EFFECT OF AN INTEGRATED CLOCKFACE TIMETABLE (DEUTSCHLAND-TAKT) ON THE RAIL PASSENGER DEMAND IN GERMANY

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1. SUMMARY

A nationwide integrated clockface timetable for Germany, known as "Deutschland-Takt", has been discussed for a while; and a study on behalf of the federal government is ongoing. The analysis of three scenarios shows a benefit for medium cities, profiting from shorter connections in neighbouring node stations to long-distance trains in all directions. The analysis of a proposal by Breuer and Uekermann for a specific clockface timetable also demonstrates the benefit of shortened travel times between the nodes, especially for the metropolitan cities, which are connected to many long-distance routes directly. Finally, we argue that connections should not be created at the expense of total travel time on the route.

2. INTRODUCTION

The concept of an integrated clockface timetables (ICT) with separated transport modes and equidistant junctions was first described in August Scherls book "Ein neues Schnellbahnsystem" in 1909 (Scherl 1909). The concept was also considered by John Frederick Pownall in the 1940s in England. He developed an ICT for Southern England and proposed infrastructural improvements to ensure that the different trains meet each other in the junction stations (Minder 2009). In the 1970s, the Netherlands introduced a clockface timetable called "Spoorslag 70", for which stations were reconstructed and the speed limit was partially raised to 140 km/h (Gardenier 2014). In Switzerland there have been considerations since the 1970s to design an ICT. This resulted in the decision to realise the "Bahn 2000" concept (Hürlimann 2006).

The success of the Swiss system led to a stronger endeavour to initiate a German-wide ICT. The initiative "Deutschland-Takt" was founded in 2008 (www.deutschland-takt.de) and the federal government tendered a feasibility study which was published in August 2015 (BMVI 2015). The idea is to pick up the "Bahn 2000" concept and to adapt infrastructure development to the needs of an ICT and not to build new infrastructure only to increase speed or create more capacity. This enables short interchange times at all stations and shorter travel times for relations with train changes. In the discussion, this is perceived as a better alternative to building high-speed lines, where travel time savings may be lost while waiting for a connecting train.

Within the project "Next Generation Train" (NGT) of the German Aerospace Center (DLR), the possible travel demand for a European-wide high-speed network with a maximum speed of 400 km/h was determined. The basis is a traffic model calibrated with passenger data from 2005 (Eurostat 2005). Apart from the effect of a future NGT network, several other questions can be answered using this model. One is the calculation of an accessibility indicator for cities using the average speed to related cities by rail. Furthermore, it is possible to calculate the impact of different train route scenarios combined with corresponding interchange times. Hence, by reducing interchange times, we can determine the effect of a German ICT. Some aggregated results of this analysis were already presented in a publication about the European NGT network (Schumann 2013) and will be described more detailed in this paper.

In this paper, the term "long-distance traffic" is used for trips with an linear distance of more than 50 kilometres independently of the type of train used. This is important because the statistics in Germany only involve ICE, IC and EC trains, although regional trains often carry passengers for longer distances. In fact, many cities are only connected by regional trains, and the travel chain in the model therefore always includes the complete relation regardless of the train type. Consequently, the passenger numbers differ from the official statistics (ViZ 2014).

3. ACCESSIBILITY OF CITIES REGARDING LONG-DISTANCE TRAFFIC

The regional accessibility of long-distance rail traffic is quantified using the indicator "accessibility of cities".

Bunge analyses in (Bunge 2011) 71 cities in Germany using all timetabled connections between each other in the year 2010. Using this data, an attraction index is calculated which takes into account the total travel time, the travel time in relation to the travel time by car, the number of changes, the number of daily connections, and the percentage of ICE/IC/EC trains taking part in a connection.. Obviously, cities connected to the core high-speed network of Deutsche Bahn generate better results than peripheral cities. In particular, Berlin, Hamburg, Munich, Cologne and Frankfurt achieve the highest values, whereas the cities of Siegen, Bayreuth, Plauen, Chemnitz and Görlitz attain the lowest values.

An analysis of Technical University Dresden (Evangelinos 2011) provides a more economic view on the accessibility. The GDP of every city plays a big role in the calculation algorithm as well as the detour factor and the position in a 4 hour radius to other cities. 80 German cities were included in the study, of which again the cities lying inside the core network gain the best results. These are Frankfurt, Hannover, Cologne and Mannheim. Siegen and Chemnitz again achieve the lowest values, but bigger cities like Dresden, Rostock, Trier and Saarbrücken also perform relatively poorly.

Using the calculated travel time from the source to the target, it is possible to calculate an accessibility indicator for the NGT European model. This value is a speed in km/h computed by dividing the linear distance by the total travel time including additional access and egress times for each station, averaged over all relations originating and ending in the considered station Since the computed value is an average value for each traveller, heavily used relations influence the indicator more than rarely used ones.

This indicator doesn't take into account the quality of service offered by rail. A low rail usage can also be the result of excellent alternative traffic modes, high prices, low service level, or lack of acceptance. However, these factors enter the model indirectly by calibrating the model using Eurostat data. The calibration factors are constant for all scenarios, so that only the travel time changes the results for different scenarios.

300 cities are included in the calculation for which the timetable of 2013 with its interchange times was used. Only connections that are offered at an interval of two hours or less are considered. When computing the travel time, the fastest connection is usually preferred, but if a connection is slightly slower while reducing the number of interchanges, the latter is preferred. The access and egress times depend on the size of the city, i.e. the bigger the city, the higher the access time. For instance, Berlin has an access time of 30 minutes. Other accessibility models include more indicators, but make the results less clear.

