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Keeping track of tram-trains

Enhanced control and supervision tools have been deployed to improve the operation of tram-trains around Karlsruhe, where portion working is a common but complicated process.

Over the past three decades, Karlsruhe has become synonymous with its tram-train network which stretches many kilometres into the surrounding region. Under the so-called 'Karlsruhe Model', the city's tramways have been seamlessly integrated with the main line network. Specialist light rail vehicles which can run on both urban tram lines and the main line have been supplied in successive batches over the past 30 years.

The Karlsruhe Model was a success from the day it launched in 1992: local residents immediately took to the intuitive approach which meant they could board a tram in the heart of the city and alight at their local station in the distant valleys of the Schwarzwald, for example. The switchover between tram mode and main line running on the edge of the city is barely noticeable for passengers — yet from an operational point of view it is complicated, because tramways and railways are two very different worlds.

Not the same

The fundamental differences between the urban and main line environments were recognised as long ago as 1980, when the first tentative steps were taken towards developing a tram-train concept.

It was immediately clear, for example, that the rolling stock would need to have dual-system traction equipment (750 V DC in the city, 15 kV 16·7 Hz on the DB network), bespoke wheelsets and a modified wheel-rail interface to reflect the differing track design, and some means of closing the gap between the narrower tram cars and the railway platforms. Lastly, the vehicles would have to comply with the German EBO railway safety regulations as well as the BOStrab rules applying to trams.

Yet this focus on vehicle design underplays the significance of the difference in operating rules between the two rail modes. When crossing the boundary between the two, the way in which operations are monitored and controlled also changes considerably. This results in a degree of complexity which has characterised the tram-train operation since its inception, and work continues today to try and smooth the flow of the service.

Understanding the differences

The operational differences between the two environments can be broadly grouped around four key subjects:

Interoperability. Tramway networks are usually local systems, serving only one city and its suburbs. Around the world, subsidiarity and optimisation have led to a huge variety in key parameters such as track gauge, floor/platform height, power supply, vehicle layout and dynamic envelopes. But while such tramways are free to develop as independent 'island networks', railways need to be interoperable as they form part of much broader networks at either a national or continental level. As a result, railways need to stick to a much greater degree to common safety principles, compatible vehicle and infrastructure designs, and standardised operational procedures. A tram-train cannot simply be exempted from these stringent rules.

750 V DC

Power supply for tram mode in Karlsruhe, compared with 15 kV AC for rolling stock operating on the main line

Safety. Comparable to a bus, a tram is normally operating on line-of-sight, with the driver anticipating the traffic situation to ensure the vehicle can be stopped at any time for safety reasons. In railways, however, the much higher speeds, greater mass, and longer trains make it impossible for drivers to stop in the distance they can see, should an emergency occur. That is why main line trains are separated by signalling blocks. Again, the tram-trains must have the appropriate railway equipment and safety features, as well as suitably qualified drivers.

Governance. Most cities in Germany have a single transport authority planning a neatly integrated timetable for all its local public transport modes, but main line rail services do not usually fall within the remit of the city. While city transport operators typically get paid a lump sum from the municipality to deliver their services, the procurement of railway operations is undertaken by different authorities at regional, national, and international levels. Contracted train operators are usually paid per train-km, but they also have to pay fees for using the infrastructure. The funding and delivery of tram-train services must encompass both regimes, which adds to the challenge of calculating demand

and negotiating the required funding support from all of the various specifying bodies involved.

Infrastructure management. In Europe, it has become standard practice in the main line rail sector for train operations and infrastructure management to be handled by separate entities. Both have a safety remit, but the latter is generally responsible for capacity allocation. With multiple train operators wanting to use the same tracks, it is crucial to have an independent party to allocate the limited network capacity fairly and to be in control of traffic management. As a result, the train operators themselves have little influence in these processes and as such, they can monitor — but not truly control — their own trains. Precise documentation is required, and this applies to the tram-train services as it does for any other operator, freight or passenger.

Tram-train services seamlessly connect regional railways with Karlsruhe's tramway network, avoinding the need for passengers to change at the main station.

Operational control

In Karlsruhe, as in most cities, local public transport — mainly buses and trams — is all monitored and controlled from a single central hub using an Intermodal Transport Control System. This is the beating heart from which much of the real-time passenger information is broadcast. When necessary, the different service providers co-operate in handling disruptions and unforeseen events, and the transport authority's dispatchers make coherent decisions to restore services or help out when unexpected issues crop up. In general, these decisions are taken with a holistic view of what is right for the overall transport network in the city at any given time.

But when a tram becomes a train and it is running on third-party infrastructure, it is no longer under the remit of the local control centre. Instead, the operational supervision role is handed over to a third party, a railway infrastructure manager, which uses its own Traffic Management System. But this only manages train movements, with no oversight of any local transport or other modes. At best, the tram-train operator will have access to monitor where its trains are, and to talk to its drivers or the infrastructure manager's staff.

