Redefining passenger rail transport performance and proximity of population to stations

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Abstract

This technical paper presents two methodological refinements of the rail transport performance indicator framework. This framework compares accessibility by rail to residential population (within a predefined maximum travel time) with proximity (population living within a predefined radius) and defines this relationship as rail performance. The framework also relies upon assumptions on who has access to rail stations nearby.

In this paper a refined assessment of proximity to stations is introduced, taking into account travel time to/from stations via the street network, combined with estimates of population numbers at high spatial resolution.

Furthermore, the paper redefines rail performance as the ratio between the number people accessible within a defined maximum time, provided that they live within a defined radius, and the total number of people living within that radius. Performance is assessed for short, medium-length and somewhat longer rail trips.

Both refinements allow for a simplified and more flexible analysis of rail performance at the level of each populated 1 km² grid cell.

Introduction

The concept of rail transport performance evaluates the accessibility of destinations within a pre-defined maximum travel time and compares this with the proximity of destinations. Travel time by rail is computed between stations, whereby all arrival stations that can be reached within the determined maximum travel time (for instance 1.5 hour) are taken into account. When analysing characteristics of passenger rail services, the departure and arrival stations themselves cannot merely be used as places of origin or destination. In other words, a passenger rail trip will only seldomly have a station as the final place of destination. Consequently, we need some assumptions on the spatial relationship between the stations and the residential population.

An earlier analysis of rail performance using timetables for 2014 and 2019 used quite simple assumptions on the proximity of population relative to stations[1]. People living in a 3x3 km environment around a station were considered to be within walking distance to/from the station,

[1] More details on the rail performance analysis using timetables for 2019 in: *Martijn Brons, Hugo Poelman, Linde Ackermans, Juan Nicolás Ibáñez and Lewis Dijkstra, 2022,*
Passenger rail performance in Europe: Regional and territorial accessibility indicators for passenger rail. Working Paper, DG Regional and Urban Policy
https://ec.europa.eu/regional_policy/information-sources/publications/working-papers/2022/passenger-rail-performance-in-europe-regional-and-territorial-accessibility-indicators-for-passenger-rail_en

whereas people living in 1 km² grid cells that have their centroid at maximum 3.2 km from a station were considered to be within easy cycling distance to/from the station. While these criteria are relatively easy to implement, they disregard the characteristics of the street network and they use a population grid cell size (1 km²) that is relatively coarse when examining local population distribution and spatial relationships within short distances.

Aiming to take a step forward in the performance analysis we envisaged an alternative solution to model the proximity of population relative to the stations. Such solution should allow the use of a fine-grained spatial distribution of population and take into account the actual accessibility to/from stations via the road network. At the same time the proximity assessment should be computationally feasible for the entire EU territory. We tested a solution using comprehensive timetables for 2019, using the results of origin/destination calculations between stations prepared for the earlier analysis of rail performance.

Furthermore, we tested and applied a revised definition of rail performance. In this revised definition, both proximity and accessibility are measured within the same radius around the place of departure. Consequently, performance only takes into account destinations that can be reached within a defined maximum travel time insofar these destination are located within the defined radius around the place of departure.

Defining short trips to/from stations

People who want to use rail services often have several options to travel to/from stations. The actual choice of access/egress travel to/from stations may be determined by numerous factors, including speed, distance, network density, terrain characteristics, network safety, weather conditions, etcetera. To determine who has (easy) access to/from stations becomes a daunting task if all such factors need to be taken into account. Moreover, a sophisticated model would require numerous detailed geospatial datasets that are not necessarily available throughout the whole European territory. Using available EU-wide data we defined proximity to/from stations in a relatively simple way. Around each station we determined the area that can be reached within 15 minutes via the entire road network (i.e. including all major and minor roads and local and residential streets), at a speed of 15 km/h. These parameters have been chosen as a proxy of various travel situations:

- A short bike ride at a realistic, moderate speed.
- A short car ride, including time for parking and possible congestion.
- A short trip by public transport, assuming that, when some public transport is available, a railway station will probably amongst the destinations served.

For each of the areas reachable within 15 minutes the residential population is calculated. For this purpose a 200 x 200 m population grid is used as representation of people's location. All people living in grid cells that have their centre in the area reachable within 15 minutes are considered to live in the proximity of the stations.

