Working Papers

ROAD TRANSPORT PERFORMANCE IN EUROPE

Introducing a new accessibility framework

LEWIS DIJKSTRA, HUGO POELMAN AND LINDE ACKERMANS

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ABSTRACT

In Europe, governments invest EUR 100 billion in transport each year to provide people and firms with better access. Accessibility indicators can be used to capture the benefits of these investments, for example by measuring how many destinations can be reached. In that sense, they are a significant improvement over indicators such as speed, capacity or congestion. However, they are seldom used in decision-making. Furthermore, accessibility indicators often primarily reflect the spatial distribution of destinations rather than the performance of transport networks.

This paper presents a new accessibility framework that captures through a set of indicators both accessibility and transport performance. First, we determine how many people can be reached within a 90-minute drive (accessible population or accessibility) from a specific location. Then we check how many people live within a radius of 120 km (nearby population or proximity) of that location. This functions as a benchmark. If the entire nearby population can be reached quickly, the transport network is performing well. Transport performance is defined as the accessible population divided by the nearby population. We do this for all the 2 million inhabited square grid cells of 1 km² in the European Union (EU) and the European Free Trade Association (EFTA). To aggregate this data to a city or region, we take the population weighted average of all the cells within the city or region. In this way, we can capture the average accessibility and transport performance experienced by the residents of that city or region.

Within the EU, Bulgaria, Croatia, Poland, Romania and Slovakia have the lowest transport performance, while Belgium and the Netherlands score highest. The performance of Spain and Portugal, which have benefited from a longer period of Cohesion Funds, is now above the EU average.

However, the transport performance of a country also depends on how urbanised it is. Most metropolitan regions outperform other regions. On average, cities outperform rural areas although not all cities perform that well. Cities in eastern EU Member States achieve a lower performance, especially the smaller ones.

This paper presents the results for road travel; an accompanying paper does the same for rail travel.

CONTENTS

Introduction

Over the last decade, governments in the EU spent almost EUR 300 billion a year on transport. Public investment in transport reached over EUR 100 billion a year, accounting for roughly a quarter of total public investment (Eurostat). According to data from the International Transport Forum (ITF), the majority of those investments is used for roads. Road transport is clearly considered to be an essential service. Even slightly improving the impact of these investments could generate large benefits.

Transport analysis has traditionally focused on improving speeds and capacity. However, these measures do not fully capture the benefit that transport infrastructure provides. As a result, many researchers and organisations have promoted the use of accessibility indicators. Instead of measuring how fast or how many cars can use a specific road segment, accessibility indicators take into account the number of destinations that can be reached.

Although accessibility metrics are an improvement over speed and capacity metrics, their use in policymaking has been limited (ITF 2019b) because of three problems. First, accessibility indicators primarily reflect the spatial distribution of the population or destinations and not the performance of the transport network. Therefore, they cannot be used to assess or compare transport performance. Second, there is a myriad of accessibility indicators and no consensus on which should be used. Third, accessibility metrics are more time consuming to compute. Fortunately, all these obstacles can be overcome.

This paper describes a new accessibility framework: first it measures accessibility before identifying how both transport performance and proximity contribute to it.

In addition, it uses the degree of urbanisation to compare similar places with each other. Accessibility and transport performance differ structurally between cities and rural areas. As a result, we compare cities with cities and rural areas with rural areas, which makes comparisons more realistic and informative.

In parallel to this paper, we have worked with the ITF and the Organisation for Economic Co-operation and Development (OECD) to develop a new urban accessibility framework which aims to build a consensus around a new and small set of indicators. While the urban indicators focus on short (15 to 45 minutes) trips inside a functional urban area, this paper deals with longer trips (90 minutes) and covers the entire territory of EU and EFTA countries

With more powerful computers and cloud computing, it has become easier to calculate accessibility metrics for large areas – for example, this paper covers all of the EU and EFTA. The calculations took several months, but it shows that the framework can be applied for larger territories.

1. EARLIER EU-WIDE ACCESSIBILITY STUDIES

Several ESPON studies have analysed accessibility within the EU. Territorial Dynamics in Europe: Trends in Accessibility[1], for example, measures the potential access to population and gross domestic product (GDP) by NUTS-3 region. This potential accessibility indicator uses a distance-decay function to simulate the greater importance of destinations nearby compared to more remote ones. Inevitably, the shape and slope of this decay function have a big impact on the outcome. A slow decay function leads to a strong core periphery effect, while fast decay functions show more variation with high accessibility for large agglomerations outside the core of the EU, too. Theory does not provide a clear indication as to what kind of decay function should be used. As decay functions make the result more difficult to interpret and are more time consuming to calculate, we opted to sum the population within a fixed time-travel threshold of 90 minutes. This travel time was chosen to measure regional accessibility, i.e. a trip that allows for a return trip plus time for a (half) day meeting. The same approach can be used with shorter times to capture local accessibility. This is approach is also known as a cumulative opportunity or isochrone method (Miller 2018).

These studies, and many others, use a single point to represent a NUTS-3 region. However, this creates two problems: first, a single point cannot properly represent an entire NUTS-3 region, especially if it covers a large area and a dispersed population. This method assumes that travelling from the centre of NUTS-3 region to the centre of another NUTS-3 region is a good approximation of the average travel time between all people in one NUTS-3 region and all people in another NUTS-3 region. In NUTS regions covering a large area, this approximation is less accurate, while NUTS-3 regions[2] vary a lot in size. The largest NUTS-3 regions are around 100 000 km²: Norrbottens län in Sweden and Lappi in

Finland. The smallest are around 25 km²: Melilla and Ceuta in Spain and Tower Hamlet and Westminster in the UK. In short, the size of NUTS-3 regions differs by a factor of 4000.

Secondly, the method does not solve the issue of how to consider access to the population within the NUTS-3 regions, so-called self-accessibility. Studies have responded to this problem in three different ways: 1) exclude self-accessibility; 2) include self-accessibility with zero travel time; and 3) include self-accessibility with an estimated self-accessibility travel time specific to each NUTS-3 region. All three responses are suboptimal as a change in the size or number of the NUTS-3 regions would change the outcome without any changes in the transport network or the population. For larger NUTS-3 regions this would mean that a large population is either excluded, included with zero travel costs, or included with a different method to estimate travel time.

Accessibility studies with EU-wide coverage use points for entire NUTS-3 regions because this is computationally far more efficient. Using local administrative units would mean using almost 100 000 points compared to only 1 348 NUTS-3 regions. Likewise, using local administrative units does not solve the problem of the differences in the shape and size of the spatial units – it merely reduces it. Starting from local administrative units would also change the results at the NUTS-3 level and thus reducing comparability.

Using a population grid with cells of 1 by 1 km as both origins and destinations solves this issue because: a) these cells have the same shape and size; and b) assuming zero travel time to the population within this cell for analysing regional accessibility does not significantly distort the results. However, it does mean that calculations have to be done for the approximately 2 million inhabited grid cells, which is only feasible thanks to better computing power and cloud computing. The benefit of starting with small grid cells is that the results can be aggregated to local administrative units and to NUTS regions without losing comparability.

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[1]. https://www.espon.eu/topics-policy/publications/territorial-observations/territorial-dynamics-europe-trends-accessibility
[2]. Regions in the European Union.

2. MEASURING HOW TRANSPORT PERFORMANCE AND PROXIMITY BOOST ACCESSIBILITY

Accessibility or cumulative opportunities are often expressed as a volume of opportunities that are within reach, for instance, an absolute number of inhabitants or a volume of GDP. While this is unquestionably an important characteristic of accessibility, it ignores the differences in spatial concentration of opportunities in the surroundings of the place of departure.

Many accessibility indicators are so heavily influenced by the spatial distribution of population that the impact of the transport network is barely visible. Only by using fast distance-decay functions and showing the difference in accessibility before and after the construction of a better network can the impact be seen, as shown in the 7th Cohesion Report (EC 2017).

This paper proposes a new approach to distinguishing how the transport network boosts accessibility from the impact of population distribution. This can be applied to any mode of transport, but this paper explores accessibility by car. A companion paper covers passenger rail trips. A recent ITF paper uses the same approach to capture local accessibility in functional urban areas for walking, cycling, driving and public transport. It uses three shorter travel times: 15, 30 and 45 minutes (ITF 2019a).

We have opted for three simple metrics which are easy to interpret:

1. Accessibility is the total number of destinations that can be reached within a fixed period of time. This depends on the density and speed of the road network and the spatial distribution of the destinations.
   In this paper, we have used a 90-minute threshold with (very) population as the destination.
2. Proximity is the total number of destinations located within a fixed distance. It captures the spatial distribution of destinations, and depends on planning, policy and investment decisions.
3. Transport performance is the ratio between accessibility and proximity. It compares the number of accessible destinations to the number of nearby destinations. In other words, it shows the performance of a transport mode while controlling for the spatial distribution of destinations. This ratio is multiplied by 100.
   A ratio of 100 or more means the mode performs (very) well; a ratio close to 0 means the mode performs poorly in providing access to nearby destinations.

To capture the experience of an average resident, these three indicators are aggregated using a population-weighted average. It can be aggregated by local administrative units, regions, countries, cities or degree of urbanisation.

3. BRIEF EXPLANATION OF THE METHOD

We start with a residential population grid with square grid cells of 1 km² in Europe[3]. All these grid cells, including their population figures, are used both as places of origin and destination.

Since we want to measure regional accessibility, we will look for all the destinations that can be reached within 90 minutes. This is a reasonable journey time allowing for a return trip within a day and for a (half) day meeting. Thus, for each of the departure grid cells, we compute the number of residents who can be reached within 90 minutes (accessibility).

To capture transport performance, we need to control for the spatial distribution of the destinations. For this purpose, we computed the population living within a 120-km radius around the point of departure (proximity). This is would be identical to the accessible population if it was possible to travel as the crow flies at a speed of 80 km/h.

Finally, by dividing the accessible population (within 90 minutes) by the nearby population (within a 120-km radius) multiplied by 100 we are able to calculate transport performance.