The results: Berlin has one of the highest values with 81 km/h; only Freiburg, Offenburg and some cities in the vicinity of Berlin achieve higher values. Other cities with high values are Hamburg, Hannover, Cologne, Mannheim and Frankfurt. It can be observed that the location near to a high-speed line and the corridor Hamburg – Frankfurt – Basel is advantageous. In the upper middle range lie cities like Leipzig, Nuremberg and Munich. The cities with the worst results are Trier, Siegen, Wetzlar, Plauen, Hof and Konstanz.

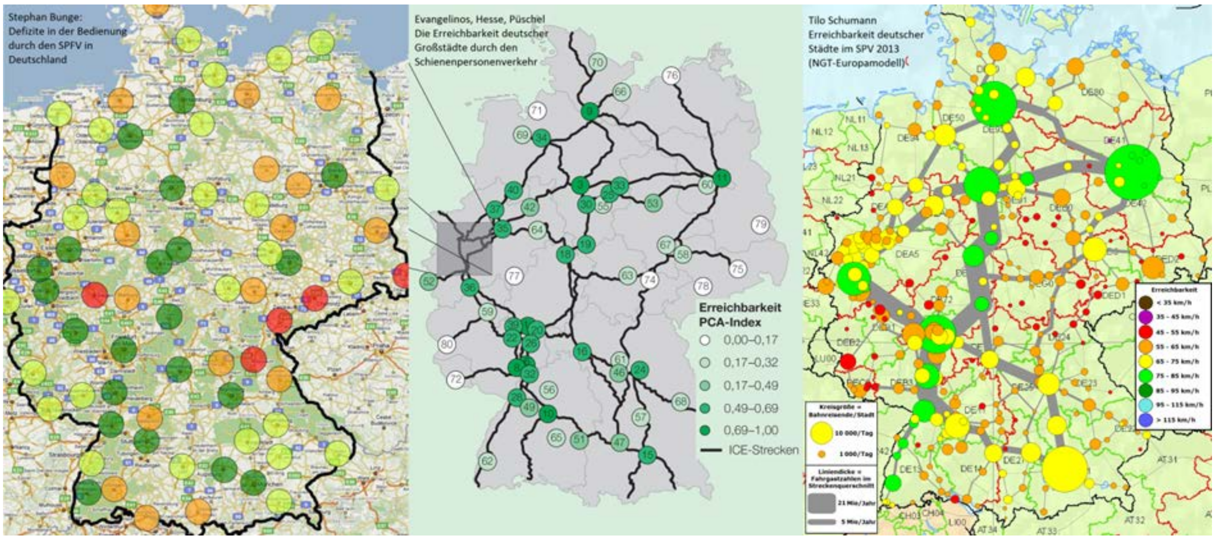

Figure 1: Comparison of three studies of the railway accessibility of German cities

Figure 1 shows the results of the three studies on a map. The colour green corresponds to a good accessibility, and the colour red to a bad one. However, the study in the middle uses white for a bad result. You can observe similarities: Most metropolitan regions like Berlin, Hamburg and Frankfurt can be reached easily by rail. The NGT model and Bunge also show good accessibility along the Rhine corridor and along the north-south-route Hamburg-Frankfurt, while the study of Evangelinos has worse results for Cologne and the Upper Rhine area. There are also disparities in the evaluation of Leipzig and Dresden, for which the other studies generate much better results. There are also similarities for the bottom-of-the-table cities in South West Saxony and some Western cities (Trier, Siegen).

