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The accessibility of European regions and airport network

By

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The accessibility of European regions and airport network

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Abstract

The objective of this work is to evaluate the accessibility of European municipalities by ground and air transportation. We compute the quickest paths between any origin municipality and any destination municipality separated by more than 500 km. The total travel time includes three components: i) travel by car to reach the origin airport; ii) travel by air from the origin airport to the destination airport, including waiting times when no direct flight is available; and iii) travel by car from the destination airport to the municipality of destination. For each city, we calculate the average travel time to reach any other city in Europe, weighted by the populations of the destination cities. This statistic identifies which European regions are "remote" due to difficulties accessing the nearest airport and/or a limited offer of flights. Finally, based on the proportion of travel time spent reaching the origin airport and the extra ground travel time in routes that do not leave from the closest airport, we propose a general framework to evaluate policy options for improving the accessibility of remote regions.

Key words: Accessibility; Remote regions; Airport Network.

1. Introduction

Wegener et al. (2002) defined accessibility in terms of indicators that "describe the location of an area with respect to opportunities, activities or assets existing in other areas and in the area itself, where 'area' may be a region, a city or a corridor." Evaluating the accessibility offered to citizens has always been an important issue for policy makers and regional governments, so a large body of literature has studied the relationship between accessibility and regional development (for example, Spiekermann and Wegener, 2006).

The objective of this work is to study accessibility in terms of travel times between pairs of municipalities in Western Europe, taking into account both air and ground transportation. Previous studies on European intermodal accessibility have considered only NUTS2-3 regions (Lutter et al., 1992; Chatelus and Ulied, 1995; Wegener et al., 2000 and 2002; Spiekerman et al., 2002). This paper computes travel times in a much more detailed network with 76,498 distinct municipalities.

Air transportation accounts for a significant portion of travel times between most pairs of municipalities. Burghouwt and Veldhuis (2006) employed air-side accessibility measures to evaluate the connectivity of European airports involved in the transatlantic market. Paleari et al. (2010) compared air-side accessibilities for Europe, US and China. Shaw (1993) and Shaw and Ivy (1994) studied the accessibility of the hub-and-spoke structure to US airline passengers. When computing travel times by air, this work employs a definition similar to that of Paleari et al. (2010): the total air travel time includes both flight times and waiting times spent in intermediate airports when no direct flight is available.

The paper is organized as follows. The next section describes our methodology and dataset. Section 3 describes our empirical results on the overall accessibility of cities. In this section, we also identify remote regions and analyze the main components of travel times to and from such regions. Section 4 summarizes the main findings of the paper and describes how two statistics derived from travel times from remote regions can be used to find the optimal policy for improving accessibility. Section 5 concludes.

2. Methodology and data

Table 1 shows the twenty Western European countries and territories covered by our analysis. Our dataset includes 76,498 different municipalities, with a total population of more than 378 million and an average population per municipality of about 5,000.

This paper computes travel times for journeys between each pair of municipalities in the sample, including ground and air travel. The overall travel time to connect municipalities i and j, denoted $t_{i,j}$, is separated into three components:

1) $t_{i,o}$: travel time by car from the origin municipality (M_i) to the origin airport (A_o).

2) $t_{o,d}$: travel time by air from the origin airport (A_o) to the destination airport (A_d). If no direct flight is available between the origin and the destination airports, this component includes both flying times and waiting times in intermediate airports. To compute the minimum travel time $t_{o,d}$ by air, we apply the methodology introduced by Malighetti et at. (2008).

3) $t_{d,j}$: travel time by car from the destination airport (A_d) to the destination municipality (M_j).

Before this analysis can begin, we need to link each municipality with the airports most likely to be employed by its population. We consider the two nearest airports for each

municipality, in terms of travel times in 2010. We also include any other airports offering more than 50 routes (again, in 2010) within 200 km of the municipality.

We do not consider travel times between pairs of municipalities whose distance is less than 500 km, since air travel is probably not necessary to complete the journey.

