European Commission

PASSENGER RAIL ACCESSIBILITY IN EUROPE'S BORDER AREAS

HUGO POELMAN AND LINDE ACKERMANS

Working Papers

A series of short papers on regional research and indicators produced by the Directorate-General for Regional Policy

WP 11/2017

Regional and Urban Policy

> Contents

Luxembourg: Publications Office of the European Union, 2017

> SUMMARY

Cross-border cooperation in the EU addresses the needs of border areas and has been helping to remove obstacles between them for more than 25 years already. To support this policy, quantitative evidence needs to be developed, especially in the areas of transport infrastructure endowment and accessibility. By using passenger rail timetables in combination with spatial data on stations and population density, we highlight the diversity of border areas regarding the availability, speed and frequency of cross-border rail services. In addition, we compare these services to domestic services linking the border areas to their hinterland.

In many cases, cross-border links are less frequent and often slower than domestic connections of similar length. In some border areas, efficient rail connections enable cross-border commuting, while in many other areas, low speed and frequency of services severely limits the attractiveness of rail as an efficient regular travelling mode.

1. INTRODUCTION

Among the diverse territories of the European Union, border regions occupy an important place. Regions along the terrestrial borders – both internal and external borders – account for one-third of the EU population. Hence, territorial cooperation has been an essential instrument of EU Cohesion Policy for more than 25 years already. One of the main instruments of this cooperation policy is the group of Interreg cross-border cooperation programmes, specifically operating in regions along both the internal borders and borders with the EFTA countries[1].

To underpin this ongoing cooperation policy, a recent study has collected quantitative evidence which helps to assess the needs, challenges and opportunities to be addressed in border situations[2]. This study also confirms that EU-wide data on cross-border infrastructure endowment and accessibility are quite problematic, and proposes the development of new indicators that should shed light on cross-border public transport bottlenecks.

By analysing spatial data on rail infrastructure and population distribution, combined with timetable data on rail passenger services, we will try to fill part of the data gap concerning services in border areas. The aim is to describe how rail infrastructure provides accessibility services for passengers in border areas by comparing cross-border services with domestic ones. This paper verifies whether cross-border trips between stations less than 100 km and 1h30 apart are available, and measures their frequency and speed. It shows that in most border areas stations across the border are less well connected and trips to these stations tend to be less frequent and slower.

2. DEFINING BORDER REGIONS AND AREAS

Seen from a spatial perspective, cross-border cooperation programmes are defined as clusters of NUTS level 3 regions, including all regions that are contiguous with the border, complemented by some additional regions directly affected by border situations[3]. Initially, terrestrial border regions were taken into account. Since then, in the programming period 2007-2013, selected maritime border regions have been added to the cooperation programmes.

While the NUTS-3-based programme area definition has a clear legal basis with obvious implementation advantages, this definition can hamper the possibilities for a comparable quantitative analysis of border areas. This is mainly due to the wide diversity in the size of the NUTS-3 regions throughout the EU: NUTS-3 regions are not always the appropriate spatial level to describe border and cross-border phenomena. On the other hand, well-established statistical systems essentially provide regional data down to NUTS-3 level, while EU-wide data availability below this level is mostly limited to a selection of data collected in population and housing census years.

An analysis of the characteristics of border areas, focusing on opportunities and challenges related to the specific cross-border situations, benefits from a two-fold approach. First, it is essential to fully exploit NUTS-3-related statistical data sources. In addition to this, a more spatially neutral analytical approach is interesting to pursue. This approach calls for an alternative definition of border areas, independent from the NUTS boundaries or from any other level of administrative boundaries. For the analysis of spatial data sources, we define border areas as buffer areas covering 25 km either side of the border. Insight into population distribution in these areas is crucial for further analysis. This information is provided by a regular population grid that includes population counts for each square cell 1 km² in size[4].

Hence, the geographical scope of this analysis will be the extent of the terrestrial border areas along all internal EU borders and along the borders with EFTA countries[5]. These areas cover almost 13 % of the EU population.

1. For a comprehensive overview of the history of these cooperation programmes, see: Wassenberg and Reitel (2015).
2. European Commission (2016).
3. Typical cases are small regions that do not touch the border but are surrounded by the border region.
4. We used the data from the Eurostat GEOSTAT 2011 population grid: (http://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/population-distribution-demography/geostat). In most of the Member States, this grid has been created by aggregating address-based population counts from the 2011 census, providing a reliable spatial population distribution at quite high resolution.
5. The analysis also covers areas in Norway, Switzerland and Liechtenstein bordering the EU.

3. PASSENGER RAIL SERVICES IN BORDER AREAS

For an analysis of the provision of scheduled passenger rail services for border areas, we need comprehensive timetable data, combined with complete and reliable station-location data[6]. Most of the data refer to timetables covering the second half of 2014[7]. Using this combination, together with the grid population distribution, we will develop indicators on the availability of services in border areas.

We will take into account all the stations located in border areas from where passenger services are operating on an average weekday. We will assess the proximity of the population around these stations and examine the availability of rail connections to stations in the border areas of the neighbouring country and in the border areas' domestic hinterland.

4. POPULATION WITH ACCESS TO RAIL PASSENGER SERVICES

First we examine which part of the border areas' population has access to rail passenger services, regardless of the destinations of these services. We take into account all people living in a neighbourhood covering 3 x 3 km around a station from where the services operate. Map 1 shows this population, expressed as a share of the total population of the border area[8]. The highest shares of population with access to rail services are found in the Danish border area with Sweden (i.e. Copenhagen and part of its surroundings) and in the Swiss border areas with Germany and with Austria. On average, 44 % of the population of all border areas has access to rail services. These figures can also be interpreted as access to domestic rail services, as it is extremely improbable that a station would only offer cross-border services but no domestic services.

While the availability of any services is definitely a prerequisite, not all stations with passenger train departures offer the possibility to travel by rail to other countries. In principle, many stations in border areas will offer some opportunity to (indirectly) travel to a neighbouring country. Nevertheless, such trips may become cumbersome and very long, for instance when a connection is available only once a day, or requires multiple transfers and/or detours. To assess which cross-border connections are effectively available and offer a reasonable minimum service level we have analysed the connectivity between individual stations on either side of the border.

In practice, we analyse all possible connections starting at any station in a specific border area and having as their destination any station in the neighbouring border area, providing that the arrival station is a maximum of 100 km away (in a straight line) from the departure station. For each of these connections, we compute the travel time observed during the morning peak hours on an average weekday. This process allows us to select only the destinations that can be reached within 1 hour and 30 minutes, using the fastest available route according to the timetables[9].

