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Docking trains: A Comparison

P. J. Nordlander

Jo-Jo Tåg, Linköping
Sweden

Abstract

In this paper are descriptions of vertical, parallel and linear docking trains. Their advantages and consequences are given, and a simple comparison between them is in a table. A few words are also devoted to a comparison of traditional trains with docking trains. Passengers like to reach their goal in a short time. Trains might have a high top speed and we strive to get them even higher. However, what counts is a high average speed, for the traveller. If station distance is short, then the average speed becomes comparatively low. The conflict between many served stations, short travel time and high average speed can be solved with another approach than the traditional. The idea of docking between a train, that runs continuously, and shuttles/railcars that provide the transport between the train and the stations is since long well known. We can call them docking trains. They genially solve the conflict between short travel time and the number of stations served. All persons travel nonstop from start to goal and thus average speed is high. All trains serve all stations and we can have many stations. Linear docking using the Jo-Jo Concept seams to be preferable.

Keywords: vertical, docking, parallel, linear, Jo-Jo train, average speed

1 Introduction

Historically the railway has been streamlined. The narrow tracks have become replaced and a great number of the stations closed. Still though remains the problem to balance the number of served stations to the travel time between end stations. For traditional trains each stop at a station, for passenger exchange, results in a travel time increase with 7 – 13 minutes [1]. Passing urban areas the train has to lower its speed and "lose" time, more for the larger urban area and more "lost" time for a longer distance within the urban area. High speed trains "lose" more time as compared to low speed trains.

From the perspective of the traveller it is good to have

- many stations,
- frequent train departures and a
- short travel time

From train operator perspective mandatory is of course a nickel over at the end of the day. This is best achieved by

- many travellers and
- filled trains, which as a consequence, leads to
    - few stations,
    - not so frequent train departures and
    - long trains

Obviously there is a mismatch, which has to be met by a balance. Today we see more railcar trains of 3 - 4 "fixed" units. At need two such units can be hooked together. So called high speed trains can be 400 metres long, which generally is giving low running cost. Short travel time is achieved by exchange of travellers at only few stations and by increase of train top speed. High speed can be accommodated by a flat straight railroad. Active dampers and/or tilted wagon are other means to allow higher speed in curves. Another disadvantage of high speed, is the increased air resistance. At speed above 250 km/h the air movement also give rise to vibrations leading to extra demands on both track and vehicles. Docking trains of various kinds is an alternative method to solve the inherent conflict between travellers and train operators.

2 Docking trains

In principle, docking can be divided into three different categories:

2.1.Parallel docking
2.2.Vertical docking
2.3.Linear docking.

2.1 Parallel docking

Parallel docking [2, 3] which means that a railcar runs on a track parallel to the train and a cross-connection is opened between the railcar and the train, see Figure 1. Passengers or goods can be exchanged between the train and the railcar. When this is done, the cross-connection will be removed and the railcar will continue on its circular path and drive back to the station. . In other words, the railcar is not integrated into the train, but is stationed at a place and its "circular" line.

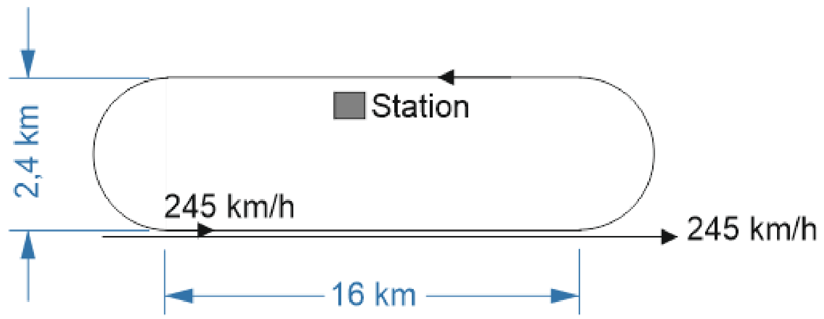

Figure 1: Illustration of railroad geometry close to a station for a parallel docking train. A station localised shuttle run on o closed track. At one long side it runs parallel with the main line where the train runs. Here persons and goods can be exchanged.

