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The Potential for Regional Express Trains when Introducing High-speed Operation

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1. Abstract

When improving railway capacity by increasing the number of tracks, it is often discussed if the new tracks should be built along the existing railway line or a new railway line should be built. This paper examines the two possibilities regarding to a capacity perspective, increased speed, and possible changes in the route network.

More trains can be operated with a homogeneous operation compared to a heterogeneous operation. However, operation with fast Intercity Express and Intercity trains, and slower regional and freight trains leads to a heterogeneous operation if the different train classes are not operated on separate tracks – alternatively the fastest trains have to be slowed down.

Different railway lines for fast and slower train operation results in an approximately homogeneous operation and thus more capacity. The extra capacity can be used to operate more (regional) trains on the existing railway line, better service for long distance commuters by having skip stop services, and/or regular interval timetables.

Keywords: Railway, High-speed, Regional Express Trains, Railway Operation

2. Introduction

When railway capacity has to be improved by increasing the number of tracks of a railway line or building a new railway line it is often discussed which solution is the best – this is also the case for improving the capacity for the Danish railway line between Copenhagen and Ringsted. Often the urban communities take part in the discussion and put forward their local arguments for their local community. These local arguments are often affected by e.g. the fear for reduced railway services for the community. Often these local arguments are more based on fear than facts about how the railway can and will be operated when the construction work has been carried out. This paper describes the how the different alternatives for more tracks affect the possible future railway operation.

Section 2 gives a brief introduction to railway capacity. High capacity consumption often reduces the speed of the (fastest) trains. Therefore, section 3 describes the possibilities for increasing the speed of the operation for both the existing and improved infrastructure. This is, in section 4, followed by a description of how a better regional service can be achieved if new (high-speed) lines are introduced. Finally, section 5 draws up the conclusions.

3. Railway capacity

Railway capacity is a complex, loosely defined term that has numerous meanings (Krueger 1999), and the definitions differ by country (Rothengatter 1996). In 2004 the International Union of Railways (UIC) (re)defined railway capacity as (UIC 2004): *Capacity as such does not exist. Railway infrastructure capacity depends on the way it is utilized.*

The reason why railway capacity is difficult to define—and measure—is that railway capacity consists of several parameters that can be measured, cf. figure 1. The parameters seen in figure 1 (number of trains, stability, heterogeneity and average speed) are dependent on each other. This further complicates the definition and measuring of railway capacity.

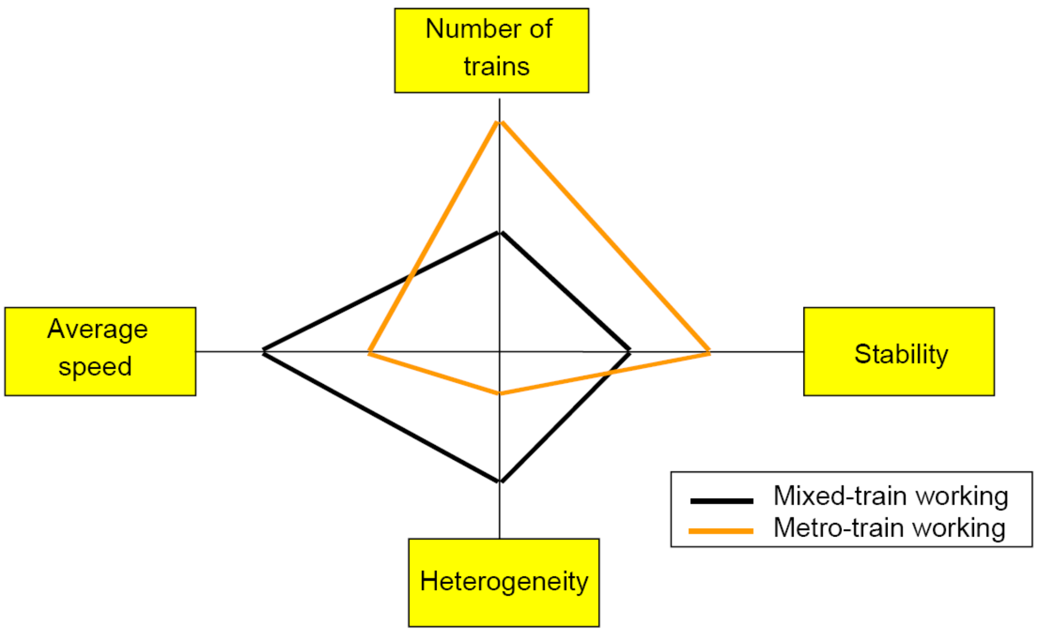

Figure 1: The balance of railway capacity (UIC 2004).