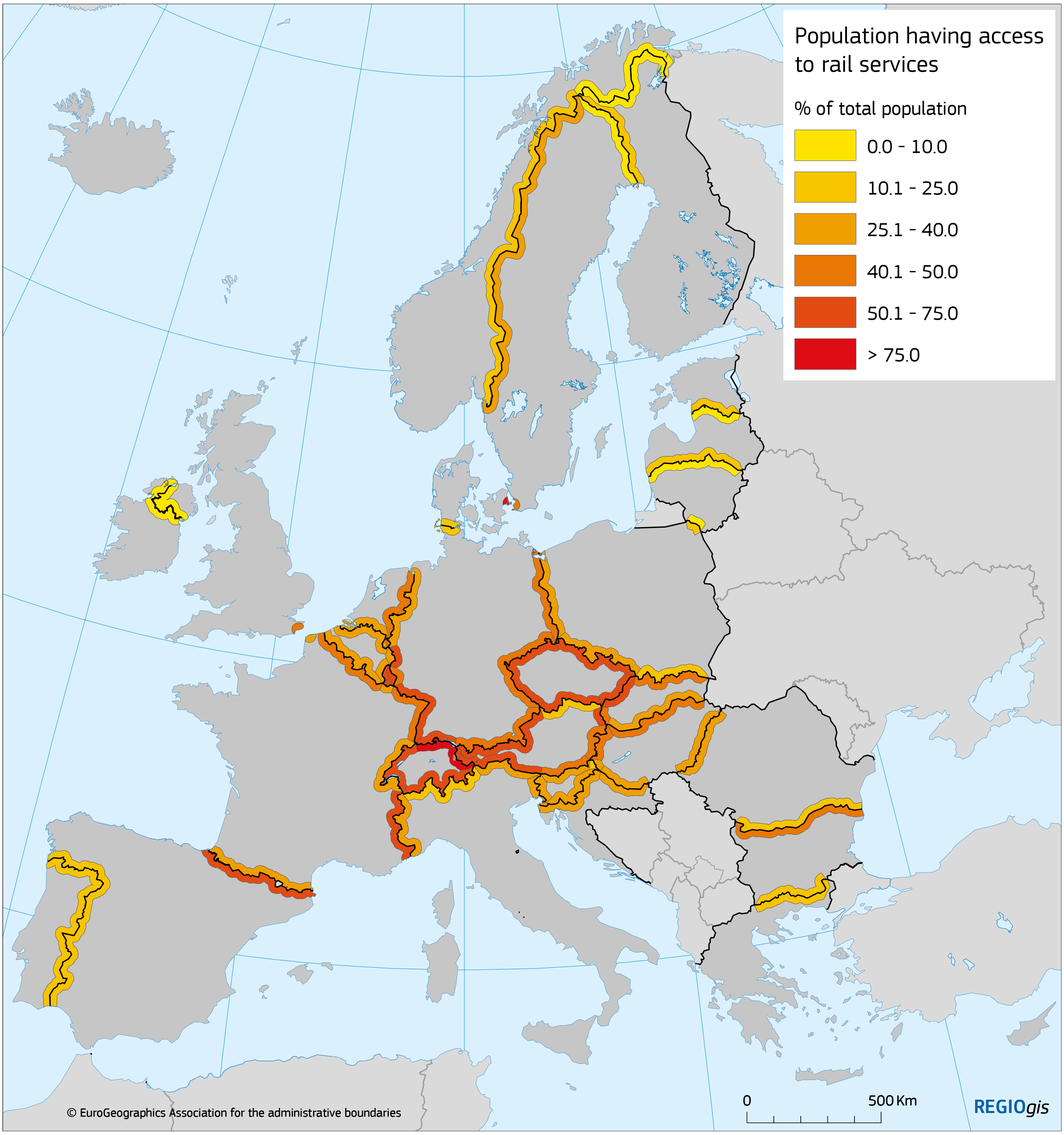
The availability of these selected cross-border services is shown in Map 2. When we only take cross-border services into account, the average share of people with access to nearby services drops to 31.6 % of the total border area population. Map 2 shows that in most border areas the availability of cross-border services is substantially lower than that of domestic services. Nevertheless, in 12 border areas, located mainly in Austria, Luxembourg and Switzerland, more than half of the population has easy access to cross-border services. In many border areas between Eastern European countries, cross-border services are only available to less than 10 % of population. This is also the case in Scandinavian border areas, although most of these areas are very sparsely populated.

6. The preparatory work on data collection, transformation, correction and integration is described in Poelman and Ackermans (2016).

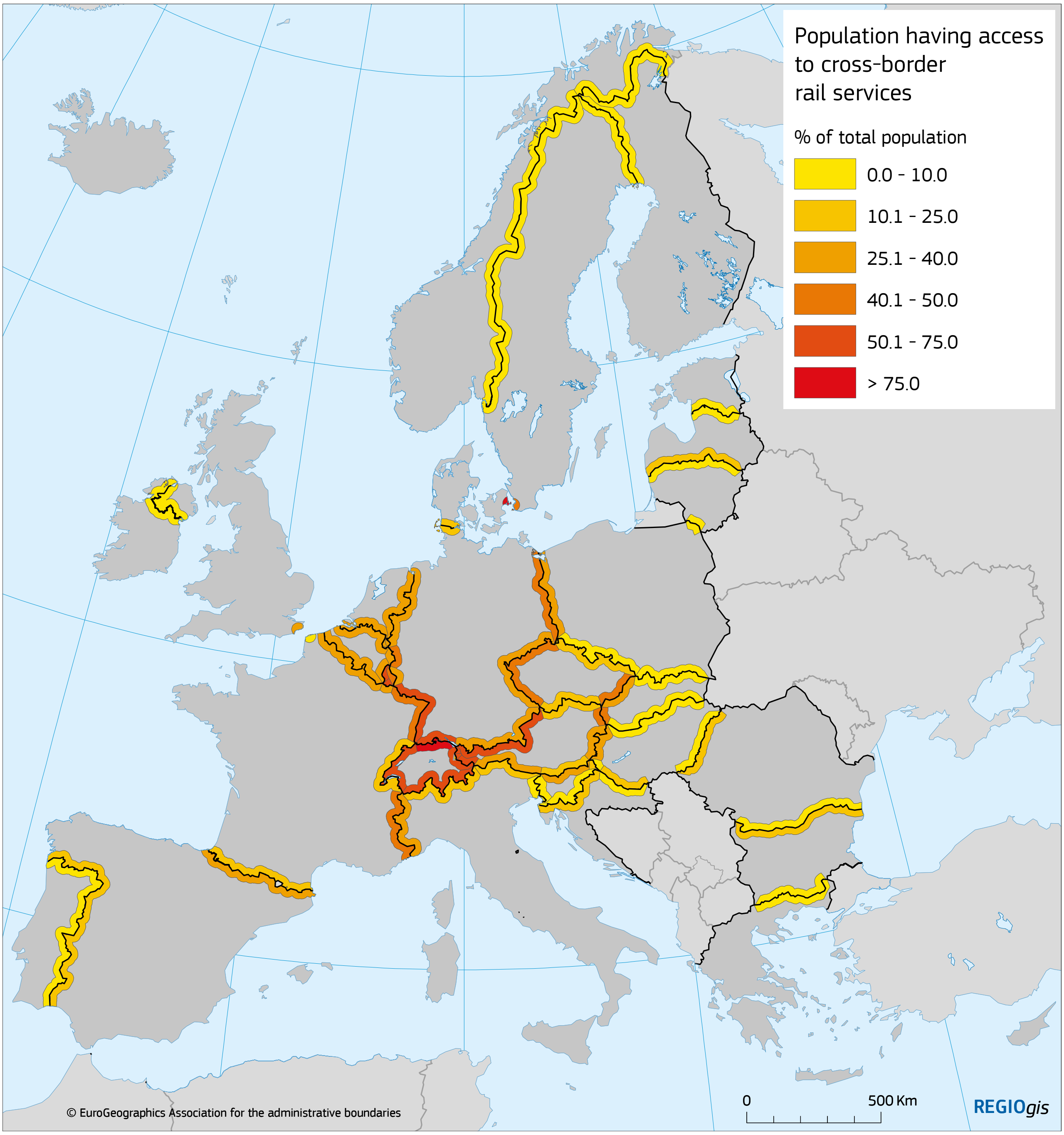
7. Exceptions are: Estonia and Ireland: 2013; Greece, Northern Ireland (UK), Corsica (FR) and Norway: 2015.

8. Where the borders of three countries meet, border areas 25 km wide partially overlap. To simplify the maps, we have represented the border areas by non-overlapping areas, by distributing the overlapping zone between the border areas concerned. This has been done purely for the purpose of cartographic simplification. Rail networks are not present in any of the outermost regions. Therefore, the outermost regions have not been represented on the maps.

9. Travel time includes waiting time and transfer times, if needed. For a more detailed technical explanation, see the methodological annex.



Map 1: Population with access to rail services



Map 2: Population with access to cross-border rail services

Finally, Figure 1 relates the values of cross-border service availability to those of overall service availability, in combination with the population size of the border areas. Points on the graph further away from the diagonal line indicate a larger discrepancy in access to services between cross-border and domestic services. Cross-border services in relative terms are especially rare between Poland and Slovakia, Slovenia and Italy, or Bulgaria and Greece.