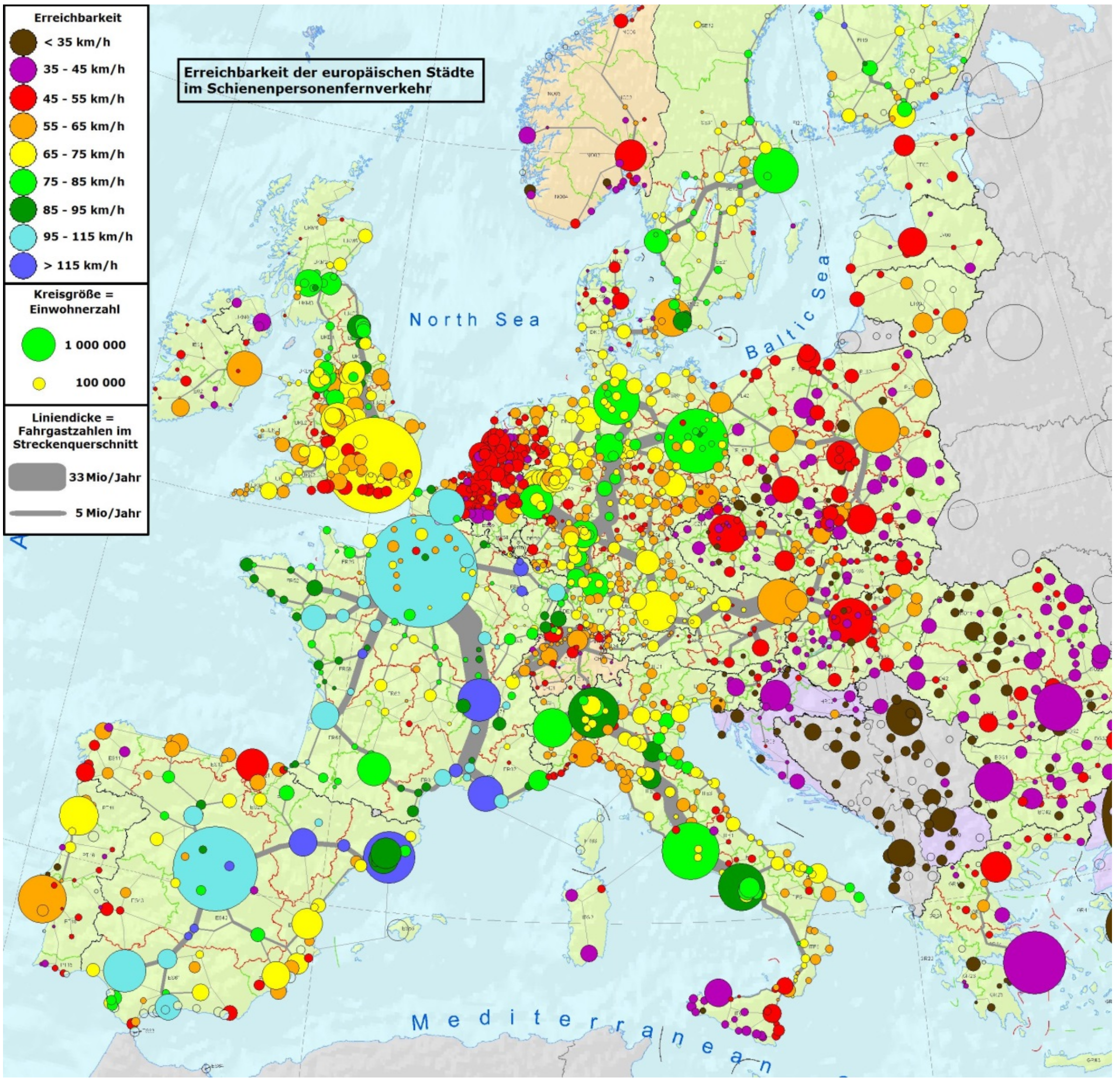

Figure 2: Accessibility of European cities by national rail traffic in 2010 – Countries with extended high-speed networks (Spain and France) and higher distances achieve faster accessibilities, small countries have lower accessibility speeds, also the low quality in Eastern Europe and former Yugoslavia is visible; the circle size represents the population

The NGT model covers almost all of Europe. Therefore it is possible to calculate the accessibility of all European cities in 2010 (see Figure 2). The calculation method is the same as for Germany, so only long-distance passengers are taken into account and only national travel relations. This is important to understand the low values in smaller countries.

Spanish and French cities achieve the top position in Europe. This could be expected, since AVE and TGV have the fastest travel speed of all high-speed systems in Europe. For instance, Barcelona has an accessibility value of 111 km/h, Zaragoza 110 km/h, and Madrid 101 km/h. In France the top cities are Metz (123 km/h), Nancy and Lyon (both 118 km/h) and Marseille (113 km/h), while Paris has achieves a value of 105 km/h. The high accessibility values are depicted in blue with green coming next. Sweden and Finland have higher values due to the flat topography with straight rail lines, whereas the speed in mountainous Norway is much lower.

On the other hand, many cities in East-Central Europe and Southeast Europe achieve a very low accessibility by rail, for which the colours magenta and brown have been introduced, coming after red. Especially in the former Yugoslavia, the speed level is very low. This is not only because of a bad service level, but also difficult topography and a low-dense rail network, which has been reduced since the collapse of Yugoslavia.

The accessibility values in the Benelux states and Switzerland are rather low. This is due to the small country size and the absence of fast long-distance relations. Great Britain is divided into two parts: South of London the level is low (because of the low average distances to London), but towards Scotland the level rises. In Spain, the region around Valencia and the Northwest were not connected to the high-speed network in 2010. Italy has a fast north-south line, which connects most of the cities except the regions of Liguria and Sicily. The latter has lower values because of the detour through Calabria and the ferry section to Messina.

4. INTERCHANGE SITUATION IN GERMANY

The assignment of traffic demand allows an analysis of the interchange situation in German railway stations. As mentioned before, the assignment prefers the fastest connection, except if there is a slightly slower connection with a smaller number of interchanges. In particular, such a connection is preferred if the additional travel time does not exceed 10 minutes. Due to this method, it is likely that the number of interchanges is higher than in reality, but this effect is partly compensated because a direct connection in a 2-hour-interval is preferred over a possible interchange connection one hour later, which can be found very often in the German timetable. The access and egress traffic modes are not included in the number of interchanges, so that interchanges within a suburban rail or metro system, which may be used to reach the station, are not taken into account.

