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Measuring road congestion

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Executive summary

Congestion is an important problem for road transport and a main challenge for transport policy at all levels. The cost of road congestion in Europe is estimated to be equivalent to 1% of GDP and its mitigation is the main priority of most infrastructure, traffic management and road charging measures. Measuring congestion is however complicated due to the non-uniform temporal and spatial distribution of traffic.

Efficiency in transport networks is a main priority for transport policy at EU level as expressed through the European Commission's White Paper "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system". The existing links on the European road transport network vary significantly in terms of transport volumes served and, consequently, reach different levels of capacity utilisation and congestion. Statistics such as road counts are not widely available and are normally given on an annual average daily traffic (AADT) basis. Such data do not allow a quantitative estimation of congestion levels, which tend to concentrate on a limited numbers of nodes and links during short time periods.

The methodology presented here allows to measure and monitor road congestion across Europe using data from TomTom in-vehicle navigation systems. The approach is based on the analysis of a large number of real vehicle speeds that have been measured on each road link and the application of algorithms that allow the estimation of congestion indicators for specific types of roads during selected time periods. The results include the detailed mapping of recurrent congestion both geographically and temporally, as well as the comparison of the quality of service of road networks between different zones.

The data used represent real speed measurements from in-vehicle navigation systems for different time periods and days of the week. The large number of "probes" (over 1 trillion of measurements) gives a highly accurate and representative picture of the actual driving conditions across the European road network. The data collected are clustered in groups of speed profiles which represent change in average speed behaviour along a road link in five-minute time intervals over a 24-hour period. Each road link has a specific speed profile assigned per day of the week. The average speed on a specific link during a certain time period can be compared to the benchmark speed estimated for the link under free flow conditions or against selected threshold values. As a result, indicators of congestion for different time periods can be measured and compared across links, regions and countries. The methodology can be useful for policy making in transport through various applications:

- Mapping congestion and monitoring its evolution over time, by comparing the level and distribution of congestion in two different points in time
- Application of the congestion indicators in European transport policy, by comparing average congestion between the peak hour and wider time periods and identifying measures to improve the temporal distribution
- Combination of congestion indicators with traffic counts in order to improve speed flow curves used in transport network models

The key conclusion from the analysis is that congestion mainly affects urban areas and a few key bottlenecks in Europe. The results also suggest that the reason for congestion in many cases is not a lack in capacity of road infrastructure, but rather an issue of demand management.

Table of Contents

List of figures

List of tables

1. Introduction

Congestion is an important problem for road transport and a main challenge for transport policy at all levels. The cost of road congestion in Europe is estimated to be over €110 billion a year and its mitigation is the main priority of most infrastructure, traffic management and road charging measures. Measuring congestion is however complicated due to the non-uniform temporal and spatial distribution of traffic.

Efficiency in transport networks is a main priority for transport policy at EU level as expressed through the European Commission's "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system" [1]. The existing links on the European road transport network vary significantly in terms of transport volumes served and, consequently, reach different levels of capacity utilisation and congestion. Statistics such as road counts are not widely available and are normally given on an annual average daily traffic (AADT) basis. Such data do not allow a quantitative estimation of congestion levels, which tend to concentrate on a limited numbers of nodes and links during short time periods.

The methodology presented here allows to measure and monitor road congestion across Europe using data from TomTom in-vehicle navigation systems. The approach is based on the analysis of a large number of real vehicle speeds that have been measured on each road link and the application of algorithms that allow the estimation of congestion indicators for specific types of roads during selected time periods. The results include the detailed mapping of recurrent congestion both geographically and temporally, as well as the comparison of the quality of service of road networks between different zones.

2. Methodology

The data used represent real speed measurements from in-vehicle navigation systems for different time periods and days of the week [2]. The large number of "probes" (over 1 trillion of measurements) collected during 2008 and 2009 gives a highly accurate and representative picture of the actual driving conditions across the European road network. The data collected are clustered in groups of speed profiles which represent change in average speed behaviour along a road link in five-minute time intervals over a 24-hour period [3, 4]. Each road link has a specific speed profile assigned per day of the week. The average speed on a specific link during a certain time period can be compared to the benchmark speed estimated for the link under free flow conditions or against selected threshold values. As a result, indicators of congestion for different time periods can be measured and compared across links, regions and countries.

Average speed for a road link can be calculated at any time of the day by combining the free flow speed of the link with the appropriate profile for the current time period. Figure 1 shows a sample of typical speed profiles. The value in the y-axis of the profile is a percentage value of the free flow speed for a road link, while the value on the x-axis represents the change in time over a 24-hour period.

Congestion indicators

The average speed on a road link can be calculated as the moving average of probe speeds over a period p:

$$\overline{v}_{i,p} = \frac{1}{p}\sum_{j=i}^{i+p} v_j \qquad \text{[Eq. 1]}$$

Where
p is the duration f the time period p
i is the start of the period
v_j is the average probe speed in time slot j

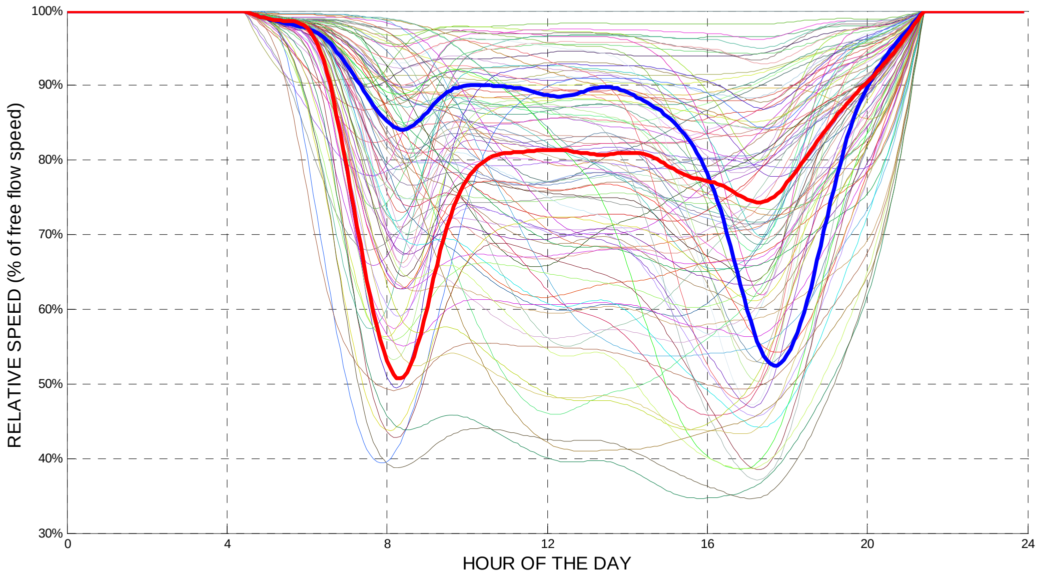

Figure 1: Typical speed profiles

Free flow speed is considered as the maximum measured average speed over the period:

$$v_{free} = \max_{j\in[t_0,t]} v_j \qquad \text{[Eq. 2]}$$

while the period with the lowest average speed would be:

$$\overline{v}_p = \min_{i\in[t_0,t]} \overline{v}_{i,p} \qquad \text{[Eq.3]}$$

There are two main indicators of congestion that can be derived from the above. The ratio of the average speed during the most congested period p with respect to the maximum speed:

$$c_p = \frac{\overline{v}_p}{v_{free}} \qquad \text{[Eq. 4]}$$

and the average delay during period p expressed in minutes per km (or mile):

$$d_p = \frac{60}{\frac{1}{\overline{v}_p} - \frac{1}{v_{free}}}$$ [Eq. 5]

These indicators allow a direct mapping of recurrent road congestion in Europe, offering a flexible framework of analysis. Modifying the period p can limit the estimation on specific peak periods of e.g. 1 hour, or extend it to wider periods (e.g. 3, 6 hours or even a whole 24 hour period). Filtering in terms of the free flow speed can help focus on specific types of roads such as highways/freeways or urban roads. Figure 2 presents an example of a map of congestion in Europe, for the most congested 3-hour period in each link and for roads with free flow speeds over 80 km/h.