Among all possible combinations of origin airport and destination airport for a given pair (i,j), we find those which give the minimum travel time $t_{i,j} = t_{i,o} + t_{o,d} + t_{d,j}$.

In general, the most well-connected municipalities are close to airports linked by a direct flight. In contrast, remote municipalities often involve long travel times by car to reach the origin airport and/or an indirect flight to the destination airport.

The accessibility index for a municipality, denoted t_i, is defined as the population-weighted average travel time to all other municipalities:

$$t_i = \frac{\sum_{j=1}^{n_i} p_j \cdot t_{ij}}{\sum_{j=1}^{n_i} p_j}$$

Here n_i is the number of municipalities farther than 500 km from municipality i and p_j is the population of municipality j.

3. Empirical results

Table 2 reports our statistics on accessibility, grouping the municipalities by country or territory. The average accessibility index of a country depends on its geographical position with respect to the other countries. England is the most well-connected country in Western Europe, with the smallest weighted average travel time t. It is noteworthy that in terms of travel times, England is more accessible than countries that are

geographically central such as Austria, Germany and Switzerland. As expected, the least connected countries are Finland, Norway and Sweden. Norway has the greatest variation in the weighted average travel times of individual municipalities, with a standard deviation of 74.8 minutes.

Figure 1 shows the distribution of municipalities by accessibility index t. Almost 90% have a weighted average travel time less than 400 minutes. Given than the overall average is about 300 minutes (Table 2), the vast majority of municipalities have accessibility indexes not exceeding the average by more than 30-35%. However, the least connected municipalities have accessibility indexes exceeding 600 minutes, almost twice the average.

Figure 2 shows the geographic distribution of the accessibility index. It shows that even municipalities located near the geographic center of Europe may have low accessibility. This phenomenon is more accentuated in France, where small airports tend to have just a few European connections. In Spain, low accessibility affects cities close to Portugal and those located midway between the seaside and Madrid.

Table 3 aims to identify the remote territories. In particular, it shows the total populations of the least connected areas in each country, counting all municipalities with travel times above the 90%, 92.5%, 95%, 97.5% and 99% percentiles computed for the entire sample.

Interestingly, Austria, Belgium, Luxemburg, Northern Ireland, Netherland and Switzerland do not have any municipality with an accessibility index above the 90% percentile. The countries with the largest populations in remote municipalities are the three Scandinavian countries (Sweden, Norway, and Finland) together with France, Spain, and Italy.

The remainder of our analysis deals with those municipalities whose accessibility indexes are above the 95th percentile, meaning that their travel times are greater than 445.9 minutes. Henceforth, the term "remote territory" refers to one of these cities. The number of remote territories is 3,817, and their total population is more than 6 million. Following this definition, Austria, Belgium, Luxemburg, Netherland, Northern Ireland and Switzerland do not have any remote territories. In fact, from table 2 one would observe that their maximum accessibility indexes are lower than the limit of 445.9 minutes.

In the following section we identify which variables are responsible for the long travel times of remote territories.

4. Remote territories and policy implications

Table 4 shows statistics on travel times for remote territories. Interestingly, France comes first in terms of the total population in remote territories, followed by Finland and Sweden. All three countries have more than one million people living in their remote territories. Spain has about 780,000 people living in remote territories, and Norway has about 580,000. Table 4 also decomposes the travel times from remote territories into three components: i) travel to the origin airport, ii) travel by air, and iii) travel from the destination airport to the destination territory. (These components were defined in Section 2.)

Long air travel times imply that the origin airports do not have direct flights to many destination airports, so travelers accumulate waiting time in intermediate airports. Long travel times to or from an airport indicate problems of geographical accessibility.

For the six countries with the largest populations in remote territories, Figure 3 plots the percentage of travel time to the origin airport against the percentage of air travel time.

For Sweden and Finland, the main factor contributing to long travel times is the quality of connections offered from origin airports. In Spain and France, on the other hand, the main problem is the excessive distance between remote territories and the most suitable origin airports.