The reference years used for this analysis depend on the availability of the required datasets. The road network depicts the situation in 2016; the population grid refers to the year 2011 (census year).

Map 1 illustrates the different concepts in the case of Luxembourg. Starting from the city of Luxembourg, the area accessible by road within 90 minutes includes Namur, Liège, Koblenz, Kaiserslautern, Nancy and Charleville-Mézières. The number of people who can be reached in 90 minutes – i.e. the accessible population – is 5.97 million.

To assess if the accessible population is high or low, we have compared it to a neutral benchmark, the population within a 120-km radius. The residential population within 120 km from the same point in Luxembourg City is 5.53 million. This represents the nearby population or proximity.

The ratio between accessibility and proximity (or accessible population divided by the nearby population) times 100 gives the transport performance by car equals 93 = 5.53 million / 5.97 million * 100.

The accessible population falls mainly within the 120-km radius, although along some of the major highways it extends beyond that circle. For example, Namur is more than 120 km away but can be reached within 90 minutes. Therefore, in some cases, the accessible population can be larger than the nearby population, resulting in a transport performance greater than 100.

A more in-depth methodological description can be found in annex 1 to this paper.

MAP 1: Areas accessible within 90 minutes and within 120-km radius around the city of Luxembourg

Area within 120 km radius
Area accessible by road

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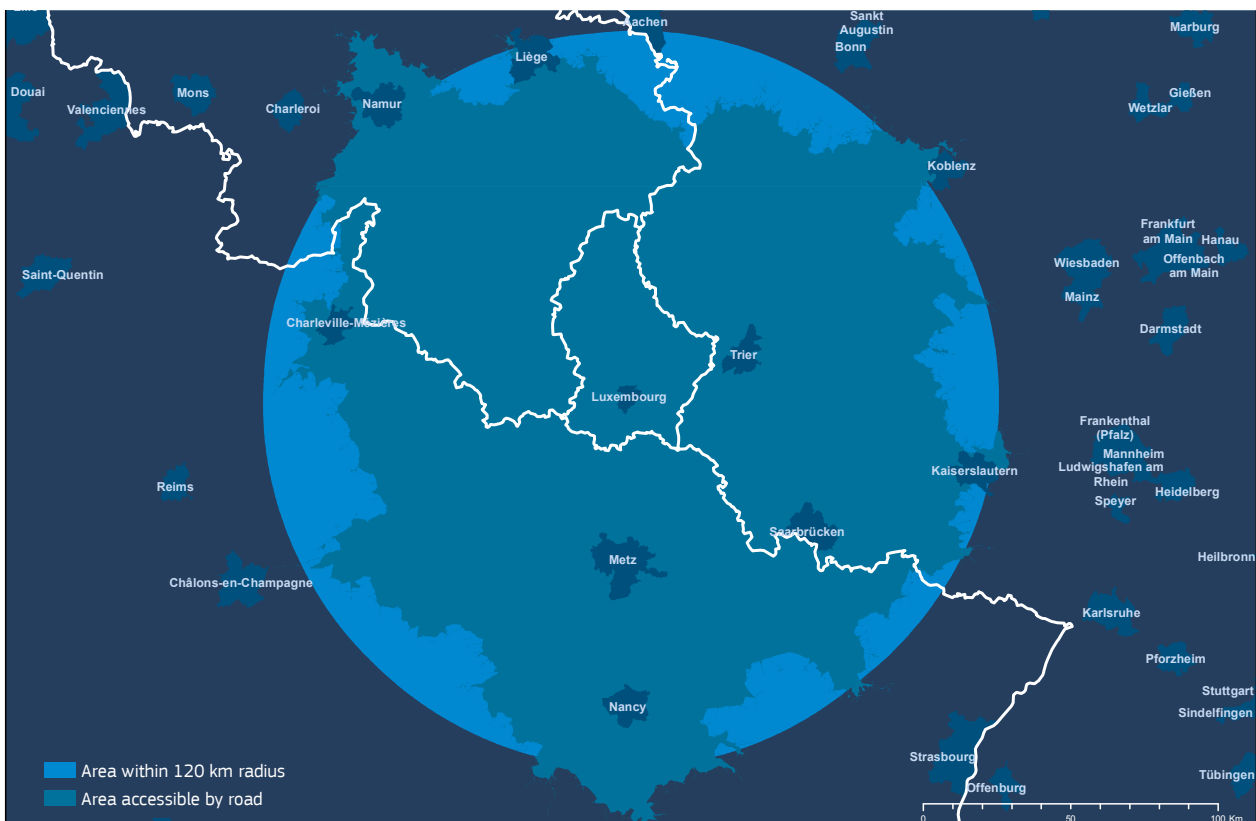
[3]. The analysis covers the EU-28 and EFTA countries (Iceland, Liechtenstein, Norway and Switzerland), including the outermost regions. In the EU-28 + EFTA countries, there are about 2 million populated 1 km² grid cells.
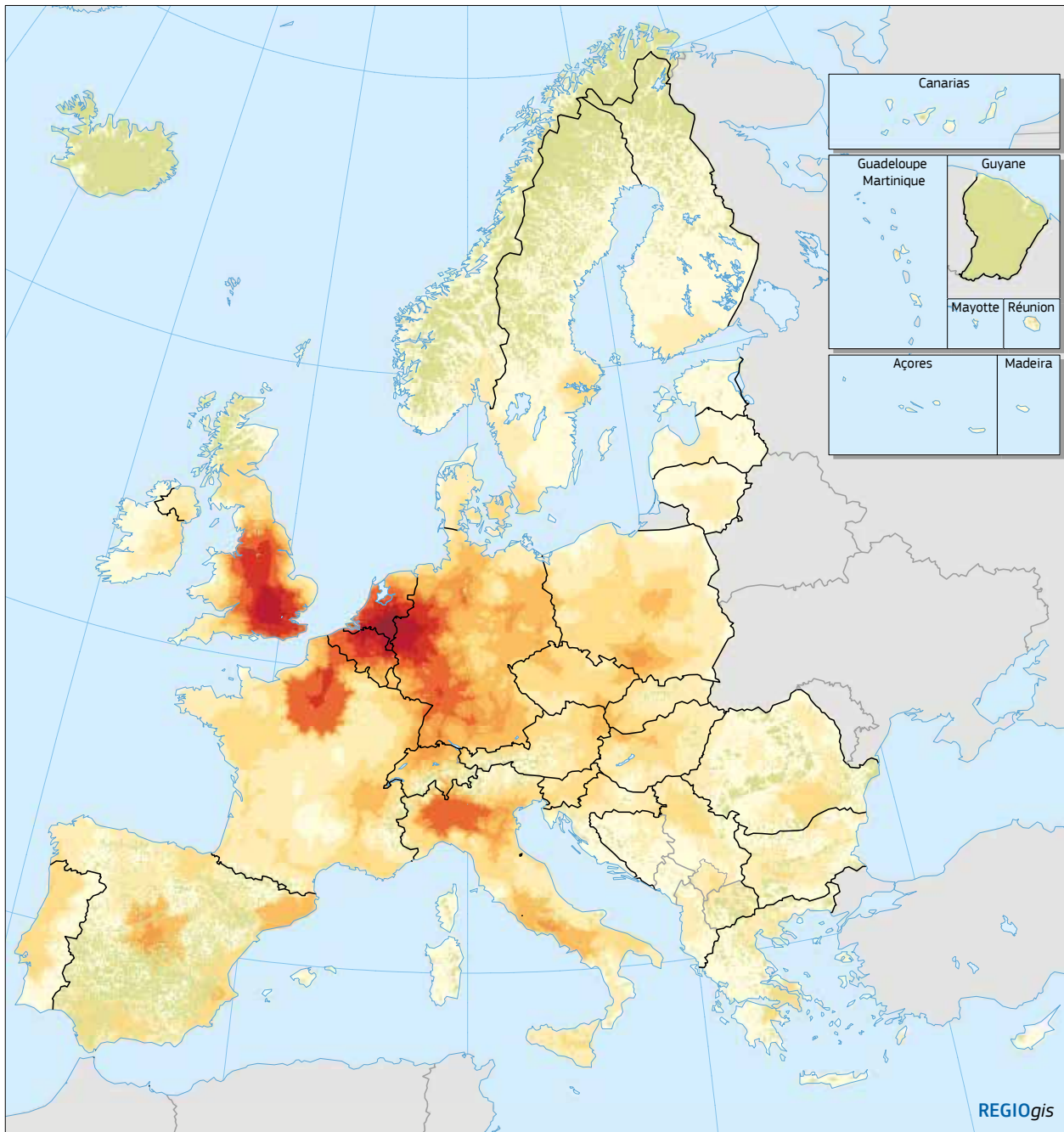
3.1   ACCESSIBILITY

Accessibility patterns measured at grid-cell level provide a subtle and varied pattern. This is not surprising given that we are dealing with more than 2 million observations, i.e. the number of populated grid cells in the EU + EFTA. These patterns may be quite hard to capture on small Europe-wide maps. A complete and more in-depth exploration of local and regional grid-level results is possible using the interactive map viewer that accompanies this paper[4].

Map 2 shows the accessible population by road, i.e. the number of inhabitants who can be reached within 90 minutes[5]. Travel times are computed using an estimate of free-flow speed. Possible congestion issues are not taken into account as congestion data has yet to cover all EU and EFTA countries. In congested areas, car performance would be much lower if congestion had been taken into account. Obviously, to a large extent, this map reflects the big population concentrations in the north of Italy and in north-western Europe where, in some areas, more than 25 million people can be reached in less than 90 minutes. Please note that this map and the following ones only depict the accessible population starting from inhabited grid cells. Non-inhabited grid cells are shown in light green.

[4].   https://ec.europa.eu/regional_policy/mapapps/transport/rail_road_accessibility.html

[5].   For the purposes of quantifying accessible population, the area of analysis (i.e. EU-28 + EFTA) is considered to be a closed system, which means that destinations outside this area are not taken into account. As an exception to this rule, road accessibility from areas bordering the Western Balkans also includes the accessible population living in non-member countries.

