Potentials of the digital automatic coupling in European rail freight transport

R. Bulteel[a], M. Al-Mousa[a], B. Kordnejad[a] and B. Djordjevic[a,*]

[a] KTH Royal Institute of Technology, Brinellvägen 23, 100 44 Stockholm, Sweden
bulteel@kth.se, mohamam@kth.se, behzad.kordnejad@abe.kth.se, boband@kth.se
[*] Corresponding author

Extended abstract submitted for presentation at the Conference in Emerging Technologies in Transportation Systems (TRC-30)
September 02-03, 2024, Crete, Greece

April 29, 2024

Keywords: Digital Automatic Coupling, Marshalling yards, Emerging Technologies, Freight Trains, Capacity

1 INTRODUCTION

Rail freight transport is a potential player in the decarbonisation of freight transport. Further improving the role of rail freight in this regard is possible through the automation and digitalisation of rail freight transport to improve rail performance, multimodal services and end customer satisfaction. Various technologies are being considered and tested as part of the digitalisation of rail freight transport (RFF, 2020, CER, 2020). The introduction of digital automatic coupling (DAC) is recognised as a means of improving rail freight performance and competitiveness in the freight market (ERFA, 2022).

In rail freight transport, a distinction is traditionally made between three degrees of automation for couplings: manual, semi-automatic and fully automatic. In Europe, couplings are still predominantly coupled manually with screw couplings. This means that manual coupling involves entering the space between the buffers, which is a danger zone. Power and data cables are not included, and all media must also be connected manually. Therefore, this traditional way of coupling freight wagons is not efficient, physically demanding, time-consuming and labour-intensive. Semi-automatic couplers, which do not exist in rail freight transport in Europe, provide automatic coupling of the mechanical connection between the wagons but still have to be uncoupled manually. The waggons are also coupled manually. According to the Technical Innovation Circle for Rail Freight Transport (Hagenlocher *et al.*, 2020), the automatic coupling is categorised and defined in five automation levels (see Table 1). Type 4 and higher automatic couplings can be referred to as DACs, as only these types offer automatic connection of the power and data lines. A DAC Type 5 offers fully automatic coupling and uncoupling (Hagenlocher *et al.*, 2020, Cantone *et al.*, 2022).

The digital automatic coupler (DAC Type 4 and DAC Type 5) is an important building block for modern and digital European rail freight transport. Not only will it increase efficiency through automation processes, but it will also ensure a sufficient energy supply for telematics applications and secure data communication throughout the train. The introduction of DAC Type 4 will enable integrated power lines and data bus cables. DAC uses airlines, power lines and data cables to ensure simplified uncoupling, sufficient power supply and secure data lines, further automation and digitalisation of operational processes such as train integrity monitoring, automatic brake testing and wagon order recording, operational health and safety and increased productivity. In addition, electro-pneumatic brakes (simultaneous braking) can be used with DAC (Shift2Rail, 2021, Rail Cargo Group, 2021).

However, there is a major dilemma between the different stakeholders regarding the introduction of DAC in rail freight, the benefits, the specifications and the requirements for DAC in Europe. To solve this problem, the benefits of DAC introduction in rail freight should be quantified. In this study, the positive impact of DAC on train processing time and capacity within the Hallsberg marshalling yard has been analysed for the first time.

Table 1 – *Categorization of Automatic Coupling*

Automation level	AC Type 1	AC Type 2	DAC Type 3	DAC Type 4	DAC Type 5
Mechanical connection	✓	✓	✓	✓	✓
Main brake pipe		✓	✓	✓	✓
Power line			✓	✓	✓
Data connection				✓	✓
Automatic uncoupling					✓

As a part of the TRANS4M Rail project, comprehensive results of this study are useful both for science and for the rail freight transport industry. The results indicate the influence of DAC on marshalling yard processing activities and capabilities. In addition, the results of the study will be useful for decision-makers when making decisions on the use of DAC in Europe. As for the academic community, the initiative to assess the positive impact of DAC can be extended to other potential impacts.

2 METHOD

For analysing the influence of DAC on marshalling yard train processing time and yard capacity, AnyLogic software simulation tool has been used (Grigoryev, 2023) for modelling Hallsberg marshalling yard as presented in Figure 1.