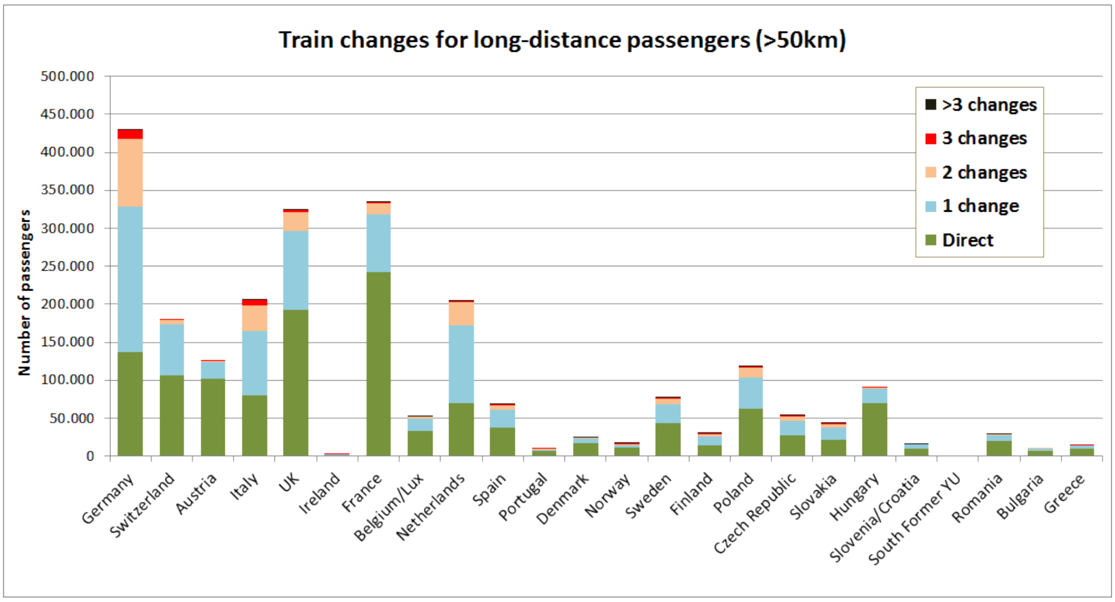

Figure 3: Number of train changes for long-distance passengers per day within each European country

Figure 3 shows the number of necessary train changes for long-distance passengers within each European country. In Germany, only a minority of 35% of the passengers travel to its destination directly; 41% have to change one time, 20% two times and 4% more often. In absolute terms, this is the highest number of all countries. In most other states, the share of direct connections is higher. Even in Switzerland, that is famous for its working ICT, more than half of the passengers travel without interchange. A very high number of direct connections can be found in France, Austria and Denmark, where there are strong travel demands from and to the capital city and more than three quarters of the passengers gets directly to their destinations.

The number of changing passengers and the average interchange time per passenger is shown in Figure 4. Most changes occur in Frankfurt, Cologne, Hannover, Hamburg, Mannheim, Stuttgart, Nuremberg, Berlin and Würzburg. Less passengers change in Munich because it is situated in the fringe of Germany and international connections are not included in this analysis. The average interchange time varies in the mentioned stations between 11 and 18 minutes.

A station with a much higher value of 25 minutes is Offenburg because the connection between the ICE from Cologne and the regional train to Konstanz takes 30 minutes. The two trains have a shorter connection time in Karlsruhe, but the ICE saves time between Karlsruhe and Offenburg, which could be used for a shorter travel time. This example demonstrates one option for improvements by timetable changes.

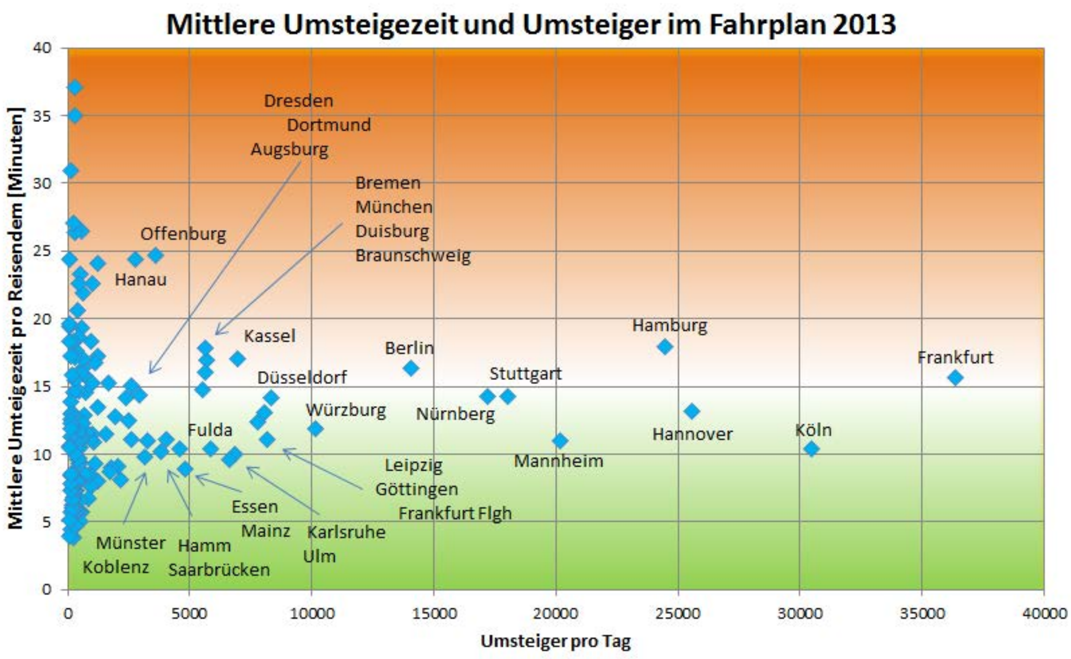

Figure 4: Average interchange time per passenger and number of changing passengers for the German rail network – important node stations have change times of 10 – 20 minutes

In summary, the important junction stations have an average change time of 10 – 20 minutes, which is less than half of the standard interval of one hour. Therefore, we can observe that the German timetable already consists of a lot of short connections. The most important change relations with more than 1000 passengers a day are the connection in Cologne between the IC from Hamburg and the ICE to Frankfurt and in Hannover between the ICE from Cologne and the IC to Leipzig and vice versa.

