Dynamic Coupling: a new technology to fast-forward the future of railways.

Authors
Alberto Mandler, DTS, Israel
Eyal Ben-Shahar, DTS, Israel
Moti Topf, DTS, Israel
Dr. Ir. Egidio Quaglietta, Delft University of Technology, the Netherlands

February 2022

1 Introduction

To face the challenge of a progressively increasing rail transport demand, infrastructure managers are in need of increasing capacity of existing networks. The railway industry is hence currently looking into next-generation signaling technologies such as Moving Block and Virtual Coupling (Figure 1) which could reduce train separation as much as possible while keeping required safety and comfort standards. Moving Block (MB) [1] could decrease train separation from a given number of block sections (as it currently is for conventional multi-aspect fixed-block signalling) to just an absolute braking distance, by migrating safety-critical systems for train integrity monitoring and braking supervision from track-side to onboard the trains. To even further reduce train separation, the concept of Virtual Coupling (VC) is currently under investigation [4].

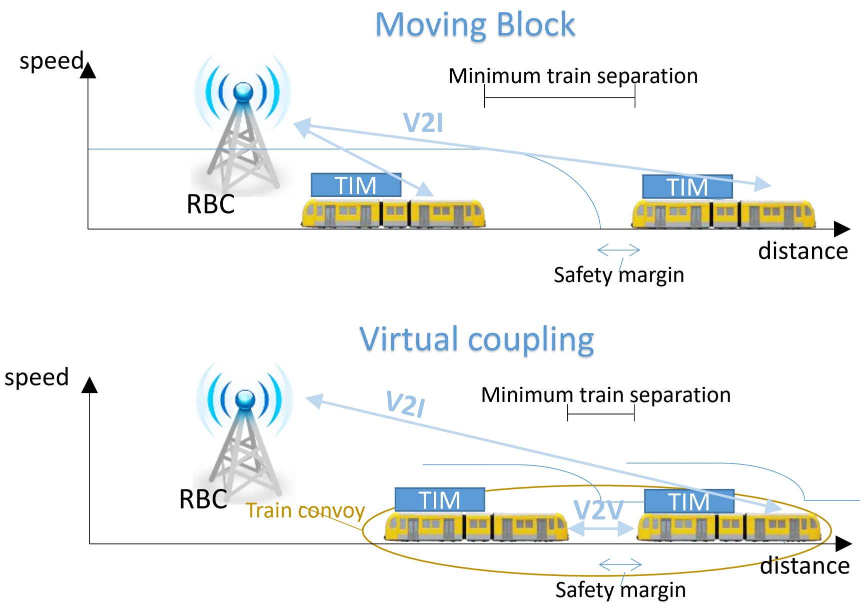


Figure 1 Schematic system architecture for Moving Block and Virtual Coupling

A Vehicle-to-Vehicle (V2V) radio layer enables trains to exchange dynamic information (speed, acceleration, and position) to run at a relative braking distance from each other or even move synchronously in platoons which could then be considered as a single train to improve capacity at bottlenecks. Automatic Train Operation (ATO) would be necessary in that case since human driving reaction times would be unsafely long for such short train separation distances. Several concerns exist however around the concept of VC for keeping safe train separation in presence of risk factors such as delays of the V2V communication, emergency braking applications of trains in a platoon, prolonged ATO intervention times, point malfunctioning at diverging junctions. Furthermore, there no clear requirements yet for high-frequency and wide-range V2V radio technology which could support a safe and effective train communication under VC. To solve most of the mentioned operational and technological unsolved concerns of Virtual Coupling, the Israeli startup DirecTrainSystems (DTS) proposes the alternative concept of Dynamic Coupling (DC). Based on their experience in the aviation sector, DTS introduces a novel technology to physically couple/decouple trains on-the-run to enable train platooning without the need of an extensive V2V communication layer deployment. Dynamic Coupling is hence expected to provide even more capacity benefits than VC while removing V2V comms-related safety risks and needing less investment costs.

2 Safely coupling trains-on-the-run with DTS's Dynamic Coupling

The proposed concept of Dynamic Coupling envisages that trains could physically couple/decouple on-the-run by means of extendible telescopic couplers to form longer trainsets (which can be seen as platoons) with the objective of improving capacity at bottlenecks.