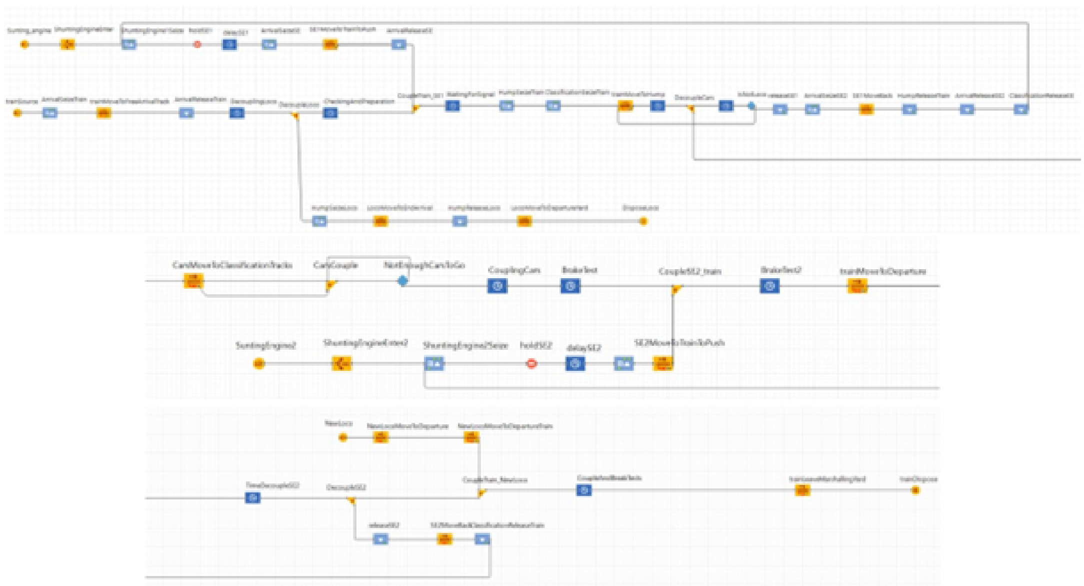

Figure 1 – *AnyLogic blocks in Hallsberg marshalling yard*

To analyse the influence of DAC, different scenarios have been developed (see Table 2). The first scenario is a basic scenario where all coupling and uncoupling activities are conducted manually. The second scenario is under the assumption that DAC Type 4 is implemented and times related to wagon coupling were reduced by 15%, while time for wagon partly automatic coupling is reduced by 10%. In the third scenario, the assumption of DAC Type 5 introduction is made, where all times related to coupling and uncoupling activities are reduced by 15%. For all these scenarios, it was assumed that the trains arriving at the yard with characteristics given in Table 2. Also, it was assumed that we have one shunting locomotive in the arriving yard and an additional one in the classification yard. Since DAC is an enabler of longer freight trains, all these scenarios were also tested for longer trains as given in Table 3.

Table 2 – *Times of train processing in base scenario and DAC scenarios*

Activity	Without DAC (base scenario)	DAC level 4 scenario	DAC level 5 scenario
Coupling time per wagon	0.5 minute	0.2 minutes	0.2 minutes
Uncoupling time per wagon	0.5 minute	0.3 minutes	0.2 minutes
Coupling line loco	0.2 minute	0.1 minutes	0.1 minutes
Uncoupling line loco	0.5 minute	0.3 minutes	0.2 minutes
Coupling shunting loco	0.1 minute	0.05 minutes	0.03 minutes
Uncoupling shunting loco	0.1 minute	0.8 minutes	0.5 minutes

Table 3 – *Assumptions for different train-length scenarios*

	Base scenario (without DAC)	Longer trains scenario
Wagon type	SS intermodal wagon	SS intermodal wagon
Wagon length	24.05 m (94.7 inch)	24.05 m (94.7 inch)
Number of wagons	26	30
Train length	640 m	740 m

3 RESULTS

Each of the scenarios was run in 10 hours of simulation analysis. In the first hour of the simulation, the arrival yard was filled with trains, assuming that trains arrive every 5 minutes. After filling the arrival yard, the trains started to be pushed over the hump. As can be seen in Figure 2, after 9 hours, 10 trains are prepared for departure with manual uncoupling. Figure 2 shows that the number of trains in the departure yard increases with increasing length. However, with the introduction of DAC type 4 and DAC type 5, the number of trains increased in all parts of the marshalling yard.