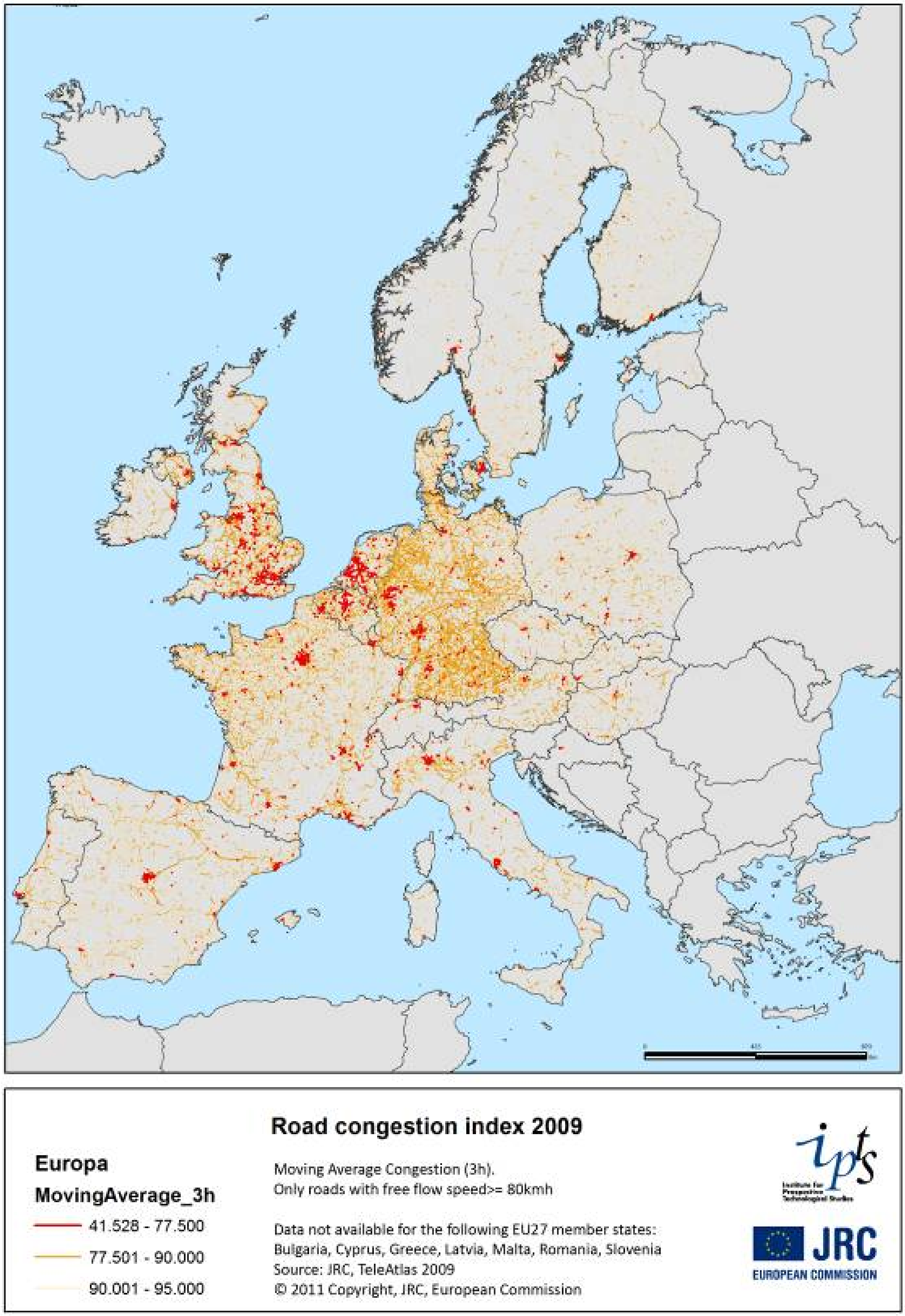

Figure 2: Map of road congestion in Europe, indicator $c_{(3h)}$ for roads with free flow speed over 80km/h

Apart from the map itself, the data also allow the estimation of aggregate congestion levels for each geographic zone, from country level to a local area.

The congestion indicator for a zone based on the ration of average speed to free flow speed would be the weighted average:

$$c^{v}_{zone} = \frac{\sum_{r \in [zone]} (L_r \frac{\overline{v}_{r,p}}{v_{r,free}})}{\sum_{r \in [zone]} L_r} \quad \text{[Eq. 6]}$$

The congestion indicator for a zone using the average delay would also be a weighted average of the form:

$$c^{t}_{zone} = \frac{\sum_{r \in [zone]} L_r d_{r,p}}{\sum_{r \in [zone]} L_r} \quad \text{[Eq. 7]}$$

where L_r is the length of each individual link

The measured speeds for each link can also be used as an indicator. The share of the length of the network with an average speed within a certain range can be used to evaluate the overall performance of the network:

$$S_{p,v_{\min},v_{\max}} = \frac{\sum_{r \in [zone]} L_r \overline{v}_p}{\sum_{r \in [zone]} L_r}, \; for\, v_{\min} < v_p < v_{\max} \quad \text{[Eq. 8]}$$

In a similar fashion, the share of the network for which average delays during a period are within a certain range can give an indication of the distribution of congestion:

$$W_{p,d_{p\min},d_{p\max}} = \frac{\sum_{r \in [zone]} L_r d_p}{\sum_{r \in [zone]} L_r}, \; for\, d_{p\min} < d_p < d_{p\max} \quad \text{[Eq. 9]}$$

3. Application for the European road network

The selection of the suitable indicator to measure congestion depends on the specific application and on the policy variable of interest. The formulation of the congestion indicators depends on:

- The expression of delay used, ie ratio of measured to free speed or delay per km
- The time period for which congestion is measured, ie. the moving average used
- The type of road (urban, inter-urban, etc.) or the characteristics the road has (eg free flow speed)
- The threshold values used to define congestion
- The geographic area for which the analysis is made

For transport policy at European level, an indicator at both member state and EU level is probably the most relevant level of analysis. After testing various moving averages, the 1h and 3h moving averages are the ones that give a reasonable representation of the duration of peak periods. Although not accurately reflecting whether a road is urban or not, the free flow speed can be a good proxy as regards its type and characteristics. Roads can be therefore divided in three groups, one below 50km/h and one over 100km/h to represent local and inter-urban links. A third group, roads with a free flow speed over 80km/h is also useful in order to analyse inter-urban traffic in areas with few highways.

What is more relative, though, is the threshold value for which congestion is important. The ratio of average to free flow speed is an easy to understand metric, especially when comparing zones or types of roads between them or over time, but does not necessarily give a clear indication on how important congestion is.

Average delay per km is an indicator with a simpler physical interpretation, since it allows a direct estimate of total delay for a given trip. Measuring congestion in such a way also highlights the fact that the impact on delays from a similar drop in average speed is much more profound at lower speeds. Reducing the speed from 50 km/h to 40 km/h generates a delay of 0.3 minutes per km, while a proportional 20% reduction from 100 km/h to 80 km/h leads to a delay of only 0.15 km/h.

Table 1 summarizes the results for the main indicators at EU level. It is evident that congestion is more pronounced at local level than when considering inter-urban links (defined as the ones with a free flow speed of more than 100km/h). Comparing the real delays though shows that in practice the delays in roads with higher speeds are far less important than in local roads. It is also obvious that the moving average of 1h gives significantly higher congestion levels than the one of 3 hours (figure 3 gives the whole range of moving averages from 0.5 to 24 hours for the speed based congestion indicator, EU wide weighted average).

Table 1: Main congestion indicators per member state, for roads with free flow speed <50km/h, >80km/h and >100km/h, 1h and 3h moving averages

	Ratio of average to free flow speed (%)						Average delay per km (seconds)				
	Free flow speed <50km/h		Free flow speed >80km/h		Free flow speed >100 km/h		Free flow speed <50km/h		Free flow speed >80km/h		Free fl speed > km/
Country	Mov avg 1h	Mov avg 3h	Mov avg 1h	Mov avg 3h	Mov avg 1h	Mov avg 3h	Mov avg 1h	Mov avg 3h	Mov avg 1h	Mov avg 3h	Mov avg 1h
Austria	86.7	88.2	92.8	94.1	93.9	95.1	15.7	13.7	3.0	2.4	2.0
Belgium	**84.0**	85.9	**89.8**	91.3	**88.9**	90.3	19.9	17.1	**4.4**	3.6	**4.3**
Czech Republic	88.0	89.5	92.5	94.2	92.5	94.3	13.3	11.5	3.1	2.4	2.5
Germany	85.0	86.6	**89.9**	91.2	**89.9**	90.9	17.3	15.3	**4.2**	3.6	3.5
Denmark	85.9	87.7	92.5	93.9	92.4	94.2	17.1	14.5	3.2	2.6	2.8
Spain	89.5	91.2	92.5	94.1	92.0	93.7	12.7	10.4	2.9	2.2	2.8
Estonia	87.3	88.9	95.6	96.8	93.5	95.2	14.6	12.5	1.9	1.3	2.5
Finland	87.4	88.9	94.3	95.5	94.4	95.6	14.5	12.6	2.4	1.9	2.0
France	87.6	89.1	93.0	94.3	92.7	94.3	15.2	13.1	2.9	2.3	2.5
United Kingdom	**80.9**	**82.7**	90.4	92.2	90.2	92.4	**24.3**	**21.5**	**4.3**	3.4	**3.9**
Hungary	**82.2**	**84.0**	91.3	92.9	91.0	92.8	**22.1**	19.3	3.5	2.8	3.1
Ireland	**80.7**	**82.1**	93.1	94.3	94.7	96.0	**26.7**	**24.4**	3.1	2.5	1.9
Italy	87.7	89.3	93.2	94.5	93.8	95.0	15.0	12.8	2.8	2.3	2.2
Lithuania	**84.0**	85.7	93.8	95.5	93.4	95.3	19.6	17.2	2.5	1.8	2.3
Luxem-bourg	85.8	87.7	**87.3**	**89.6**	**84.4**	**87.0**	16.8	14.1	**5.7**	**4.4**	**6.6**
Nether-lands	85.6	87.2	**88.2**	**90.0**	**86.6**	**88.7**	17.8	15.6	**5.4**	**4.3**	**5.6**
Poland	**82.2**	**83.6**	92.9	94.4	93.2	94.7	**23.1**	**20.9**	3.1	2.4	2.4
Portugal	88.7	90.3	93.3	94.8	93.3	95.0	13.3	11.2	2.6	2.0	2.3
Slovakia	**84.9**	86.5	91.6	93.2	91.3	93.1	17.5	15.3	3.6	2.8	3.0
Sweden	86.5	87.9	94.3	95.4	94.3	95.4	15.8	13.9	2.4	1.9	2.1
EU weighted average	**86.3**	**87.9**	**92.2**	**93.6**	**91.8**	**93.4**	**16.6**	**14.4**	**3.3**	**2.6**	**3.0**

The congestion indicators are a relative measure and the use of thresholds is necessary in order for them to be used for the actual evaluation of the situation as regards congestion. Table 1 allows the comparison between member states:

- Seven member states have a 1h speed based congestion indicator below 85% for local roads, four of which remaining below that threshold even for the 3 hour most congested period. All four have average delays of more than 20 seconds per km during the 1 hour peak, while three of them still do so during the 3 hour peak. By most measures Ireland, United Kingdom, Poland and Hungary are identified as the member states where local/urban congestion is highest.
- No member state presents similar congestion levels for the inter-urban links/highways (roads with free flow speed of more than 100km). Four member states have a speed based congestion indicator below 90% for the 1 hour peak

period, while two of them remain below 90% during the 3 hour peak period as well. The average delays per km are rather low however, the maximum being 6.6 seconds per km. Luxembourg and the Netherlands demonstrate the highest inter-urban congestion levels. Data for Belgium, Germany and United Kingdom suggest that inter-urban congestion may be an issue.