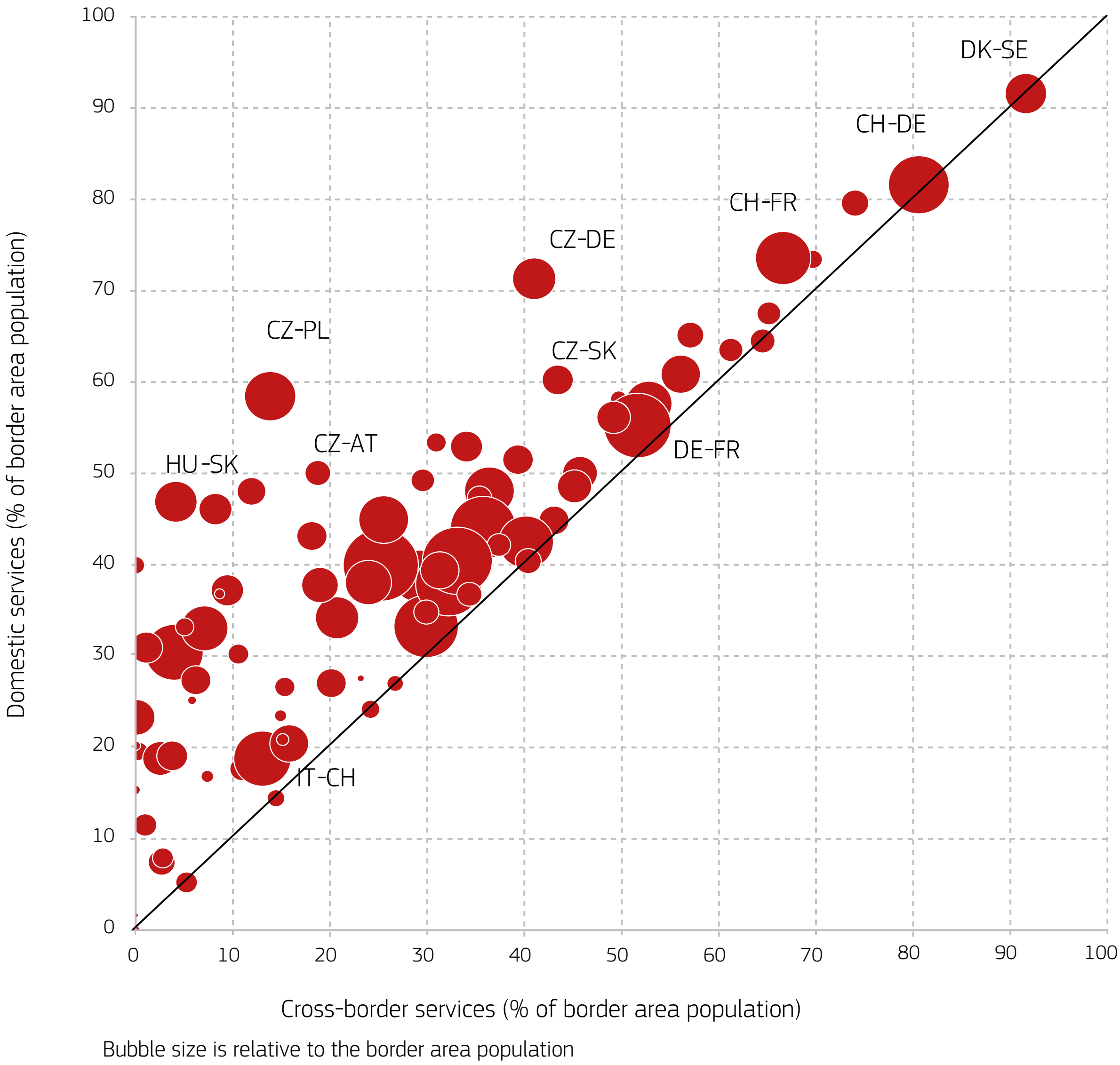


Figure 1: Population with access to domestic and cross-border rail services

5. CONNECTING THE AREAS AT EITHER SIDE OF THE BORDER

Some of the examples of poor availability of cross-border services are definitely caused by the absence of adequate cross-border network infrastructure, although the mere presence of operational railway network border crossing points is not a sufficient precondition for efficient and useful connections.

Using the actual timetable data in combination with the stations' location allows for a more in-depth look at the characteristics of cross-border rail links. We will examine to what extent relatively nearby stations can be reached with a decent frequency of services and within reasonable travelling time. As before, we only take into account services linking stations located within 100 km of one another and within 1h30 of effective travel time.

As we have noted that the availability of cross-border services can be very different compared to domestic services, we will compare the indicators relative to cross-border connections with those relative to domestic connections, starting from within the border areas. For this purpose, we will also analyse all connections starting at a station in a border area with a destination in the same country, located a maximum of 100 km in a straight line from the departure station.

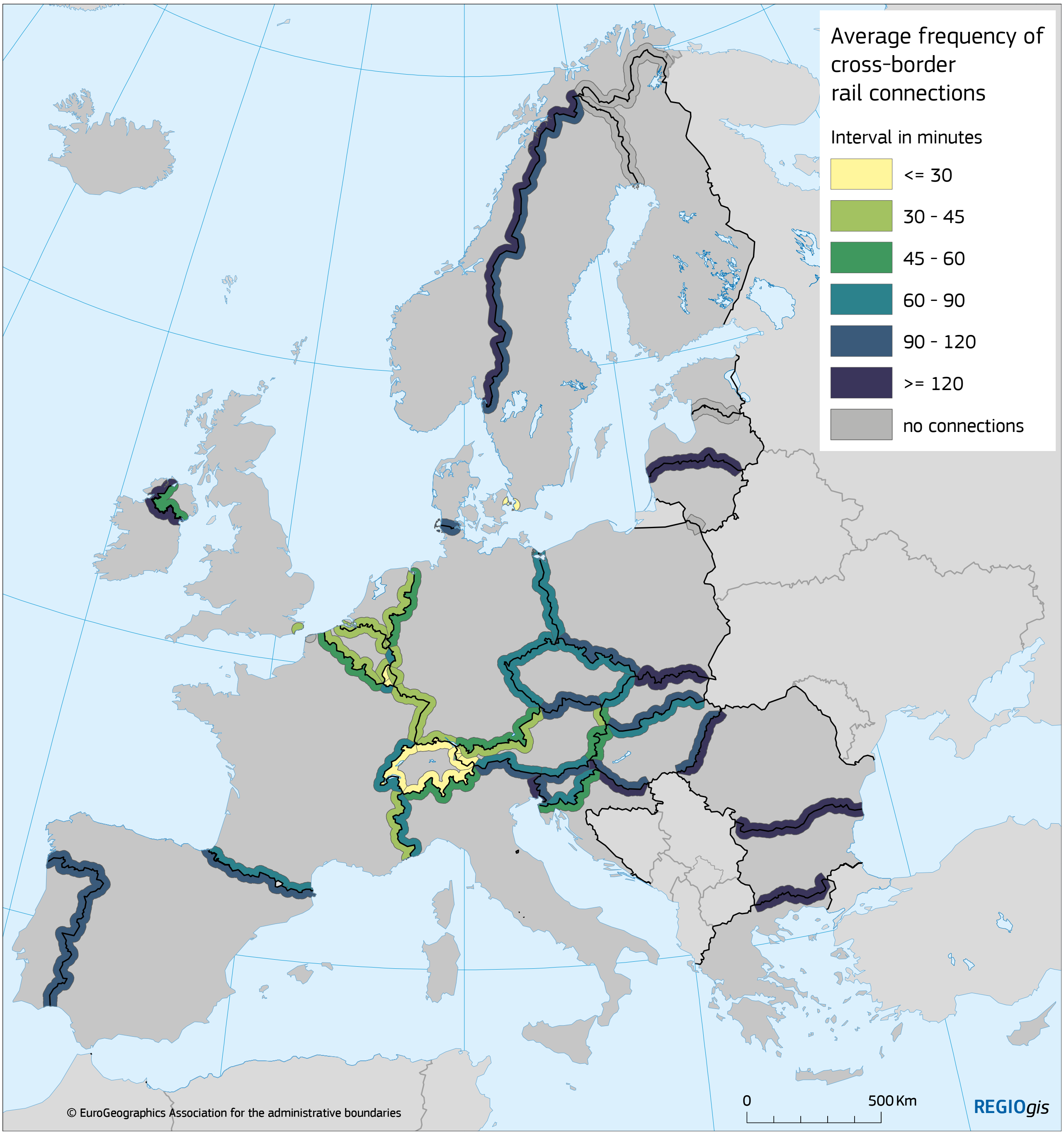
The usefulness of relatively short-distance rail connections for daily or regular travel will depend on the frequency of the available services. As we have checked the availability of station-to-station connections at various preferred departure times during morning peak hours, we can compute the average waiting time between the reported services. This interval, expressed in minutes, indicates the frequency of the most efficient services found for a particular connection during the examined morning peak hours[10]. The average interval computed by border area takes into account the population living nearby the departure and destination stations. Hence, connections linking densely populated places are weighted more than those connecting smaller centres. Maps 3 and 4 depict the average service interval in cross-border and domestic situations.