5. EFFECT OF AN ICT IN GERMANY (DEUTSCHLAND-TAKT)

To calculate the effect of a nation-wide integrated clockface timetable in Germany, a detailed timetable concept is necessary. With such a timetable, it is possible to determine the requirements to the infrastructure such as edge times as well as station- and node capacities. An enhancement of the infrastructure is necessary if connections are not only created by lengthening travel times and wasting time inside stations. Unfortunately, edge times and station locations are frequently not in favour of an ICT in Germany, for example the travel time for the future high-speed line from Erfurt to Leipzig will be 40 minutes, which is much more than 30 and much less than 60 minutes.

Elaborated concepts for an ICT in Germany are rare. Breuer and Uekermann (Breuer/Uekermann 2011) developed such a concept for 2020. We analyse this concept using the NGT European demand model. Furthermore, we analyse a hypothetic timetable with nationwide 5-minute interchange times and the same travel and edge time as in the current timetable. Obviously, such a timetable is not feasible, but it can be used to derive an upper bound on the effect of an ICT in Germany.

5.1. Concept of Breuer and Uekermann

The route network of Breuer and Uekermann is an enhanced version of the current long-distance network of DB. In many places, travel time reductions realized by upgrading lines or building new ones are assumed.

The high-speed line “VDE8” (a rail project originating in the reunification of Germany, which is still not completed and scheduled for 2017)) from Leipzig to Nuremberg via Erfurt is included and shortens the travel time from 3:10 h to 2:05 h. However, the new high-speed line from Stuttgart to Ulm, which is under construction, is not included. Alternatively, the authors proposed a short new section to avoid the Geislingen slope. In the following line section towards Munich, many improvements are need to be implemented to shorten the travel time from Stuttgart to Munich from 2:15 h to 1:45 h.

Some IC routes are changed to ICE (for instance Hamburg – Cologne). The new trainset “ICx” serves some of the new ICE routes because the current number of ICE trainsets is not sufficient for the enhanced timetable. In order to be faithful to the original study, our model uses the same proposed route network as well as the travel and station times as found in the work of Breuer and Uekermann. Using our model, we can evaluate the concept regarding the resulting demand and the effect of route changes.

The results: The biggest demand increases occur in Munich, Berlin, Wiesbaden, Dresden and Cologne (see Figure 5). Proportionally Erfurt, Bamberg, Erlangen and Aschaffenburg profit the most. The accessibility of Erfurt increases from 62 to 77 km/h.

The number of changing passengers increases. This can be explained by an improvement of connections, but also by a stricter routing and stopping pattern of the routes resulting in fewer direct connections compared to the existing network. The number of changing passengers increases extraordinarily in Mannheim and Erfurt, but also in Stuttgart, Augsburg, Berlin and Halle. On the other hand, the number of changes in Cologne decreases because of the new direct route from Hamburg via Cologne to Frankfurt.

Travel time reductions generate a big part of the benefits of the concept. Cities like Halle, Erfurt, Leipzig, Dresden, Bamberg, Nuremburg and Munich profit from the VDE8 high-speed line. Munich benefits from better travel time to Stuttgart. Some cities profit from new regular routes like Rostock, Aachen, and especially Wiesbaden.