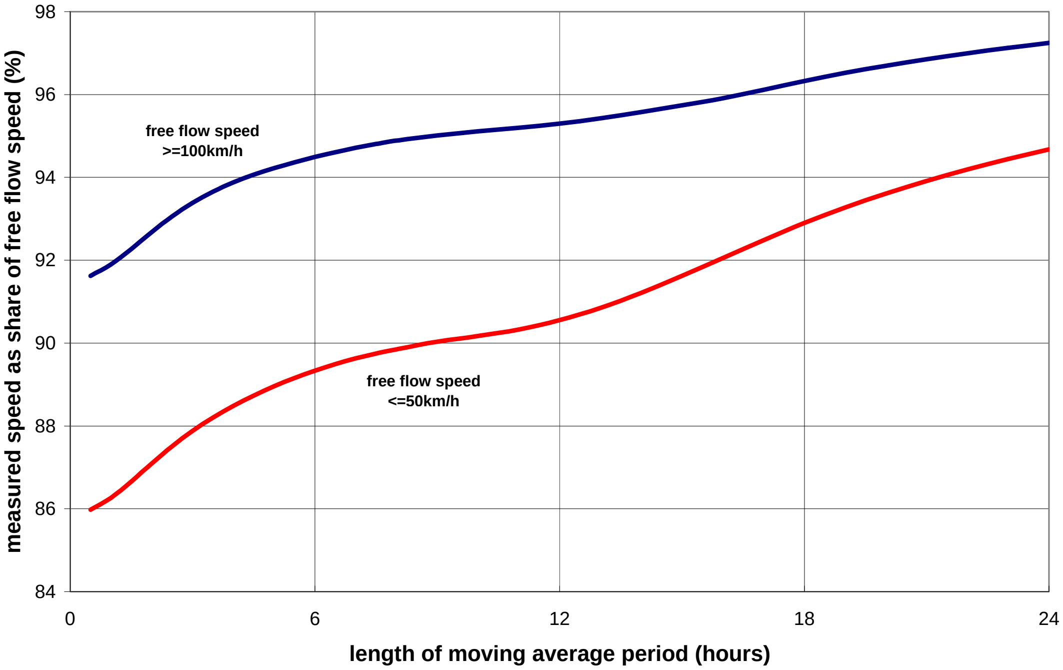

Figure 3: Congestion indicator during different calculation periods (length of moving average), EU weighted average

Mapping the average delays on the road network across Europe gives a similar message. The interurban network (Figure 4) presents a limited number of links with a delay of over 10 seconds per km[1], mainly located in the Netherlands, parts of Belgium, Luxembourg, inter-urban connection in the United Kingdom, parts of Germany, around main population centres (Paris, Madrid, Rome, Milano) and on the links between Copenhagen and the rest of Denmark and with Sweden.

The map for local road congestion (Figure 5) suggests that it is spread more uniformly across the EU and is highly dependent on urban densities and the quality and capacity of infrastructure. A large number of links with an average delay of 45 seconds per km is visible[2], corresponding to urban road in most of the medium and big cities across the EU.

The key conclusion from the analysis is that congestion mainly affects urban areas and a few key bottlenecks in Europe. The results also suggest that the reason for congestion in many cases is not a lack in capacity of road infrastructure, but rather an issue of demand

[1] Setting 10 seconds per km as a threshold allows a comprehensive coverage of congested links at inter-urban level. Lowering the thresholds results in blurring the map with too many links appearing, while raising the thresholds results in a limited number of links appearing, not sufficient to draw conclusions.
[2] The threshold here is 45 seconds per km for practical reasons, in order to obtain a readable map. Obviously the resulting map cannot be directly comparable to the one on inter-urban links, it only serves to identify where urban congestion is most likely to occur.

management. Average delays are important during peak periods, but since demand is not spread uniformly during the day, a large part of road capacity is underutilised outside the one or two peaks of 3 to 6 hours a day.

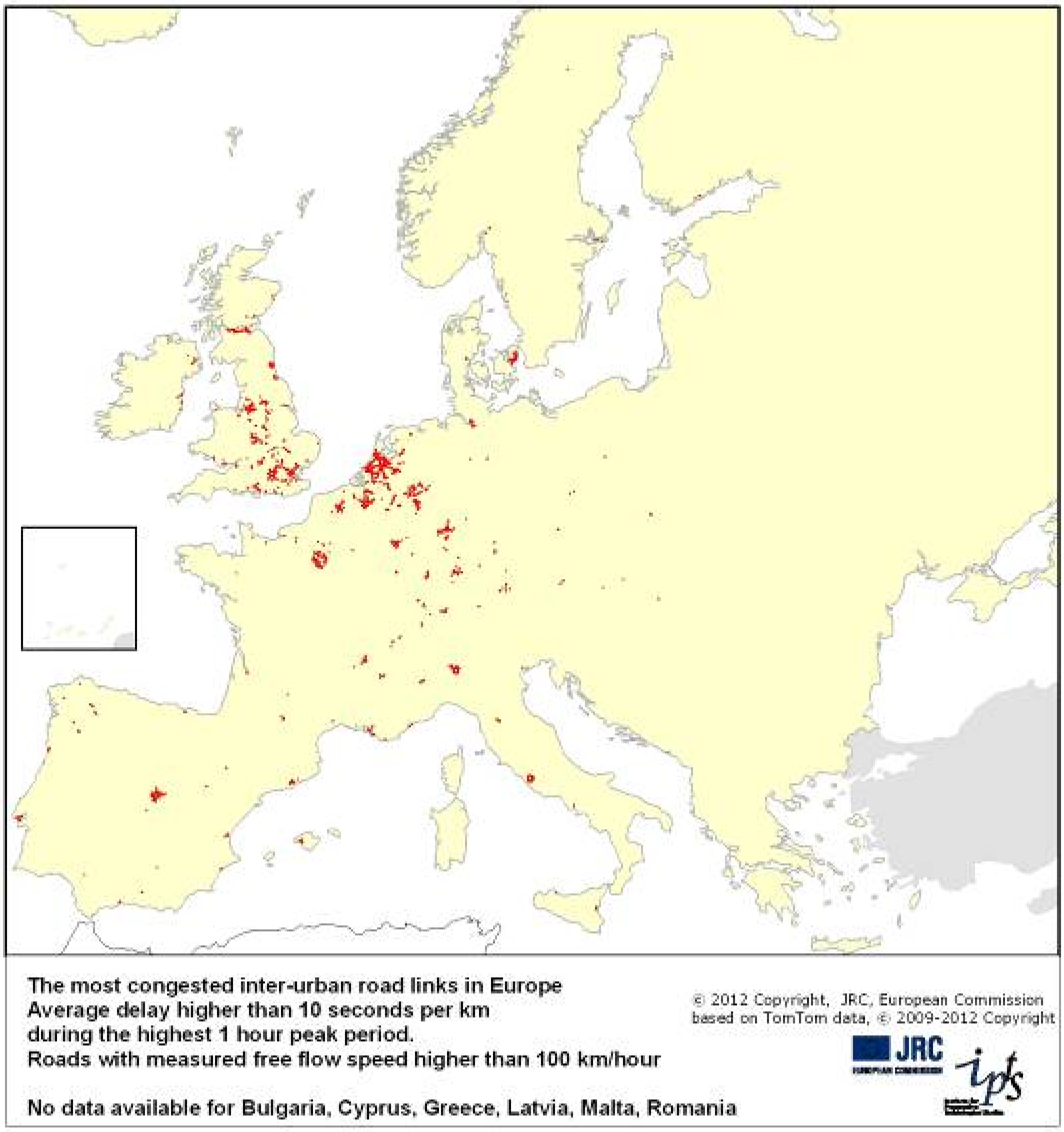

Figure 4: Inter-urban congestion in the EU, 1 hour peak period, average delays higher than 10 seconds per km, free flow speed higher than 100 km/hour