The division into land and air travel offers insight into the types of policy remedies that would be effective. When a country's remote territories require long air travel times, their accessibility could be improved by increasing the origin airports' offer of direct flights, especially to the major European airports (Redondi et al., 2010). However, this is not always the most effective policy. For example, it could be that an airport serving several remote territories is very small, with a very limited capacity. In this case, the bottleneck could be overcome by improving land-side accessibility to larger airports.

When the main problem faced by remote territories is high travel times to reach origin airports, the most evident solution would be improving land-side infrastructure. For example, a government could improve existing roads or build new highways from remote regions to serve major airports. Another solution would be to create new airports to serve the remote regions. However, it could also be that the airports closest to remote territories are not often employed by the population, due to a low number of offered flights and destinations. If this is the case, travelers would sometimes drive to a farther airport with better connectivity. Thus, land travel times could also be reduced by increasing the connectivity of nearby airports.

4.1. Statistical properties of remote regions

In order to better differentiate the policies required to improve the accessibility of remote regions, Table 5 provides detailed information regarding the land-side accessibility of origin airports in each country. The first column is the total population of remote territories in that country, and the second column is the average number of origin airports linked to each remote territory (see Section 2). From the methodology section, the minimum number of airports linked to each territory is two. The second and third columns describe the propensity of the population to use just one of the linked airports. The concentration is the value of the Herfindahl-Hirschman Index.

A relatively high value of the concentration indicates that the remote territories tend to employ just one of their linked airports. The fourth column reports the percentage of the population that finds it quicker to travel to the closest airport, regardless of destination. Table 5 also reports the average travel time to reach the closest airport, and the average travel time to reach the linked airport or airports that are located farther away.

In order to compare the connectivity of the closest airport with the connectivity of other potential origin airports, we define the following index:

$$C_d=(1-\%Pop)\times\Delta TT$$

Here %Pop is the percentage of the population that finds it quicker to employ the closest airport, reported in the 4th column of Table 5. ΔTT is the difference between the average travel time required to reach the closest airport and the average travel time to other airports, reported in the 5th and 6th columns of Table 5 respectively.

We name C_d the "connectivity deficit" of the closest airport with respect to the other airports that serve the area. It measures the average time lost by a person living in one of

the remote territories who has to use an airport farther from their community but with better connections than the closest airport.

Among countries with a large population in remote territories, the connectivity deficit is highest for Italy, at 23.7 minutes. The value of this index is 20.4 minutes for Norway, and 14.4 minutes for Spain. The closest airports in these countries are not always employed as origin airports; on average, people living in these countries who require better connectivity will spend this much extra time travelling to reach farther airports. On the other hand, Finland has an index of 5.6 minutes while France has an index of merely 0.4 minutes. In these countries, the airports closest to remote regions are better equipped to serve their population.

4.2. Policy implications

The connectivity deficit index allows us to distinguish between the possible causes of a large population in remote territories, as described at the beginning of Section 4. Based on this index and the percentage of total travel time spent reaching the origin airport, the following framework can point to the appropriate policy remedy.

- If the percentage of travel time to reach the origin airport is above average (see Table 4), the priority is to reduce land-side travel time.

  - If the connectivity deficit in the remote territories is below average (see Table 5), it means that the airports are already well suited to serve the remote territories. To improve accessibility, the best policy is to improve roads and create new highways serving the airports. This is the case of France.

  - If the connectivity deficit in the remote territories is above average (see Table 5), the remote population is spending time traveling to airports that are farther away but

have better connectivity. The priority of policy-makers should be to increase the closest airports' offers of flights and destinations. The population will then choose the closest airport more often, and spend less time traveling by road. If the air service of the closest airports cannot be improved, the best policy is to improve land-side accessibility to larger but more distant airports. This is the case of Italy, Spain, and Portugal. It also applies to Germany, even though this country has a much lower population in remote territories.

- If the percentage of travel time by air is above average for remote territories (see Table 4), the priority is to reduce air-side travel time.