Figure 1 shows that capacity is a balanced mix of the number of trains, the stability of the timetable, the level of average speed achieved and the heterogeneity of the operation. It may, for instance, be possible to satisfy a market demand for a high average speed by having high heterogeneity—a mix of fast Intercity Express, Intercity and slower Regional trains serving all stations. However, the consequence of having high average speed and high heterogeneity is that it is not possible to operate as many trains with a high stability (punctuality) as when all trains are operated with the same speed and stop pattern. If there is market demand for operating more trains, it may be necessary to have a less mixed operation and thereby have a lower average speed (assuming that the fast trains are adapted to the slower trains) as it is known from, for example, metro systems.

Building more tracks on an existing railway line or as a completely new railway line may reduce the heterogeneity and allow for more trains, better stability/punctuality, and higher average speeds. Although both solutions increase the capacity the two solutions still have different effect on the capacity – this is described in the following sections.

4. Possibilities for higher speed

Different possibilities for increasing the speed on the railway network exist. These possibilities can be everything from cheap and simple changes in the timetable via reduction of the dwell time and times for acceleration and deceleration, and minor upgrades of the infrastructure to more expensive solutions where new tracks are built either in on the existing railway line or as completely new railway lines. This section describes the different possibilities for increasing the speed.

4.1 Heterogeneity and scheduled waiting time

A timetable is heterogeneous (or not homogeneous[1]) when a train catches up with another train. As a result of a heterogeneous timetable it is not possible to operate as many trains per time interval as if the timetable were homogeneous—trains running at the same speed and having the same stopping pattern, cf. figure 2.

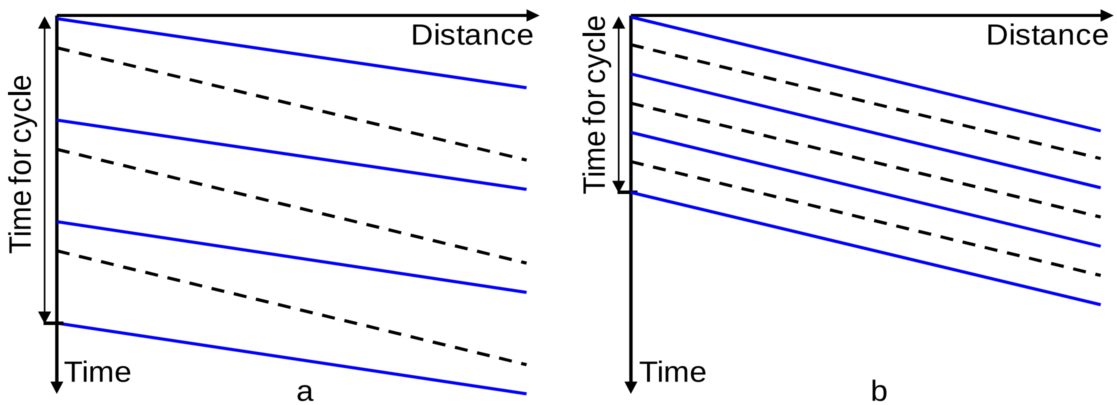

Figure 2: Heterogeneous (a) and homogeneous (b) timetable (Landex 2008).

When the railway operation results in high capacity consumption, the speed of fast trains (e.g., intercity) must adapt to that of the slower trains (e.g. local), cf. figure 3 (left)[2]. This will increase the running time (scheduled waiting time) for these trains that could run at higher speeds if they were not hindered by other trains (Salling, Landex 2006). For single track lines it is difficult for trains in different directions to pass each other, which can result in additional dwelling time at the crossing stations (scheduled waiting time), cf. figure 3 (right).

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[1] A timetable is homogeneous when there is no variation in the speed, the stop pattern, and the headway times.
[2] It is also possible to adapt the slower (regional) trains to the faster (intercity) trains by omitting stops and/or in the longer term changing the existing trains for trains with better acceleration, for example.