MAP 2: Accessibility: population within a 90-minute drive, 2016

Accessibility: within a 90-minute drive, 2016

Millions of inhabitants
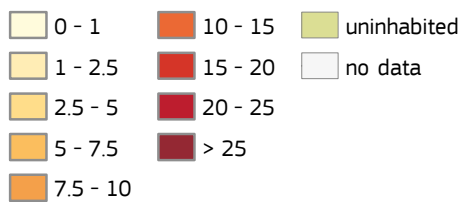
0 – 1	10 – 15	uninhabited
1 – 2.5	15 – 20	no data
2.5 – 5	20 – 25	
5 – 7.5	> 25	
7.5 – 10		

Map shows the population weighted average for cells of 5x5 km for better visualisation. Analysis was done for 1x1 km cells.
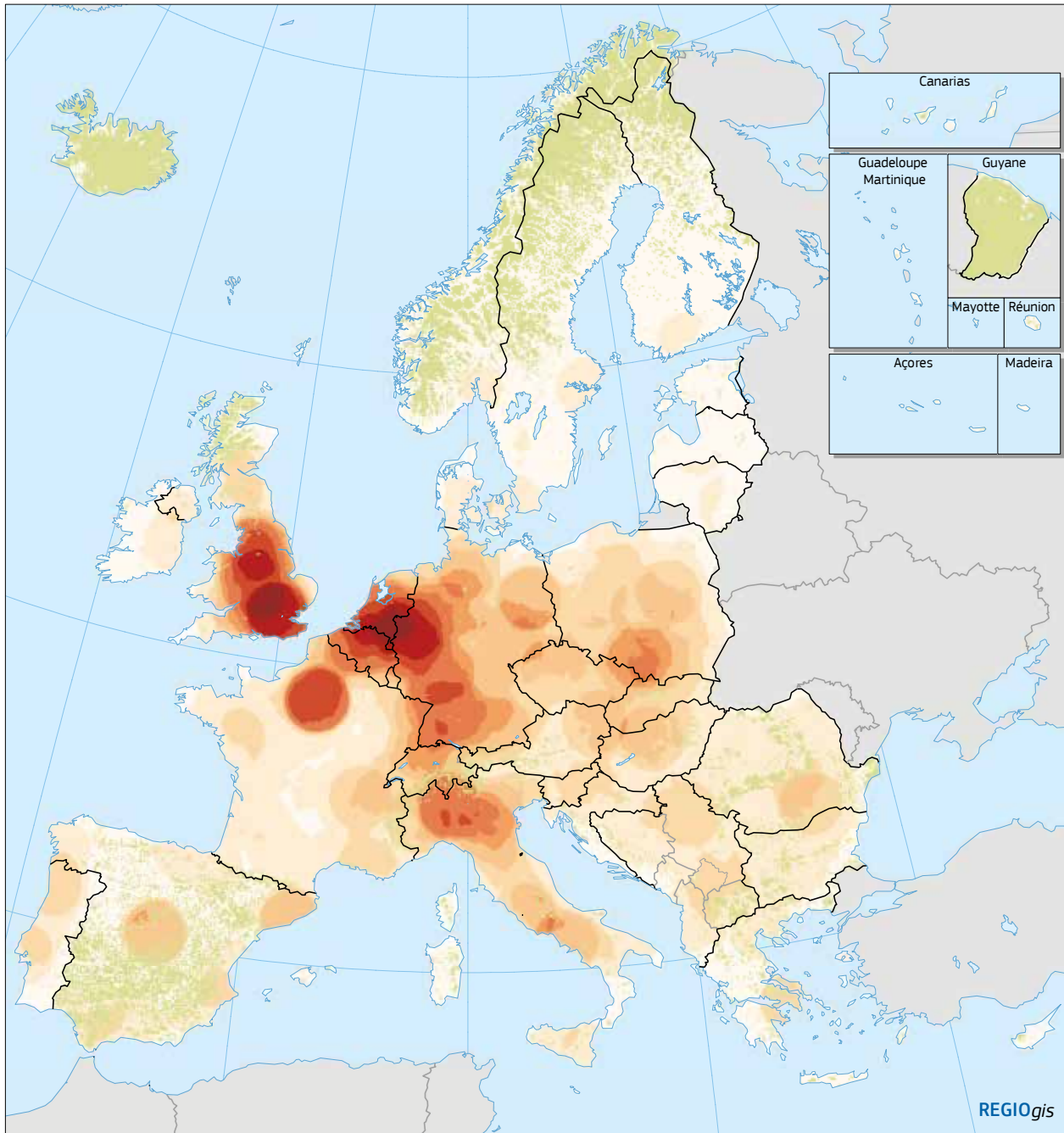Sources: REGIO-GIS, Eurostat, JRC, TomTom, IGN-F

0   500 km

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3.2.   PROXIMITY

Proximity, i.e. the benchmark against which we will interpret the accessibility values is presented in map 3. It shows the population living in a circular neighbourhood of 120-km radius around each of the grid cells. This map provides a smoothed pattern of the large population concentrations in Europe. Consequently, the highest values are found in places surrounded by major agglomerations: in the UK between London and the Midlands, or in the south-east of the Netherlands and the adjacent German areas, all located between the Ruhr area, the Dutch Randstad, Antwerp and Brussels.
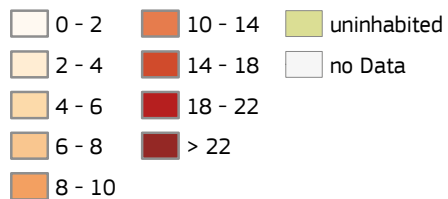
It is also very similar to the accessible population map. The NUTS-3 results for the accessible and the nearby population are very highly correlated: 96 % of the variation in one can be 'explained' by the other (R square of 0.96). Given the strength of this correlation, it is inevitable that accessibility does not indicate how well the transport system works in an area.

Because most areas in Europe have a highly developed road network, it is logical that these two indicators are highly correlated. It is in the exact areas where this correlation is weaker that the transport system does not work as well. Such areas are shown on map 4, where we have divided the accessible population (map 2) by the nearby population (map 3) and multiplied by 100. This indicates transport performance by car.

MAP 3: Population in a neighbourhood of 120-km radius around 1 km² grid cells, 2011

Canarias

Guadeloupe
Martinique

Guyane

Mayotte | Réunion

Açores

Madeira

REGIO*gis*

Proximity: population within a 120 km radius, 2011

Millions of inhabitants

0 – 2	10 – 14	uninhabited
2 – 4	14 – 18	no Data
4 – 6	18 – 22	
6 – 8	> 22	
8 – 10		

Map shows the population weighted average
for cells of 5x5 km for better visualisation.
Analysis was done for 1x1 km cells.
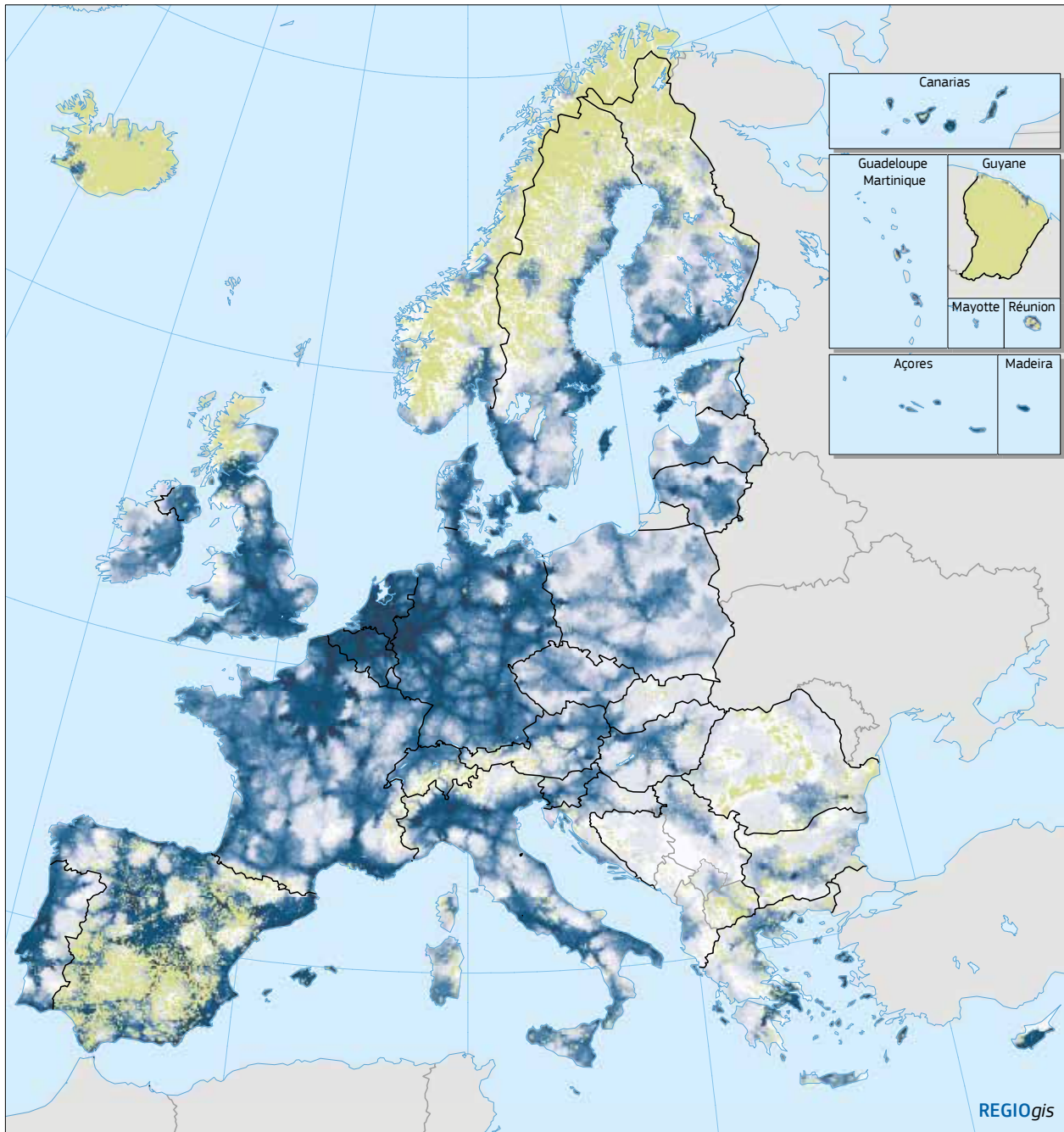Sources: REGIO-GIS, Eurostat, JRC

0   500 km

© EuroGeographics Association for the administrative boundaries

3.3   TRANSPORT PERFORMANCE BY CAR

The 120-km radius benchmark assumes a straight-line speed of 80 km/h. Hence, in areas with very good connections to a motorway network that provides fast access to large population concentrations, even if they are further than 120 km away, the transport performance can be higher than 100. This can be seen along the major motorways in Belgium and the Netherlands and in the adjacent areas of France and Germany. This also occurs in many major cities across Europe, although such high values are almost completely absent in Greece and in those Member States that have joined the EU since 2004.

