International Technical Committee
Report on topic 39

ERTMS Level 4, Train Convoys or Virtual Coupling

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Railways around the world are facing demands to transport more passengers and freight, but constructing new tracks is both expensive and unpopular. This leads to an ambition to run more trains on existing tracks, with challenges to the fundamental principles of present-day railway operations being proposed to achieve this goal.

One such principle is that trains following one another on the same track must be separated by a sufficient margin to ensure every train is capable of braking to a standstill before reaching the last known position of the train in front. With braking rates limited by the adhesion between steel wheel and steel rail, the required separation increases dramatically with speed — on a high speed line, trains must run several kilometres apart. The migration from fixed block to moving block signalling (e.g. CBTC or ERTMS/ETCS Level 3) is driven by an ambition to maximise capacity within this constraint, but demand for ever-increasing capacity means that the principle itself is now under challenge.

The argument for an alternative approach starts with the assertion that it is unrealistic to assume the train in front will stop instantly. Provided the two trains have similar braking rates, the trains can run much closer together. A communication link between the trains can ensure that if the leading train starts to brake, the following train will do the same and maintain separation as the two trains slow together. This concept has been described by its proponents as 'ERTMS Level 4', 'Train Convoy', or 'Virtual Coupling', and it features in national and international research agendas such as the UK Railway Technical Strategy and the European Shift2Rail research initiative.

The general concept is shown in Figure 1 below.

The precedent for this mode of operation is on roads, where vehicles routinely run with a spacing based on the distance travelled while the driver reacts to the brake lights of the vehicle in front, not the full braking distance to a stop. Whilst the safety levels achieved are orders of magnitude lower than on the railways, this is primarily due to the reliance on human drivers. Autonomous road vehicles are now a major research topic and this is likely to deliver an automated version of the existing style of motorway driving that will be considerably safer than at present and could have technology spin-offs for railway applications.

So is this an idea that railway signal engineers should be taking seriously? Three questions arise:

1. Is the technology feasible?
2. Is it safe?
3. Does the concept create useful additional capacity?

Is the technology feasible?

The answer to this is undoubtedly yes. The odometry systems that report train location for CBTC or ETCS Level 3 also report train speed, and braking characteristics are a known parameter within the system. Sensors developed for automated road vehicles may also play a part. A direct communication link between the trains would be needed and there are various technologies that can be used for this purpose. Automatic driving of the trains would be essential, but this is already required