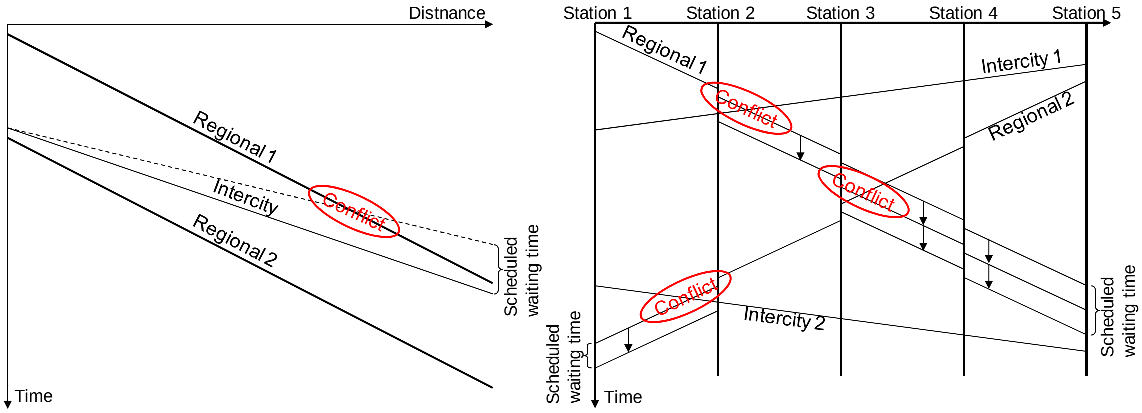

Figure 3: Extended running time (scheduled waiting time) for trains due to other trains on the railway line (double track on the right and single track on the left). (Landex 2008) - partly based on (Salling, Landex 2006).

Scheduled waiting time for trains can be added to the dwell time at stations and to the running time (Pachl 2008). In Norway, travel time is extended by scheduled waiting time at the railway lines in the suburbs (Skartsæterhagen 1993). In the Netherlands, the stations at The Hauge (The Hauge Holland Spoor and The Hauge Central Station) are examples of stations where the dwell time has been extended due to conflicts with other trains (Nie, Hansen 2005). It can therefore be argued whether there is scheduled waiting time at the stations at The Hauge.

If the scheduled waiting time is high[3], it might be decided to use this time, or part of it, to include extra stops for the fastest train services, cf. figure 4. In this way the planned timetable has trains with more stops than desired in the wanted timetable.

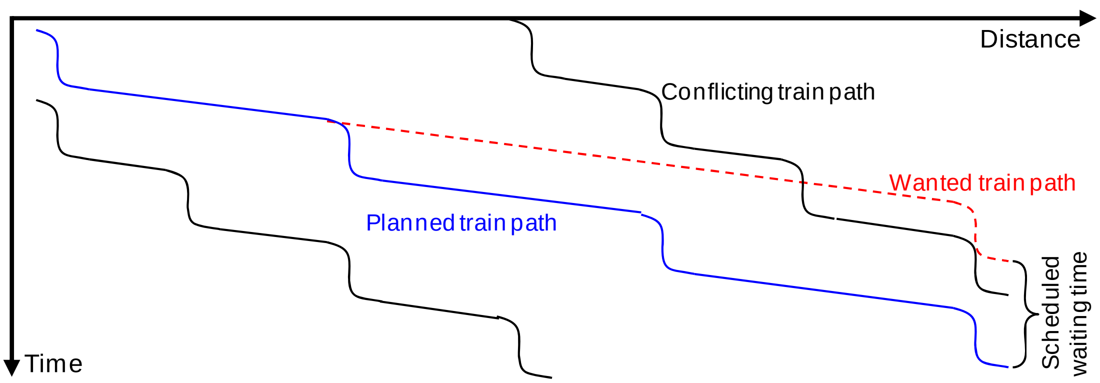

Figure 4: Scheduled waiting time due to extra stops (Landex, Nielsen 2007a).

To speed up the fastest trains, the scheduled waiting time can be reduced by changing the order of the trains, adding (more) overtakings, speeding up the slowest trains (cf. section 4.2), or increasing the capacity.