With a speed of 245 km/h and e.g. 0.5 minutes for docking and undocking and 3 minutes for changing passengers or goods, the train has time to travel 16.3 km during the exchange. With an acceptable lateral acceleration (1.5 m/s2), we can have a turning radius of 1.2 km even at 245 km/h. Accelerating from 0 to 245 km/h takes about 70 seconds, i.e. the distance of 4.7 km, with acceptable linear acceleration (1 m/s2) and acceleration change/jerk (0.3 m/s3). The shuttle's rails could be built with the geometry of a 400-metre running track. Its circumference would then be (16.3 * 2 + 3.14 * 2 * 1.2) about 40 km and take at least a little over 8 minutes to drive around. Of course half the speed of the train at the main track will give half numbers.

2.1.1 Advantages

The train on the main line can run continuously at high speed regardless of the number of stations. It uses traditional infrastructure with its tracks and switches. The main line can be located outside the station town. The frequency of services on the main line may be high. The same train can carry both goods and passengers. The train can be of a traditional kind, but rebuilt for sideways docking.

2.1.2 Consequences

The docking procedure is completely new. Severe demands on the parallel track's compliance with the main line along the entire docking section, 16 kilometres (assuming train speed being 245 km/h). The transport of goods requires technology to transfer the goods to/from the shuttle and to secure the goods. The train is divided into a section for goods and a passenger section with free passage between the wagons. Capacity changes are only possible in the traditional way, i.e. the length and content of the train are determined from the beginning. Freight wagons run empty until they are loaded. The minimum distance between stations will be about 20 kilometres. Regardless of which stations the journey takes place between, the journey will be about 20 kilometres longer and the travel time about 5 minutes longer than that of a linear docking train.

2.2 Vertical docking

Vertical docking [4, 5, 6] which means that a cabin on the roof of the train is used to transfer passengers from the station to the train and vice versa. For an illustration se Figure 2. At the station, above the height of the train, there is a cabin D for depart (see fig.), where passengers to depart are sitting.

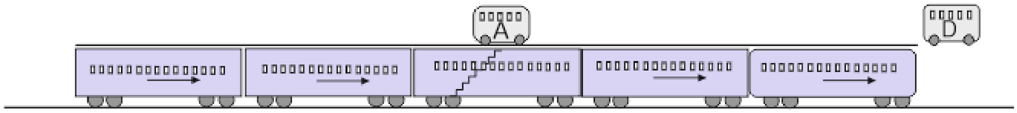

Figure 2: Vertical docking here illustrated at the station where the train passes without stop. The cabin D for departure is by the train hooked up and accelerated to train speed. Simultaneously the cabin A for arrive is Caught and braked by the station.

The train comes at a reasonable speed, enters under the cabin, which is hooked in and accelerated to the train's speed. At the same time, there is a corresponding cabin on the roof of the train that has passengers getting off at the station. This is hooked to the station and braked to a stop. The stopping distance is shorter than half the total length of the train.

2.2.1 Advantages

The train on the main line can run without stopping at the station, but must pass at a reduced speed. Traditional infrastructure with standard tracks and switches can be used.

2.2.2 Consequences

The docking procedure is completely new. The station built to fulfil this idea would have a complex construction. The train must be specially constructed with a track for cabins at its roof. The middle train wagon must have an opening and a staircase, or other solution, for passengers to enter or leave the cabin on its roof. The technology inherently has a high acceleration and braking of the cabins even if the train is to have a moderate speed when passing through the station. Capacity adjustment can be only in the traditional way. The length of the train is determined from the beginning. The principle does not work for the transport of goods. Adding more stations means adding more travel time for all.