Map 3 showing cross-border connections indicates very low frequencies in several border areas of Eastern and Southern Europe, making the rail connections in these areas hardly usable for regular cross-border travelling. Frequent cross-border services are available from Switzerland, around Luxembourg and between Denmark and Sweden. As Map 4 indicates, many border areas experience more frequent connections to inland destinations. Nevertheless, frequent domestic connectivity is problematic from border areas like those in Greece, Spain and the Baltic countries, while border areas in the Netherlands, Luxembourg and Switzerland are efficiently connected to their hinterland.

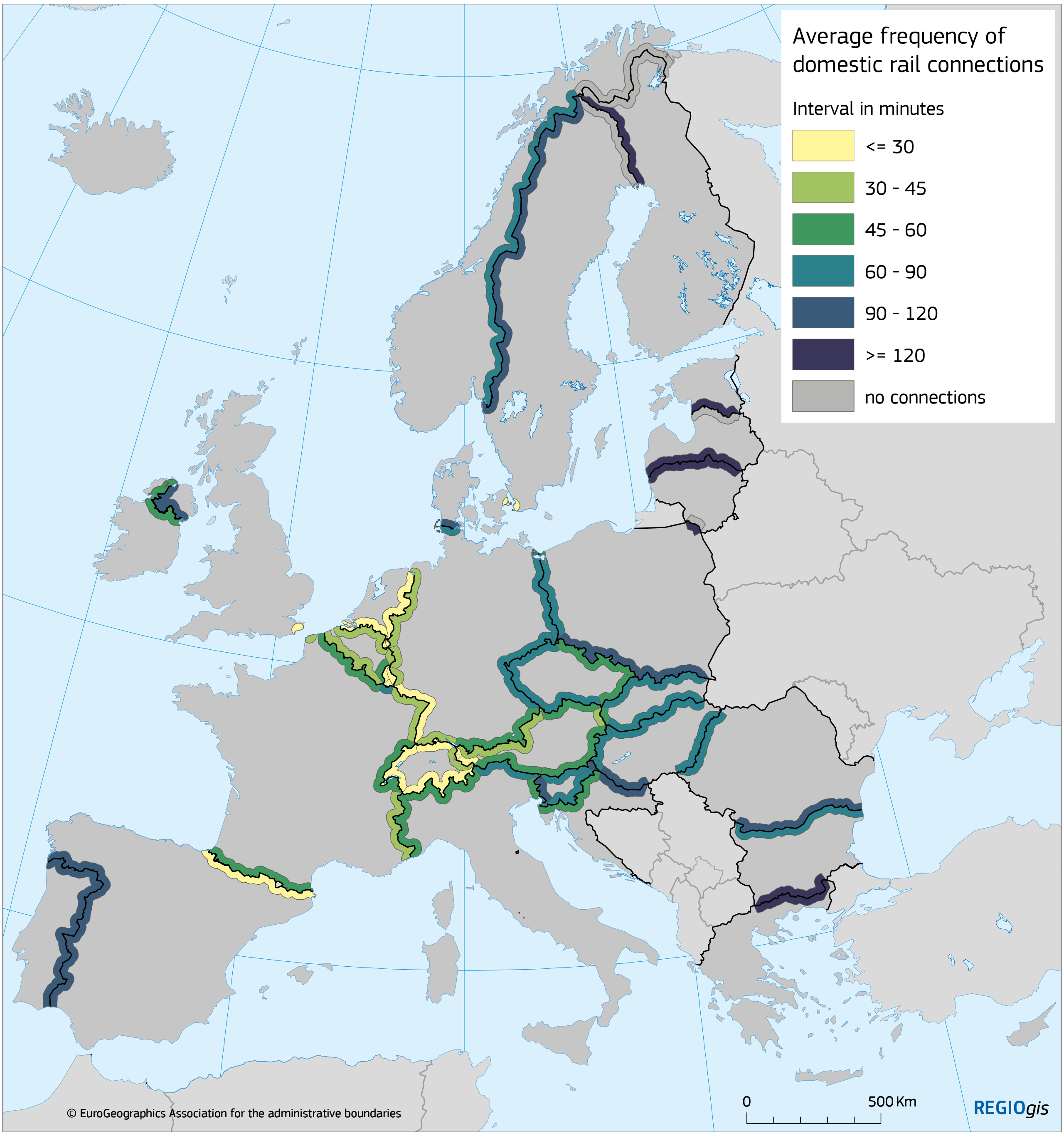
Figure 2 shows the relationship between the border areas' weighted population density[11] and the frequency of optimal cross-border and domestic services. All points below the diagonal line represent areas where cross-border frequency is lower than that of domestic services. Despite this diversity, the average interval of cross-border services in all border areas is, at 38 minutes, almost identical to the average interval of domestic services starting in border areas (39 minutes). This can be explained by the fact that cross-border frequency is quite good in some densely populated areas where cross-border commuting or other functional travelling occurs. Typical cases are the areas around Luxembourg and Basel (CH), and between Copenhagen (DK) and Malmö (SE). Alternatively, cross-border services from Spain to France operate with an interval of 90 minutes, while domestic services from the same area in Spain are much more frequent (interval of less than 25 minutes). This is a border area, extending along a very long border, where there is quite a high concentration of the population in just a small part of the border area, especially along the Atlantic coast. Yet, even in urbanised regions, there are often considerable differences in frequency between cross-border and domestic connections: e.g. the interval from Kortrijk (BE) to the major nearby agglomeration of Lille (FR), or between Aachen (DE) and Verviers (BE) is 1 hour, while from the same stations the frequency is at least doubled to other cities in the same country (such as to Ghent or Bruges from Kortrijk, or to Köln from Aachen).

10. The most efficient service reported, given a requested departure time, is the one that provides the earliest arrival time. In addition to such services, other – slower – services might operate on the same connection.