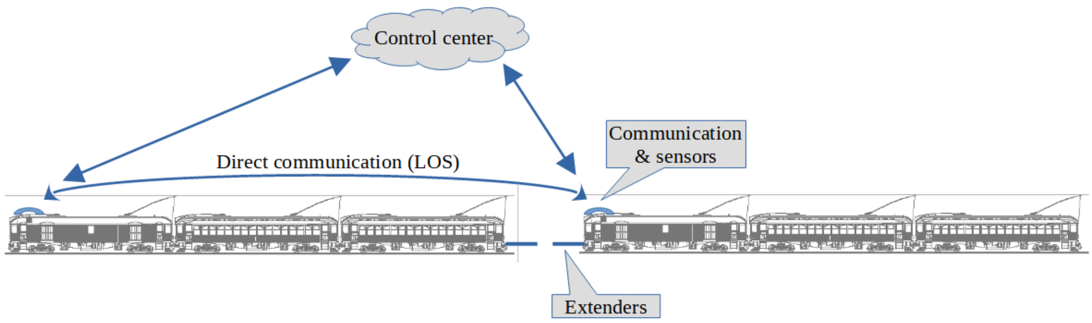


Figure 2 schematic system description

Differently from Virtual Coupling, the Automatic Train Operation and the V2V communication layer would not need to be equipped across the entire network but only in limited "coupling zones" which are the only areas where trains would be allowed to get closer than an absolute braking distance to perform physical coupling/decoupling while on-the-run. Trains entering a "coupling zone" would reciprocally exchange dynamic information as in Virtual Coupling while being automatically controlled from a central controller until the coupling is safely performed by means of telescopic couplers extending from the trains until they are connected. Similarly to the aviation sector[1], the coupling zones could be considered as the runaway where aircrafts are allowed to get closer to each other and perform special activities such as taxing. On tracks outside these coupling zones, trains would instead run as they do today under the supervision of existing signalling systems. DC has potentials to be a much less expensive and a faster-to-develop alternative than Virtual Coupling, given that ATO and V2V radio technologies will be only required in the coupling zones. Also, less safety risks would be raised since trains would be forming platoons by being physically coupled, thereby removing any concern due to delayed V2V communication, extended ATO reaction times or sudden emergency brake applications which can affect trains in a virtually coupled platoon.
Using dynamic coupling is not mutually exclusive with conventional multi-aspect or radio-based (e.g. ETCS Level 2) fixed-block signaling. This means that a train platooning could be quickly implemented with DC without needing to remove existing signaling or bring costly modifications to the infrastructure. In addition DC could be deployed in

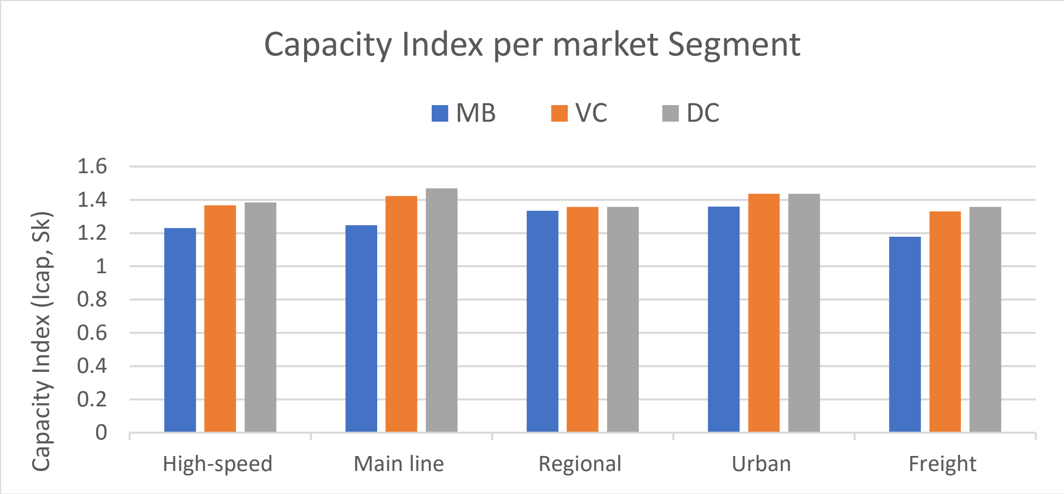
[1] Example of such regulation can be found at: FAA Order JO 7110.65, Para 3-7-1, Section 7, Taxi and Ground Movement Procedures: https://www.faa.gov/air_traffic/publications/atpubs/atc_html/chap3_section_7.html

combination with MB and/or VC to potentially provide improved safety and service performance than using one of them alone.

3 Comparing potential impacts of DC versus Moving Block and Virtual Coupling

To analyze the implications of Dynamic Coupling and identify possible advantages and/or limitations with respect to Virtual Coupling and Moving Block a multi-criteria impact analysis is performed in this research. The three technologies are compared in terms of both quantitative and qualitative criteria and then benchmarked with respect to the current state of practice for different rail market segments. Quantitative criteria include total costs, infrastructure capacity, system stability, travel demand, and energy consumption. Qualitative criteria instead refer to public acceptance, regulatory approval, and safety. The multi-criteria analysis is performed based on a hybrid AHP-Delphi method for real case studies belonging to different railway market segments. Specifically, the High-Speed rail segment is analysed considering the Rome to Bologna corridor in Italy, the Main-line market instead refers to a portion (from London Waterloo to Surbiton) of the British South West Main Line. The regional rail segment considers part of the British line between Peterborough and Leicester, while the urban rail segment is represented by part of the London Central line (between Lancaster and Liverpool Street). The freight segment refers to the German-Dutch freight corridor between the ports of Hamburg and Rotterdam. For more details about the characteristics of the case studies, the considered assessment criteria and the corresponding KPIs the reader can refer to the scientific work presented in Aoun et al. 2021 [2] which summarizes some of the main outcomes from the research project MOVINGRAIL [3], funded by the European Commission's Shift2Rail programme [5].

