthermore, in comparison to a heavy rail network that might only have one major station within a city-centre where all passengers must alight at once, a tram-train system would have numerous stops, avoiding a large build-up of passengers in one area. A single heavy rail station is also likely to be further from each passenger's intended final destinations than a tram-train stop and may even require further onward travel within the city.

Another notable benefit of tram-train vehicles is that they are lighter than heavy rail vehicles, with Class 399 tram-train vehicles weight approximately 66 tonnes and a Class 390/0 Pendolino weighing approximately 466 tonnes and as a result they cause less rail wear. This in turn reduces the frequency and cost of track maintenance. As mentioned earlier, a key factor in driving the tram-train expansion is that tram-train is a good way of opening up wider heavy rail capacity, typically with more modest price tags compared to heavy rail. This can help generate the demand for the expansion work and strengthen the business case behind both tram-train and potentially future heavy rail interventions.

CHALLENGES

One of the challenges with tram-train systems is the requirement to comply with both light rail and heavy rail standards and the relatively unknown, added complexities when transitioning between the two. This applies to both the vehicles themselves and other rail infrastructure. As part of Northern Powerhouse Rail development, both heavy and light rail experts have worked together to manage these challenges in the feasibility design process. Below are a few of the examples of the challenges that have arisen, and how they have been overcome.

LOW HEIGHT PLATFORMS

Tram platforms typically have a height of approximately 375mm above rail level, whilst heavy rail vehicles are designed for a standard 915mm height platform. The safety implications of placing a low height platform on a heavy rail line have been at the forefront of the design process. One of the major concerns is that heavy rail lines will be mistakenly identified by users as light rail due to the lower platforms, causing pedestrians to potentially act with a false sense of safety when moving around or interacting with the heavy rail lines. For example, pedestrians may attempt to cross the heavy rail track at grade, rather than using designated footbridges or underpasses, putting them at significant risk of harm. Precautionary measures such as platform staggering, safety fencing and signage have all been considered to manage and mitigate this risk.

For example, the safety fence not only needs to comply with heavy rail gauging standards but also must act as a sufficient deterrent for passengers not to climb over, nor end up ‘trapping’ a pedestrian in an emergency situation.

SAFETY

There are a number of safety precautions that have to be considered for tram-train systems which do not typically apply to heavy rail projects, such as on street running. For example, when considering on street running the safety of pedestrians and road vehicles must also be taken into account. How tram-train vehicles interact with both of these other methods of transportation in a city centre environment needed to be considered throughout the design development. Measures such as segregating tram-train vehicles and road vehicles at complex junctions, increasing white lining to control how road vehicles can operate, and analysing how pedestrians and drivers might interact with tram-train vehicles within the city environment and traffic network, aim to reduce or mitigate some of the risks. Engagement with the local authority and the infrastructure owner to gain an understanding of the issues they normally experience is key to informing the final solution. All of these safety considerations aim to reduce the risk of collisions between pedestrians or road vehicles with the tram-train vehicles.

TRACK GEOMETRY

The track geometry was also a key consideration. Light rail vehicles can navigate steeper gradients and tighter curves than heavy rail vehicles. Whilst designing new alignments, it was imperative to ensure that, when necessary, it complied with both heavy and light rail vehicle standards. For example, tram-trains can run on a minimum 25m radius curve, whilst a standard minimum curve for trains is 250m for new track. This means that for tram-trains to navigate a curve, significantly less land take would be required in comparison to heavy rail. Another example is gradients, tram vehicles are capable of climbing an 8% (1 in 12.5) gradient, whereas the maximum gradient for a passenger train would be 3.5% (1 in 28.5), more than doubling the length of infrastructure needed to achieve the required height. The length of infrastructure required for a freight line would need to be greater still, with a maximum gradient of 1.25% (1 in 80) for freight vehicles.

TRAIN CONTROL

Different methods of train control are typically used on heavy and light rail systems, conventional colour-light signalling and ‘Line of Sight’, respectively. Tram-train vehicles on the heavy rail network need to work with the heavy rail conventional signalling, with heavy rail passenger services tending to take priority. Where both vehicle types share track and where the tram-train vehicles join and leave the heavy rail network, signalling had to be a key part of the design process. Tram-trains cannot operate using line of sight signalling on the heavy rail network, due to the interaction with heavy rail vehicles, existing curves and obstructions on the heavy rail network.

Tram-train vehicles can stop relatively quickly in comparison to passenger trains, with freight trains even slower still. For example, travelling at 55mph a light rail vehicle could have a braking distance of approximately 180m, where as a train at the same speed would be closer to 1600m. Largely, tram-train vehicles share rail lines with freight trains, meaning the signal design needs to plan in sufficient time and distance for freight trains to stop if required.

Figure 1: Sheffield tram-train. Image © Chris Morgan (cc-by-sa/2.0).

Figure 2: Example of a tram at a low height platform.
Source: Image © Robert Schwandl (cc-by-sa/2.0).

Figure 3: Example of a train at a full height platform.
Source: Image © Pauline E (cc-by-sa/2.0).