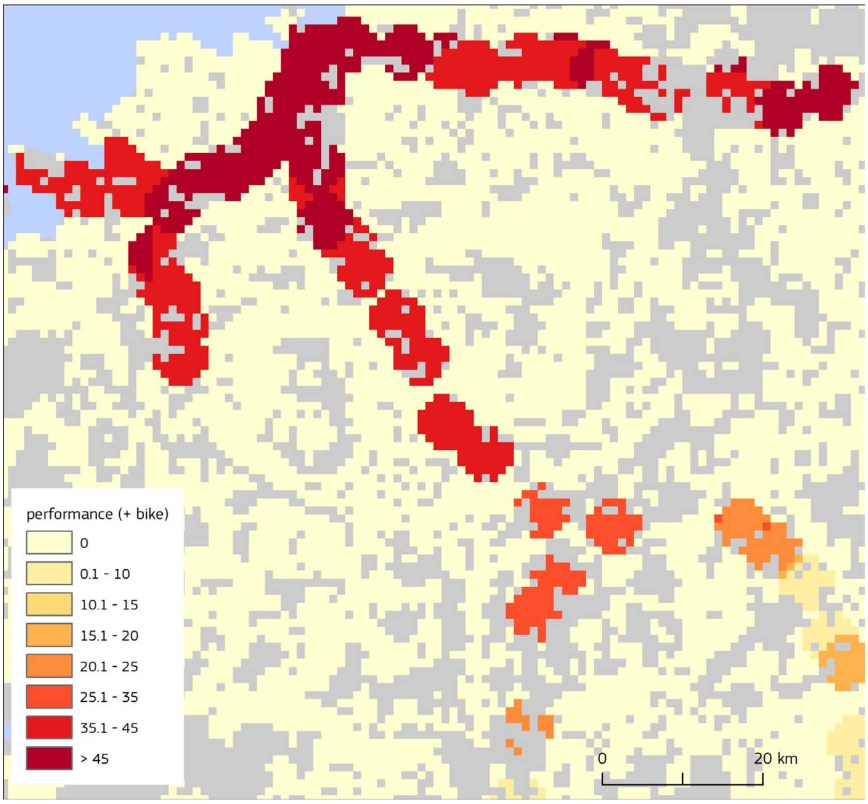
Calculating accessibility and performance

Using this definition of proximity to stations, the accessible residential population is defined as the number of people living in an area reachable within 15 minutes at a speed of 15 km/h around any station that can be reached by train within 1.5 hour. This figure is allocated to any populated place that is within 15 minutes travel at 15 km/h around a departure station.

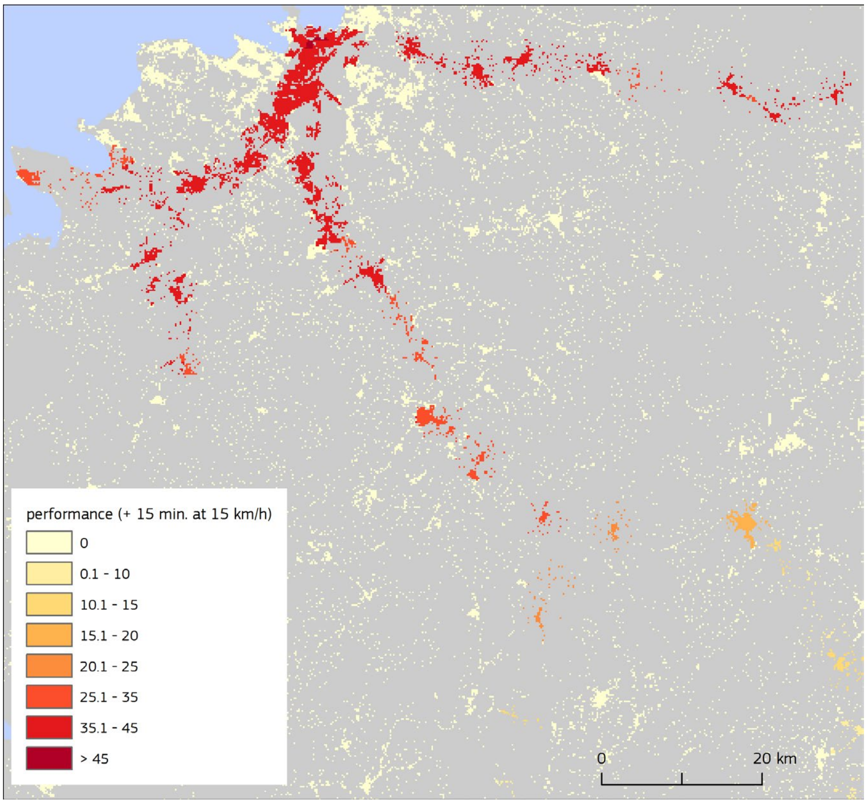
For each populated place nearby departure stations rail performance is calculated by dividing the accessible population by the number of people living in a 120-km radius and multiplying the result by 100. Aggregated figures by NUTS3 region show that performance of rail travel combined with a trip up to 15 minutes to or from the stations lies somewhere in the middle between the scenarios where we modelled proximity by means of 1 km² grid. Table 1 provides this comparison for the NUTS3 regions of Estonia. Maps 1 and 2 illustrate the difference in performance and of spatial definition of proximity to stations in part of Estonia. Map 3 shows the performance metric aggregated by NUTS3 region.