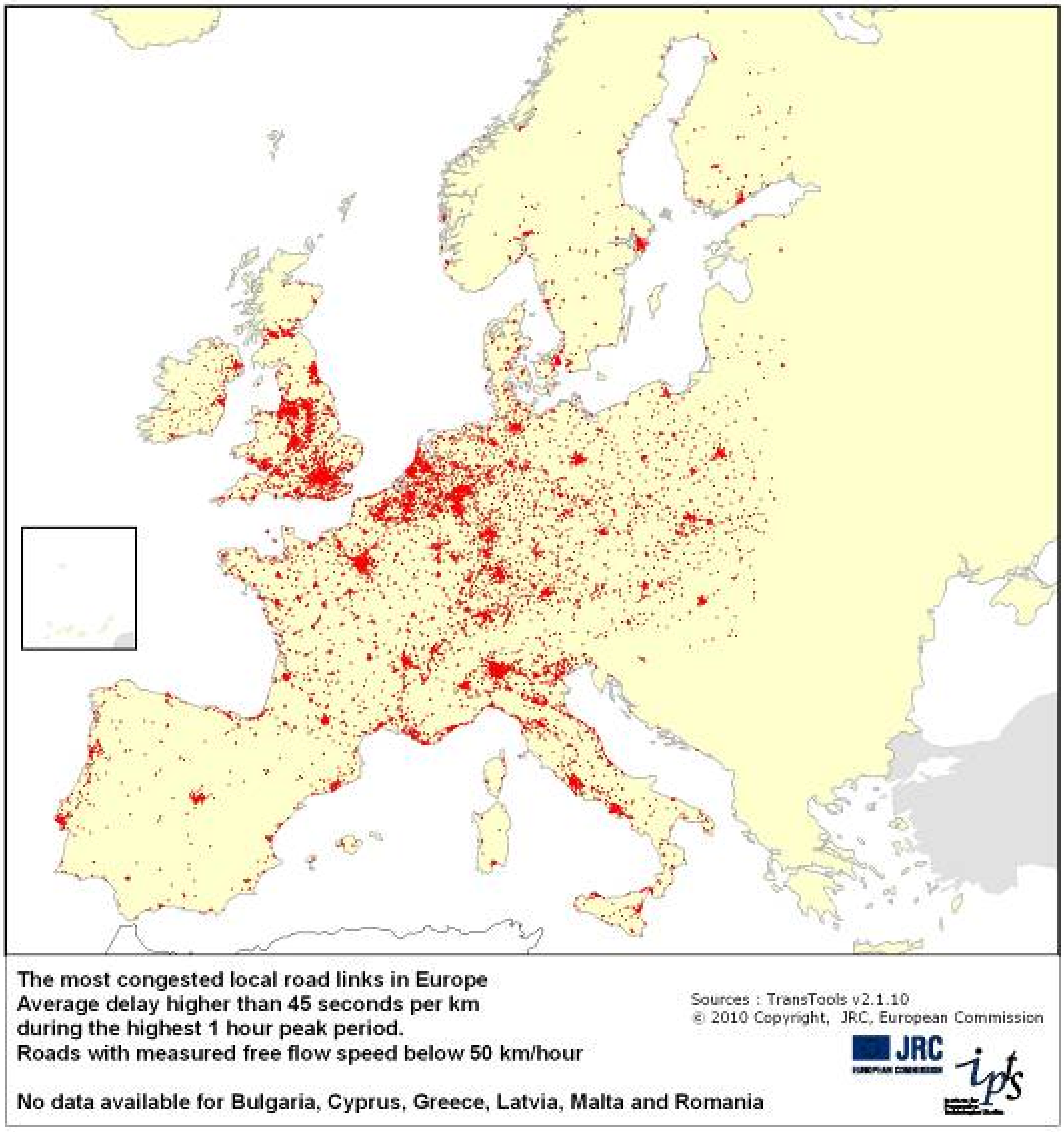

Figure 5: Local/urban congestion in the EU, 1 hour peak period, average delays higher than 45 seconds per km, free flow speed below 50 km/hour

Table 2: Share of road network for each average speed level

	Total length of network for which data is available (kms)	Roads with average speed below 50km/h	Roads with average between 80-and 100 km/h	Roads with average speed above 100km/h
Austria	27907	16.9%	19.9%	12.9%
Belgium	29984	22.5%	11.0%	12.8%
Czech Republic	25158	13.7%	21.1%	9.0%
Germany	225605	19.4%	21.0%	11.6%
Denmark	18762	9.9%	35.5%	11.7%
Spain	112945	16.5%	22.4%	28.6%
Estonia	5178	5.5%	65.9%	2.9%
Finland	37002	5.7%	52.7%	6.1%
France	274426	18.0%	24.4%	10.7%
United Kingdom	94155	17.7%	18.2%	13.9%
Hungary	9208	7.1%	39.3%	22.9%
Ireland	13567	9.6%	23.1%	10.0%
Italy	129103	24.7%	10.6%	12.9%
Lithuania	5793	5.6%	57.9%	12.8%
Luxembourg	2456	20.7%	11.3%	10.3%
Netherlands	36840	25.8%	11.9%	13.0%
Poland	49358	8.3%	38.8%	6.2%
Portugal	28559	19.1%	16.1%	19.5%
Slovakia	6063	6.1%	33.4%	15.2%
Sweden	43098	7.8%	45.5%	13.0%
Total EU (available countries)	**1175167**	**17.5%**	**23.3%**	**13.3%**

Table 2 summarizes the results for the indicator of Eq.8, the share of the road network in each EU member state that has an average measured speed of below 50 km/h, between 80 and 100 km/h and over 100 km/h. The differences among member states reflect the local conditions as regards the quality of the road network infrastructure (e.g. the large share of highways in Spain results in more than 28% of the network having an average speed of more than 100 km/h) or speed limits (e.g. in Finland where only 6% is higher than 100 km/h, but more than half the network has an average speed between 80 and 100 km/h).

Table 3 shows the results for the indicator of Eq.9, the share of the network with average delays within a certain range, ranked according to the share of roads with an average delay of more than 10 seconds per km. This indicator gives a clearer picture of overall congestion, since it is based on the difference between the average and the free flow speeds.

Table 3: Congestion classification: Average delay per km during 1 hour peak period (share of total road network)

	Average delay per km (seconds)				
	1 to 5	**5 to 10**	**10 to 20**	**Higher than 20**	**Higher than 10**
United Kingdom	48.2%	25.7%	11.1%	8.8%	19.9%
Belgium	42.7%	35.1%	12.6%	6.4%	19.1%
Netherlands	46.3%	32.0%	11.6%	6.4%	18.0%
Luxembourg	44.5%	36.2%	9.6%	5.8%	15.3%
Germany	46.7%	36.8%	9.5%	4.3%	13.8%
Italy	50.7%	25.2%	7.9%	4.7%	12.6%
Hungary	65.7%	19.0%	7.3%	4.1%	11.4%
Poland	60.8%	21.7%	6.4%	4.5%	10.9%
Slovakia	57.8%	26.6%	7.6%	2.6%	10.2%
Ireland	61.8%	18.7%	5.2%	4.1%	9.3%
Czech Republic	52.8%	28.0%	6.3%	2.5%	8.8%
Austria	55.7%	28.4%	5.8%	2.7%	8.5%
France	61.1%	19.4%	5.3%	2.7%	7.9%
Portugal	57.3%	21.0%	5.5%	2.3%	7.9%
Denmark	62.8%	20.9%	5.2%	2.3%	7.5%
Sweden	70.7%	13.6%	3.5%	1.5%	5.0%
Spain	68.2%	16.8%	3.7%	1.2%	4.9%
Lithuania	78.6%	9.4%	1.9%	1.7%	3.6%
Estonia	74.4%	8.3%	1.9%	1.2%	3.2%
Finland	74.8%	13.4%	2.1%	0.8%	2.9%

The data available allow the quantification of average delays per km for specific roads and across the road network of wider zones. The indicators presented here measure the share of the network that is congested during various time periods, but do not give a precise picture of the share of traffic that is on the road during congested periods. The distribution of traffic volume is not uniform either during a specific time period, or among the links of a road network. There is a clear correlation between distribution of traffic volumes and congested network links, but the relationship is not linear and does not allow a direct transformation.

The estimation of the total congestion delays, for all trips, requires an additional step that takes into account the distribution of trips during each time period and each type of network:

$$D^t_{zone} = \sum_{\forall p,w} c^t_{zone,p,w} V_{zone,p,w} \qquad \text{[Eq. 9]}$$

where D^t_{zone} the total delay for all trips in the zone, $c^t_{zone,p,w}$ the weighted average of delay per unit of length for each time period p and type of network w for the specific zone, and $V_{zone,p,w}$ the total traffic for the specific combination of period, network type and zone (in vehicles or passenger or tonnes x length).

Since data on the distribution of traffic volumes at this level is not available, an approximation is made using results of the TRANSTOOLS model v 2.5 [5, 6]. For the term $V_{zone,p,w}$ the results of the model as regards the share of total traffic during the various peak and off-peak periods for each of the three types of network (<50km/h, >80km/h and >100km/h) is used. These shares are then applied of the total transport activity for 2009 in each country as published by Eurostat [7]. The term $c^{t}_{zone,p,w}$ corresponds to the figures in Table 4 for average delay per km.

The estimate of the total delay for each zone can also be used as a basis for the estimation of the cost of congestion. Applying the time values proposed by HEATCO [6], adjusted for inflation, produces the results that are summarised in Table 2. On average, road congestion costs for passenger and freight transport represent 1% of GDP, with important variations among EU member states.