INTEGRATION WITH HEAVY RAIL VEHICLES

Tram-train vehicles operating on the heavy rail network can travel at higher speeds than when using the intra-city tram network, usually operating at a maximum speed of 60mph. However, the interaction of these tram-train vehicles with other, potentially faster, heavy rail vehicles and with services that stop less frequently on the same network also needs to be considered. It is vital that these other services are able to operate unimpeded.

The drivers of both tram-train vehicles and heavy rail vehicles need to be mindful that the network won't operate exactly like a typical heavy rail system. Factors such as passengers behaving differently on low height platforms to standard heavy rail platforms are differences drivers of these vehicles need to be aware of and prepared for. More specifically for Tram-train drivers, there are the additional challenges of operating between different power sources and transitioning between signalling methods.

A further consideration is that as the tram-train system needs to integrate into both the heavy rail network timetable, and the existing tram timetables. The Sheffield tram network currently operates four service groups which operate on three different service frequencies, (6 trains per hour (tph), 2tph & 3tph). It is desirable to operate all service groups on even-interval headways, (ie 6tph, all ten minutes apart). However, with a mix of service frequencies increasing the number and destination of the tram-trains whilst also needing to integrate with the heavy rail timetable building a timetable that is both attractive to users and also reliable was challenging. A practicable solution to resolve this challenge is to provide further infrastructure in some locations. These infrastructure interventions, such as adding an additional platform and doubling currently single-lead junctions, provide the necessary timetabling flexibility to accommodate the proposed service pattern and frequencies in a cheaper and less disruptive manner than what could be expected for providing equivalent heavy rail interventions.

POWER SUPPLY

Particularly on the Sheffield system, the tram-train vehicles will need to operate on both 750V DC power and 25kV AC power supplies during different parts of the journey. How and when to operate this power supply change-over was a key point of design. To determine the optimum solution both static and dynamic handovers were considered, as well as evaluating electrical clearances, overline structures, gradients and stations/stops.

As a potential solution to manage the increased power requirement of the extension to the tram-train network, it is being considered, that battery powered vehicles may provide a more sustainable, lower cost solution. This innovative approach to powering the vehicles could alleviate the need for new traction power and overhead line infrastructure if factors such as journey length and charge time deem this a suitable solution.

DEVELOPMENT OF TRAM-TRAIN SYSTEMS

As mentioned previously, although tram-train is not a new concept, it is novel for the UK and for those designing, operating and working on heavy rail systems within the UK. Therefore, it is paramount that knowledge from other tram-train systems designed and deployed around the world is utilised in this and other similar projects. For example, experts have provided knowledge from the existing pilot scheme in the area. Other industry experts within the design team have provided research and experience from other European tram-train systems to inform the approach to the Sheffield tram-train extension, for example specifically Mulhouse and Karlsruhe were used to inform the power change-over design, to understand what the common approach is.

THE FUTURE OF TRAM-TRAIN IN THE UK RAIL INDUSTRY

Tram-train has an increasing role to play in the future of improving connectivity within and between cities and city regions. With cities constantly expanding outwards and the population of cities increasing, innovative ways to improve the reach and capacity of the transport network are in extremely high demand. Tram-train systems provide a cost-effective, less intrusive solution to this, whilst utilising the existing infrastructure to maximum effect. The understanding of the potential benefits of a tram-train solution over a separate light or heavy rail system are evident, even within the UK where tram-train systems are only in the early stages of development and deployment. As the introduction of tram-train systems across the country and the rest of the world increases, this will drive innovation in the field, improving the understanding of what the possible further capabilities of these systems could be.

The prospects of tram-train are being recognised across the country with plans already underway in Manchester, Glasgow and parts of Wales to bring more tram-train systems to the UK. Despite the challenges that these systems bring, it is clear that they will become an increasingly integral part of the railway industry.

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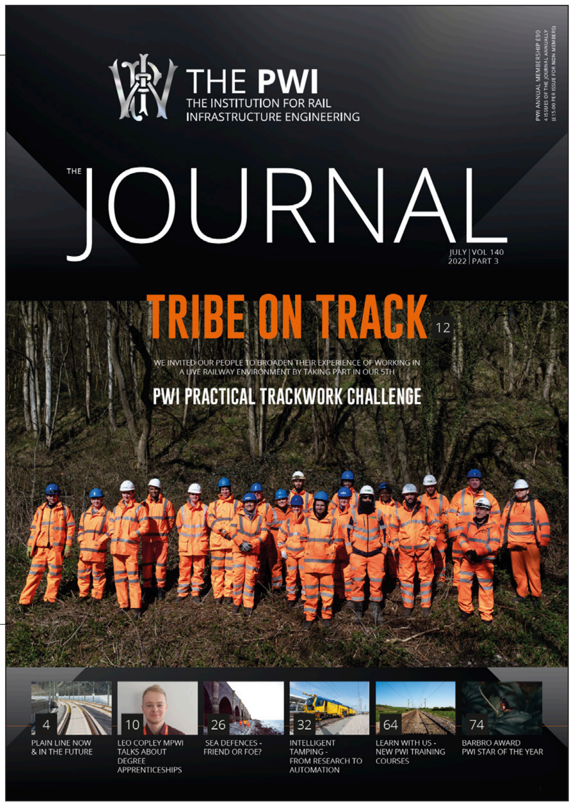

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