  - If the airports closest to remote territories have a below-average connectivity deficit (see Table 5), it means they are already well placed to serve the remote population. The optimal policy is to increase the number of flights and destinations offered by the closest airports. If that is not possible, the government should improve both land- and air-side connectivity to larger airports farther away. This is the case of Finland.

  - If the airports closest to remote territories have an above-average connectivity deficit (see Table 5), it means that some of the population can shorten overall travel times by leaving from more distant airports. However, given that air travel time is already excessive, even the more distant origin airports do not have good air-side connections. The priority should be to increase the number of flights and destinations from those airports. An alternative policy is to improve the land-side accessibility of large airports in the remote region (those with the most extensive network of destinations). The risk of this policy is an increase in the time spent traveling to reach the origin airports. This is the case of Sweden.

5. Conclusion

To the best of our knowledge, this work is the first to address the issue of accessibility in Western Europe at the municipality level. Our measure of accessibility is based all the overall travel times required to connect each pair of cities in the network, including ground travel to and from airports and waiting times between connecting flights when a direct flight is not available.

The paper defines remote territories as municipalities whose average travel time to other cities is above the 95th percentile. Norway, France, Finland and Sweden suffer most from remoteness.

We also propose a framework to evaluate the best policy options for alleviating travel times from remote territories. The first criterion is the average proportion of time spent traveling to an origin airport, and the second is the excess time spent in ground travel by those who need to leave from an airport that has better connections but is farther from their city. Based on these statistics, it is possible to determine whether improving land-side infrastructure or increasing the number of routes offered by airports will have the greater impact on accessibility.

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Table 1. Countries, municipalities and populations covered by the analysis. Year 2010.

Country	No. of airports considered	No. of municipalities	Population	Population per municipality
Austria	6	2,259	8,208,012	3,633
Belgium	5	580	10,801,107	18,623
Denmark	6	96	5,399,255	56,242
England	47	2,109	44,021,561	20,873
Finland	12	414	5,295,918	12,792
France	45	36,040	60,884,686	1,689
Germany	39	12,187	81,551,275	6,692
Ireland	3	78	2,327,507	29,840
Italy	38	8,101	60,045,068	7,412
Luxemburg	1	36	314,046	8,724
Netherlands	5	491	15,761,607	32,101
Northern Ireland	2	16	840,290	52,518
Norway	30	423	4,440,441	10,497
Portugal	3	283	9,934,918	35,106
Scotland	8	583	4,590,490	7,874
Slovenia	1	200	1,935,248	9,676
Spain	39	7,983	45,076,146	5,647
Sweden	36	1,886	7,520,741	3,988
Switzerland	5	2,524	7,494,142	2,969
Wales	1	209	2,320,880	11,105
All territories		76,498	378,763,338	4,951

Table 2. Accessibility statistics by country (in minutes).

Country	Weighted average	Median	Minimum	Maximum	Std. Dev
Austria	287.5	307.8	227.6	406.7	27.0
Belgium	309.0	296.5	279.5	384.0	20.2
Denmark	286.1	290.9	221.9	456.6	46.4
England	266.1	260.6	216.3	595.3	35.7
Finland	402.0	453.4	297.4	634.7	69.2
France	310.5	334.8	220.7	706.5	60.7
Germany	306.0	298.9	217.7	548.2	35.8
Ireland	293.1	309.3	231.8	461.8	67.8
Italy	303.8	309.1	210.4	681.0	55.4
Luxemburg	369.2	297.8	322.3	394.5	14.4
Netherlands	312.1	309.7	276.1	416.1	19.2
North. Ireland	297.9	295.5	276.7	341.9	17.6
Norway	377.9	417.7	271.9	691.2	74.8
Portugal	322.2	342.0	267.1	564.0	41.9
Scotland	293.4	293.0	229.9	634.4	54.1
Slovenia	337.2	348.3	295.9	459.4	25.9
Spain	305.2	339.3	204.7	674.0	60.2
Sweden	370.7	409.7	274.7	640.3	71.4
Switzerland	271.8	282.5	231.7	387.0	23.4
Wales	313.9	311.3	243.7	504.8	42.3
All territories	305.4	324.5	204.7	706.5	60.8

Table 3. Identification of remote territories.