Table 4: Annual cost of congestion per EU member state, in absolute terms and as share of GDP

	Annual cost of congestion (€ billion)	Cost of congestion as % of GDP 2009
Austria	1.8	0.6%
Belgium	3.4	1.0%
Czech Republic	0.8	0.6%
Germany	24.2	1.0%
Denmark	1.5	0.7%
Spain	5.5	0.5%
Estonia	0.1	0.8%
Finland	1.4	0.8%
France	16.5	0.9%
United Kingdom	24.5	1.6%
Hungary	0.7	0.8%
Ireland	1.8	1.1%
Italy	14.6	1.0%
Lithuania	0.5	1.7%
Luxembourg	0.3	0.7%
Netherlands	4.7	0.8%
Poland	4.8	1.6%
Portugal	1.2	0.7%
Slovakia	0.3	0.5%
Sweden	2.6	0.9%
Total EU (available countries)	**111.3**	**1.0%**

4. Application for Spain

Applying the methodology described above for Spain, some interesting conclusions can be drawn. The road network in Spain is less congested than in the EU on average, mainly due to the lower population density and the better quality of the road network compared to other EU member states.

- The average delay on Spanish urban roads is 12.7 seconds per km during peak periods, compared to 16.6 seconds per km in the EU as a whole.
- For inter-urban roads congestion levels are much lower, on average 2.9 seconds per km during peak periods, compared to 3.3 seconds per km in the EU as a whole.
- In terms of quality, the Spanish road network is among the best in the EU, with 28.6% of the network allowing travel at an average speed higher than 100 km/h.
- Congestion is, however, still a main problem in Spain. About 5% of the network suffers delays of more than 10 seconds per km, concentrated mainly in Madrid, Barcelona and other main cities.
- Drivers and passengers in Spain spend more than 420 million hours a year in congestion, with an estimated annual cost of more than € 5.5 billion.

Figure 6 presents the most congested points of the urban road network, while the main points where inter-urban road congestion is concentrated can be seen in
Figure 7. Figure 8 gives an overview of congestion across the whole road network.

Focusing on specific cities, the maps for Sevilla (Figure 9) and Madrid (Figure 10) identify the main bottlenecks of the respective urban road networks. In the case of Sevilla, congestion is concentrated on the main points of entrance to the city centre, with highest delay levels in the Tablada area (where construction works caused significant delays during 2009). In Madrid, congestion is spread throughout the city centre, including the main ring roads (M-30, M-35 and M-40) and the links with the inter-urban network.

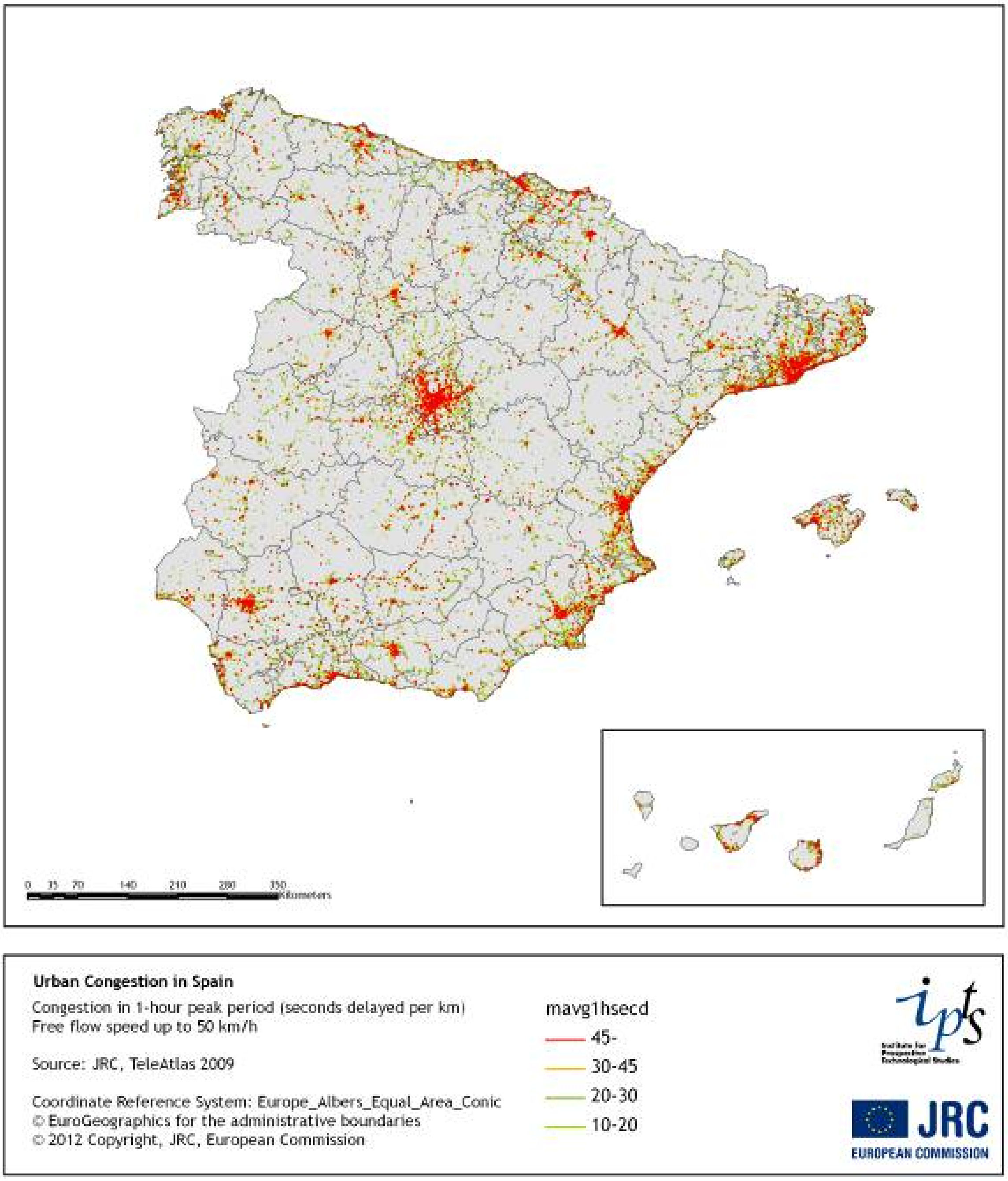

Figure 6: Urban congestion in Spain: Average delay per km (in seconds) during the 1-hour peak, for roads with a free flow speed lower than 50 km/h

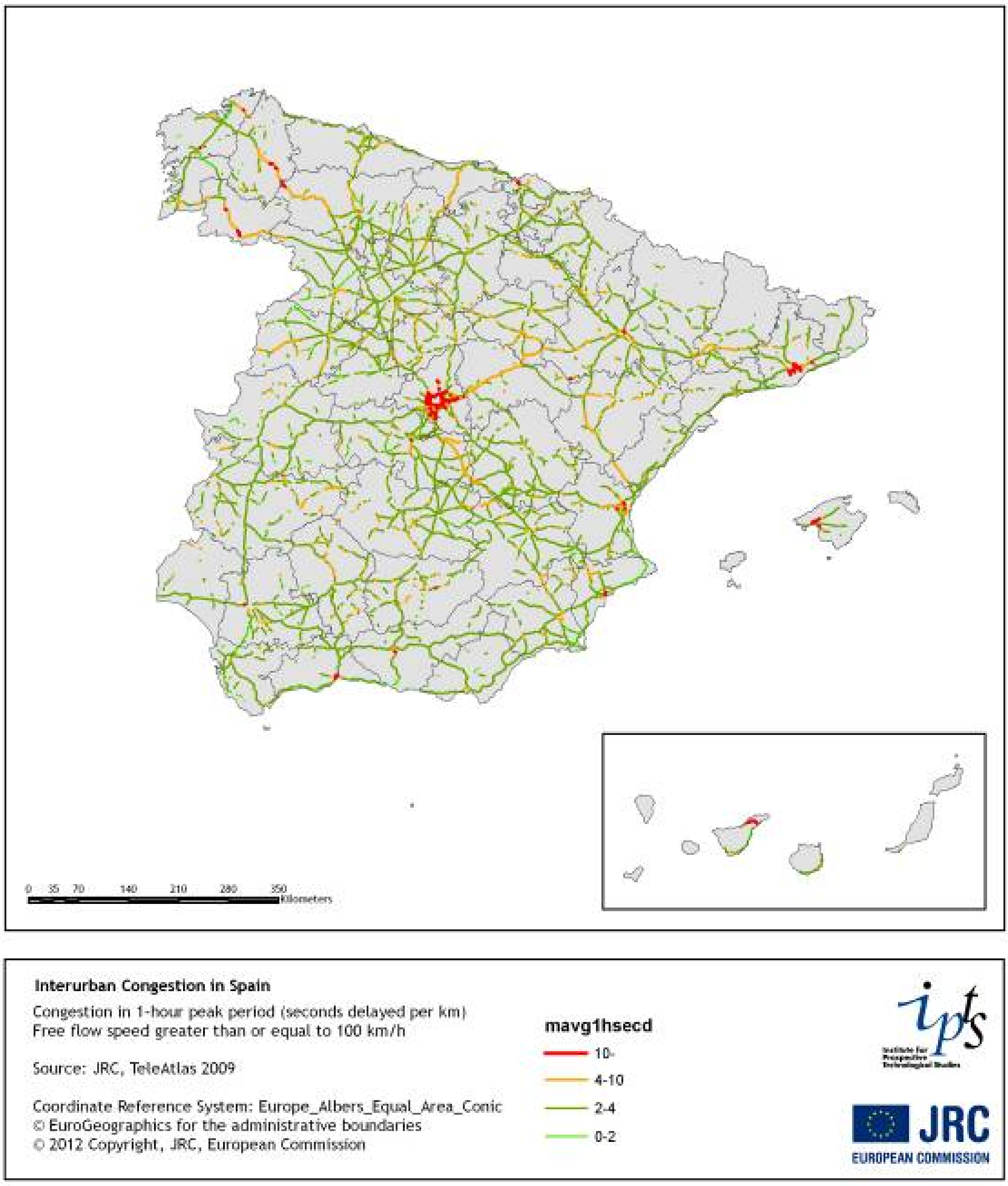

Figure 7: Inter-urban congestion in Spain: Average delay per km (in seconds) during the 1-hour peak, for roads with a free flow speed higher than 100 km/h