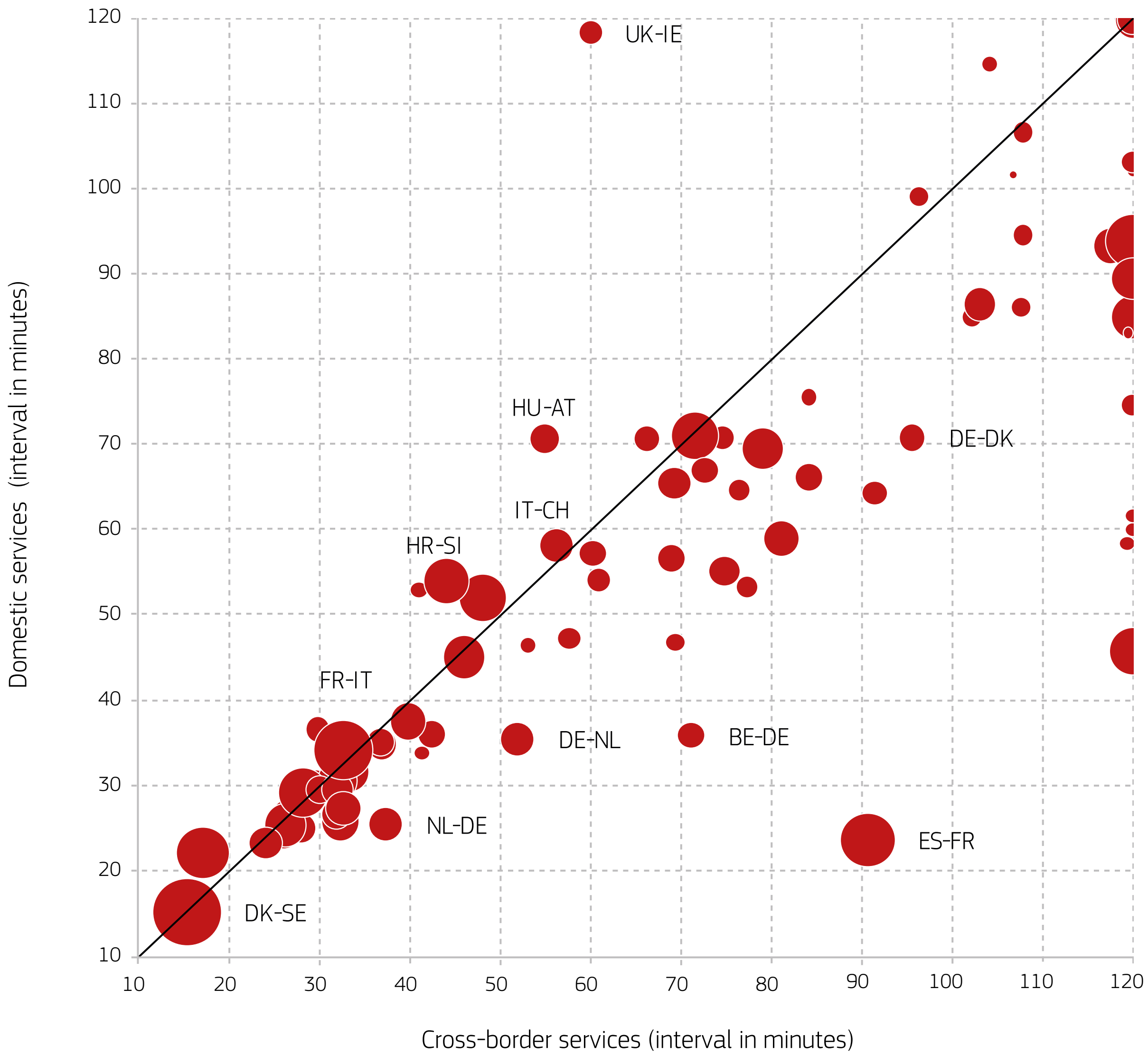
11. Weighted population density measures the concentration of population within a given territory. It uses data on population density at a homogeneous spatial level (in this case: at the level of 3 x 3 km grid cells) and provides the average (in this case: at the border area level) of that density, weighted by the population of each grid cell.



Map 3: Average frequency of optimal cross-border services



Map 4: Average frequency of optimal domestic services departing in border areas



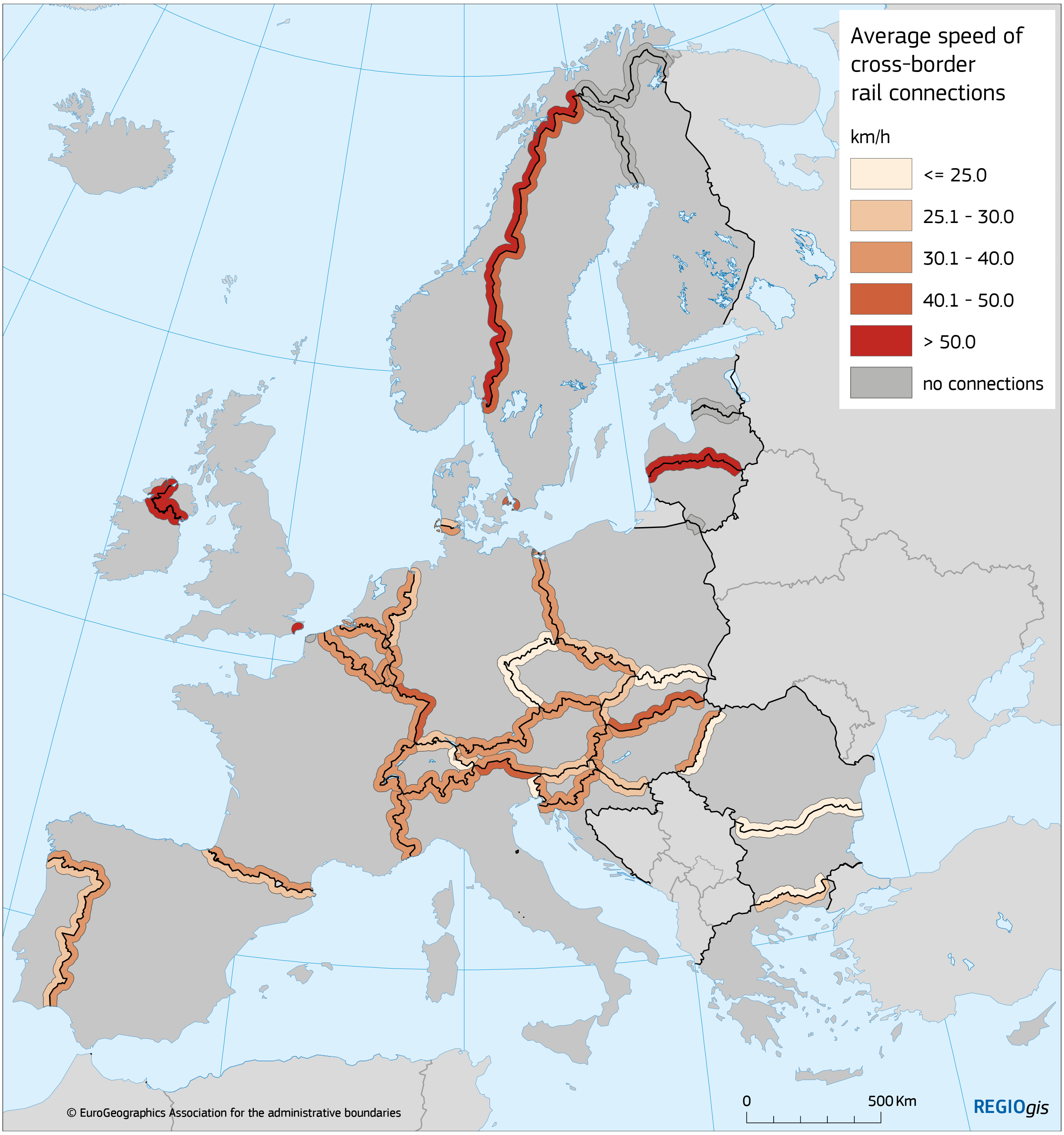
Bubble size is relative to the weighted population density of the border area

Figure 2: Average frequency of optimal domestic and cross-border services, relative to border areas' weighted population density

Apart from an appropriate frequency of services, the attractiveness of rail connections also relies on an adequate speed. Many factors, including geographical constraints, can influence the speed of the services. We will compare the average speed of cross-border connections with that of domestic connections departing in border areas. The speed of the rail links is estimated by dividing the straight-line distance between the departure and arrival station by the fastest travel time[12] observed during morning peak hours. Currently, the available data do not allow for a systematic calculation of the actual network speed of the services. For this reason, the speed is calculated assuming a straight line between the stations. Hence, the actual speed of the trains will be faster, because railway lines will often not be able to follow straight lines for a considerable distance.