	Population in Remote municipality				
Percentile	90.0%	92.5%	95.0%	97.5%	99.0%
Travel time limit	408.0	421.1	445.9	487.9	536.5
Denmark	2,089	1,993	1,993	-	-
England	40,022	5,999	2,275	2,275	2,275
Finland	2,386,398	2,218,248	1,602,466	876,529	178,535
France	3,908,435	3,132,755	1,857,975	992,279	320,457
Germany	211,778	82,304	60,890	55,650	8,903
Ireland	316,869	290,308	82,558	-	-
Italy	2,290,288	1,323,297	122,309	15,498	6,170
Norway	1,046,552	853,572	584,225	239,851	125,144
Portugal	471,728	291,870	66,058	29,721	29,721
Scotland	56,600	49,630	44,300	42,420	41,800
Slovenia	16,883	16,883	9,334	-	-
Spain	2,422,075	1,616,118	781,126	378,091	91,381
Sweden	2,396,662	2,028,237	1,133,261	575,144	77,271
Wales	64,831	49,737	4,515	4,515	-
Number of territories	7,634	5,725	3,817	1,909	764
Population	15,631,210	11,960,951	6,353,285	3,211,973	881,657

Table 4. Statistics on travel times for remote territories (travel times in minutes).

	No. of remote territories	Population	Average Access. Index	Travel to origin airport	Travel by air	Travel from dest. airport	Std Dev.
Denmark	1	1,993	456.6	28.9%	56.7%	14.4%	-
England	1	2,275	595.3	39.5%	49.2%	11.4%	-
Finland	222	1,602,466	495.2	16.0%	70.8%	13.2%	37.5
France	2,145	1,857,975	503.2	25.9%	60.5%	13.6%	52.4
Germany	41	60,890	519.5	54.6%	33.6%	11.8%	27.9
Ireland	7	82,558	449.4	27.8%	58.0%	14.2%	5.1
Italy	49	122,309	470.4	33.9%	52.0%	14.1%	34.9
Norway	288	584,225	497.6	21.0%	67.4%	11.6%	70.8
Portugal	6	66,058	504.1	41.7%	45.4%	12.9%	41.9
Scotland	13	44,300	588.8	11.2%	78.4%	10.4%	63.2
Slovenia	1	9,334	459.4	35.4%	50.4%	14.2%	-
Spain	414	781,126	493.4	23.9%	62.9%	13.2%	36.5
Sweden	628	1,133,261	490.5	11.1%	75.3%	13.6%	34.7
Wales	1	4,515	504.8	41.1%	44.7%	14.2%	-
All territories	3817	6,353,285	517.3	22.6%	64.5%	12.9%	49.4

Table 5. Statistics on land-side accessibility for remote territories (travel times in minutes).

	Population	No. of Territ.	No. of origin airports	Concentr. by origin airports	% pop. to closest airport	Travel time to the closest airport	Travel time to other airports	Connectivity deficit of the closest airport (C_d)
Denmark	1,993	1	2.0	8,080	89.2%	124	201	8.3
England	2,275	1	3.0	8,824	0.0%	193	237	43.5
Finland	1,602,466	222	2.7	7,992	78.0%	74	99	5.6
France	1,857,975	2,145	1.9	8,217	84.8%	133	136	0.4
Germany	60,890	41	4.0	7,497	16.9%	119	319	166.2
Ireland	82,558	7	3.0	6,675	79.6%	109	191	16.8
Italy	122,309	49	3.9	4,667	40.6%	138	178	23.7
Norway	584,225	288	2.0	8,104	75.0%	63	145	20.4
Portugal	66,058	6	2.6	7,713	52.3%	201	227	12.7
Scotland	44,300	13	2.8	9,905	76.7%	77	85	1.9
Slovenia	9,334	1	1.0	10,000	100.0%	163	-	-
Spain	781,126	414	2.6	7,208	62.8%	105	144	14.4
Sweden	1,133,261	628	2.1	8,563	81.0%	44	101	10.9
Wales	4,515	1	2.0	5,790	30.1%	196	213	11.9
All territories	6,353,285	3,817	2.2	8,021	79.6%	114	141	6.9