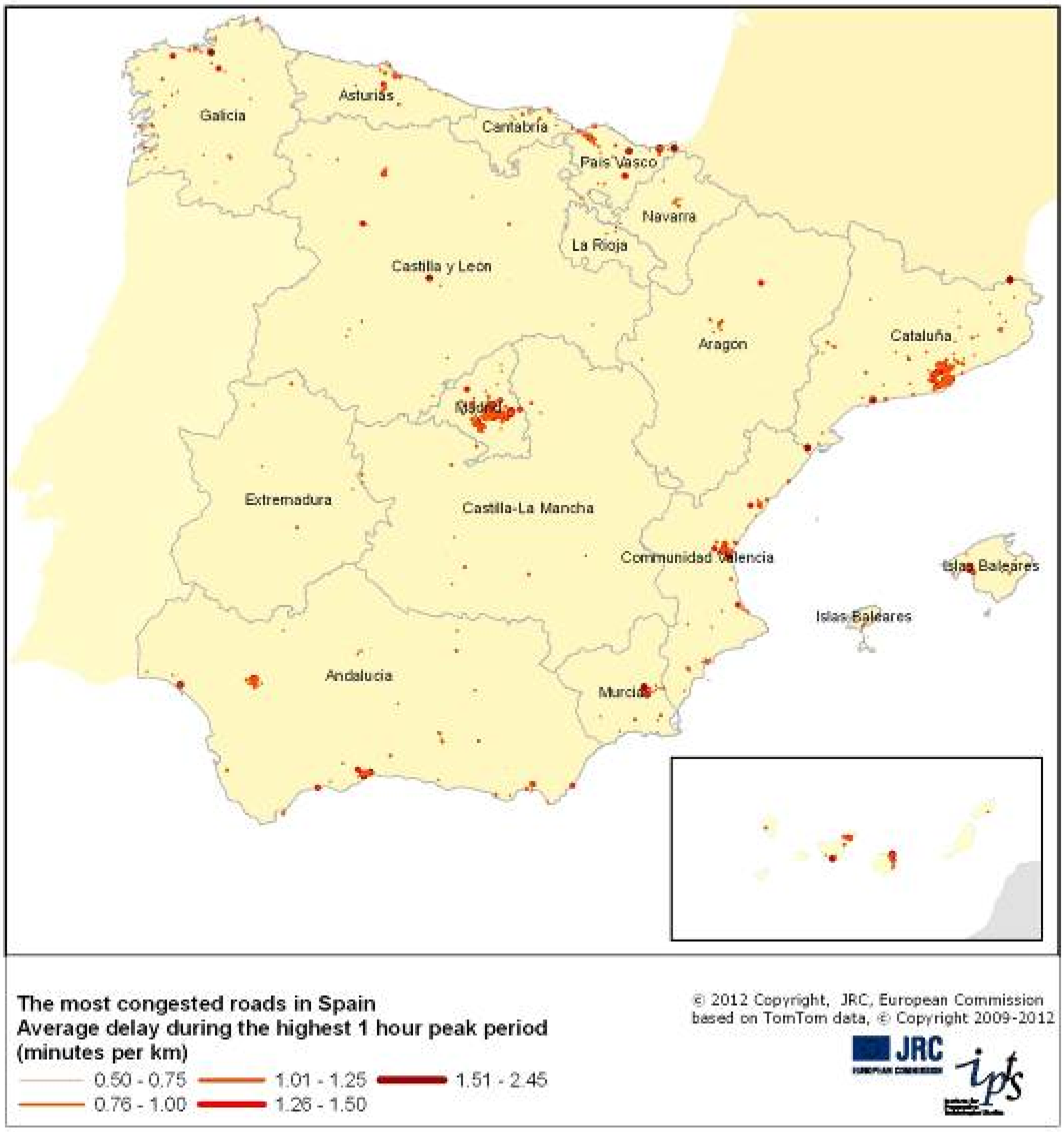

Figure 8: Most congested roads in Spain: Average delay per km (in minutes), all types of roads

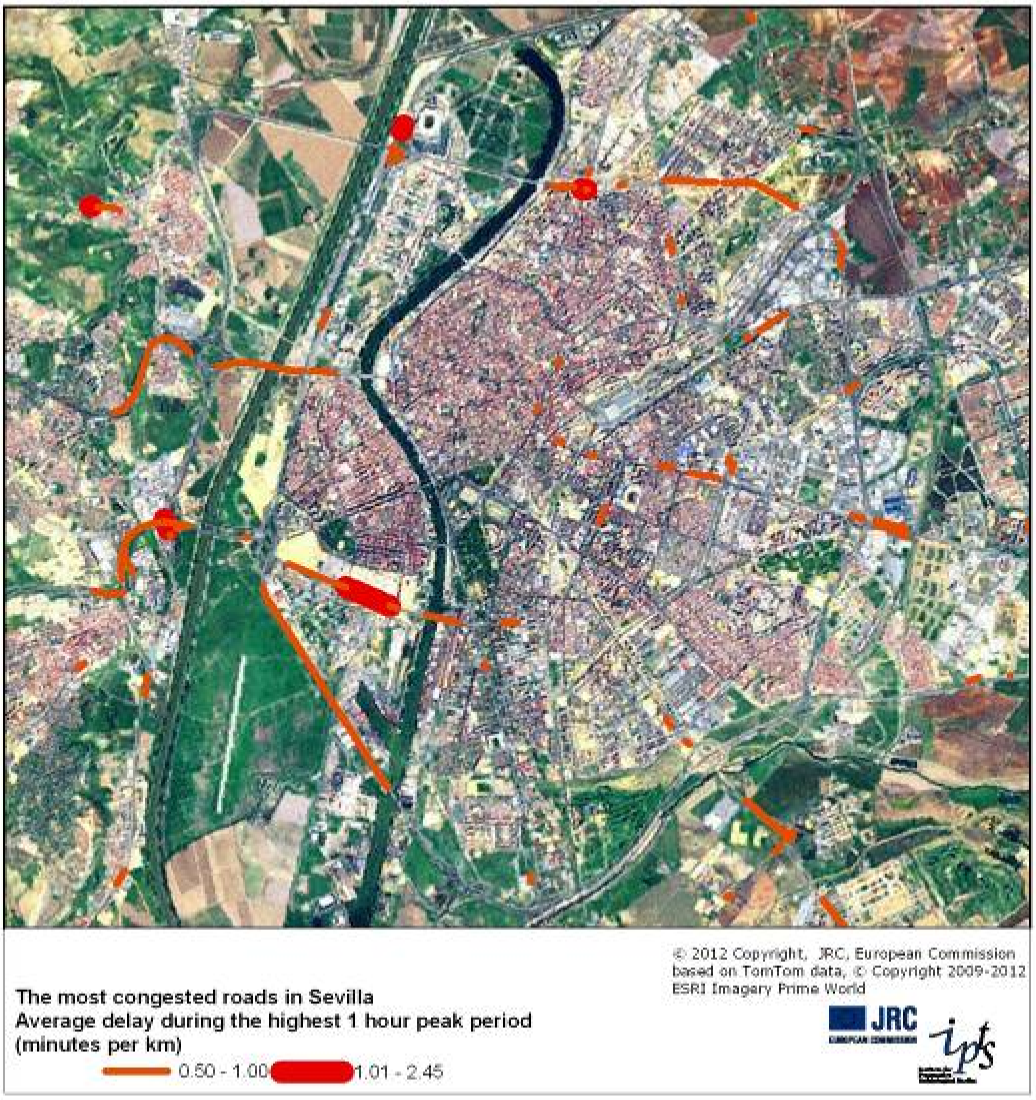

Figure 9: Most congested roads in Seville: Average delay per km (in minutes), all types of roads