		Optimal rail trips combined with a short trip to/from the station					
		Scenario using 1 km² grid cells				Scenario using 200 m grid cells	
		Walk + rail + walk		Bike + rail + bike			
		Population within a 3 x3 km environment around stations	Rail performance	Population within a 3.2 km radius around stations	Rail performance	Population within a 15-minutes walk to a station	Rail performance
EE001	Põhja-Eesti	239 733	12.4	379 262	32.4	320 140	**23.1**
EE004	Lääne-Eesti	10 301	0.1	32 816	0.8	22 573	**0.3**
EE008	Lõuna-Eesti	86 618	2.2	146 790	7.0	123 320	**4.9**
EE009	Kesk-Eesti	32 488	4.9	53 819	14.8	49 982	**11.1**
EE00A	Kirde-Eesti	39 800	2.8	98 303	16.8	84 277	**12.0**

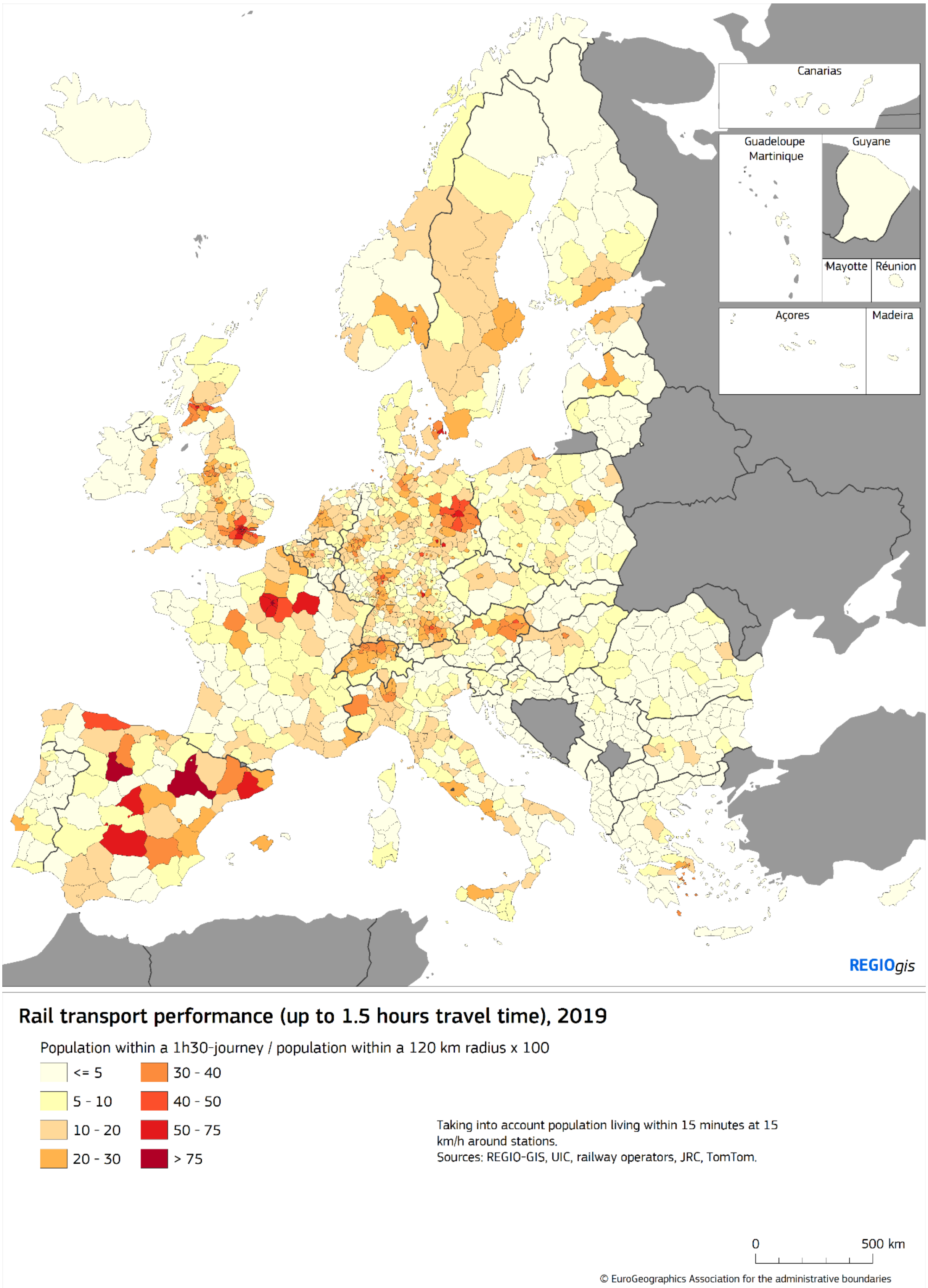
Table 1: Comparison of station proximity definitions and related rail performance metrics for the NUTS3 regions of Estonia.