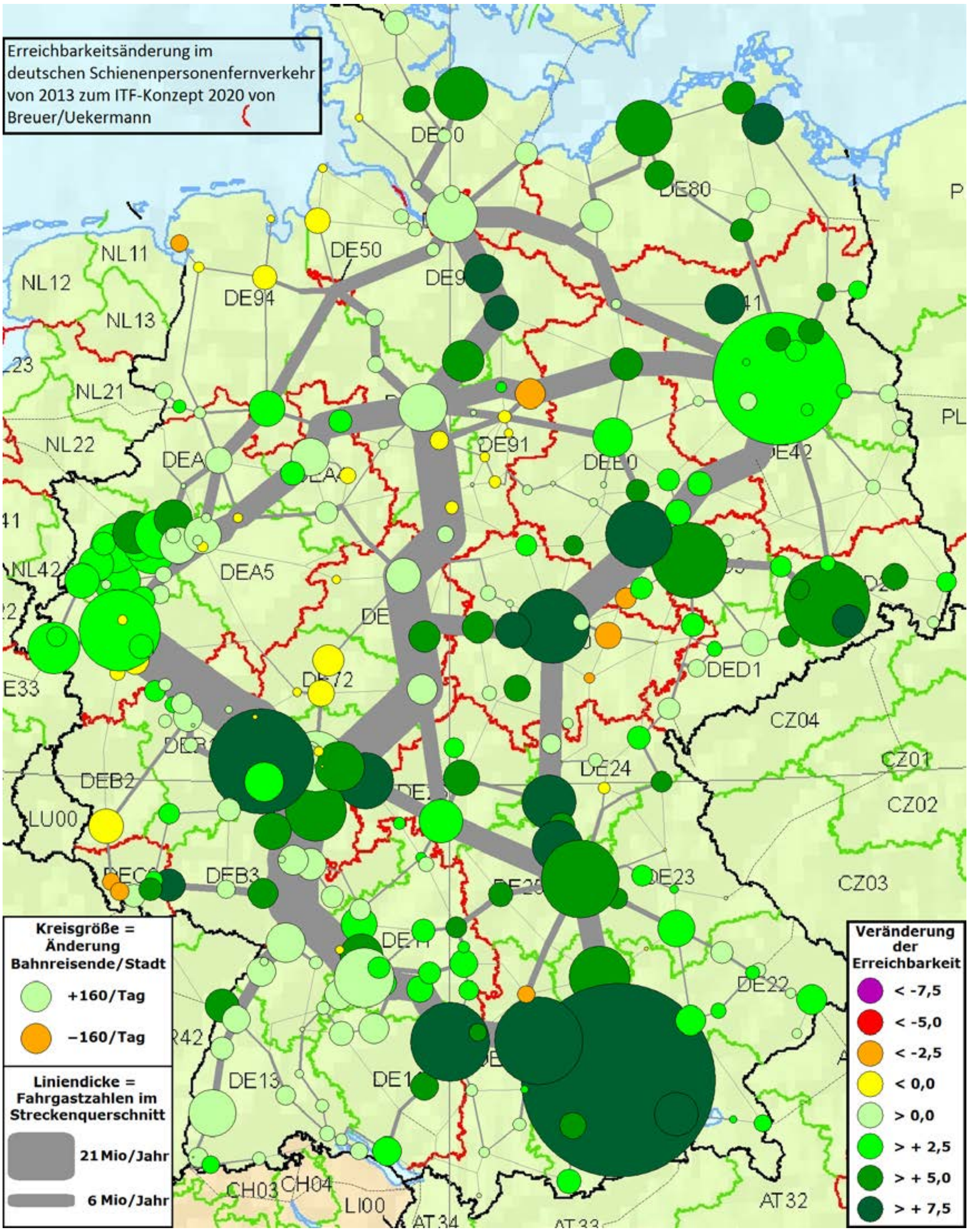

Figure 5: Changes of the accessibility and passenger numbers and line load with the timetable concept of Breuer and Uekermann

For some cities, the benefit can be traced back to better connections in important node stations. Kiel has a better connection to Hannover with a shorter change time in Hamburg; Lüneburg, Uelzen and Celle also profit from a better connection to the ICE to Southern Germany in Hannover. Oberhausen receives a better connection in Münster to Hamburg, and from Darmstadt travel to Cologne and Hamburg is improved by better connections in Frankfurt.

Not all cities benefit from the concept: East Friesland and Bremerhaven have connections with long waiting times in Oldenburg and Bremen, which negatively compensate the new direct connections to the rest of Germany. Wolfsburg loses its ICE stop. The alternative IC route has no adequate connections anywhere to compensate this. Dropped long-distance stops affect Naumburg, Jena, Trier and Donauwörth in a negative way. The new hourly IC route Berlin – Kassel – Gießen – Frankfurt is hardly used along the Main-Weser rail line due to an increase in travel time of one hour. This is made worse by a long scheduled stop (20 minutes) of this train in Kassel. According to our model, almost all passengers would change from this train in Kassel to the ICE on the high-speed line to Frankfurt. Even Gießen attains a lower accessibility value because of the long stopping time in Kassel.

Summarized, the concept improves the rail traffic in Germany: passenger numbers rise by 5.9% from 148.0 to 156.7 Mio per year compared to 2013. The passenger-kilometers rise by 7.1% from 45.2 to 48.4 bn. and the average travel speed from 68.5 to 71.5 km/h. It is obvious from the results that the travel time of long-distance connections should not be extended to achieve shorter interchange times.

5.2. Effect of a nationwide 5-Minute-Connectivity

Realizing 5-minute interchange time at every station without changing the infrastructure is possible only in theory. But it’s worth to have a look at such a timetable because it draws attention on cities and relations with a big potential, which would not be considered using a classic approach. For some of these cities, better connections could be realized only at the expense of other cities. Therefore the overall results of this approach should not be overrated. Figure 6 shows the results on the map.

The biggest increase occurs in the big cities where many traffic relations come together. The cities are in descending order: Berlin, Hamburg, Munich, Wiesbaden, Frankfurt, Aachen, Darmstadt, Hannover, Bremen, Cologne, Kiel and Karlsruhe. Remarkable are the improvements for Wiesbaden, Aachen, Darmstadt and Kiel, where the increase can be traced to better connections in node stations: Aachen benefits from better connections in Cologne to the Ruhr area and the Rhine region (although this effect is questionable since long-distance trains are more expensive than local trains while only slightly faster in this region). Darmstadt receives better connections to long-distance trains towards Cologne and the East and North of Germany in Frankfurt; Kiel profits from better connections in Hamburg.

In proportional terms, smaller cities benefit the most from this scenario. These cities are for instance Sangerhausen, Wertheim, Salzgitter, Nordhausen, Nördlingen, Straubing, Aschaffenburg and Bad Kissingen.