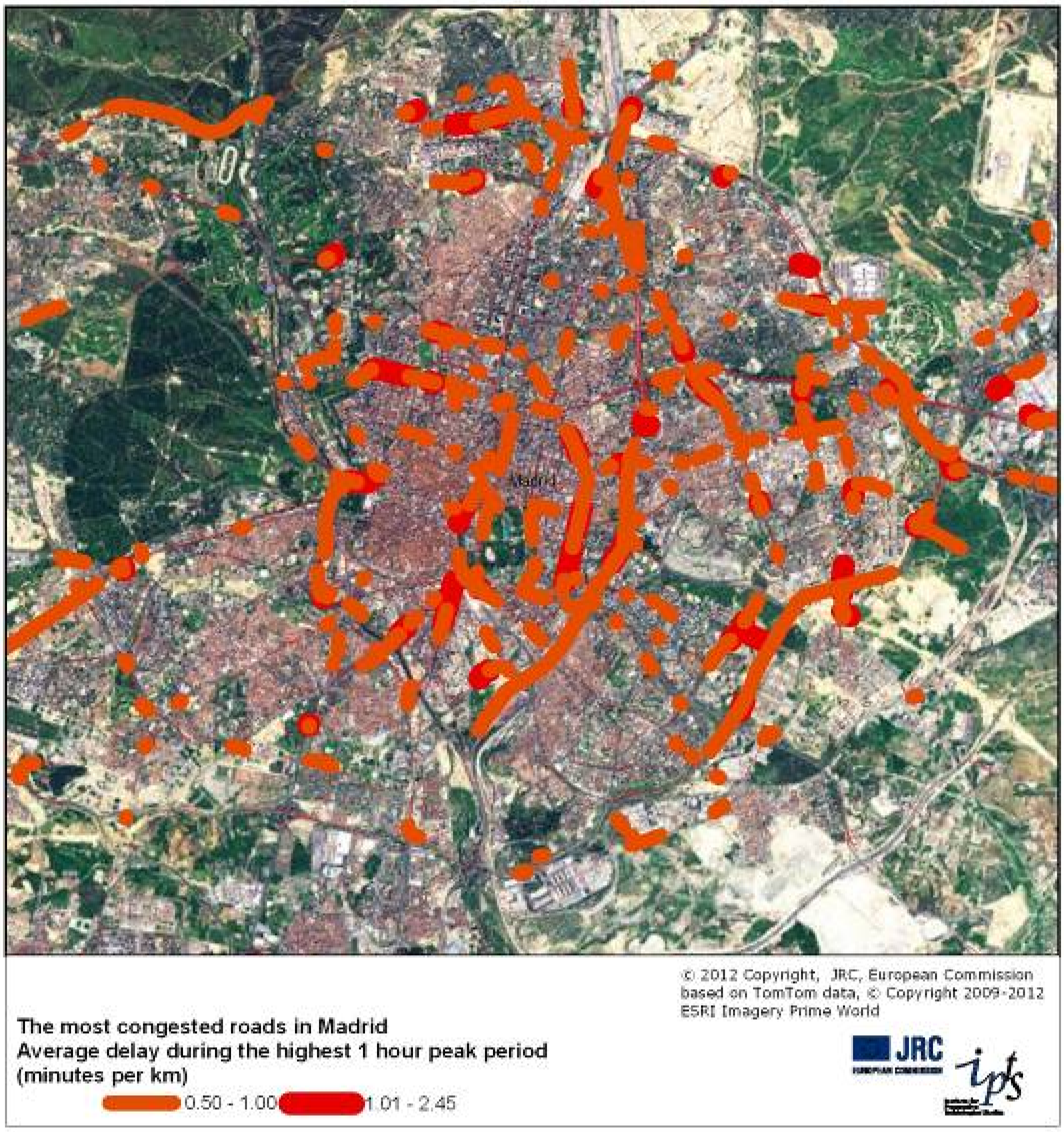

Figure 10: Most congested roads in Madrid: Average delay per km (in minutes), all types of roads

5. Ways to fight congestion in Spain

The results for Spain suggest that congestion is a serious issue for urban areas. Reducing congestion requires a combination of policy measures that can modify the patterns of demand and/ or increase the efficiency of the use of road infrastructure. Increasing or improving road infrastructure itself is probably a counter-productive approach: apart from the lack of space and the high costs it would entail, the existing situation in Spain in terms of both quantity and quality of roads is very good, compared to other EU member states.

The main options to combat congestion seem to be on the demand management side, by either motivating users to change the time or route of their trip, or by re-directing them to alternative transport modes, especially public transport (bus, tram, metro and train) or slow modes (bicycle, walking).

A particularly successful way of changing urban travel patterns is congestion pricing, a measure successfully applied in London, Stockholm and other European cities. The concept behind congestion pricing is for the users to pay a toll if they use a congested part of the network during a certain (peak) period. Ideally, the total amount of charges for congestion should be subtracted from the total taxation for road transport (vehicle or fuel taxes). This way, on aggregate level the measure would be budget neutral but at individual level users avoiding congestion would face a lower tax burden. Such measures normally result in a re-distribution of traffic in time and space that leads to a "peak shaving" of demand and significantly lower levels of congestion. Figure 11 gives an example of how a congestion charge can lead to a more uniform distribution of traffic levels during a day.

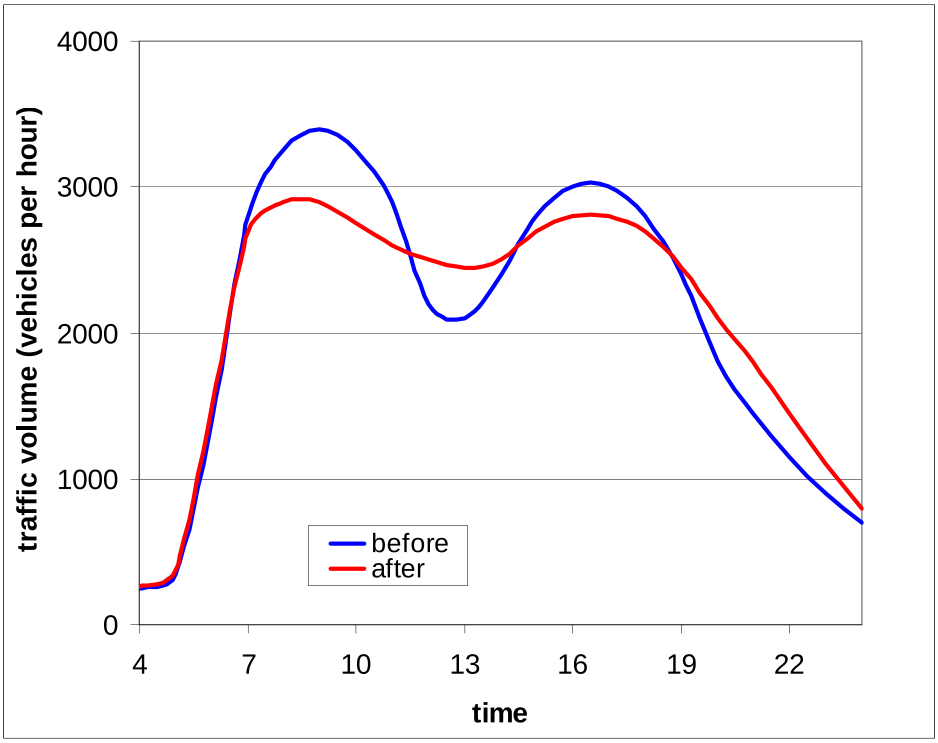

Figure 11: Example of peak shaving as a result of congestion charging

The other main policy measure is related to making public transport and other alternative modes more attractive. Particularly in the case of Spain, there seems to be significant margin for improvement. The responses to the Eurobarometer survey on the future of transport [8] highlight several differences among EU member states, but also help in identifying possible measures that can decrease road congestion and improve transport in general.

The majority of respondents in Spain (53%) and the EU as a whole (50%) express a favourable opinions as regards a replacement of existing car charges such as registration and circulation taxes with charging schemes that take into account the actual use of the car such as the kilometres driven, or the use of it in peak hours.

The survey also identifies possible improvements in public transport (Figure 12). The lack of connections and the low frequency of service are the main reasons for not using public transport. Respondents in Spain highlighted these reasons more frequently than in the rest of the EU, something that may imply the need for an increase in the supply of public transport services in Spanish cities. The lack of information on schedules is a more important factor in Spain, with more than half of the respondents identifying it as a main obstacle for more frequent use of public transport. Cost seems to worry users in Spain at comparable levels as in the rest of the EU, but security concerns are significantly higher, probably as a result of the relatively recent terrorist attacks in Madrid. Spanish public transport seems to compare positively as regards reliability, which was identified as the less important reason for not using public transport in Spain, but was still important in the other member states.