[3] *(Salling, Landex & Barfod) showed that the scheduled waiting time is approximately 20% of the travel time for the railway line between Copenhagen and Ringsted in Denmark.*

4.2 Shorter dwell times and better acceleration

A way to reduce the travel times is to reduce the dwell time at the stations. Some train types (typically long distance trains) have longer dwell times at the stations than other train types. An example of the difference in dwell times can be seen from table 1 where the suburban train uses only half a minute longer travel time than the regional train despite it has three more stops.

Table 1: Timetable for suburban train (train route E) and regional train (the coast line) between Hellerup and København H (DSB 2009)(DSB S-tog 2009).

	Suburban train	Regional train
Hellerup	08½	09
Svanemøllen	11½	|
Nordhavn	13½	|
Østerport	15½	15
Nørreport	17½	18
Vesterport	19½	|
København H (arrival)	21	21
Total time	**12½ minutes**	**12 minutes**

One of the reasons why the regional train has longer dwell times than the suburban train is the difference in the departure procedure. In the S-train it is the engine driver who closes the doors with a push of a button while it for the regional train is the train guard who close the doors, controls that the doors are closed, closes his own door, and tells the engine driver that the train is ready for departure. The more complex departure procedure for the regional train takes about 15 seconds longer than for the S-train at each station.

As seen on figure 5, the procedure for closing the doors is only one part of the total dwell time. According to (Kirchoff 2003a & b) the dwell time among others also depends on:

- The number of passengers and luggage
- The gap between the train and the platform
- The difference between the platform height and height of the train floor
- The number of doors
- The width of the doors
- Potential bottlenecks in (and outside the train)
- The location of platform exits/entrances[4] (affects the number of passengers)

[4] *The number of exits/entrances also affect the size of the catchment area (Landex et al 2006a), and thereby the number of passengers.*