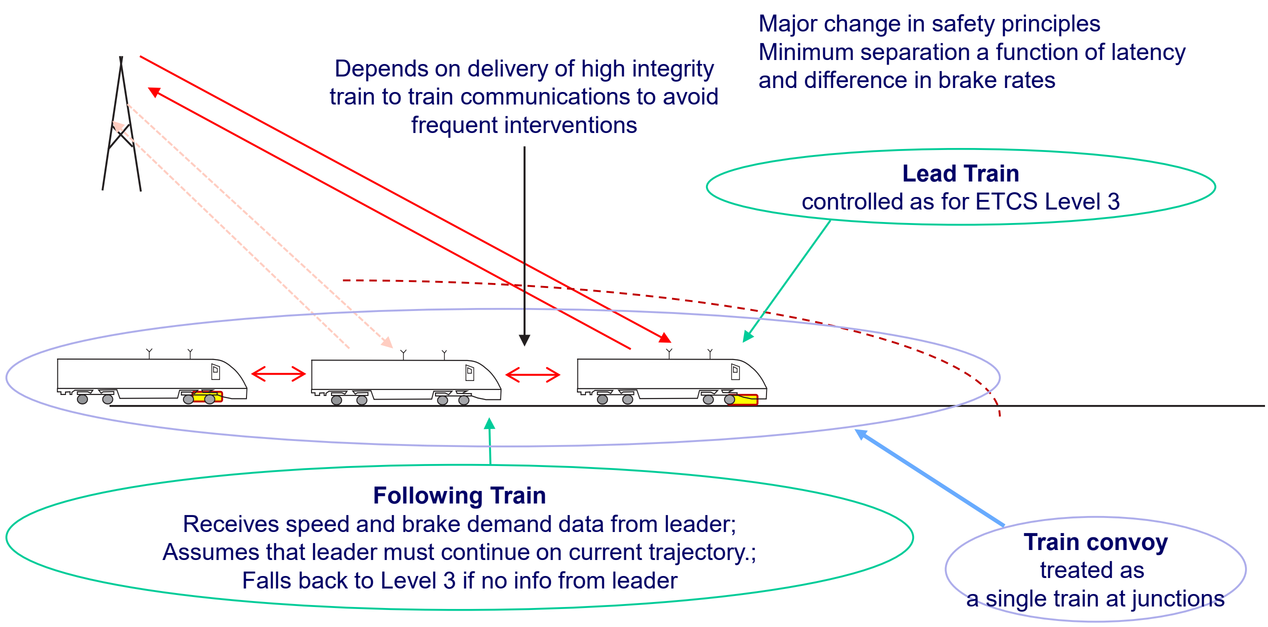

Figure 1 – Train convoy concept.

to exploit the maximum available capacity from our existing signalling systems, e.g. on the Thameslink project in UK. The greatest technical and operational challenge is probably in the management of transitions — how to insert or remove a train from a convoy?

Is it safe?

Safety is much bigger question. The instinctive reaction of every signal engineer will be that for trains to operate closer than braking distance is an intolerable risk. This is confirmed by a simple risk assessment — a train coming to a stand in less than its normal braking distance is a credible consequence of a derailment due to a train or track defect, or hitting an obstacle, and the collision of a following train that is running too close to stop could have catastrophic consequences with multiple fatalities.

However, think about it another way — instead of running two trains as a convoy, we could couple them together. Then, if the combined train derails, twice as many passengers will be affected by the initial derailment. Whereas if the trains had been running separately in a convoy, there is a least a chance that the second train would have been able to stop in time — in this situation the convoy option would actually be safer.

Depending on the separation of the trains, and how quickly the leading train stops when it becomes derailed, there will be a spectrum of consequences. The key parameter is likely to be the speed differential when the following train catches up with the derailed train in front. If this is significant, then it is very likely that the loss of life from derailment of the first train followed by collision of the second will be greater than from derailment of a double-length train.

The mechanical and structural design of the vehicles could have a significant effect — modern rolling stock is designed according to 'crashworthiness' standards that consider collision with a fixed obstacle, and to allow coupling with a stationary train. How will these features perform in the derailment followed by collision scenario described above? Paradoxically, with the right vehicle design, trains running very close together could be relatively safe, with the risk increasing as they become further apart. When the first train derails, a second train very close behind will catch up before the first train slows significantly, and the speed differential may be within the crashworthiness and coupler capabilities. The consequences would then be the same as for derailment of a double-length train.

Accident scenarios involving a train on a parallel track also need to be considered — at present we are happy to allow trains to run at full speed in opposite directions on parallel tracks where a derailment on one track could block the other, but historically the accidents with greatest loss of life are those where a derailment as a result of two trains colliding on one track has resulted in a third train running into the wreckage (e.g. Quintinshill, Harrow and Clapham in the UK). Would this type of accident become more likely? Or could the technologies used for train convoys provide additional warning to the train on the parallel track?

As well as the probability of occurrence, the other key issue for the adjacent line derailment case (and to some extent for 'sudden stop') is that whilst the causes remain essentially unchanged, the consequences for an event involving convoys, rather than single trains, might be significantly greater and thus there may be an increase in risk.

From this very superficial safety analysis, it is apparent that there is no absolute answer, and the safety of a train convoy, or convoys, compared to single trains with equivalent capacity, will depend on a number of parameters. The mechanical and structural design of the trains needs to be taken into account as well as the mode of operation that is envisaged, along with the possibility of designing-in additional controls and/or mitigations.

Does the concept create useful additional capacity, given the other constraints on the railway system?

There is no doubt that the train convoy principle would improve plain line capacity, but is this really the factor that puts limits on the useful capacity of the railway system?

The experience of metros that have adopted moving block CBTC signalling is that the achievable capacity depends largely on station dwell times for passengers to board and alight at the busiest stations, and on turnaround arrangements at termini. If this is the case, abandoning the principle of absolute braking distances for the train convoy concept will not deliver any further improvement.