This transport performance captures the efficiency of the road network for a return trip in a single day allowing time for a meeting or other activity at the destination. Low levels can be associated with a suboptimal road infrastructure, but also with geographical characteristics such as mountains or rivers.

MAP 4: Transport performance by car, 2016

Transport performance by car, 2016

Population within a 1h30 travel/population within a 120 km radius x 100
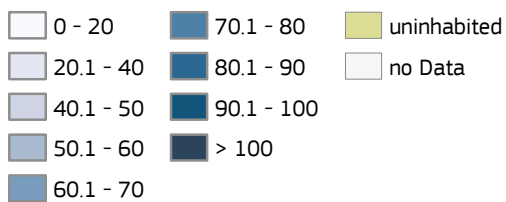
0 – 20	70.1 – 80	uninhabited
20.1 – 40	80.1 – 90	no Data
40.1 – 50	90.1 – 100	
50.1 – 60	> 100	
60.1 – 70		

Map shows the population weighted average for cells of 5x5 km for better visualisation. Analysis was done for 1x1 km cells.
Sources: REGIO-GIS, Eurostat, JRC, TomTom, IGN-F

0   500 km

© EuroGeographics Association for the administrative boundaries

Canarias

Guadeloupe
Martinique

Guyane

Mayotte | Réunion

Açores | Madeira

REGIO*gis*

4. ANALYSING RESULTS BY COUNTRY, REGION, DEGREE OF URBANISATION AND MOUNTAIN AREAS

While grid data provide the highest level of spatial detail, there is also a clear need for more aggregated indicators, especially at geographical levels facilitating the combination with other sources of indicators. First, we describe national-level results, then by NUTS-3 region, and finally by type of grid cell using the degree of urbanisation and mountain areas.

4.1 TRANSPORT PERFORMANCE BY CAR IS HIGHER IN MORE-DEVELOPED COUNTRIES

Belgium and the Netherlands score the highest in terms of transport performance by car (see figure 1). On average, 90 minutes driving enables people to reach more people than are located within 120 km. Both countries are relatively small, highly urbanised and have a high road density. Due to a lack of consistent data on pan-European congestion, this has not been taken into account. Therefore, this result should be seen as the performance on a quiet Sunday morning rather than during the morning rush hour. The analysis by degree of urbanisation (see below) shows that urban areas consistently outperform rural areas in terms of car performance.

Malta and Cyprus score third and fourth highest, respectively. In part, this is because both islands are relatively small and most destinations on each island can be reached within 90 minutes. Ferry connections have not been taken into account, nor has the population located on other islands. For smaller islands, a shorter travel time and shorter distance would reveal more variation.

Portugal and Spain, two countries which have benefitted from several decades of Cohesion Policy investments to improve their transport infrastructure, have caught up and now perform as well as Germany and are above the EU average.

Romania, Slovakia and Bulgaria have the lowest car performance, which is mainly due to a road network that is not yet fully developed, but also to mountain areas where car performance is lower (see below).

Figure 1 also shows the close link between accessibility and proximity. Accessibility alone cannot be used to assess the performance of car travel. For example, Poland's accessibility is more than double that of Finland or Sweden. However, this does not mean that Poland needs less road infrastructure investment. Transport performance shows that in Poland only 62 % of the population within a 120-km radius can be reached in 90 minutes, while in Finland and Sweden it is around 80 %.

FIGURE 1: Accessibility, proximity and transport performance by car per country, 2016


Accessibility (lefthand axis) ■ Proximity (lefthand axis) ▲ Performance (righthand axis)
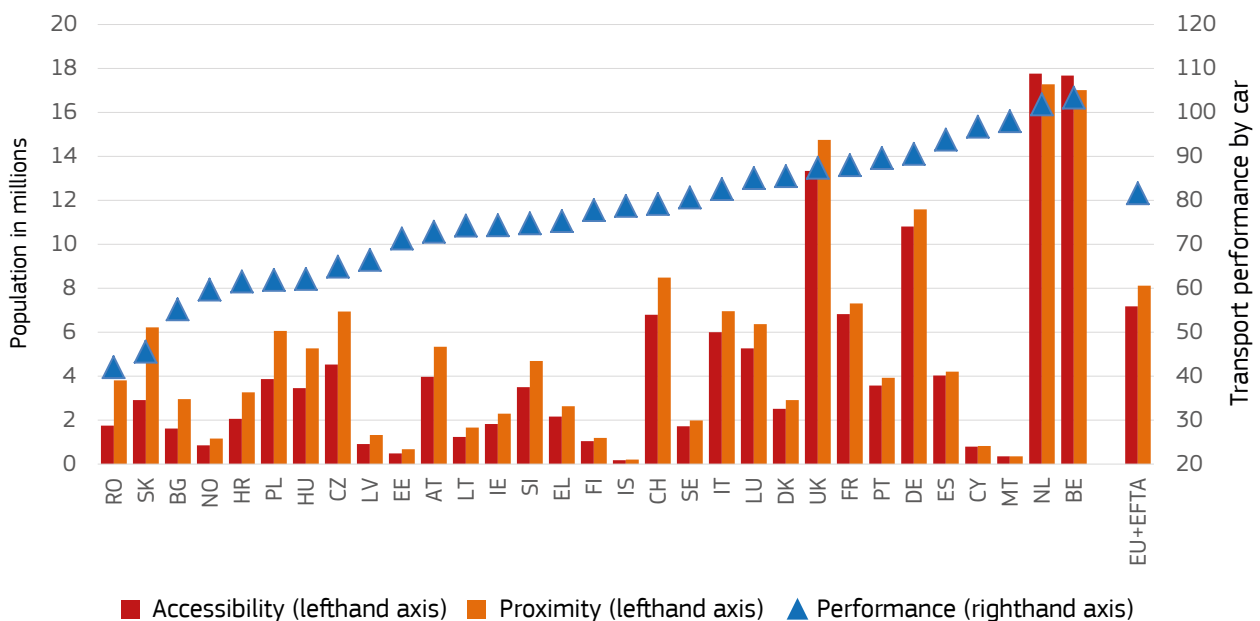
4.2 METROPOLITAN REGIONS HAVE BETTER TRANSPORT PERFORMANCE BY CAR

This section discusses the transport performance of NUTS-3[6] regions[7]. Map 5 shows that the transport performance by car varies substantially within many EU and EFTA countries, both in less-developed and more-developed countries. For example, Bulgaria, Greece and Poland show substantial variations; as do Finland, Norway and the UK.

Most of the capital metro regions have a good transport performance (see figure 2). In countries with a relatively low transport performance, the capital metro region really stands out. For example, the capital metro regions of Bulgaria, Croatia, Romania and Slovakia score around 80, while the national score is only between 40 and 60. Sometimes, a small metro region scores as well as or even better than the capital metro region. This can happen when the smaller city is connected by a highway to the capital and the capital city's population is included in the accessible population (within 90 minutes' driving time), but not the nearby population (it is not within the 120-km distance). In other cases, a smaller city may be just as well connected with good access to multiple nearby cities.