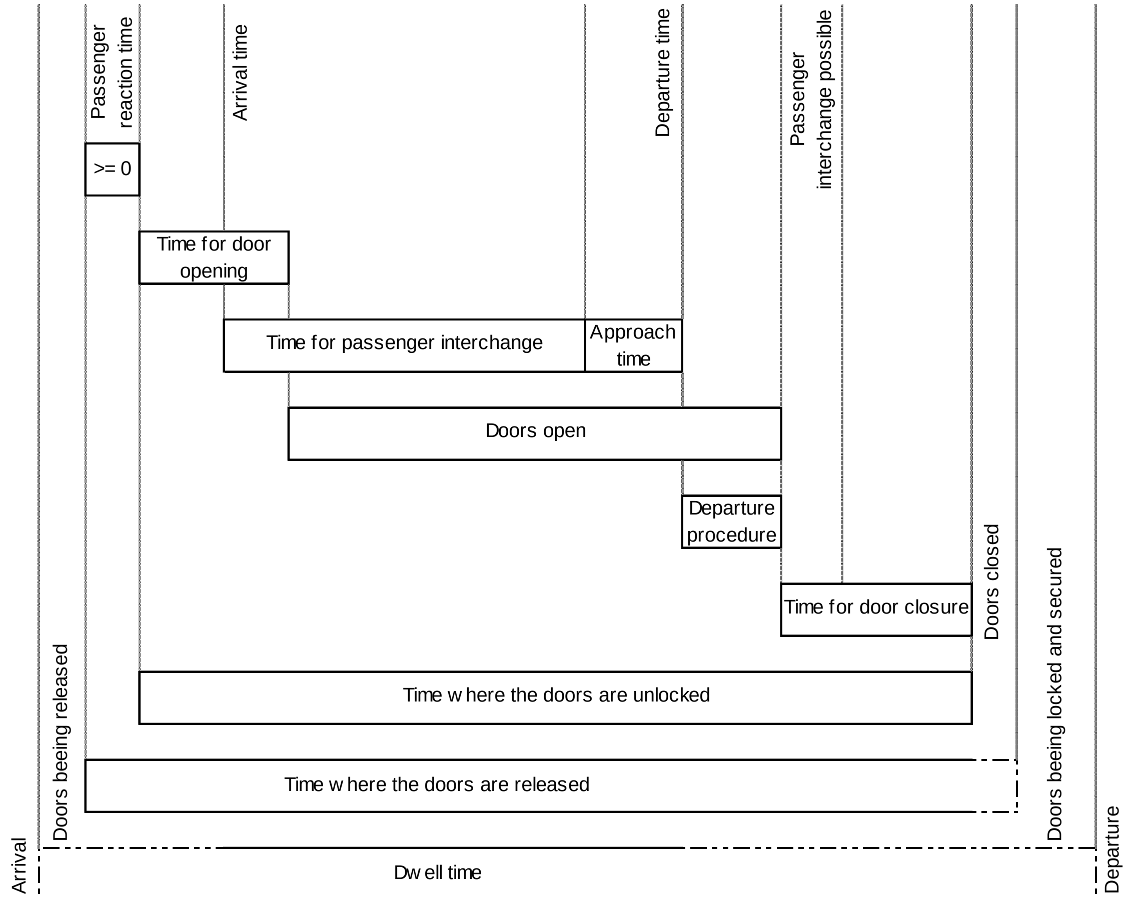

Figure 5: The different time elements in dwell time. Based on (Kirchoff 2003 a & b).

Besides the actual dwell time, also a faster acceleration and deceleration can reduce the time loss of a stop and thereby improve the travel time. All improvements reducing the time loss of stops benefits the trains with many stops the most why the speed of the fastest trains is not improved directly. However, the speed of the fastest trains is improved indirectly as it takes longer time for the fastest trains to catch up with the slower trains why the scheduled waiting time—and thereby the travel time—may be reduced.

4.3 Upgrade of existing railway lines

Existing railway lines can be upgraded for higher speed by re-location of the line having larger radiuses within curves and changing the signalling system. Often the focus is on achieving as high speed as possible on the railway line although the trains cannot operate with maximum speed for longer distances. Therefore, the effort should be put into removing—or reducing—the sections of the railway lines where the speed is reduced. In fact, the maximum line speed has been lowered from 180 to 160 km/h between Fredericia and Århus without increasing the travel time as other sections with speed restrictions have been mended[5].

[5] *As a result of the smoothing of the speed profile the trains use less energy (Rail Net Denmark 2008).*

It may not always be enough to increase the speed of the railway line. If a mix of fast and slow trains are operating the railway line it may also be necessary to increase the line and/or station capacity to avoid scheduled waiting time (cf. section 4.1). The increased capacity can be achieved e.g. by changing the timetables and upgrading the signalling system but it may be necessary to build more tracks at stations and/or at open lines.

4.4 New (high-speed) railway lines

Existing (old) railway lines are often curved since these railway lines have not been build for high-speed operation[6] but to serve many smaller communities and areas with manufacture. The curved railway lines limit the maximum speed but it may not be possible to re-locate the existing line without worsening the local services. However, building new railway lines makes it possible to operate the faster train services due to higher speeds and more direct routes.

The new railway line most often reduces the capacity consumption on the existing railway line(s). The regained capacity can be used to develop the services on the existing railway line(s) with e.g. introduction of regular interval timetables and/or higher frequencies. Also in the construction phase new railway lines may have advantages compared to upgrading existing lines as the construction of the new line most likely will less impact on the operation than the upgrade work[7].

The current Danish ATC system can look only 2-3 block sections ahead. This makes it necessary to adapt the lengths of the block sections to the high-speed operation[8] which may result in longer headway distances for the slower trains. Therefore, and due to more homogeneous operation, new railway lines dedicated for high-speed operation often more than doubles the overall capacity of the corridor.

Although, freight and passenger trains may have very different driving properties the operation on the existing railway line may become more or less homogeneous when the high-speed trains are operated on a dedicated railway line. This is because the slower freight trains catch up with the passenger trains at the stations, cf. figure 6.

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[6] At the time the railway lines have been build the maximum speed may have been much lower than today.
[7] In the comparison of benefits the construction cost should also be taken into account. The construction cost of a completely new railway line may be more expensive than upgrading the existing railway line but the opposite may be the case too – e.g. if more tracks have to be build along the existing railway line in build up areas.
[8] See (Landex et al 2006b) for information about calculation of length of block sections and maximum allowed speed.