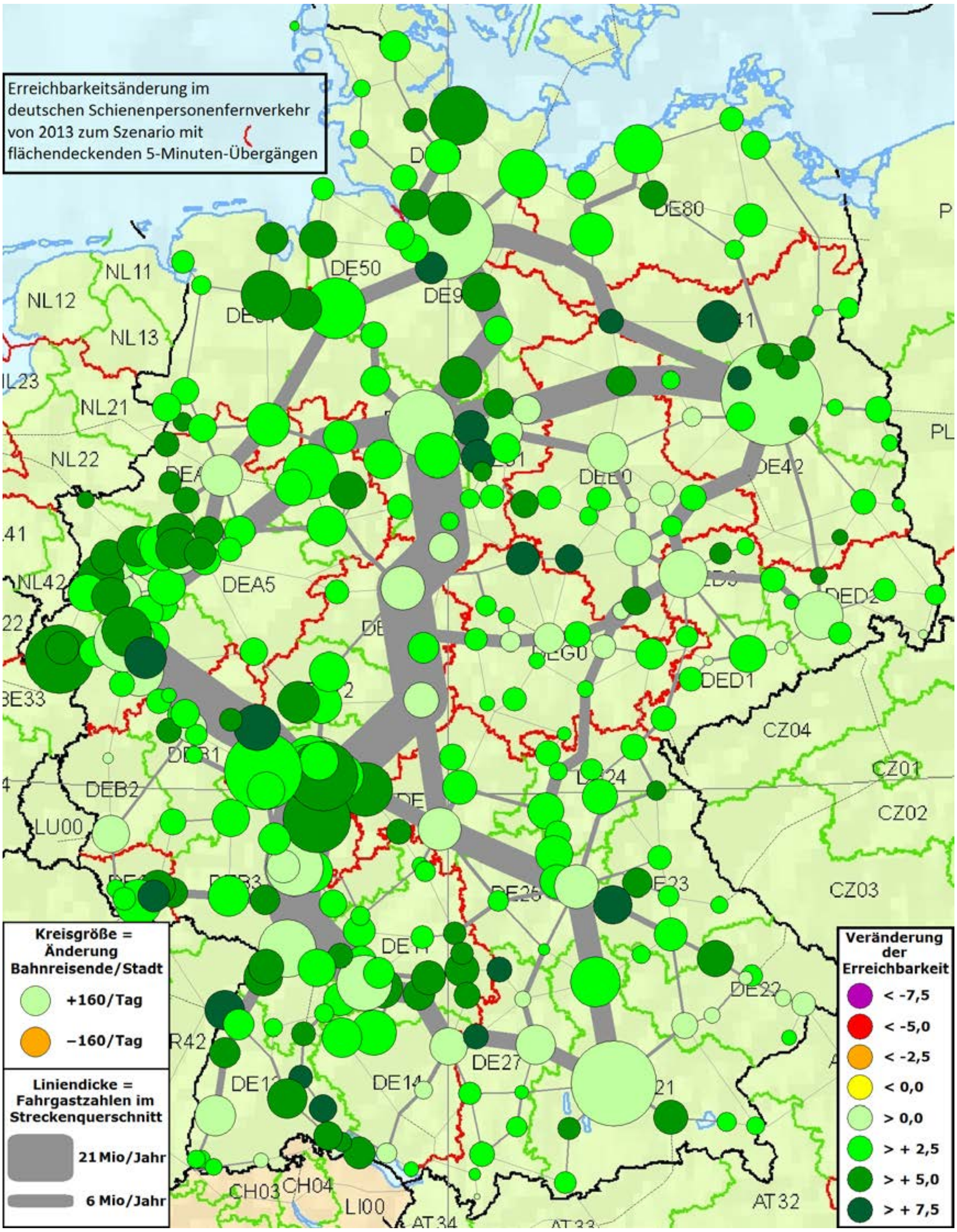

Figure 6: Changes of accessibilities and passenger numbers for all cities using a theoretical nationwide 5-minute-connection approach

A look at the interchange stations draws attention to the cities in which better connections are necessary: Frankfurt, Hamburg, Stuttgart, Würzburg, Cologne, Bremen, Berlin and Hannover. So the need for better connections occurs in the highly used node stations. At these stations, there will hardly be additional capacity to introduce an ICT without infrastructural extensions. This is worsened by the high requirements of an ICT with respect to conflict-free entry and exit and the number of platforms.

The number of passengers increases in this theoretical scenario from 148.0 to 159.6 Mio; the passenger-km rise from 45.2 to 48.5 and the average travel speed increases from 68.5 to 71.5 km/h.

Compared to the Breuer/Uekermann scenario a difference in the change of accessibility occurs in Bavaria (e.g. Munich) and Central East Germany (e.g. Erfurt, Halle). Since there are no new high-speed lines included in this scenario, the accessibility of these cities in these regions doesn't increase much as in the Breuer/Uekermann scenario. However, the situation in many West German cities gets better. This can be explained by the higher population in this area, who benefit even from small enhancements.

5.3. Impact of the Network 2025

One scenario of the NGT European study is the network for 2025, which includes all probably inaugurated new or upgraded railway lines at that time (NGT 2013). This scenario makes it possible to evaluate the effects of new and upgraded lines without other factors. The following lines are taken into account for Germany:

- High-speed line Leipzig/Halle – Erfurt – Nuremberg (VDE8)
- High-speed line Stuttgart – Ulm
- Upgraded line Erfurt – Eisenach
- Upgraded line Leipzig – Dresden
- High-speed line (new and upgraded) Karlsruhe – Basel

Under the assumption of similar travel behavior and equally short connections compared to the last scenario, this scenario leads to an increase in passenger numbers from 148.0 to 163.8 Mio and in passenger-km from 45.2 to 50.5. Figure 7 shows the results on a map.