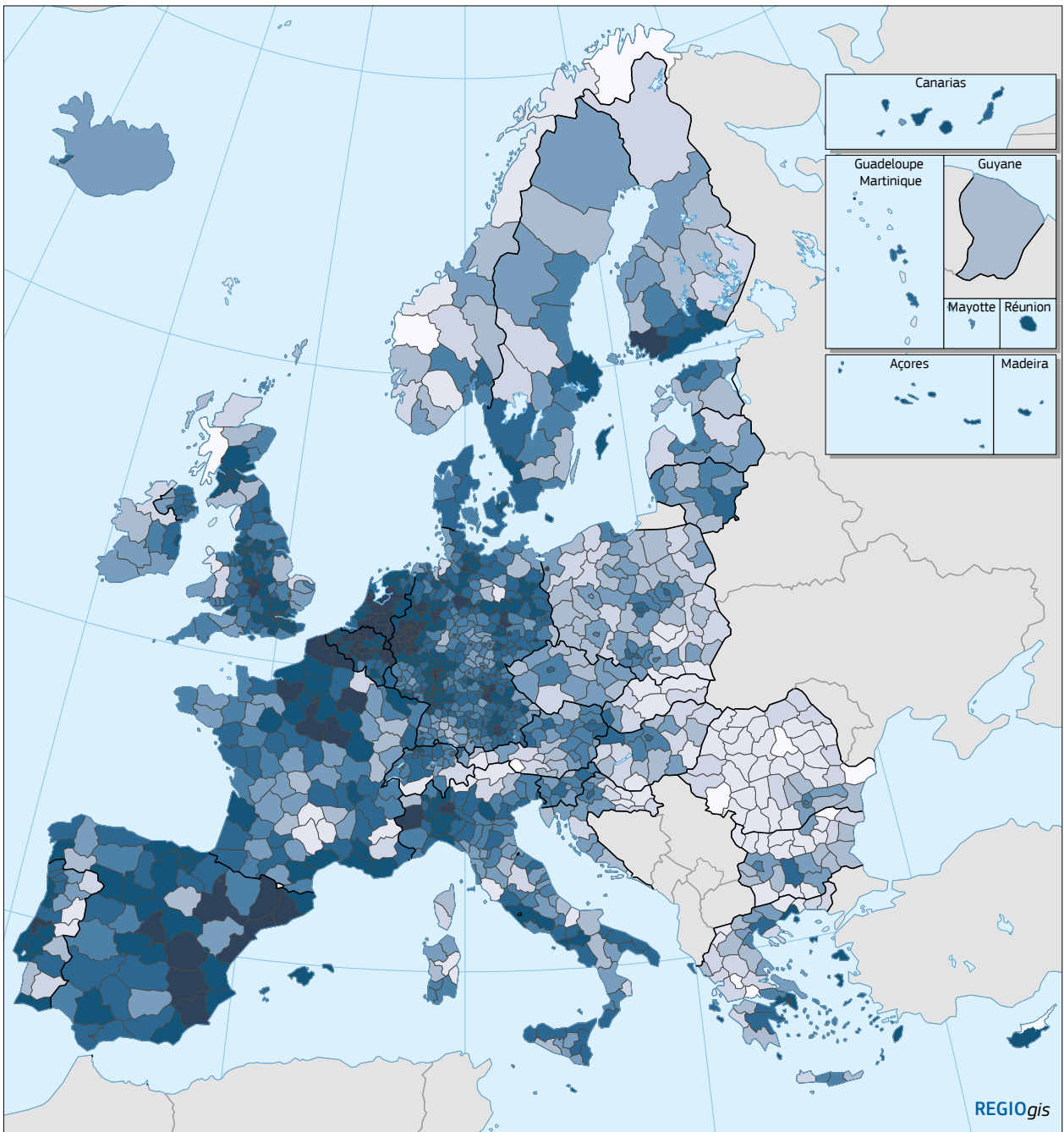**FIGURE 2:** Transport performance by car per metro region, 2016
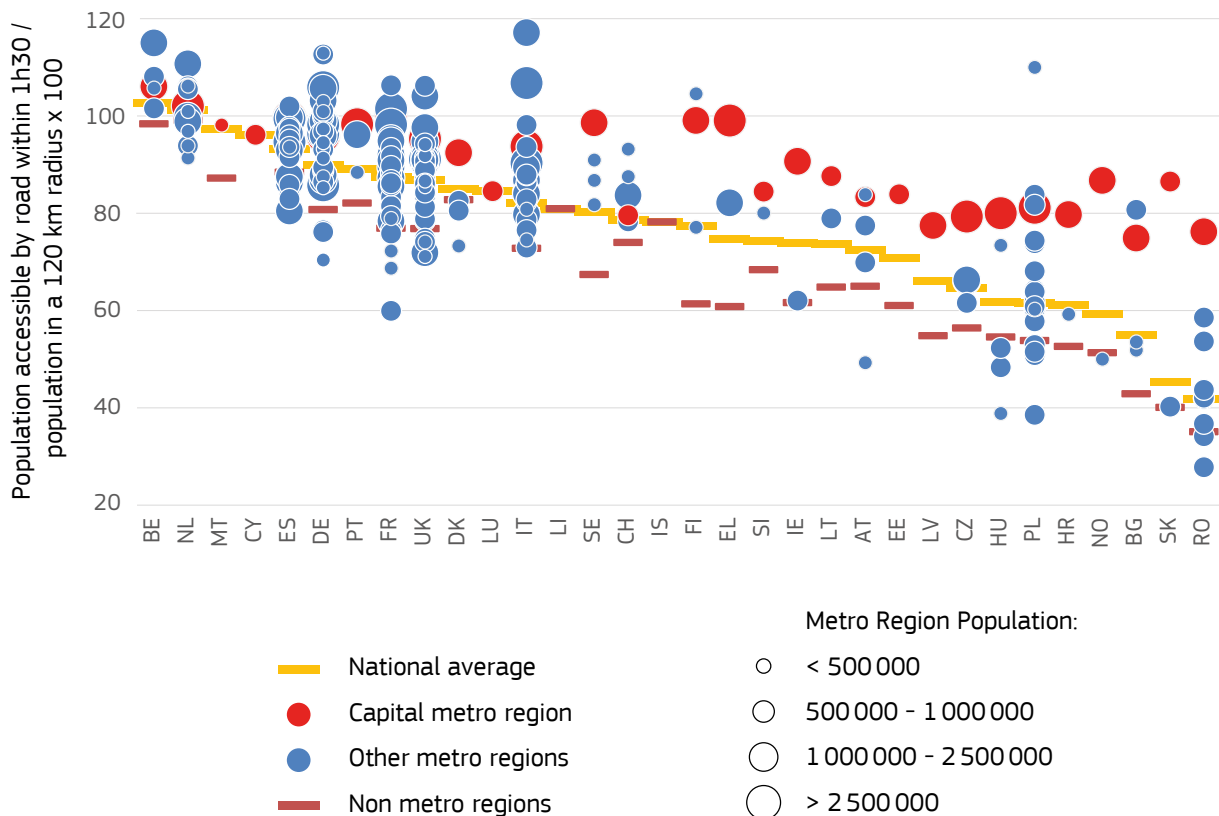
Source: Regio-GIS

6. The data annexed to this paper also provides values for NUTS-0, 1 and 2.
7. The regional values are population-weighted averages of the grid data. This means that cells with a big population have a big impact, those with a small population have a small impact, and the cells without population have no impact on the regional average.

MAP 5: Transport performance by car per NUTS-3 region

Transport performance by car per NUTS-3 region, 2016

Population within a 90-minute travel/population within a 120-km radius x 100
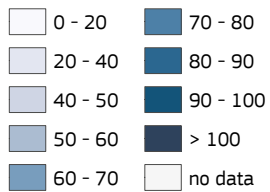
0 - 20	70 - 80
20 - 40	80 - 90
40 - 50	90 - 100
50 - 60	> 100
60 - 70	no data

Sources: REGIO-GIS, Eurostat, JRC, TomTom, IGN-F
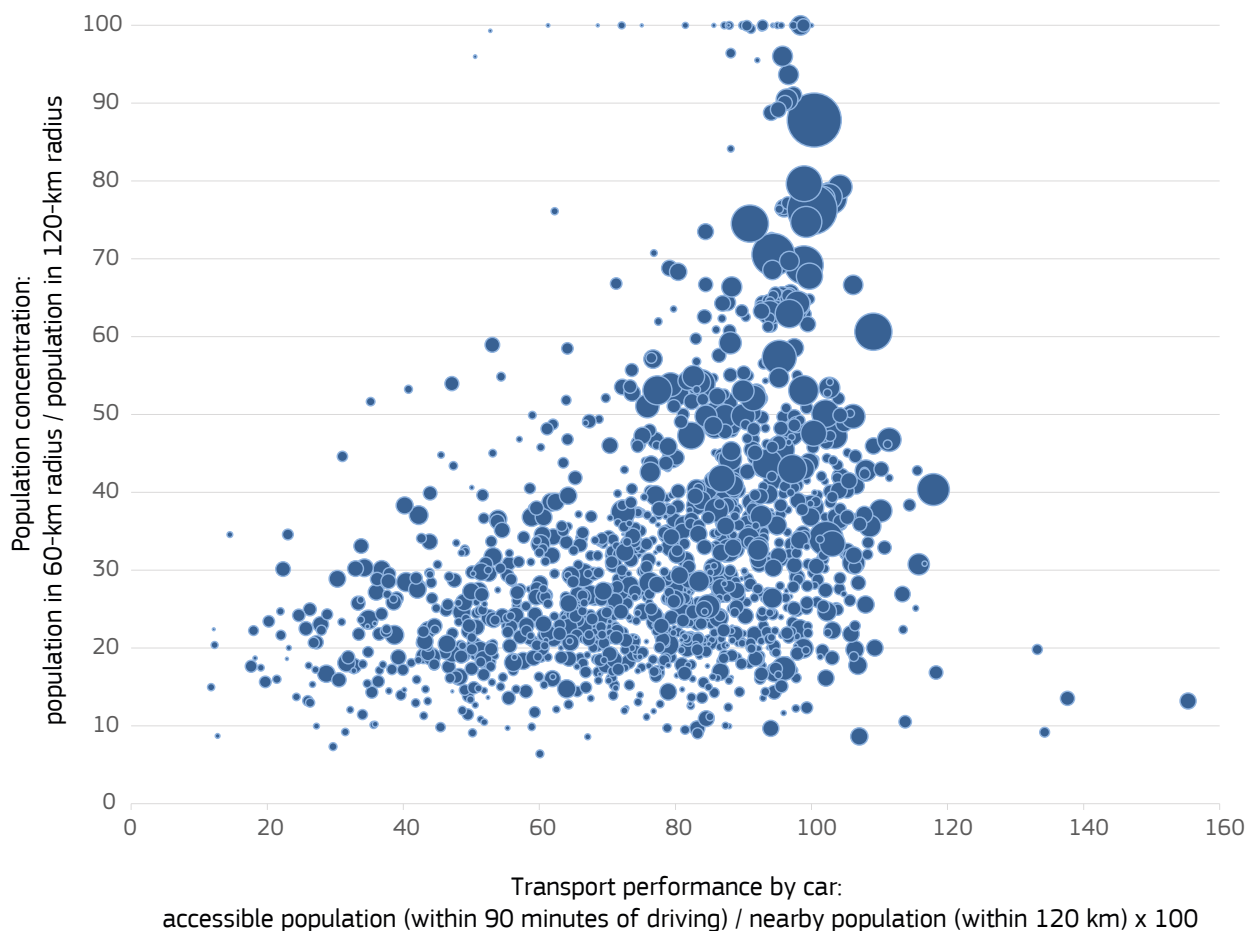
0   500 km

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The average of the non-metro regions is consistently lower than the national average (figure 2), which means that, on average, the metro regions score better than the non-metro regions. Nevertheless, some metro regions score below the non-metro average, for example in France, Austria and Poland, which may be due to their more mountainous surroundings.