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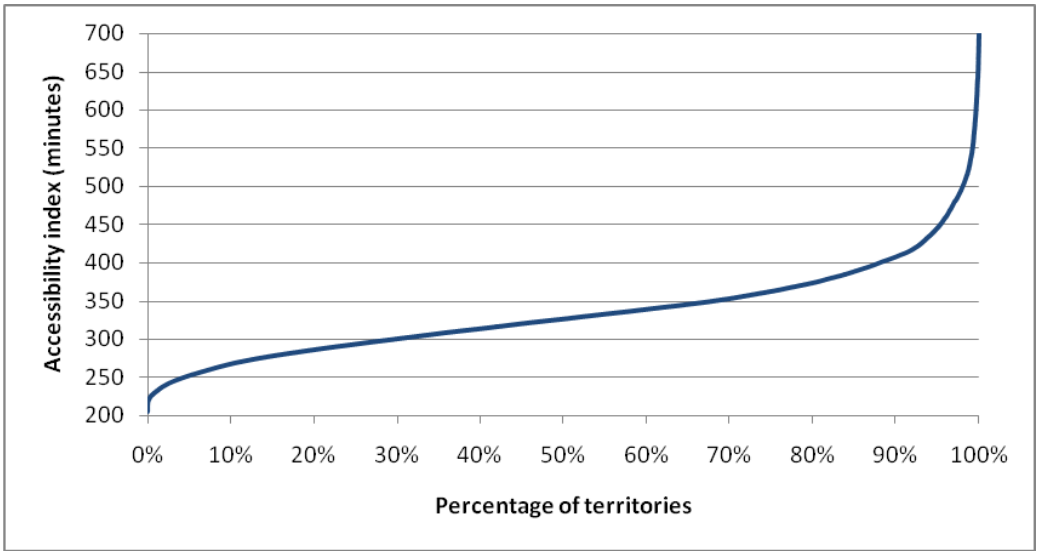

Figure 1. Distribution of territories by accessibility index.