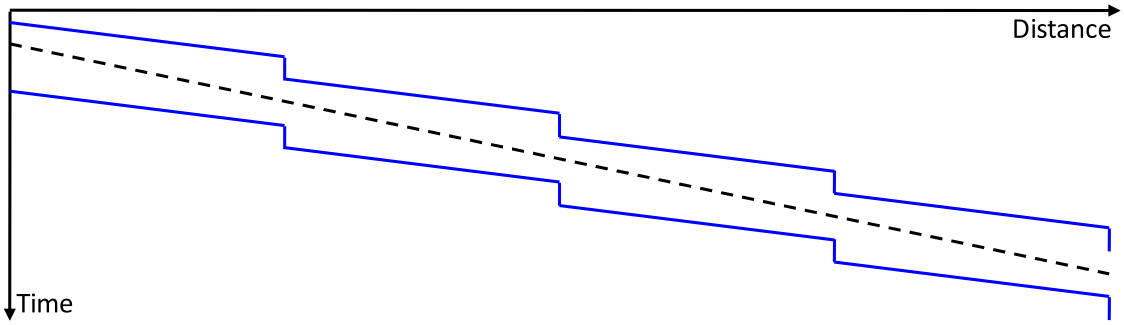

Figure 6: Timetable with regional (blue line) and freight (broken line) operation that is nearly homogeneous.

5. High-speed trains and regional express trains

Building tracks for high-speed operation can benefit the regional train operation too. This is (as mentioned in section 4.4) due to reduced capacity consumption on the railway line and a more homogeneous operation. However, the regional trains may also use (a part of) the high-speed railway line and thereby offer a fast skip-stop service for long distance commuters. An example could be having a regional service between a large city (A) and provincial town (B), cf. figure 7. If a high-speed railway line is build (with a connection between the two lines at (C)), it would be possible to offer a faster service for the long distance commuters for the urban communities between B and C using the high-speed line between A and C. The benefits for the long distance commuters are achieved without having higher capacity consumption on the existing regional railway line.

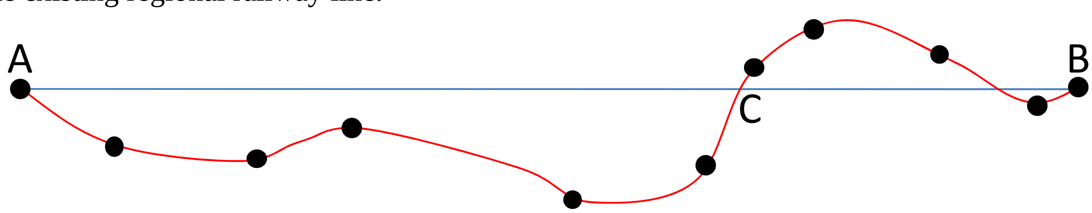

Figure 7: Regional railway line (red) and new high-speed railway line (blue).

Although the example above is imaginary, it is of relevance in Denmark. When a new railway line is build from Copenhagen via Køge to Ringsted[9]. In this case commuters from e.g. Vordingborg and Nykøbing Falster can have a faster regional service by using the new railway line from Ringsted via Køge to Copenhagen – potentially with stop at Køge, cf. figure 8. In the future, the long distance commuters may save even more time if the railway line between Køge and Næstved (named Lille Syd) is upgraded for higher speed and double track – potentially with a stop in Haslev, cf. figure 8. In this way faster regional services and potential travel routes can be offered.

[9] *It is discussed to build an extra (fifth) track between Høje Taastrup and the technical station Hvidovre Fjern too. At the moment the majority of the politicians support the new railway line via Køge. Therefore, and because an extra track will not achieve the same benefits, only the new railway line is described.*