Map 1: Rail performance in part of Estonia, combined with areas within 3.2 km radius around stations (bike + rail + bike scenario).



Map 2: Rail performance in part of Estonia, combined with areas within 15 minutes at 15 km/h around stations.



Map 3: Rail transport performance of all trips up to 1.5 hours of travel time, combined with population living within 15 minutes at 15 km/h around stations.

In most cases performance lies between 0 and 100, but in places where high-speed rail services are available that allow travel within 1.5 hour to major cities located at more than 120 km from the place of departure performance can exceed 100.

Redefining performance

Alternatively, the performance metric can be redefined as the share of people living in a 120-km radius that can be reached within a 1.5-hour trip by rail (to be combined with the short trips to/from the stations as required). In that way, performance will always be a value between 0 and 100 %, excluding the benefit of longer-distance high-speed trips.

Table 2 provides the list of EU27 NUTS3 regions where performance of rail trips up to 1.5 hour exceeds by at least 5 percentage points the performance of rail trips up to 1.5 hour within a 120-km radius. These are regions that benefit from higher-speed connections that serve destinations reachable within 1.5 hour. Many of these regions are found in Spain, France and Germany. Several of these are predominantly rural or intermediate regions but are located within reach of a large city to which one can travel at high speed. If that city falls outside the 120 km radius it boosts the performance value if the latter is not constrained to trips within the 120 km radius. Other regions are urban regions themselves, benefiting from good and fast connections to a wide variety of destinations.

NUTS3 region		Urban/rural typology	Performance (trips up to 1.5 h)	Performance (trips up to 1.5 h within 120 km radius) (%)	Difference (percentage points)
			a	b	a-b
ES418	Valladolid	intermediate	114.3	21.9	92.4
ES422	Ciudad Real	intermediate	70.4	6.8	63.6
ES243	Zaragoza	predominantly urban	91.4	32.4	59.0
FRF23	Marne	intermediate	74.7	18.9	55.9
ES513	Lleida	intermediate	35.8	2.0	33.8
ES421	Albacete	intermediate	39.5	10.1	29.4
FRG04	Sarthe	predominantly rural	35.4	6.6	28.9
DEE02	Halle (Saale), Kreisfreie Stadt	intermediate	53.5	34.2	19.3
FRB04	Indre-et-Loire	intermediate	29.8	10.9	18.9
ES423	Cuenca	predominantly rural	18.6	0.8	17.7
DE254	Nürnberg, Kreisfreie Stadt	predominantly urban	51.5	34.4	17.1
DED51	Leipzig, Kreisfreie Stadt	predominantly urban	58.9	42.1	16.8
AT312	Linz-Wels	intermediate	34.4	19.7	14.7
DE40F	Prignitz	predominantly rural	31.0	16.3	14.7
ES414	Palencia	intermediate	31.6	17.2	14.4
ITC11	Torino	predominantly urban	33.5	20.3	13.2
DEG0N	Eisenach, Kreisfreie Stadt	predominantly rural	29.2	19.2	10.0
FRF22	Aube	intermediate	11.8	2.7	9.2
EL612	Larisa	intermediate	16.6	8.2	8.4
FR101	Paris	predominantly urban	85.3	77.2	8.2
DEG01	Erfurt, Kreisfreie Stadt	intermediate	42.9	35.3	7.7
DE712	Frankfurt am Main, Kreisfreie Stadt	predominantly urban	48.7	41.5	7.1
DE253	Fürth, Kreisfreie Stadt	predominantly urban	40.8	33.7	7.1
SE313	Gävleborgs län	intermediate	16.8	10.3	6.5
DE731	Kassel, Kreisfreie Stadt	intermediate	25.8	19.4	6.5
ES613	Córdoba	predominantly urban	19.2	13.0	6.2
SE123	Östergötlands län	intermediate	16.3	10.2	6.2
FRE12	Pas-de-Calais	intermediate	18.1	12.0	6.1
FRE11	Nord	predominantly urban	23.5	17.5	6.0
DE300	Berlin	predominantly urban	71.3	65.6	5.7
DE252	Erlangen, Kreisfreie Stadt	predominantly urban	32.9	27.5	5.5
FRI34	Vienne	predominantly rural	10.0	4.8	5.2
DE255	Schwabach, Kreisfreie Stadt	predominantly urban	36.4	31.3	5.1