2.3 Linear docking

Linear docking [7, 8, 9, 10] is docking where the railcar docked to the train becomes an integral part of the train. Docking to the train increases its length. Undocked railcars reduce the length of the train. The train runs continuously at high constant speed on the main line. Docking and undocking can take place at the front of the train (dedicated railcar), on its rear (all station railcar), or inside the train, see Figure 3.

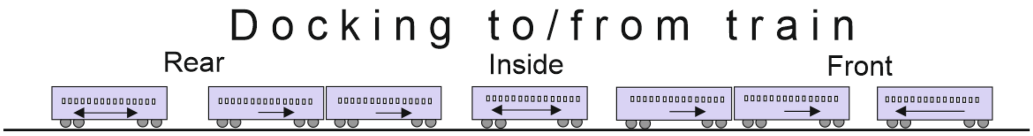

Figure 3: Illustration of Linear docking train. Railcar docking to the train does that at the rear of the train. At odd cases docking can take place inside the train. For dedicated railcars, for instance carrying goods, then docking is at the front.

A noticeable version of Linear docking trains follow the Jo-Jo Concept. Here the standard railway switch is replaced by a switch without moving parts (a contradiction in terms). Such a technology gives unexpected positive results. Here passengers are transferred between station and train using the last positioned railcar of the train. After one minute, depending on main train speed, the railcar from the station has docked to the train. Now passengers move forward in the train. Vice versa, passengers to arrive at their end station embark the last positioned railcar, which undockes the train. That railcar can adjust its speed to what is preferred by the local society. A further option in the Jo-Jo Concept is to dock railcars with goods at the front of the train. Thus achieving transport in a combined goods and person train. Railcars at front of the train are automatically ranged on the track as undocking can be done from within the train.

2.3.1 Advantages

The train on the main line can run continuously at constant high speed without stopping at stations. Adding more stations does not prolong travel time for the train. Train capacity can be gradually changed according to need during its travel. Station platforms can be very short, as compared to traditional platforms. The railroad is without moving parts. A train can at the same time transport persons as well as goods. All persons travel non-stop to their destiny. Dedicated railcars (for goods or persons) are automatically ranged on the track and go non-stop to their destiny. Linear docking can be implemented and used in combination and coexistence with traditional train operation.

2.3.2 Consequences

Docking of shuttles to/from trains at full speed is essentially unproven i.e. new technology. Linear docking needs stations to be at a siding. It can be run with traditional switches, but with a railway switch without moving parts its full potential comes alive. However, a switch without moving parts is again new technology. The automatic coupler at the end of the last railcar in the train will be more frequently used and a gangway there must be established/developed. The minimum amount of vehicles in a railway system is one railcar per station.

3. Summary

Here in Table 1 is an attempt to make a simple and short comparison between docking principles.

Docking type	Parallel	Vertical	Linear
Speed at pass of station	+ -	-	+
Relative docking simplicity	-	-	+
Standard railway switch	+	+	- +
Standard track	-	+	+
Standard station	+	-	+

Table 1: Parallel, Vertical and Linear docking principles are compared using some relevant characters for train operation.

At two locations in the table are also an opposite sign. They need explanation. Parallel docking gives the possibility of high speed station passage, but if so the passage becomes long and the technical complexity becomes overwhelming. Thus the minus sign. Linear docking can use a standard switch, but then the train speed cannot be constant. However, if a switch without moving parts are used, then linear docking reaches its full potential. Thus the plus sign.

4. Conclusion

In all, docking trains have the possibility to fulfil the travellers dream scenario without the need of high top speed. A lower but constant speed yields, thanks to linear docking trains, a higher average speed and a shorter transport time for both passengers and goods. Compared to traditional train the docking train saves energy and is more environment friendly.

Eventually this approach can be accepted by operators and track owners. Through automation the running cost can be reduced. With a railway switch without moving parts and 5G slice radio control [11] we should have the technology in place for linear docking train following the Jo-Jo Concept.

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