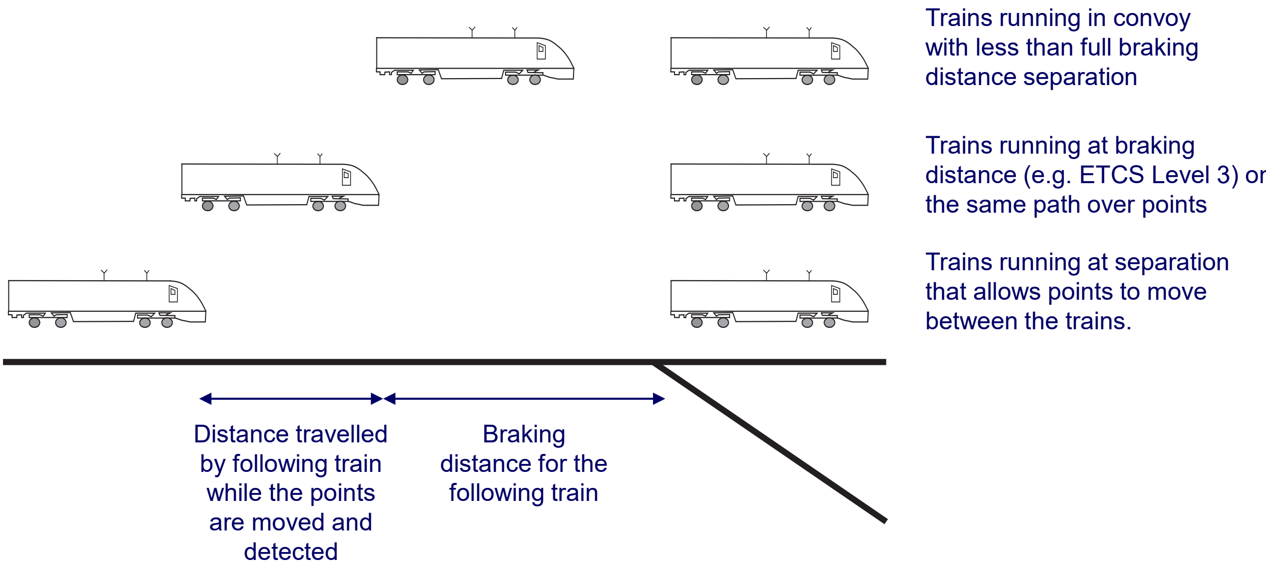

Figure 2 – Train headways at a diverging junction.

On main line applications, longer platform dwell times are required but this is compensated for by provision of additional platforms, so that the dwell time does not determine the route capacity. However, this introduces the need to switch successive trains into different platforms, i.e. moving points between trains. If the train convoy concept were adopted, this would mean moving points between trains in the convoy. This introduces another safety risk, that of the points failing in a position that would derail the train. This is a very credible scenario, much more frequent than a train derailment, hence the universal practice of proving that the points are detected in the required position before granting a movement authority to an approaching train. So trains in the convoy would have to be spaced out to braking distance on the approach to any diverging junction. The same factor limits the benefits from existing moving block signalling technologies on complex track layouts — they become fixed block at the very places on the network where capacity is most critical.

Figure 2 shows the impact on headways at a diverging junction.

This implies that on its own, the train convoy concept cannot deliver a real increase in capacity. A whole system approach is needed that starts by identifying the real limiting factors in complex areas of the network, and then seeks out relevant technical and operational concepts that will deliver an improvement in these critical locations.

Conclusion

So should we be taking the concept of train convoys seriously?

- Is it technically feasible? — Technically, it can almost certainly be made to work, but there will be significant operational challenges to make it useful in practice;
- Is it safe? — This will depend on a number of factors; we should not rule it out entirely on safety grounds but the safety argument will be difficult;
- Will it deliver real benefits? — Not without addressing other factors limiting practical capacity at stations and junctions.

Nevertheless we will no doubt hear more of this topic in the future. 'Virtual Coupling' is one of the topics to be covered in the European Shift²Rail research project, and 'Closer Running' is the title of an RSSB research project in the UK. In the meantime, if IRSE members are aware of real research results or practical experience (not just opinions please) that would support or contradict the views expressed above, please share this with the profession via the pages of IRSE NEWS.