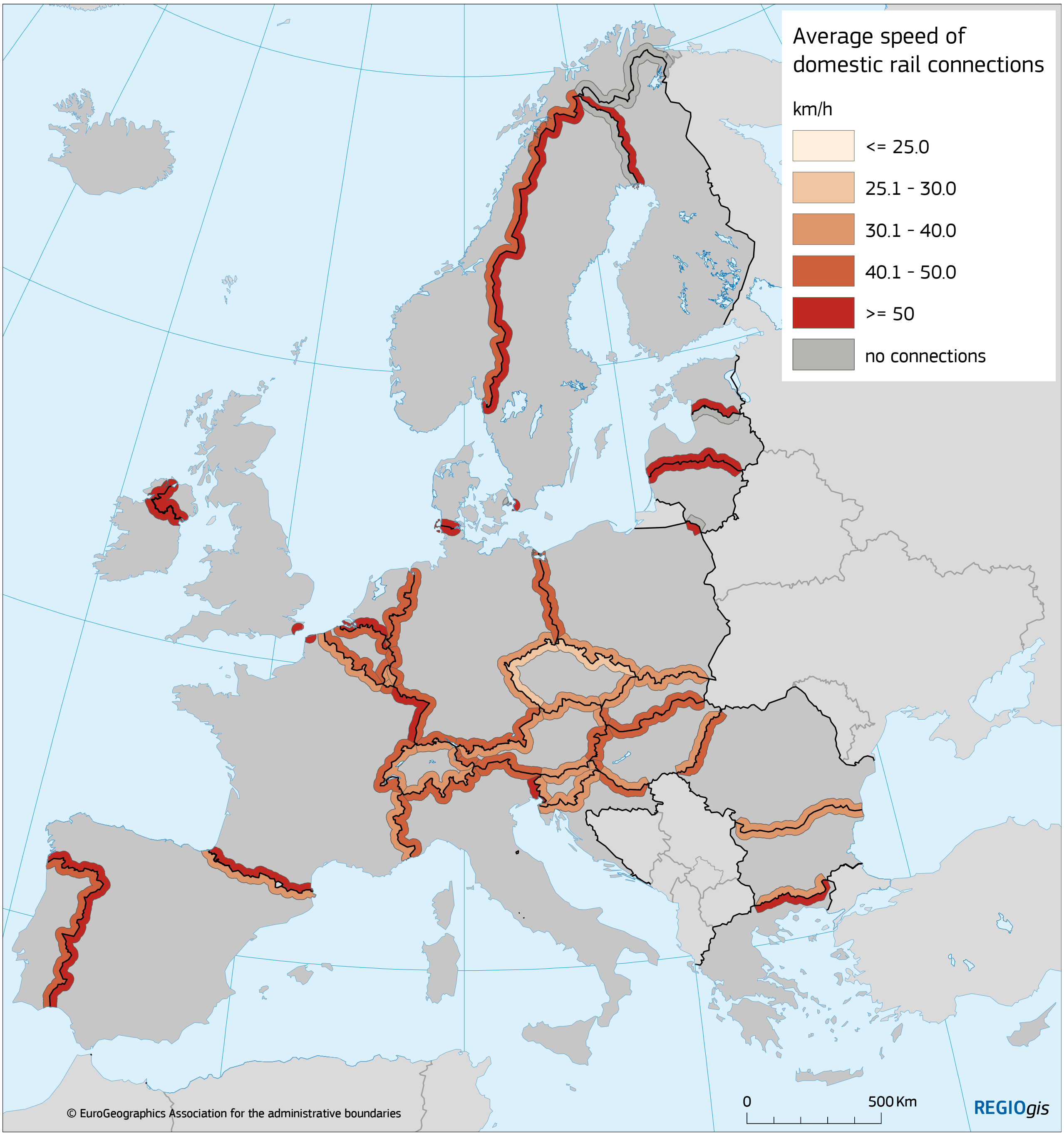
The averages by border area are computed by population weighting: they take into account the reachable population of each destination, i.e. the population living nearby the arrival station, and the population living around the departure station. In that way, the characteristics of services linking densely populated places will determine the average speed value more significantly than those of services linking smaller centres. Maps 5 and 6 illustrate the average speed of cross-border connections and domestic connections, while Figure 3 compares the speed of cross-border and domestic connections in relation with the border areas' weighted population density. In border areas represented by a large bubble, population is mainly concentrated in densely populated places.

12. This travel time excludes initial waiting time before the first boarding, but includes transfer times, if required.



Map 5: Average speed of cross-border services

Taking into account all border areas, cross-border services operate at an average straight-line speed of 33.7 km/h. This is considerably lower than the average 38.6 km/h of domestic services linking the border areas to relatively nearby destinations in the same country. As Figure 3 shows, cross-border connections operating at a higher average speed than the domestic connections occur in only a few border areas. For instance, this happens between Denmark and Sweden and between Luxembourg and France (e.g. between Luxembourg-city and Thionville (FR); fast cross-border connections are also available from Luxembourg to Arlon (BE)). On the other hand, cross-border services from Bulgaria to Romania and from Poland to Slovakia operate at a speed of less than 20 km/h, while the speed of the domestic services starting from these border areas is almost double. Even in the absence of physical geographical obstacles, specific cross-border services can be slower than domestic ones: e.g. from Breda (NL) to Antwerp (BE) the speed is less than 50 km/h, while from Breda to Amsterdam, The Hague or Eindhoven (NL) it exceeds 75 km/h. Map 6 shows that domestic connections generally operate at higher speeds, although there is still a substantial diversity between border areas.