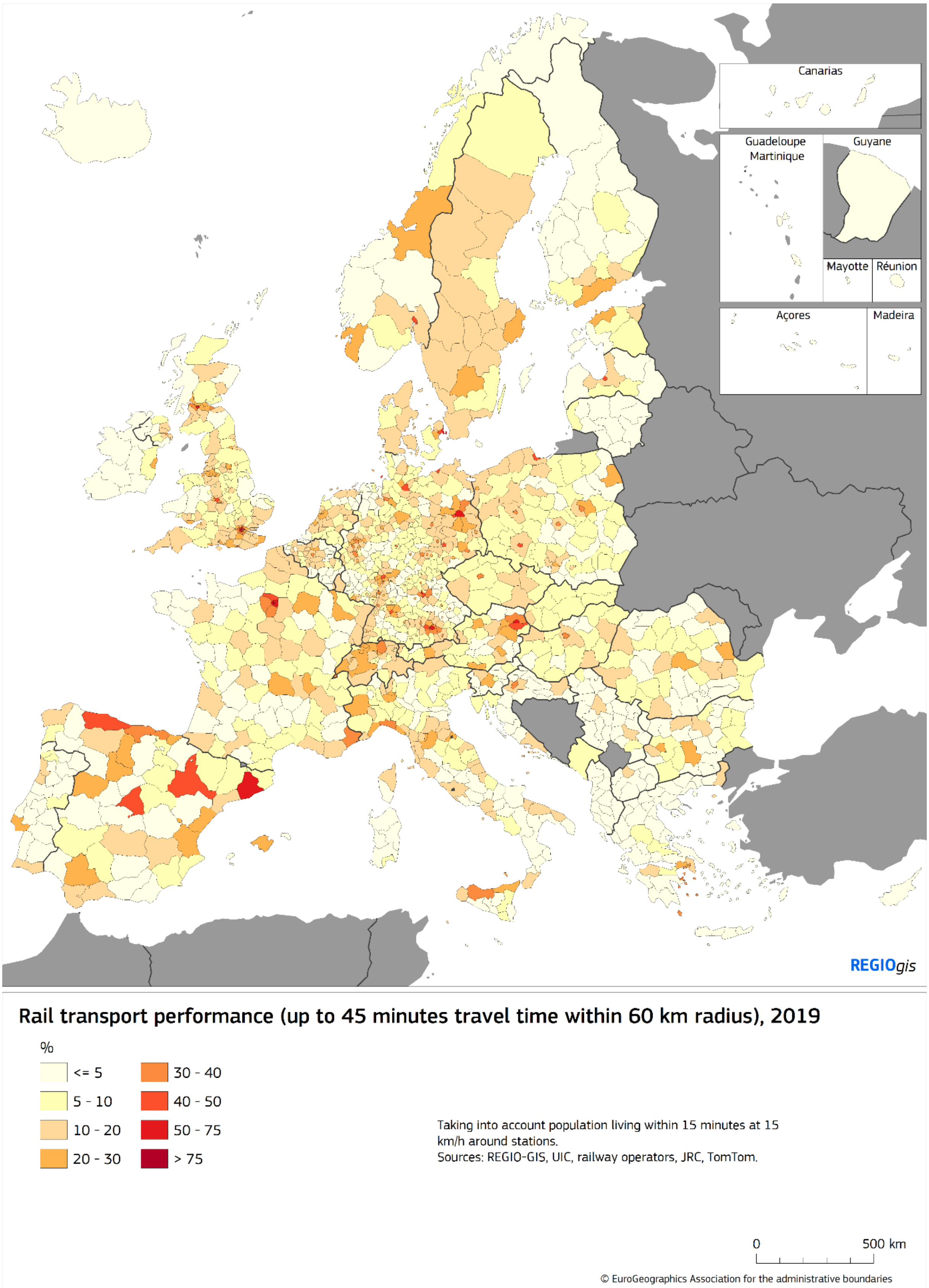
Table 2: Comparison of performance of trips up to 1.5 hour without distance constraint or within a 120-km radius (EU27 regions where the difference exceeds 5 percentage points).

Constraining the accessibility calculation to destinations within a predefined radius has also a clear technical advantage. It means that only stations that lie within the predefined distance need to be considered as potential destinations when setting up the origin/destination calculations between stations. This constraint substantially reduces the computational burden and opens opportunities to calculate accessibility and performance at a wider range than the maximum trip length of 1.5 hour.