Outcomes of the comparative impact analysis of DC versus MB and VC technologies are given in Figure 3 for two of the most relevant criteria, namely the capacity and the total costs. The Capacity is measured in terms of the relative index I_{cap} which represents the maximum number of trains which can be operated with a given signaling system with respect to the one which can be currently operated. The Total costs instead include both investment costs (CAPEX) and operational costs (OPEX) to run the system over a life cycle of 30 years. The analysis shows that DC could operate at least the same number of trains as VC for all market segments while substantially lowering the budget to implement and operate and maintain the signaling system.



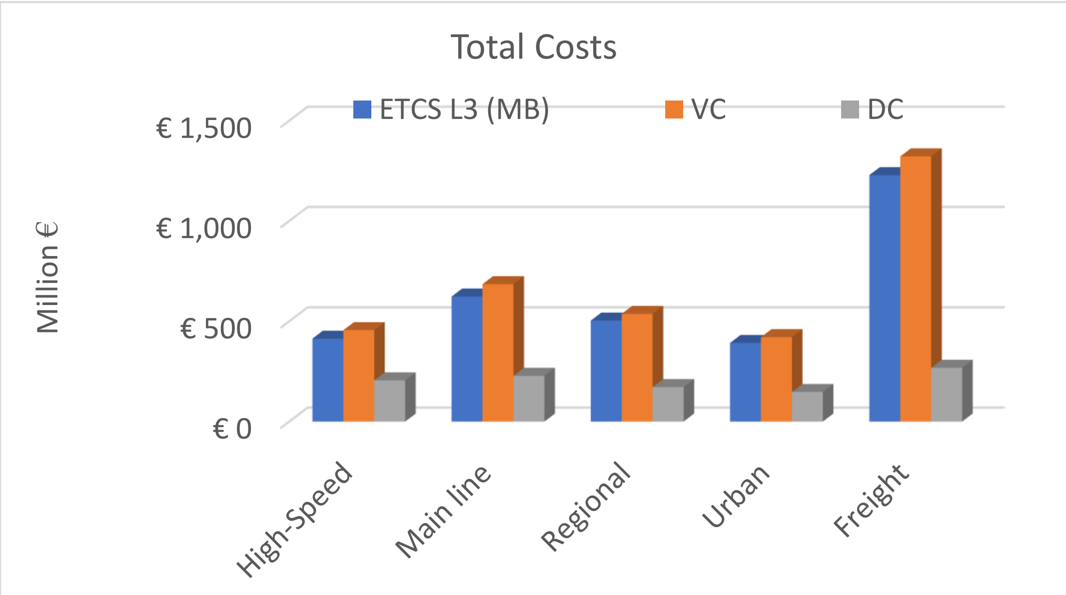


Figure 3. Comparative capacity and cost analysis of DC versus MB and VC for different rail segments

4 Conclusions

The proposed Dynamic Coupling technology could accelerate the migration to a train platooning operational paradigm to substantially increase railway capacity while providing a safe and cost-effective system. Results from a preliminary multi-criteria impact assessment illustrates that DC concept of operation could be similar to VC in many aspects, with the advantage of removing safety critical risks of this latter technology due to failures/ limitations of an extensive deployment of a V2V communication process between trains.

DCs shows to provide significant capacity improvements and overall cost reductions with respect to MB and VC with the potential of an easier regulation and safety approval process by the regulatory bodies.

It can be concluded that DC carries a great potential for rail transport and represents a much cheaper and faster alternative to the other solutions. Therefore, it is recommended to further investigate the overall benefits of this innovative train coupling technology.

5 References

[1] Theeg G., Vlasenko S., *Railway Signalling and Interlocking International Compendium*, Eurail Press, 2009.

[2] Aoun J., Quaglietta E., Goverde R.M.P., Scheidt M., Redfern B., Blumenfeld M., Jack, A., A hybrid Delphi-AHP multi-criteria analysis of Moving Block and Virtual Coupling railway signalling, *Transportation Research Part C: Emerging Technologies*, Vol. 129, 2021.

[3] MOVINGRAIL project, www.movingrail.eu, last accessed 20th July, 2021.

[4] Quaglietta E. Wang M., Goverde R. M. P., A multi-state train-following model for the analysis of virtual coupling railway operations, Journal of Rail Transport Planning and Management, Vol. 15, 2020.

[5] Shift2Rail Joint Undertaking of the European Commission, https://shift2rail.org/, last accessed 7th February 2022.