Map 6: Average speed of domestic services departing in border areas

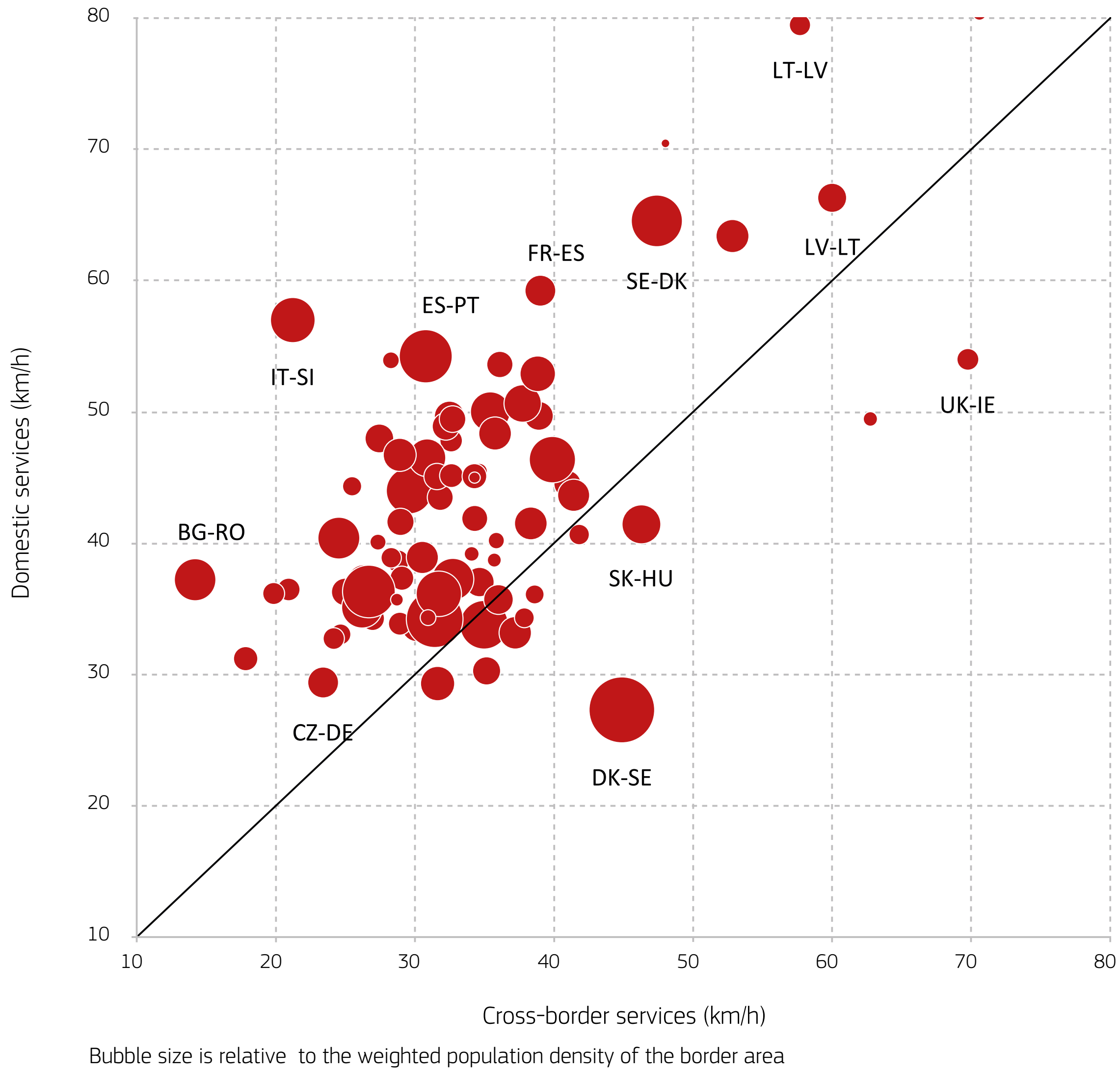


Figure 3: Average speed of domestic and cross-border services, relative to border areas' weighted population density

CONCLUSIONS

The new combination of spatial data on rail infrastructure and population distribution, combined with comprehensive rail timetable data, has enabled the development of a set of indicators able to shed more light on the diversity of the provision of rail services in border areas. These indicators are complementary to the quantitative evidence on border areas, already collected by other studies. While cross-border rail services often score lower than domestic services, border areas are definitely not a homogeneous group when considering passenger rail services. In particular, in some of the more densely populated areas, there are efficient cross-border services in operation. Despite these successes, numerous challenges remain concerning cross-border rail connections.

On average, 28 % of people living close to stations in border areas do not have access to adequate cross-border rail links. In one-third of all border areas, cross-border trips are available for less than half of the population with access to any rail journey.

In 29 % of border areas, the frequency of journeys to stations across the border is substantially lower: the average interval is at least 25 % longer than for domestic trips. Discrepancies in the speed of services are even higher: in 44 % of border areas, the average speed of cross-border trips is less than three-quarters of the speed of domestic services.

In those areas where cross-border services do not perform adequately, it would be interesting to assess the opportunities for improvement, in particular in terms of infrastructure development, removing legal or governance obstacles, etc.

Furthermore, the data management and analysis underpinning development of this indicator has shown an ongoing need for more integrated, open data, not only on rail timetables, but also in combination with spatial data on rail infrastructure. Furthermore, removing obstacles of data openness and integration will definitely open up additional opportunities for an in-depth analysis of service provision and a better understanding of the issues at stake.

METHODOLOGICAL ANNEX

DATA SOURCES

This analysis uses data on station locations, rail timetables and population distribution.

Station locations are represented by georeferenced points, collected from various data sources in order to represent all stations where passenger rail services are available. Rail timetables for most of the countries have been provided by the UIC (International Union of Railways), complemented by data from national and regional providers in order to cover the entire EU plus EFTA. All details on the source of station locations and timetables and their integration processes can be found in an earlier working paper (Poelman and Ackermans, 2016, pp. 13-15).

Population distribution data have been retrieved from the Eurostat GEOSTAT 2011 population grid, representing population data from the 2011 census. This dataset has been converted into a point layer (one point for each cell centroid) and combined with the polygons of border areas 25 km wide. In places where two border areas overlap, this process results in duplication of the population points. This facilitates later selection of populated grid cells covered by individual border areas.

STATION LOCATIONS AND POPULATION DISTRIBUTION

To assess which part of the population has easy access to rail services, we established a spatial relationship between the population grid and the station points. Quantifying the population with access to any passenger services first requires the selection of all stations with services (number of departures > 0 between 6:00 and 20:00 on a normal weekday) inside the border areas. From this point dataset, we create a raster[13] with the same spatial characteristics as the GEOSTAT population grid. In this raster, all cells containing one or more stations have the value 1. We expand this grid by 1 cell around each original grid cell. The result is a grid covering the areas located in a 3 by 3 km square around all border area stations with passenger services. This grid is converted into polygons. Inside each polygon, we select only the population grid points falling inside the border area. Adding up the population at the selected grid points by border area provides us with the population living near stations with services. This operation excludes the population living within a 3 x 3 km square around a station but in a neighbouring country.

ORIGIN-DESTINATION CALCULATIONS BETWEEN STATIONS

The origin-destination calculations or travel times distinguish between cross-border connections and domestic connections. The process begins by creating a list of station pairs to be examined. First we create a list of departure stations, i.e. all the stations located in border areas. Added to this is a selection of arrival stations, derived from the same list, whereby the arrival stations should be in a different country and the Euclidian distance between departure and arrival stations is not more than 100 km. We apply the same logic for creating the list of station pairs with domestic services (selecting the arrival stations in the same country).

These lists are used as input for the origin-destination calculations, computed using the OpenTripPlanner[14] so that the origin-destination results can easily be summarised by station pair. This allows for further aggregation by border area. All origin-destination calculations are performed nine times per station pair. The requested departure times are every 15 minutes during a two-hour morning peak period. The precise timing of the peak hours varies between countries and has been determined on the basis of the highest number of departures per hour found in the country. For each pair of stations, we calculate the minimum effective travel time (including transfer times, if needed) and the average total travel time (including initial waiting and transfer times).

The origin-destination calculations now allow us to compute the population with access to nearby cross-border services. This requires an analysis by individual border area. We start with a list of stations located in border areas, which includes the destination border area(s). This means that the same station can be mentioned more than once if it has connections to more than one other country. Hence, for each border area, we select the stations located therein, as long as they connect to the selected neighbouring country within a maximum straight-line distance of 100 km and within a minimum effective travel time not exceeding 1h30. We create a grid from the selected departure station points and expand this to create a 3 x 3 km grid around the stations. The populated points inside this grid are selected and their populations added up.