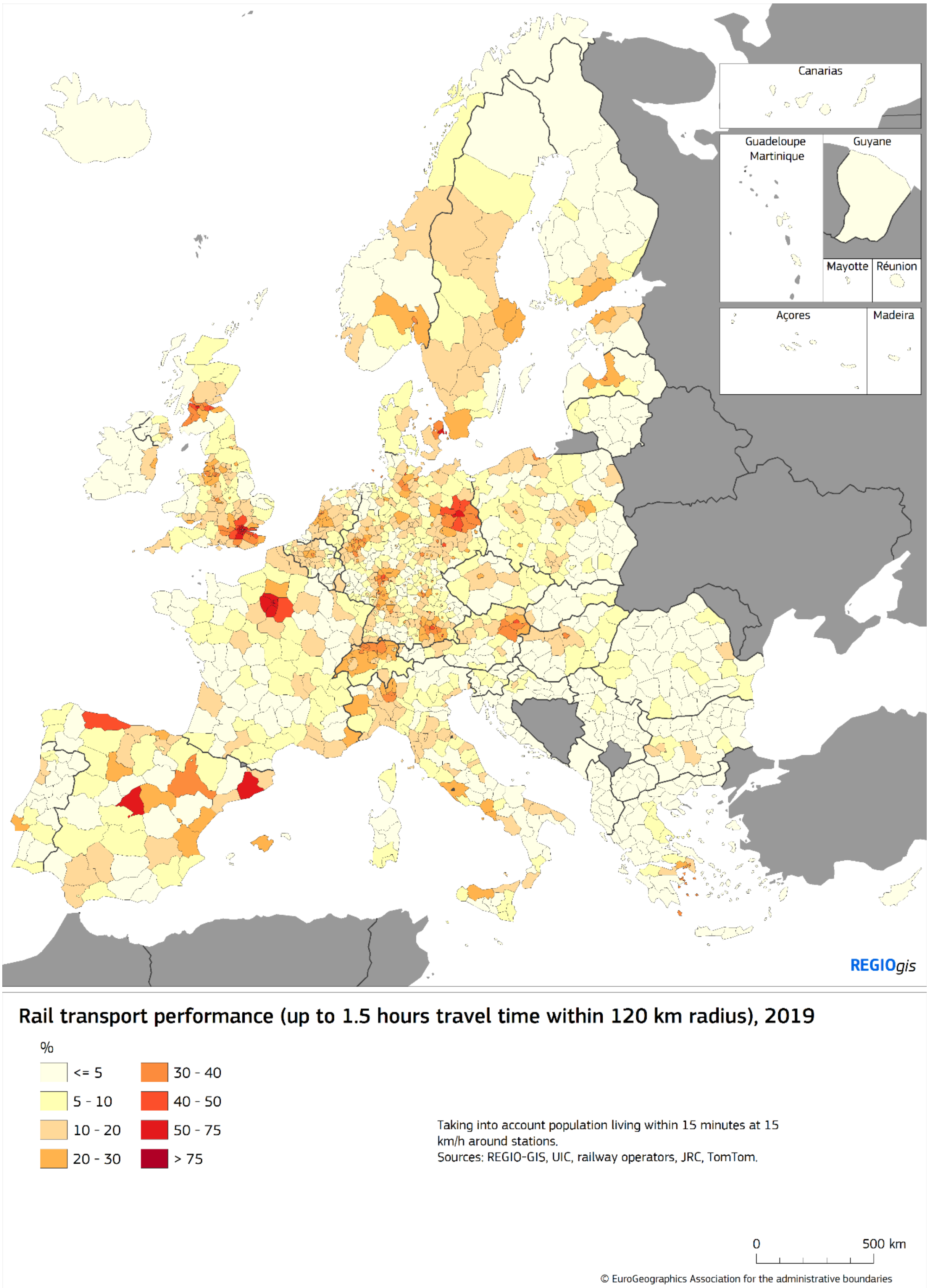
Using that approach we have calculated three variants of accessibility, proximity and performance:

A) Short distance: rail trips up to 45 minutes, within an area of 60 km radius (Map 4);
B) Medium distance: rail trips up to 90 minutes, within an area of 120 km radius (Map 5);
C) Longer distance: rail trips up to 3 hours, within an area of 240 km radius (Map 6).