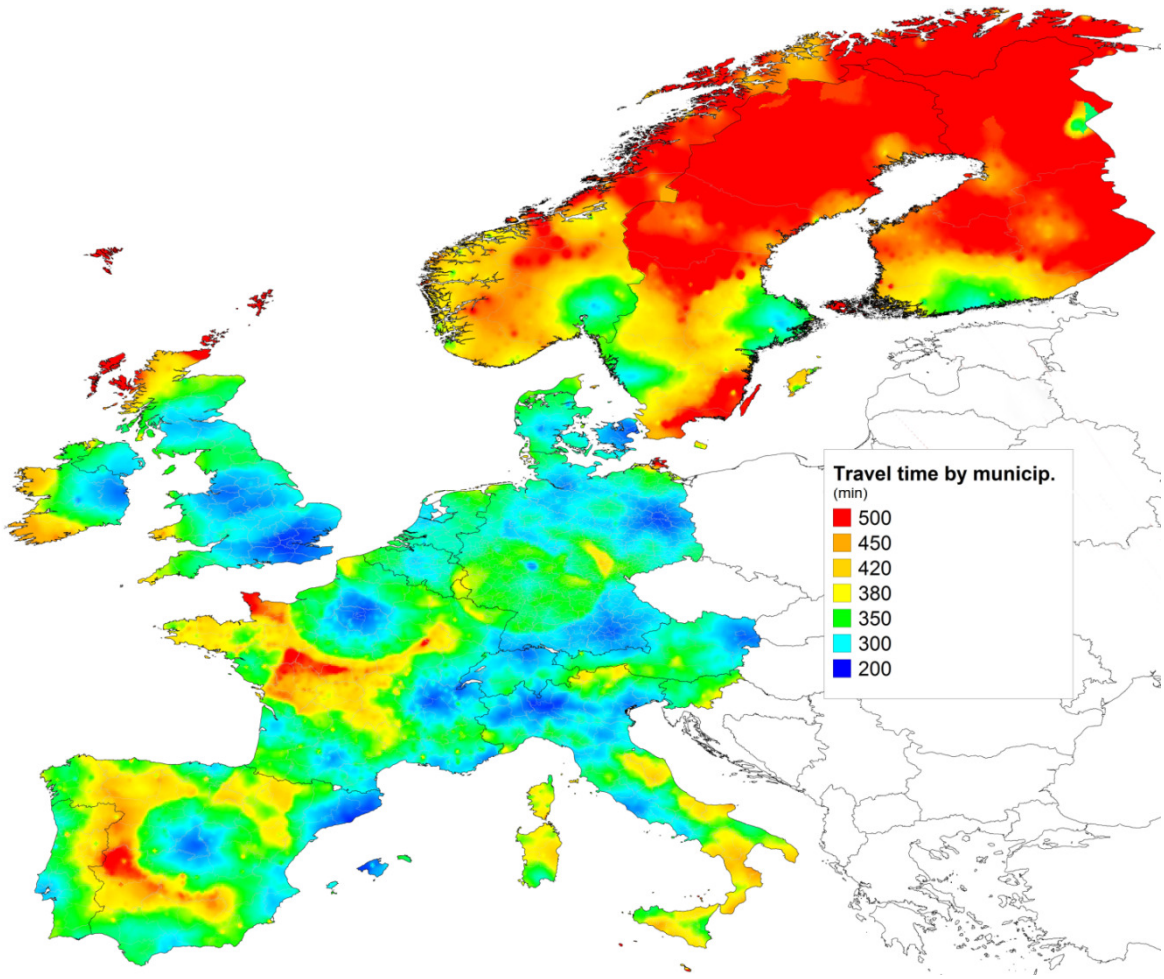

Figure 2. Accessibility index by municipality.

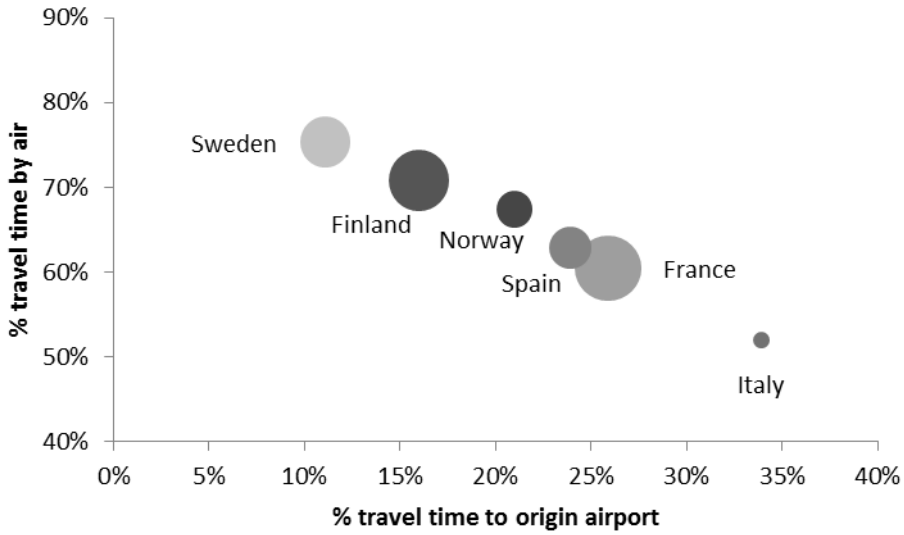

Figure 3. Proportions of travel times in remote regions due to road travel and air travel .