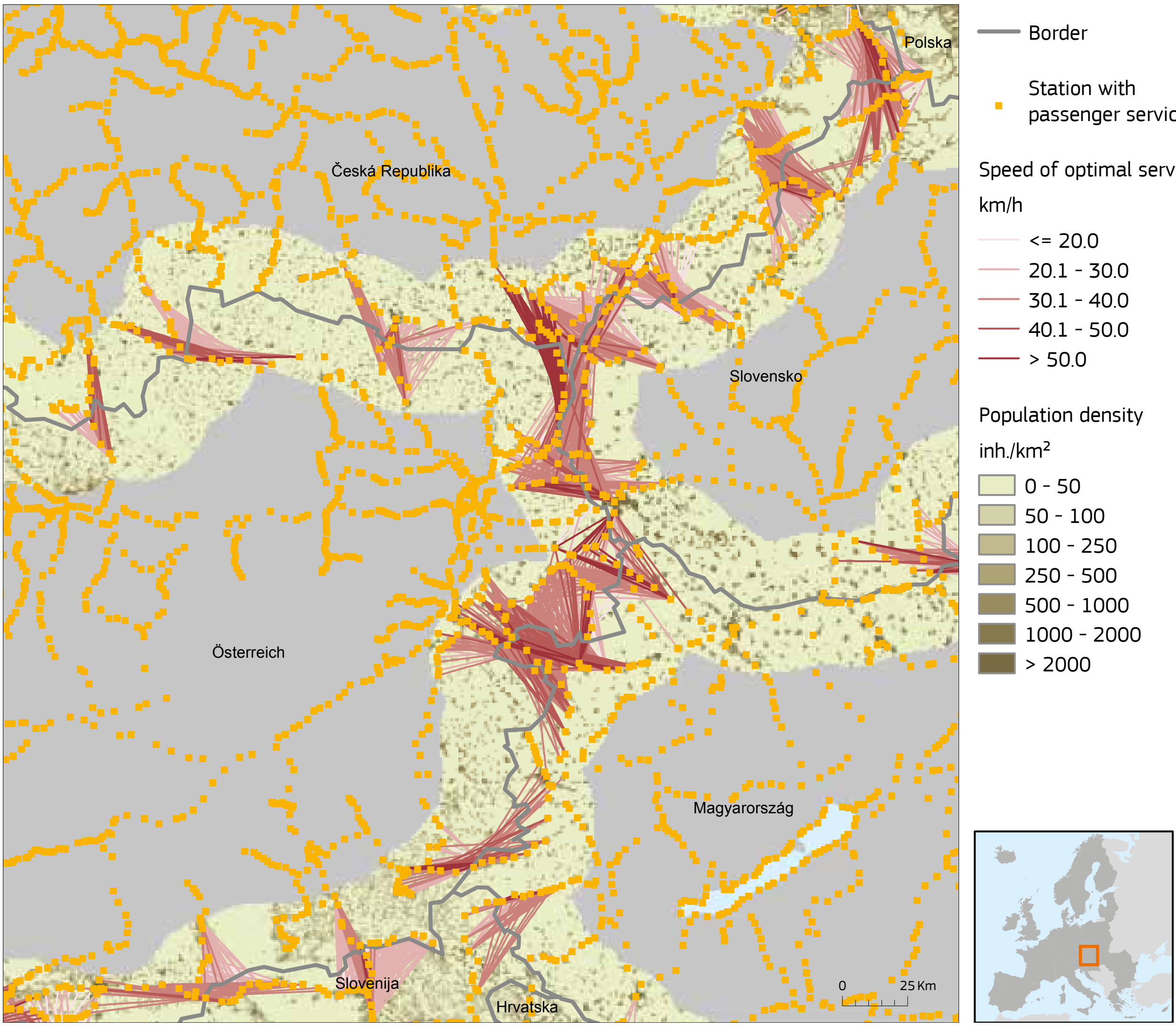
Using the origin-destination station pair, we also compute the number of different trips reported to OpenTripPlanner. For each requested departure time, OpenTripPlanner looks for the optimal trip, i.e. the one offering the earliest arrival time. If the frequency of services is low, the same trip (i.e. the one with the same departure time and the same arrival time) will be reported for several requested departure times. Counting the number of different trips reported as the optimal journey during peak hours gives an indication of the frequency of efficient services. Hence, the number of reported trips by pair of stations varies between one and nine.

Furthermore, we only keep aggregates of pairs of stations where the minimum effective travel time does not exceed 1h30. For each station pair selected (i.e. each connection within 100 km and within an optimal travel time of maximum 1h30) we can now compute the Euclidian speed by dividing the Euclidian distance by the minimum effective travel time.

The frequency of the services is assessed on the basis of the reported number of different trips. If only one optimal trip is reported, the interval between departures is at least 120 minutes. Otherwise, if more than one optimal trip is found, the average interval is 120 divided by the number of trips minus one. The main basic data and the selected connections with a maximum straight-line length of 100 km and an optimal travel time of maximum 1h30 are illustrated on Map 7.

13. A raster (or grid) divides the territory into spatial units of equal size. In this case, all units in the raster are squares with a surface of 1 km² each.

14. See www.opentripplanner.org



Map 7: Population density in border areas, stations with passenger services and straight-line speed of selected cross-border rail connections

AGGREGATIONS BY BORDER AREA

The averages of connection speed and services interval by border area are weighted according to the population living at the destinations and the places of departure. As the target population of each destination we use the sum of the residential population living in a neighbourhood of 5 by 5 km around the station. This population is calculated as the focal sum of the population at the level of 1 km² grid cells in a square neighbourhood of 5 by 5 grid cells. This focal population is allocated to the destination station. For each origin-destination pair, both travel time and service intervals are multiplied by the population at the destination.

The average speed by border area is weighted by destination population, i.e. it is the sum of the products of connection speed and destination population, divided by the sum of the destination population figures.

The border areas' speed and interval averages are computed in a two-step aggregation. First, averages are calculated for each departure station, weighted by the population around the arrival stations, i.e. it is the sum of the products of speed (or interval) and destination population, divided by the sum of the destination population figures. Specifically for the services interval, when the reported interval is 120 minutes or more, we set the value at 120.

The second step in the aggregation produces figures by border area, by calculating averages of the departure stations' values, weighted by the population living nearby these stations. We compute the population living in a 5 x 5 km neighbourhood around the departure station and multiply this figure by the average speed (or the average interval) of the services at that station. These products are added up by border area and divided by the sum of the 5 x 5 km focal population figures around all departure stations.

Finally, the averages across all border areas are weighted again by the total population living around the departure stations in the border areas.

ACKNOWLEDGMENTS

We would like to thank Olivier Draily and Emile Robe for their essential contributions to data transformation, validation and integration, and for scripting the tasks necessary for an efficient analysis. Thanks also to Lewis Dijkstra for his critical and constructive comments.

ANNEX: KEY INDICATORS BY BORDER AREA

Key indicators by border area are provided in a separate data table.

REFERENCES

European Commission (2016), Collecting solid evidence to assess the needs to be addressed by Interreg cross-border cooperation programmes. Final report:
http://ec.europa.eu/regional_policy/en/information/publications/studies/2016/collecting-solid-evidence-to-assess-the-needs-to-be-addressed-by-interreg-cross-border-cooperation-programmes

Poelman, H., Ackermans, L. (2016), Towards regional and urban indicators on rail passenger services, using timetable information. European Commission, DG Regional and Urban Policy, Brussels:
http://ec.europa.eu/regional_policy/en/information/publications/working-papers/2016/from-rail-timetables-to-regional-and-urban-indicators-on-rail-passenger-services

Wassenberg, B., Reitel, B. (2015), Territorial cooperation in Europe, a historical perspective. European Commission, DG Regional and Urban Policy (doi:10.2776/79151):
http://ec.europa.eu/regional_policy/en/information/publications/brochures/2015/territorial-cooperation-in-europe-a-historicalp-erspective

Getting in touch with the EU

IN PERSON

All over the European Union there are hundreds of Europe Direct Information Centres.
You can find the address of the centre nearest you at: **http://europa.eu/contact**

ON THE PHONE OR BY E-MAIL

Europe Direct is a service that answers your questions about the European Union.
You can contact this service
– by freephone: **00 800 6 7 8 9 10 11** (certain operators may charge for these calls),
– at the following standard number: **+32 22999696** or
– by electronic mail via: **http://europa.eu/contact**

Finding information about the EU

ONLINE

Information about the European Union in all the official languages of the EU is available on the Europa website at: **http://europa.eu**

EU PUBLICATIONS

You can download or order free and priced EU publications from EU Bookshop at: **https://bookshop.europa.eu**. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see http://europa.eu/contact)

EU LAW AND RELATED DOCUMENTS

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex at: **http://eur-lex.europa.eu**

OPEN DATA FROM THE EU

The EU Open Data Portal (**http://data.europa.eu/euodp/en/data**) provides access to datasets from the EU. Data can be downloaded and reused for free, both for commercial and non-commercial purposes.

KN-AK-17-004-EN-N

Any question, comment or contribution should be sent to the following address: **REGIO-B1-PAPERS@ec.europa.eu**

Editor: Lewis Dijkstra, European Commission, DG for Regional and Urban Policy
The texts of this publication do not bind the Commission

ISBN 978-92-79-76851-4
ISSN 2529-3303
doi:10.2776/54008