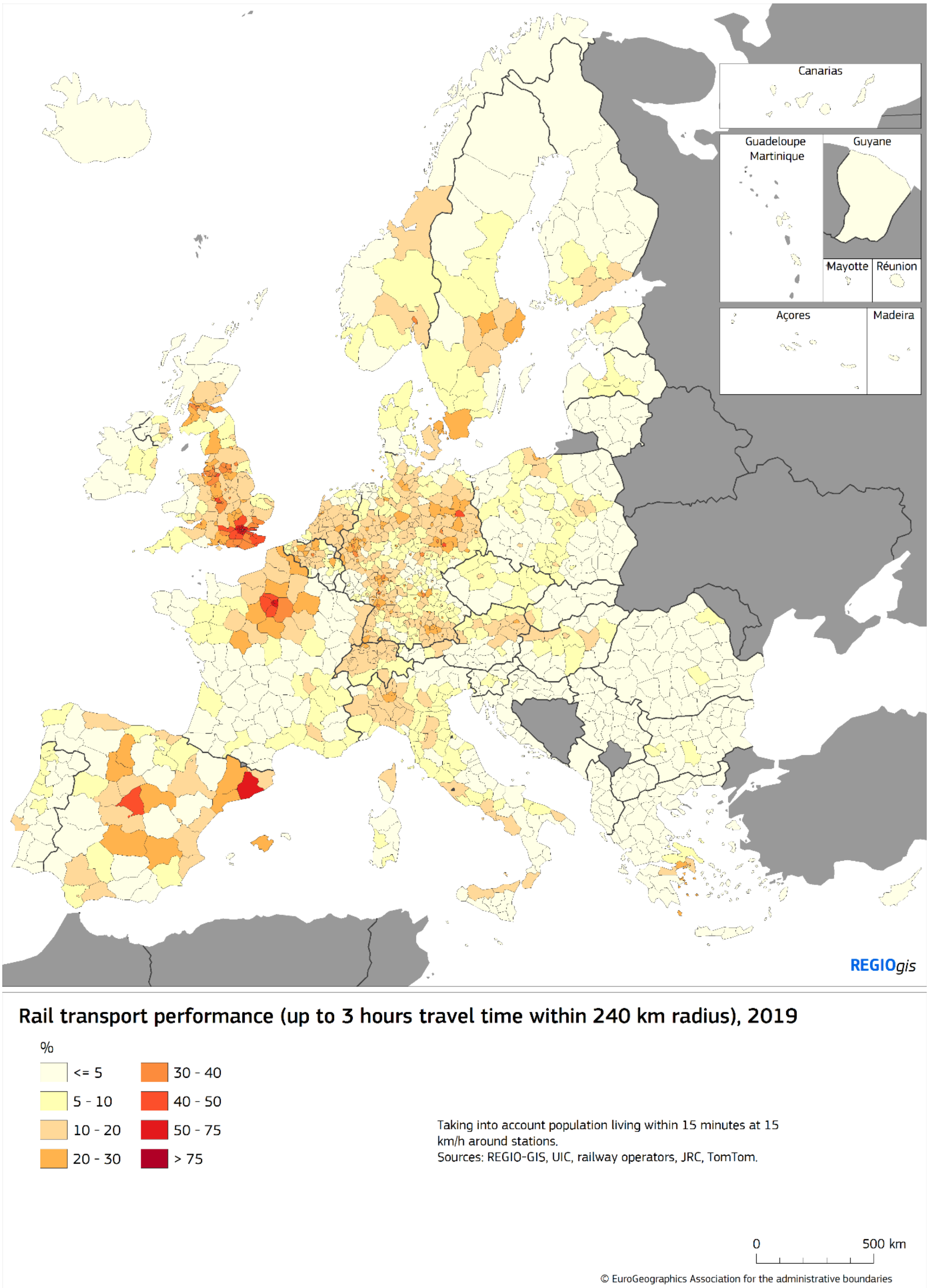
The performance metrics referring to the three maximum trip lengths can also be averaged. The average performance (Map 7) reflects the performance of short, medium-length and somewhat longer trips in a single figure by region.