Many Spanish regions have a high level of transport performance by car (map 5). In several of these regions, the population is concentrated in densely populated cities, towns and villages. Thus, a decent road network can more easily provide access within 90 minutes than a similar network could provide in regions with a more dispersed population. Higher levels of transport performance can also be expected if the population is concentrated closer to the point of departure.

To measure concentration, we have calculated the ratio between the population within a 60-km radius and that within a 120-km radius. If everyone lived within 60 km, the ratio would be one. If everyone lived more than 60 km away, the ratio would be zero. Figure 3 plots transport performance against population concentration: it shows a positive but weak correlation, which explains less than 15 % of the variation (R square of 0.12 with a linear function and 0.14 with an exponential function). On the one hand, in NUTS-3 regions with at least 60 % of population within the 120-km radius living within a 60-km radius, transport performance tends to be high. On the other hand, equally high levels of accessibility are reached in regions where the population is far-less concentrated.

FIGURE 3: Relationship between transport performance and population at NUTS-3 level

Transport performance by car:
accessible population (within 90 minutes of driving) / nearby population (within 120 km) x 100

Bubble size represents NUTS3 population

4.3 CITIES OUTPERFORM TOWNS, WHICH OUTPERFORM VILLAGES, WHICH OUTPERFORM DISPERSED RURAL AREAS

To analyse the EU territory in more detail, several local typologies have been developed[8], some of which are directly derived from the 1 km² grid level. Hence, our grid-based accessibility analysis is especially convenient for the computation of aggregates at the level of these territorial typologies.

A major grid-based typology is the degree of urbanisation, distinguishing rural areas, towns and suburbs, and cities, using a classification based on population size and density[9]. Although this three-fold typology is already very relevant for the assessment of accessibility levels, it does not distinguish towns from suburbs and provides no differentiation in rural areas. For that reason, we have presented the results according to the new degree of urbanisation level 2. This typology distinguishes towns from suburbs and creates three sub-categories of rural areas. These are villages, dispersed rural areas and mainly uninhabited grid cells[10].

Figure 4 highlights the variation of transport performance among the six degrees of urbanisation by country. The countries are ranked by the transport performance value of cities, immediately showing the big differences in the averge performance of cities in different countries. Transport performance in cities drops below 75 % in Romania, Slovakia, Bulgaria, Poland and Croatia. In addition, in some of these countries (especially Romania, Slovakia and Bulgaria), the disparities between territories are also large, resulting in extremely low levels in both villages and towns. Nevertheless, large disparities can also be found in many other countries. In some, the disparities can be explained by the low average population density and the long distances between populated places (especially in Finland, Sweden, Norway and Iceland).

FIGURE 4: Transport performance by car (2016), by country and refined degree of urbanisation
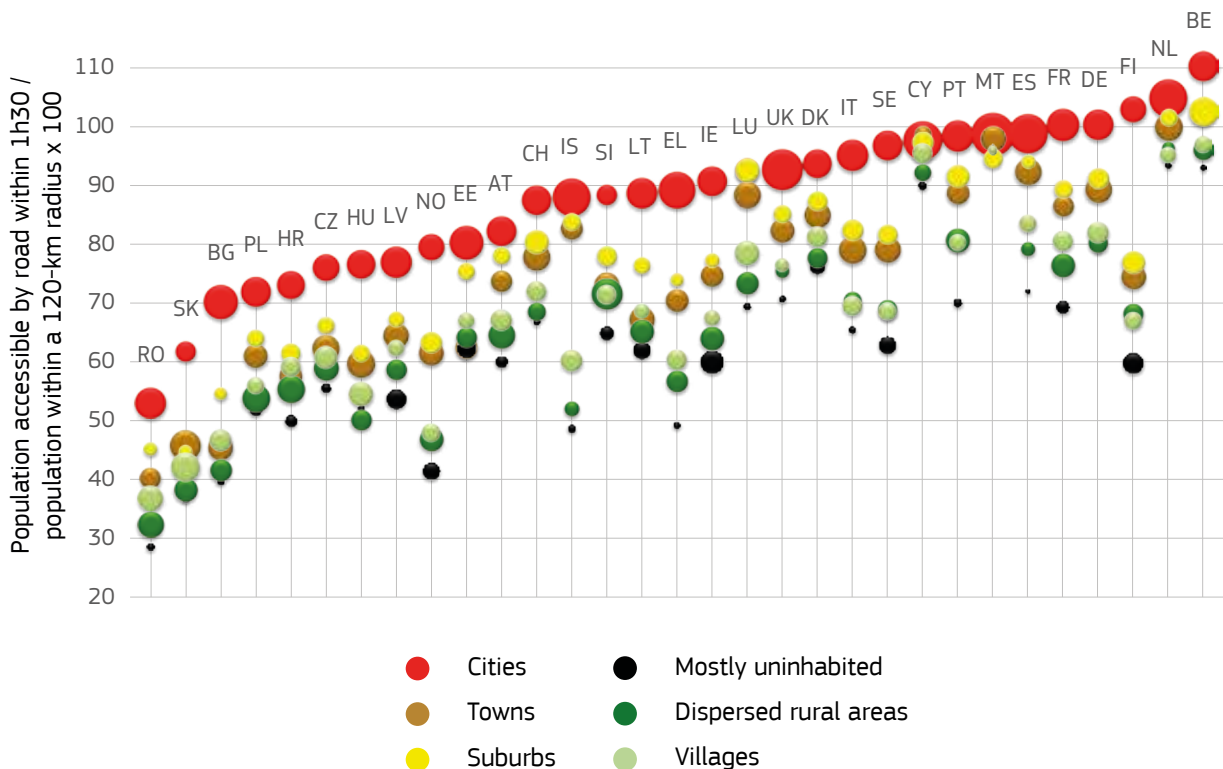
Note: Countries ranked by the value of urban centres
Source: REGIO-GIS

Bubble size is the share of national population living in the area

8. Several of these have a legal base according to the NUTS-TERCET Regulation: Regulation (EU) 2017/2391 of the European Parliament and of the Council of 12 December 2017 amending Regulation (EC) No 1059/2003 as regards the territorial typologies (TERCET), http://data.europa.eu/eli/reg/2017/2391/oj
9. For a detailed description of the degree of urbanisation, see: Dijkstra and Poelman (2014).
10. See annex 2 for a description of the refined classification.

The three types of rural areas tend to have the lowest transport performance by car in all countries. It may be tempting to conclude that rural areas must be suffering from an underdeveloped road network. However, road length per capita is far higher in rural areas (figure 5). Compared to cities, the road network per capita in villages is 4 times longer, in dispersed rural areas it is 10 times more and in mostly uninhabited areas 20 times longer. (For mostly uninhabited areas, the number was divided by five to present it on the graph.) A more dispersed population means that more roads are needed to provide good access, thereby raising the costs of that access.

Comparing the same degree of urbanisation between countries is a more meaningful approach. It responds to the question: 'Given a certain concentration (or dispersion) of population, what transport performance is achieved in different countries?'. A comparison of towns or villages across different countries can help identify what is reducing accessibility and what can be done to improve it. This analysis does not take into account the cost of improving transport performance. Therefore, project-level cost benefit assessments are needed to determine which investments would produce a high return.

Although, on average, transport performance is higher in cities than in the rest of the country, not all cities score well. In particular, smaller cities[11] and cities in countries that are eligible for the Cohesion Fund (gross national income – GNI – per capita below 90 % of the EU average) and the Western Balkan have a lower transport performance compared to cities elsewhere (map 6). National capitals and other large cities tend to have good transport performance. Smaller cities, especially in countries with a lower GDP per head, tend to have a significantly lower transport performance. For example, all cities except Bucharest in Romania score below 70 (map 6). On the other hand, all cities in Belgium and the Netherlands, including the smaller ones, score above 70. Cities in the mountains of Austria, Italy, France, Norway and Spain tend to score lower than the other cities in those countries.

FIGURE 5: Density of the road network, 2016, by country and refined degree of urbanisation
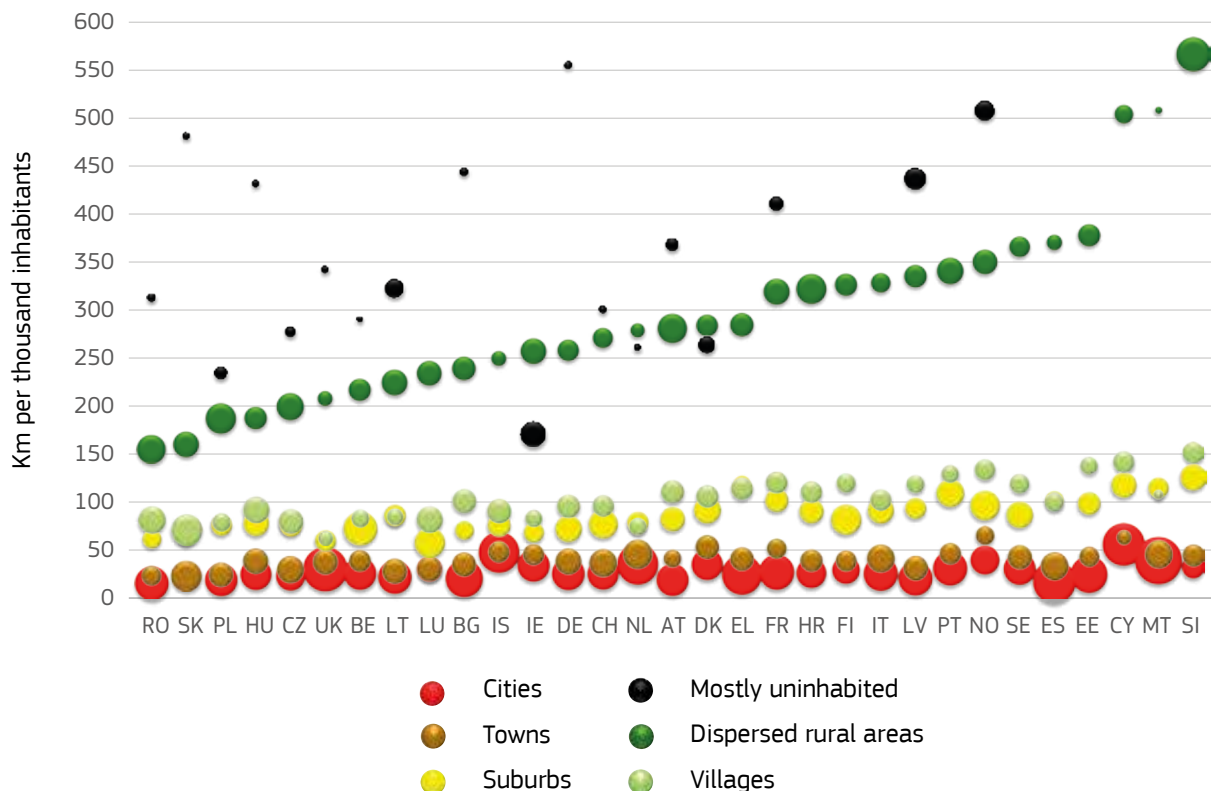