The highest increase in passenger numbers occurs in Munich, Berlin, Leipzig, Dresden, Erfurt, Ulm, Halle and Nuremberg. In proportional terms Erfurt is the city that profits the most. The average accessibility of all cities increases from 70.7 to 74.2 km/h. In detail, the cities that benefit the most are (all values are accessibilities in km/h): Erfurt (+19), Bamberg (+18), Gotha (+16), Erlangen (+15), Halle (+14), Ulm (+13), Leipzig (+10), Fürth (+10), Dessau (+8), Munich (+8), Nuremberg and Dresden (both +7).

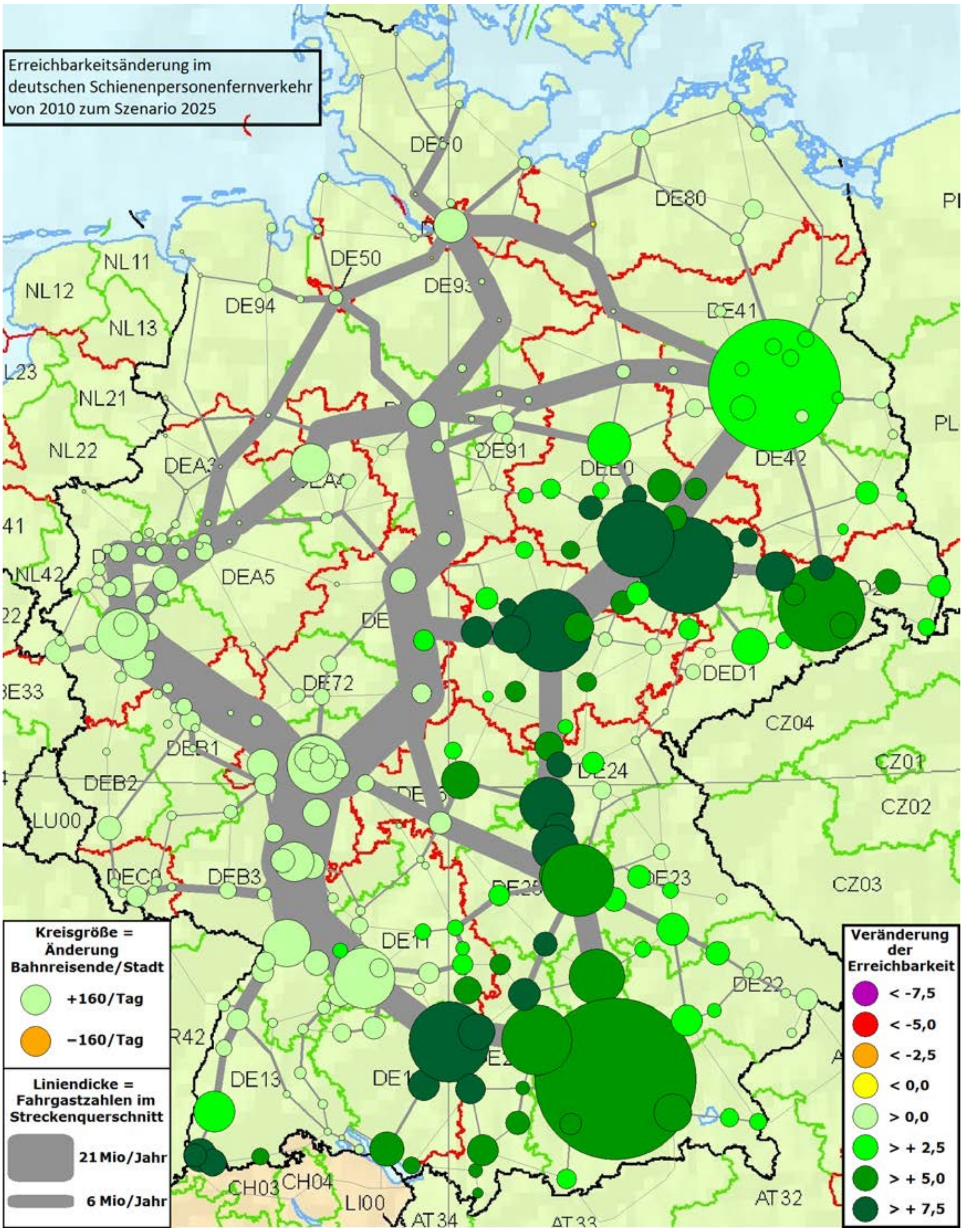

Figure 7: Change of accessibility and passenger numbers per city for the future scenario 2025

6. CONCLUSION

The introduction of a nationwide integrated clockface timetable (ICT) in Germany improves the accessibility of middle-sized cities because of better connections in the main node stations. Kiel, Aachen, Wiesbaden and Darmstadt are examples of cities that benefit the most. Therefore, the requirement for better connections is extraordinary high in the principal nodes such as Hamburg, Cologne or Frankfurt. The accessibility of metropolitan cities increases only a little bit, but the passenger number in absolute numbers grows much due to the better connected middle-sized cities.

The benefit of actions resulting in shorter travel times or new high-speed lines is high. Hence, an ICT in Germany can only be successful if the network is improved in order to reduce the travel time between nodes. An improvement of connections by letting trains stand for a long time inside a station on the other hand affects long-distance passengers in a negative way and ruins the positive effect of shorter interchange times.

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