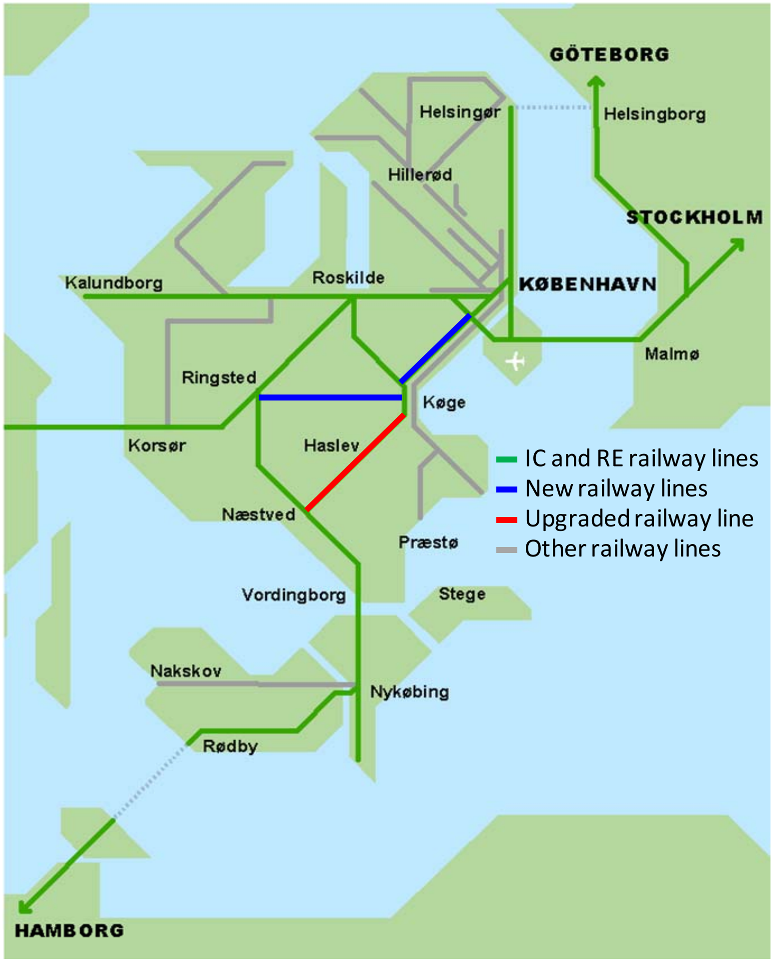

Figure 8: The railway network of Zealand.

Besides allowing a shorter travel time for commuters from the southern part of Zealand and Lolland/Falster, the new railway line can also benefit the travellers on the existing railway line. With less through traffic, and thereby a more homogeneous timetable, there is a potential for introducing a regular interval timetable[10] for regional trains between Copenhagen and Roskilde with a higher frequency than today.

Parallel railway lines (as in the case with a new railway line between Copenhagen and Ringsted) and railway lines with 4 tracks have the advantage that the fastest trains can overtake slower trains[11]. This advantage cannot necessarily be observed in the area of the railway line(s) but other places in the railway network. A new railway line between Copenhagen and Ringsted may for instance have benefits in Jutland as the fastest Intercity Express trains (if they overtake between Copenhagen and Ringsted) can run longer time

[10] *A timetable where all trains depart (and arrive) on the same minute(s) each hour with a fixed frequency. See (Liebchen 2006) for classification of timetables.*
[11] *The required length for overtaking depends on the difference in average speed and the headway time/distance on the adjacent line sections.*

before catching up with the slower IC-trains. This can result in faster Intercity Express connections and perhaps even higher frequency of the trains.

Many of the benefits of a new railway line between Copenhagen and Ringsted can also be achieved by building two new tracks on the existing railway line (instead of only one new track). These new tracks have to be built for a distance long enough to allow overtakings – and (in general) the longer line section with four tracks the more similar to a new railway line. Four tracks result in better *line capacity* than two separate railway lines as a more homogeneous operation can be achieved. However, the *station capacity* will be limiting if not the stations are extended proportionally[12].

6. Conclusion

To offer a better and faster service on railway lines with high capacity consumption it is necessary to build more tracks either in connection to the existing railway line or as a new railway line. Existing railway lines can only be upgraded for higher speed to a certain point while new railway lines can be designed for higher speeds. If high-speed operation is wanted (in the longer term), it is therefore needed to build (partly) new railway lines.

Generally, it is the fastest trains consuming the most capacity as they require longer block sections. Although freight trains and regional/local trains have very different driving properties these trains may result in an approximately homogeny operation as the freight train may catch up with the regional trains when they stop at passenger stations. Dedicated tracks for the fastest operation will, therefore, result in a more homogeneous operation.

More tracks dedicated to fast or slower operation result in more degrees of freedom when planning future operation. This is because regional express trains can use the railway line for some—or the entire—route. Furthermore, trains can overtake each other and thereby sort out capacity problems elsewhere in the network as the trains no longer catch up with each other.

If it is chosen to build a new railway line it may be possible to provide shorter travel times due to higher permitted speeds and a more direct route. In addition, the new railway lines may offer new (and more direct) travel routes for passengers.

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[12] Station capacity is generally more difficult and more expensive to expand than line capacity as the stations most often are located in build up areas and the station requires more area due to passenger facilities such as platforms.

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