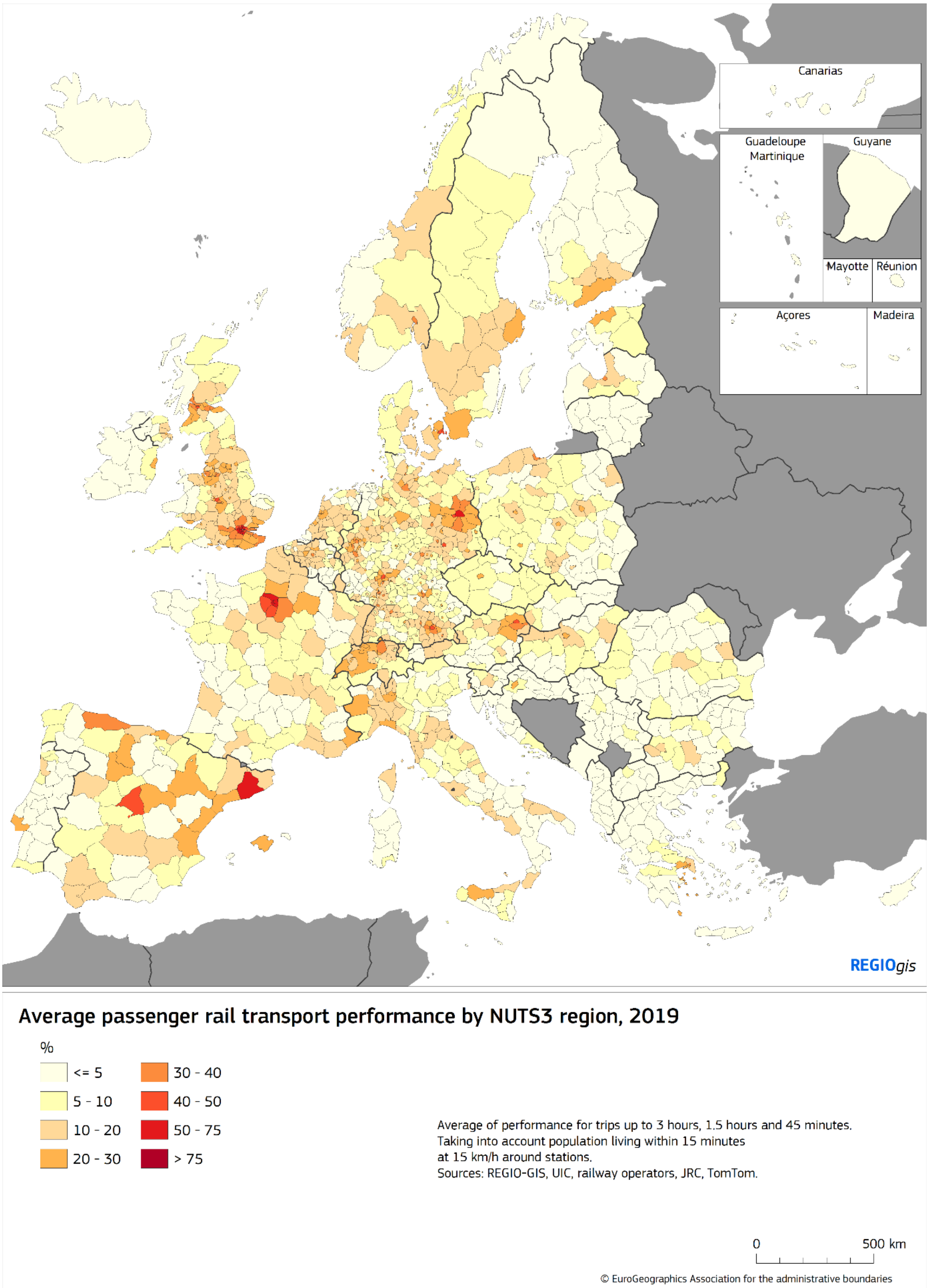
Map 4: Rail transport performance of trips up to 45 hours of travel time within a 60-km radius, combined with population living within 15 minutes at 15 km/h around stations.



Map 5: Rail transport performance of trips up to 1.5 hours of travel time within a 120-km radius, combined with population living within 15 minutes at 15 km/h around stations.



Map 6: Rail transport performance of trips up to 3 hours of travel time within a 240-km radius, combined with population living within 15 minutes at 15 km/h around stations.



Map 7: Average passenger rail transport performance, combined with population living within 15 minutes at 15 km/h around stations.

While at first glance these performance maps show a similar pattern, some notable differences can be observed. A good performance for trips up to 45 minutes is found in a wide variety of (often urban) regions throughout the European territory. Good performance for trips up to 1.5 hour is more concentrated in and around major urban regions. Performance for trips up to 1.5 hour also shows a more pronounced east/west divide than shorter trips. Finally, good performance for longer trips (up to 3 hours within a 240-km radius) essentially relies upon the presence of a high-speed network.

Conclusion

Using service areas based on comprehensive street network geodata in combination with fine-grained population location data allows to improve the representation of the proximity of population relative to rail stations. The way proximity to stations is modelled in this analysis aims to provide compromise between level of spatial detail, computational capacity and representation of real-life behaviour of people when travelling to/from rail stations. The use of a single definition of proximity to stations opens opportunities to calculate a multi-scalar set of rail performance indicators. These indicators are designed to highlight the provision of different functions of the available rail services, such as commuting opportunities, suitability for day trips and occasional longer-distance travel.

Redefining performance by measuring accessibility to population within a predefined radius facilitates the interpretation of the performance metrics and allows for an easier and more flexible computation of indicators related to rail trips of various length.

Annex

A data annex, available at https://ec.europa.eu/regional_policy/information-sources/publications/working-papers/2022/passenger-rail-performance-in-europe-regional-and-territorial-accessibility-indicators-for-passenger-rail_en provides figures on proximity, accessibility and performance by NUTS3 region and by urban centre (in the EU, EFTA countries, UK and Western Balkans).