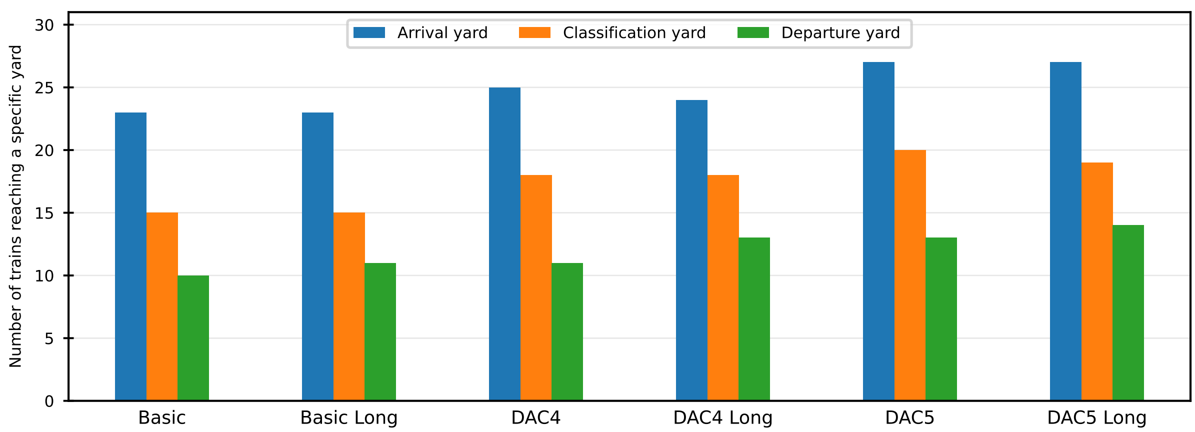

Figure 2 – *Yard capacities for different scenarios after 10 hours of analysis*

4 DISCUSSION

The results show that the capacity for train handling in the arrival, classification and departure yards has increased with the introduction of DAC Type 4. Compared to the base scenario, even more capacity will be possible with the introduction of DAC type 5. In the departure yard, however, one more train will be handled with DAC Type 4 compared to the base scenario, while three more trains will be handled with DAC Type 5. The greater length of the trains also increases the number of departing trains in the base scenario. Longer trains mean that more trains are produced in all three parts of the marshalling yards. This is because more wagons arrive so that trains can be formed more quickly. With longer trains, however, there is a problem related to the number of trains arriving at the marshalling yard, as longer trains require more time to uncouple and classify. The main reason for improving capacity from the base to DAC Type 4 and DAC Type 5, along with the introduction of longer trains in all parts of the marshalling yard, is the fact that uncoupling processes take less time.

The reduced train processing times that are introduced by DAC improve the capacity of the marshalling yard in terms of the output rate of trains that are transitioning from the departure yard into the mainline. This aspect creates a challenge for the mainline to accommodate more freight trains in a shorter time period and to allow for more interactions between passenger and freight trains in mixed-traffic lines. This possible increase in traffic heterogeneity may create larger delays for freight trains and compromise their service reliability (Dingler *et al.*, 2009, Sogin *et al.*, 2011). Since DAC enables the transfer of higher longitudinal forces as well as electro-pneumatic brakes, higher maximum speeds for freight trains with improved deceleration rates can be achieved, allowing for better harmonization with passenger trains in mixed-traffic operations. This trade-off between the increased number of freight trains transitioning from the yard into the mainline and the enablement of DAC for harmonized mixed-traffic operations will be of focus for future research direction within the TRANS4M Rail project.

References

Cantone, Luciano, Durand, Thierry, Ottati, Andrea, Russo, Giulia, & Tione, Roberto. 2022. The Digital Automatic Coupler (DAC): An Effective Way to Sustainably Increase the Efficiency of Freight Transport in Europe. *Sustainability*, **14**(23), 15671.

CER. 2020. *30 by 2030 – how rail freight achieves its goals*. Tech. rept. Community of European Railway and Infrastructure Companies, Brussels.

Dingler, Mark H., Lai, Yung-Cheng (Rex), & Barkan, Christopher P. L. 2009. Impact of Train Type Heterogeneity on Single-Track Railway Capacity. *Transportation Research Record: Journal of the Transportation Research Board*, **2117**(1), 41–49.

ERFA. 2022. *The European Rail Freight Market Competitive Analysis and Recommendations*. Tech. rept. European Rail Freight Association.

Grigoryev, Ilya. 2023. *AnyLogic in Three Days*.

Hagenlocher, Stefan, Wittenbrink, Paul, Leuchtmann, Carsten, Galonske, Boris, Kehrmann, Titus, Hecht, Markus, Leiste, Mirko, Discher, Saskia, König, Rainer, Pollehn, Tobias, Ruf, Moritz, Witte, Stefan, Gehrke, Sebastian, Hess, Roland, Röckemann, Kristian, & Steinmetz, Andreas. 2020. *Development of a concept for the EU-wide migration to a digital automatic coupling system (DAC) for rail freight transportation*. Tech. rept. Federal Ministry of Transport and Digital Infrastructure (BMVI), Karlsruhe.

Rail Cargo Group. 2021. *Part III: What's the difference between screw coupling and DAC4?*

RFF. 2020. *Green Paper – Rail Freight strategy to boost modal shift*. Tech. rept. Rail Freight Forward.

Shift2Rail. 2021. *Digital Automatic Coupling: Delivery Programme*.

Sogin, Samuel, Barkan, Christopher P.L., & Saat, Mohd Rapik. 2011. Simulating the effects of higher speed passenger trains in single track freight networks. *Pages 3679–3687 of: Proceedings of the 2011 Winter Simulation Conference (WSC)*. IEEE.