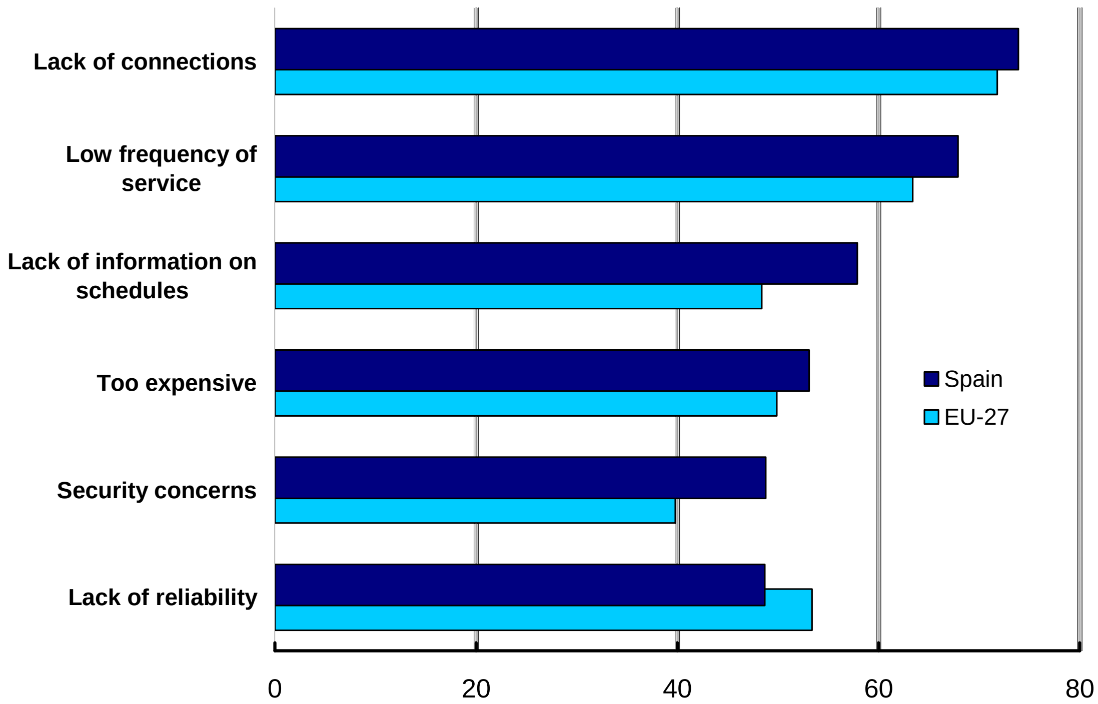

Figure 12: Euro-barometer survey: Reasons for not using public transport (Very important + rather important)

Other options to increase the use of public transport are related to technological and organisational solutions. Using a single ticket for all public transport modes in a journey is considered as a good measure by most respondents (Figure 13).

Better (online) information on schedules and the possibility to by tickets online are technological options that can certainly encourage the use of transport modes other than car (Figure 14). Respondents in Spain identified the need for such solutions more frequently than in other member states, possibly due to the more limited availability of such options. The need for more attractive terminals and better transfers between modes were also identified as important more frequently than in the rest of the EU.

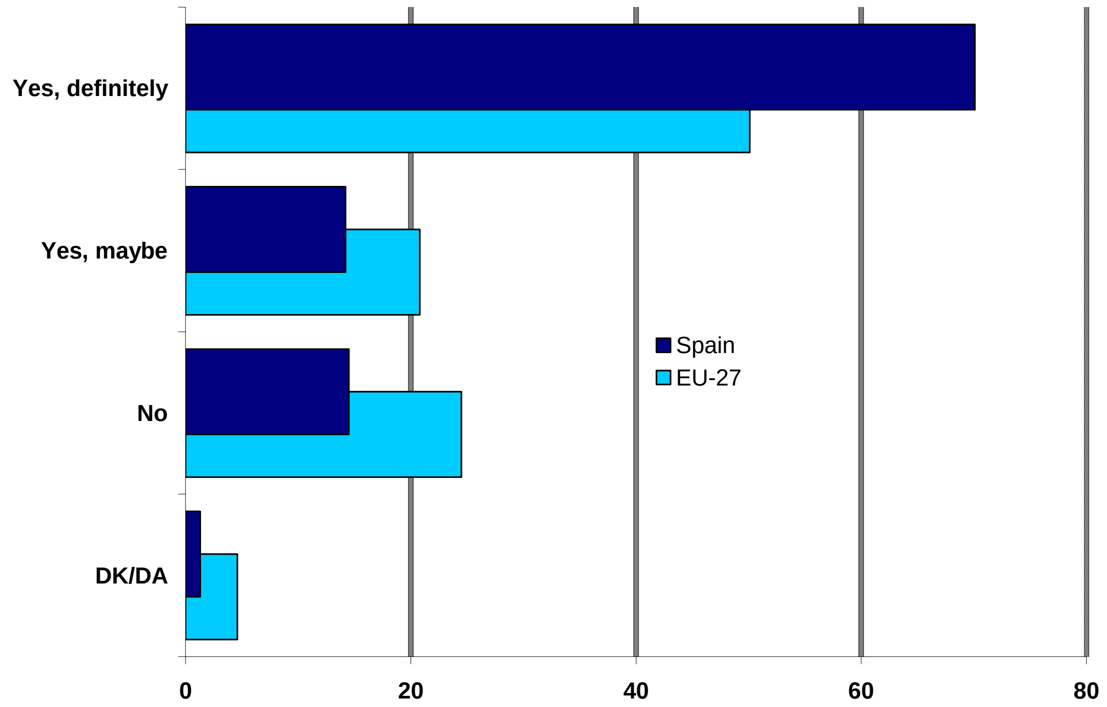

Figure 13: Euro-barometer survey: Would you consider using public transport more frequently if it were possible to buy a single ticket covering all possible transport modes (such as bus, train or tram) for your journey?

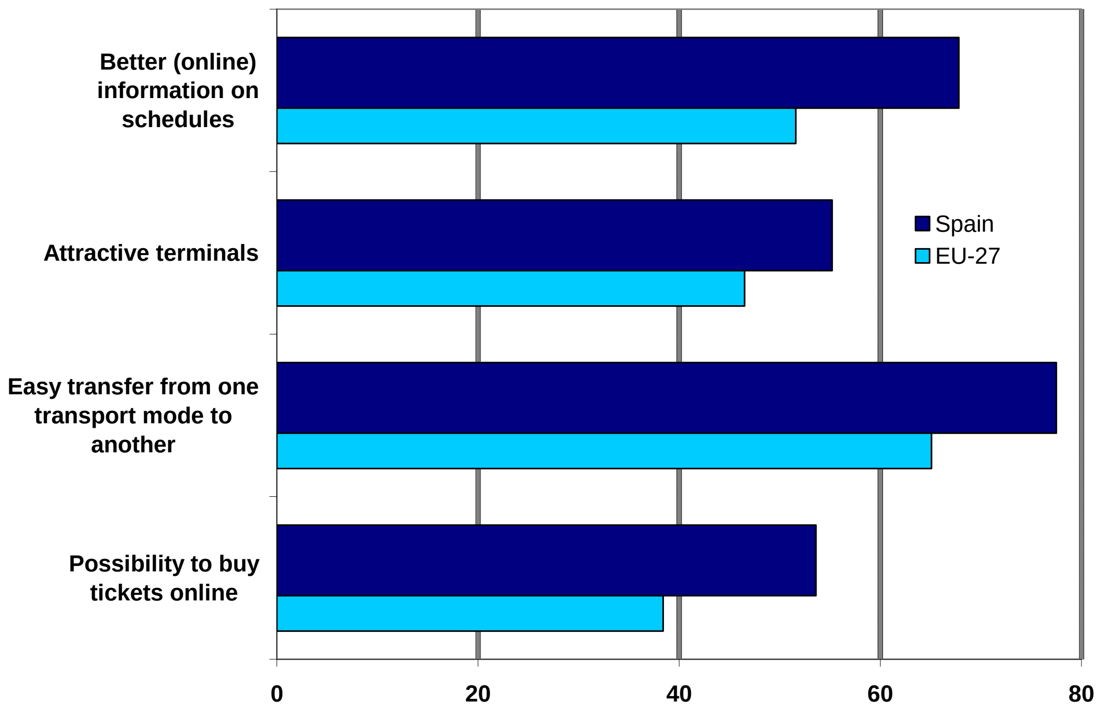

Figure 14: Euro-barometer survey: options that encourage the use of different modes of transport instead of car

6. Conclusions

The methodology presented here allows the measurement and mapping of congestion levels across the network and the comparison between different zones and countries. The results and maps that were presented give a picture of the existing situation and allow the quantification of congestion levels and of the costs for the users. The approach can be also applied to monitor the evolution of congestion over time by comparing indicators for the same road link or area over time. The results can be useful for policy makers in several ways:

- Mapping congestion and monitoring its evolution over time, by comparing the level and distribution of congestion in two different points in time. This would allow the identification of bottlenecks in the road network, the exploration of measures to avoid congestion and the monitoring of the progress.
- Application of the congestion indicators in European transport policy, by comparing average congestion between the peak hour and wider time periods and identifying measures to improve the temporal distribution. Such analysis can help in identifying whether and how demand management measures, as well as in estimating congestion charging levels and periods of application.
- Combination of congestion indicators with traffic counts in order to improve speed flow curves used in transport network models. Apart from allowing the monitoring of traffic flows, this combination can also be useful for modelling the future evolution of congestion and help anticipate potential new bottlenecks.

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Abstract

The methodology presented here allows to measure and monitor road congestion across Europe using data from TomTom in-vehicle navigation systems. The approach is based on the analysis of a large number of real vehicle speeds that have been measured on each road link and the application of algorithms that allow the estimation of congestion indicators for specific types of roads during selected time periods. The results include the detailed mapping of recurrent congestion both geographically and temporally, as well as the comparison of the quality of service of road networks between different zones.

The data used represent real speed measurements from in-vehicle navigation systems for different time periods and days of the week. The large number of "probes" (over 1 trillion of measurements) gives a highly accurate and representative picture of the actual driving conditions across the European road network. The data collected are clustered in groups of speed profiles which represent change in average speed behaviour along a road link in five-minute time intervals over a 24-hour period. specific speed profile assigned per day of the week. The average speed on a specific link during a certain time period can be compared to the benchmark speed estimated for the link under free flow conditions or against selected threshold values. As a result, indicators of congestion for different time periods can be measured and compared across links, regions and countries.

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