Note: Countries ranked by the value of dispersed rural areas. Values for mostly uninhabited areas divided by 5.
Length of major, secondary and local roads. Non-asphalted roads and roads that cannot be used by cars are excluded.
Source: JRC

Bubble size is the share of national population living in the area

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11.   Cities are municipalities where the majority of their population live in an urban centre. Map 6 shows the results at urban-centre level; for ease of reading, we refer to them as cities.

MAP 6: Transport performance by car per urban centre, 2016
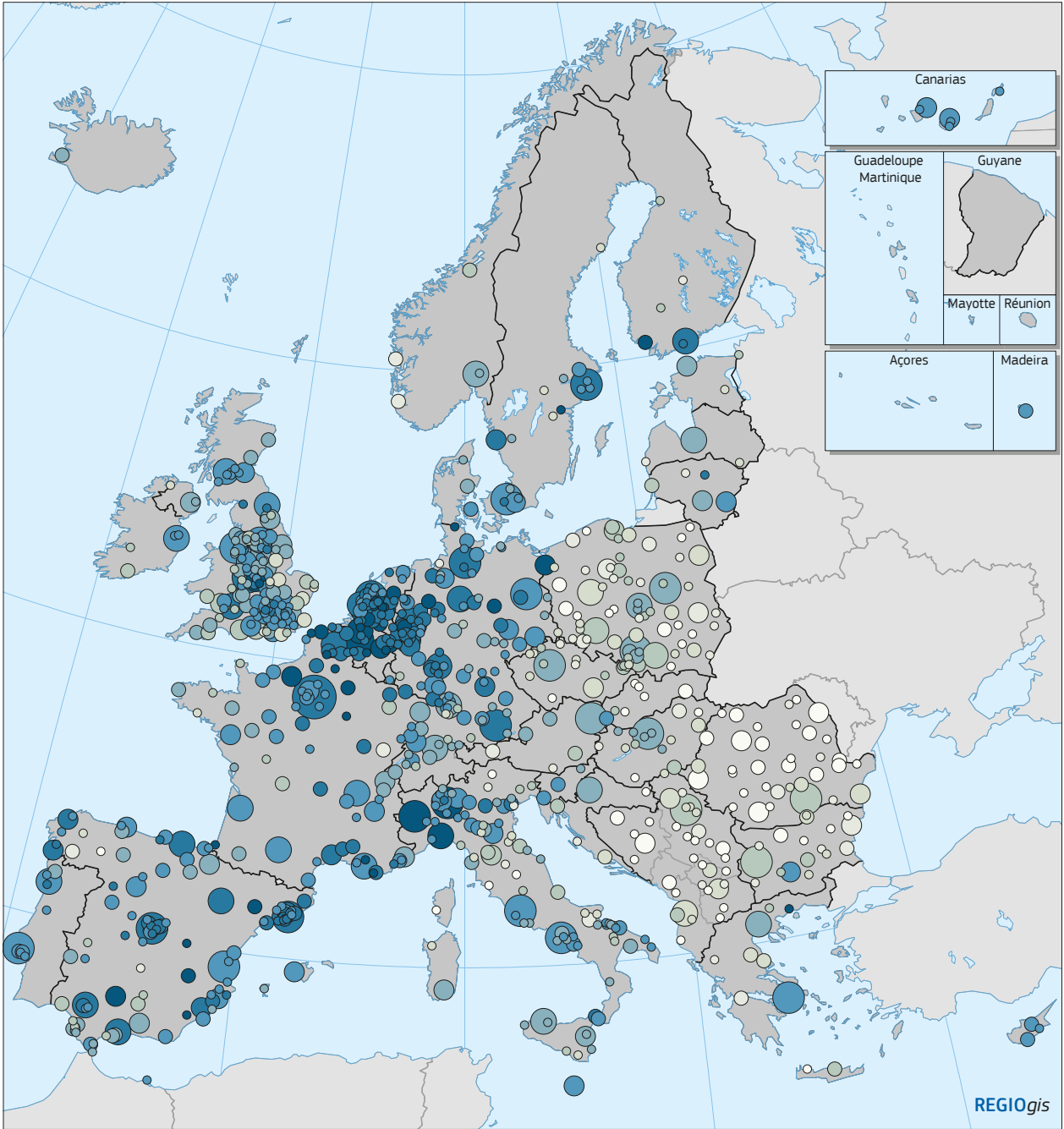
Transport performance by car per urban centre, 2016

Population within a 90- minute travel time/
population within a 120-km radius x 100

- ○ < 50
- ○ 50 - 60
- ○ 60 - 70
- ○ 70 - 80
- ○ 80 - 90
- ○ 90 - 100
- ○ 100 - 110
- ○ >= 110
- ○ No data

Urban centre population

- ○ < 100 000
- ○ 100 000 - 250 000
- ○ 250 000 - 500 000
- ○ 500 000 - 1 000 000
- ○ 1 000 000 - 5 000 000
- ○ >= 5 000 000

Sources: REGIO-GIS, Eurostat, JRC, TomTom, IGN-F

0   500 km

© EuroGeographics Association for the administrative boundaries

4.4   A LONG AND WINDING ROAD: MOUNTAINS ARE AN IMMOVABLE OBSTACLE TO FAST CAR TRAVEL

The presence of mountain massifs, as obvious obstacles to accessibility, often results in slower road connections, a less-dense network and higher construction and maintenance costs. Using a grid-level definition of mountain areas[12], we can examine the differences in transport performance between mountain areas and other areas. Figure 6 shows the results for countries in which at least 5 % of the population lives in mountain areas. In most countries concerned, performance in mountain areas is considerably lower than in other areas.

Discrepancies are lowest in Bulgaria and Croatia with an overall low performance, and Switzerland with an overall better performance. A transport performance of more than 75 can only be found in the mountain areas of Germany, Portugal, Switzerland, Spain and Cyprus. Transport performance in the mountain areas of Romania and Slovakia is particularly low.

A more detailed analysis of accessibility patterns among various territorial typologies falls beyond the scope of this paper. The detailed grid results will enable further analysis in combination with the spatial definitions of specific territories.

FIGURE 6: Transport performance by road in mountain areas and other areas, by country
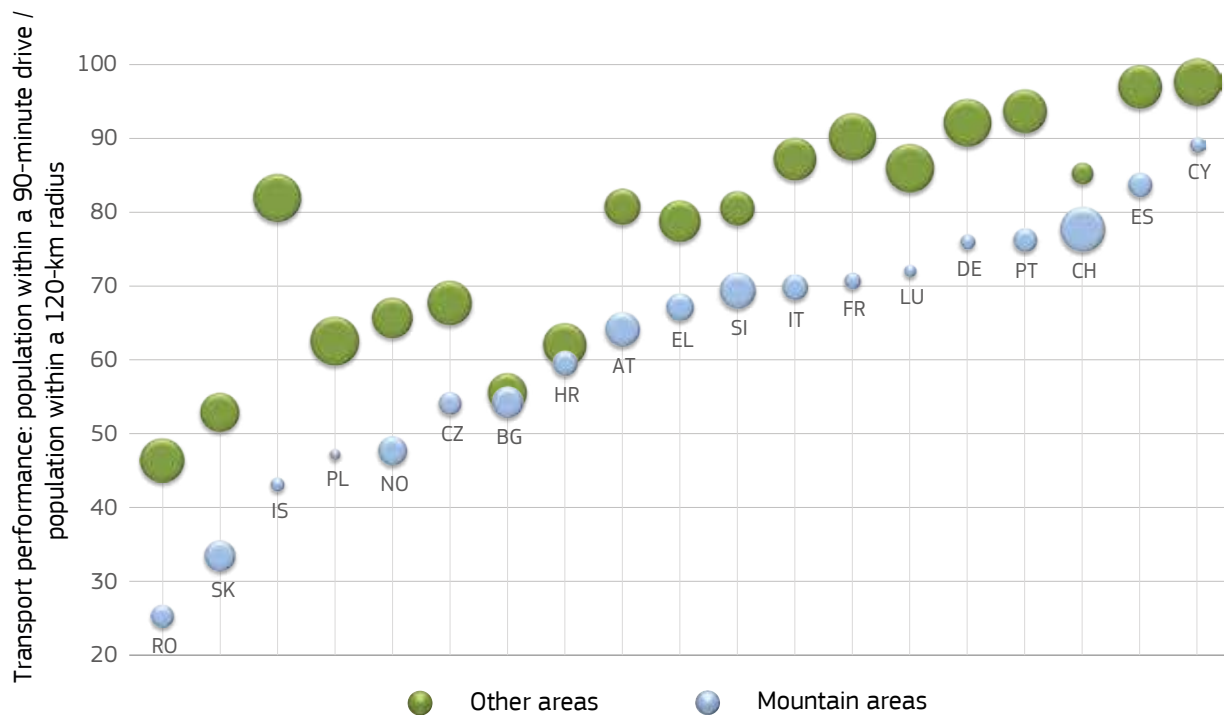
Note: Only countries where at least 5 % of the population lives in mountain areas; ranked by accessibility in mountain areas
Source: REGIO-GIS

Bubble size is the share of national population living in the area

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12.   Grid-based mountain areas are delineated using a combination of altitude, slope and local elevation range criteria. More details can be found in the report on mountain areas in Europe: Nordregio (2004).