With the operating company no longer in charge, the interest of the passenger is not always the first priority — absolute safety comes first, but after that the railway dispatchers are focused on solving any operational problems or network perturbation. Cancelled trains, missed connections, platform alterations, extended dwell times, short or reversed formations or a lack of rail replacement vehicles are all relatively common problems, but getting information to passengers in real time remains a major structural challenge for many railways.

To be fair, main line dispatchers do not always have the same advanced digital tools nor the whole-network overview that are available to urban controllers using ITCS. The main line railway is generally much less 'digitalised' than the smaller urban rail networks, and this is the area where there is still clear room for improvement with the Karlsruhe Model.

> 'With multiple operators wanting to use the same tracks, it is crucial to have an independent party to allocate the limited network capacity'

Portion working challenge

One particular challenge comes with portion working. Karlsruhe tram-train operator Albtal-Verkehrs-Gesellschaft often couples two vehicles coming from different origins to form a single service through the more capacity-constrained sections of the railway network, such as that between Rastatt and Karlsruhe. This line is heavily used by freight and inter-city services and is currently being rebuilt by DB Netz as part of the long-running upgrading and expansion of the corridor between Frankfurt-am-Main and Basel.

Where a tram officially becomes a train from the regulatory perspective, there is also a change of operational systems including monitoring and control.

Tram-trains heading towards Karlsruhe are typically coupled together some distance from the city, while the outbound tram-trains separate at the same point for their respective destinations; this procedure is known as *Flügelungsbetrieb* or flighted working, and it is not without risk. The consequences of any disruption to the process can be significant and cascade throughout the day.

As an example, it is easy to imagine that if one of the two tram-train vehicles is delayed too much, the other will not necessarily be able to wait for it. Therefore, even though it was planned to run one combined formation, there are now two separate services to be pathed along the line. The infrastructure manager has to rapidly replan its working timetable to provide a second path across the network. As an alternative, it could cancel the service, and turn the vehicle back, but that means informing everyone of the changes. There could be other consequences for the operators: drivers will be out of place, and passengers along the route will also be impacted.

However, if the information is not passed on or comes too late, the passengers waiting at the stations may think that their tram-train is still coming. In the same way, the departure time forecasts for the second portion will be incorrect, as will information about onward connections, train formation, station access for level boarding and so on. Meanwhile, the operator will have to redeploy its staff and vehicles, revise its working timetable, and document the disruption to the quality of service.

The reality is that a multitude of external situations can arise in the field which can materially change the service plan. Sometimes these can be anticipated and prepared for in advance, but often the dispatchers have to act fast and be creative, causing them significant stress.

To mitigate this risk, INIT has enhanced the ITCS functionality so that it can now handle the full array of scenarios for portion working. This enables staff from tram-train operator AVG to restore operations quickly and provide accurate passenger information.

How it works

The limited main line capacity is allocated to train operators by the infrastructure manager, in this case DB Netz, and the operator pays an access charge for each path granted. Combining different tram-train services to use only one path reduces the cost to the operator, while at the same time freeing up capacity on a route for the infrastructure manager to use.

A fundamental safety principle in railway traffic is that only one train can be in a block section at a time. In order for the IM to be able to identify trains, each must have a unique train running number or headcode. Since all the sections of the train must have a common identifier, the tram-train services using portion working have to change headcodes *en route.*

However, this change of identity creates complexity for computerised scheduling and control systems, which INIT had to overcome in supporting the Karlsruhe Model. As a first step, the ITCS scheduling and control software platform was expanded using the TransModel and railML standards. Every AVG tram-train vehicle can now be identified by both its tramway circulation number *and* its main line train identifier. In addition, the system can now identify in detail the exact sequence and orientation of each vehicle within a multi-tram formation. This gives the controllers a far greater degree of visibility and control over the tram-trains once they leave the city confines.

INIT has implemented a variety of intervention options for AVG staff in the event of a problem with portion working, for example a separation taking place much later than planned or two portions missing each other on an inbound working. The AVG dispatchers are alerted to any unexpected train compositions immediately after each coupling event, enabling them to react as necessary to inform staff and passengers or to intervene to replan diagrams at the earliest possible stage.

Bringing tangible benefits

The ITCS used in Karlsruhe was primarily developed to manage buses and trams, but thanks to the changes AVG can now use the tool to provide improved supervision of its services operating over the main line network as well. Tangible benefits include:

- accurate prediction of arrival and departure times for the different portions of a combined tram-train formation;
- visibility of train identifiers to give passengers specific information about each portion;
- relevant level boarding information at stations based on accurate train formation data;
- enhanced operational metrics;
- faster coupling and uncoupling procedures driven by better train running and location information, leading to better punctuality.

Taken together, these improvements are further enhancing the tram-train service around Karlsruhe, providing greater resilience and stability as the Karlsruhe Model itself reaches maturity.

Due to the success of the Karlsruhe Model, the tram network had to be redesigned. Tram-train services now operate through a tunnel under the main shopping district in the city centre.