CONCLUSIONS

Around 25 % of public investment in the EU is dedicated to transport investments. The goal of these investments is to improve accessibility, although most accessibility indicators only reveal population distribution and not the impact of road infrastructure investments. As a result, these accessibility indicators are rarely used to inform or influence investments decisions.

This paper presents a new approach which compares accessibility with proximity to determine transport performance. Accessibility, or the accessible population, refers to the total number of people living within a 90-minute drive by car. Proximity, or the nearby population, refers to the total number of people living within a 120-km radius. Transport performance is assessed by comparing accessibility to proximity. By controlling for spatial distribution of population, transport performance captures the impact of road infrastructure investments.

Unlike other EU-wide accessibility analyses, this analysis does not start from regional data but from each of the 2 million inhabited 1 km^2 grid cells. This makes the analysis extremely detailed and rich. Furthermore, it can detect differences between regions and within regions by using exactly the same approach.

This paper presents an analysis at the national and regional level. It shows that eastern EU Member States tend to have a low transport performance by car, while Spain and Portugal have already caught up with and even surpassed the EU average.

Thanks to the high spatial resolution of this analysis, we can show how cities compare either with each other or with towns or villages. On average, cities perform better than the rest of the country, although smaller cities, especially in less-developed EU Member States, tend to have poor transport performance by car. Although rural areas have a much higher provision of roads per capita, they tend to have a lower transport performance. Even though it is unlikely to be efficient or even feasible to provide the same level of transport performance in rural areas as in cities, a comparison of rural areas among countries shows that some rural areas perform much better than others. Notably, rural areas in Belgium and the Netherlands score very well, while those in Norway, Romania and Slovakia score poorly.

Mountains tend to reduce speeds and increase the length of journeys. As a result, it is no surprise that in most mountain areas transport performance is considerably lower than in other areas in the some country.

These new metrics were designed to support the assessment of transport investment needs in regions, cities and territories. They can help to identify where the clustering of destinations, the intensification of land use, and higher residential densities should be prioritised and where further investment in infrastructure could be considered. Such assessments should take into account the characteristics of the transport infrastructure, the geography and the cost of providing additional infrastructure.

This paper only shows the results for one point in time. The same method can monitor changes in accessibility and transport performance over time but requires detailed road-network data that capture changes over time, which is not currently available. We would also need a more powerful data-analysis infrastructure, as the current analysis for one point in time took months of computing time.

Fortunately, a new legal framework foresees a regularly updated road network and related attributes[13]. Combining this with a regularly updated population grid will allow us to monitor changes in accessibility and transport performance over time. In addition, analysing access to other destinations, such as as workplace-based employment or day-time population, would be of interest.

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[13]. Commission Delegated Regulation (EU) 2017/1926 of 31 May 2017 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide multimodal travel information services, http://data.europa.eu/eli/reg_del/2017/1926/oj

ANNEXES

ANNEX 1 – METHODOLOGICAL DESCRIPTION

DATA SOURCES

The analysis uses two major input data sets: a population grid and a road network.

The population by 1 km² grid cell is provided by the Eurostat GEOSTAT 2011 population grid[14]. This grid is based on georeferenced census results or address-based population registers, when available, complemented by disaggregated data where needed. It is enhanced by adding 1 km² population estimates for the countries of the Western Balkans[15]. For the French outermost regions, we used 1 km² grid population estimates from the global GHS-POP grid[16]. For subsequent steps in the workflow, we needed a point layer representing the grid's population values. Hence, we produced grid-cell centroid points, each having a unique identifier, and the grid-cell population figure. This point layer can easily be overlaid either with boundary datasets or with data from other grids.

The road network needs to provide a sufficient level of detail to be able to connect all populated places (grid cells) to the network and assess their accessibility. We used the TomTom MultiNet road network[17].

To aggregate the results, we used the NUTS regions' boundary data sets as well as grid-based data sets of territorial typologies, such as the degree of urbanisation and the mountain areas definition.

ROAD ACCESSIBILITY

Accessibility by road is assessed for each populated grid cell (i.e. about 2 million populated grid cells in the EU + EFTA) by creating a service area of 90 minutes of driving time around each cell centroid point. We created a routable network including all the relevant functional road classes needed for adequate routing from any grid cell. From the TomTom road-network segments, we selected the road elements (FEATTYP = 4110) with functional road class (FRC) from 0 to 6. This selection represents all major and secondary roads, as well as most of the local roads. The road segment speed attribute (KPH) from the data set is used to compute a segment travel time in minutes. This time attribute determines a service area of 90 minutes of travel time for each populated grid cell, travelling from the point of departure[18]. Each of the service areas is overlaid with the GEOSTAT grid cell centroid points, computing the total population living in the service area. This figure is stored in a table containing the identifier of the grid cell of origin. Once the process has been completed, the table is joined to the GEOSTAT cell centroid points and an accessibility raster is created.

PROXIMITY: POPULATION IN A 120-KM RADIUS NEIGHBOURHOOD

For each grid cell with a population of > 0, we need to determine the population living in a circular neighbourhood of 120-km radius. In principle this can be achieved using a simple raster operation (focal sum of population in a circular neighbourhood). For this analysis, we wanted to avoid including the population in overseas areas since we wanted to benchmark road accessibility exclusively, without taking into account possible ferry connections. As the focal sum in a grid environment does not distinguish between neighbouring land areas and overseas areas, we needed an alternative solution for those areas located closer than 120 km from the coast.

First, we divided the GEOSTAT population point layer into two parts: the interior part contains all populated points located at minimum of 125 km from any coast. We selected the relevant coastlines, buffered these by 125 km and only selected those points falling outside the coastal buffer areas. For all 'interior' cells, we acquired a grid of the population living in a circular 120-km radius neighbourhood using a simple focal sum grid operation.

For points located closer to the coast, this raster approach cannot be applied. Initially, we created a land-mass polygon layer in which each mainland territory, including possible islands connected by a bridge and/or tunnel, constitute a unique polygon. Then a Python script loops through all populated points located within the 125-km-wide coastal areas. First, this script creates a buffer of 120 km around the point which is intersected with the unique land-mass layer. The resulting intersected buffers are dissolved on the GEOSTAT point identifier and stored as single-part polygons. Next, only the buffer polygon containing the GEOSTAT point itself is selected. This excludes all overseas buffer parts that are not reachable via a fixed link. A search tolerance of 700 m is used in case a populated point falls just outside the coast. Finally, all GEOSTAT points inside the selected buffer area are taken into account. Their population is summed, allocated to the point around which the buffer was created and input in a table.

The resulting tables are all joined to the GEOSTAT grid cell centroid points and converted to a 1 km² raster.

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[14].   https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/population-distribution-demography/geostat
[15].   Source: JRC, see: https://data.europa.eu/euodp/en/data/dataset/jrc-ghsl-ghs_pop_eurostat_europe_r2016a
[16].   Source: JRC: see: https://ghsl.jrc.ec.europa.eu/ghs_pop.php
[17].   For the French outermost regions, we used a road network provided by IGN France, see: http://professionnels.ign.fr/bdtopo
[18].   U-turns at junctions are permitted, one-way restrictions are respected; and generalised service-area polygons are created.

TRANSPORT PERFORMANCE: ACCESSIBILITY DIVIDED BY PROXIMITY

In the previous steps, we have created grids of accessibility (population accessible within a 90-minute drive) and a grid of proximity (population within a 120-km radius). All these grids have data for cells with a GEOSTAT population > 0, and contain numbers of inhabitants. Hence, the creation of transport performance grids is straightforward.

For each grid cell, the accessible population is divided by the nearby population and multiplied by 100. Finally, the data from the resulting grids are also transferred to the GEOSTAT grid cell centroid points. This will facilitate tabular aggregations of the indicators.

AGGREGATING GRID DATA TO REGIONAL OR TERRITORIAL LEVELS

Aggregated values of grid-level accessibility metrics at the level of NUTS regions or any other territorial classification must take into account the population distribution inside the regions or territories. Hence, all aggregates are population-weighted averages of the grid-level data.

We have stored all grid values in a table related to the grid cell centroid points. In this table, we have also registered the identifiers of the regions or territories for which we will compute aggregates (e.g. NUTS codes, degree of urbanisation codes, codes of urban centres, etc.). Hence, all aggregates can easily be computed using that table by first multiplying the accessibility metrics with the grid cell population, summing these multiplications by region or territory, and finally dividing by the regional sum of the grid cell population.

ANNEX 2 – A REFINED CLASSIFICATION WITHIN THE DEGREE OF URBANISATION TYPOLOGY

Within the framework of the degree of urbanisation typology, a refined typology has been created, adding an additional level of classification at grid-cell level. This second level incudes six classes:

▸ **Cities**: this is the original degree of urbanisation class, i.e. settlements of at least 50 000 inhabitants in a high-density cluster of grid cells (> 1 500 inh./km²).

▸ **Towns**: these can either be dense towns, with a density of more than 1 500 inh./km² and a population between 5 000 and 50 000, or semi-dense towns with a population of over 5 000 and a density of at least 300 inh./km², providing they are located more than 2 km from cities or dense towns.

▸ **Suburbs**: these are cells belonging to urban clusters (i.e. clusters of cells with a density of at least 300 inh./km² and a total cluster population of at least 5 000 inhabitants) that are not a part of cities or towns. In other words, they must be contiguous with or within 2 km of a city or a dense town.

▸ **Villages**: settlements with a population between 500 and 5 000 inhabitants and a density of at least 300 inh./km².

▸ **Dispersed rural areas**: rural grid cells with a density between 50 and 300 inh./km².

▸ **Mostly uninhabited areas**: rural grid cells with a density between 0 and 50 inh./km².

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