

International Journey Time Benchmarking: Strategic Road Networks Analysis Report



Version Control

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1.0	23/10/2017	JG, DH	Initial Draft for Discussion
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2.1	14/11/2017	JG, DH	Minor corrections following ORR comments
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Table of Contents

Acknowledgments.....	3
Introduction	5
Methodology.....	7
The Strategic Road Networks	19
Comparing the Highways England Delay Measure with the ORR Benchmarking Approach.....	21
Benchmarking Delays on the SRN	22
Benchmarking Travel times to Key Nodes.....	27
Conclusions	31

Introduction

Given the importance road users attach to the reliability and speed of their journey times¹, the Office of Rail and Road (ORR) seeks clarity about how delays on the Strategic Road Network (SRN) compare with delays on similar networks in other countries. This report reviews an analysis of the delays experienced on England's SRN and how these delays compare with other countries. The work has been undertaken to assist ORR in delivering a robust evidence base on the performance of the network which is managed by Highways England.

The work has been approached by:

- Designing and developing the delay and congestion metrics to be used in the analysis taking account of the available data;
- Sourcing comparable data for 13 countries, including England;
- Analysing what this tells us about how delay and congestion in England benchmark with other countries.

This report, and the accompanying infographic document, constitutes this analysis. This work has been undertaken by Transport Futures Ltd. and Loop Connections Ltd.

Objectives and Scope

The primary objective of the work was to benchmark delays and congestion on the SRN in England with equivalent networks in 12 other countries across Europe. This included identifying suitable metrics for the purposes of the benchmarking covering traffic delays and economic effects.

These 12 nations were selected by ORR as part of a broader benchmarking exercise based on economic, demographic and road network characteristics. The countries included are:

- Austria
- Belgium
- Denmark
- France
- Finland
- Germany
- Italy
- The Netherlands
- Republic of Ireland
- Scotland
- Spain
- Wales

¹ Office of Rail and Road (2017) *Measuring performance of England's Strategic Roads: what users want*. URL: <http://orr.gov.uk/highways-monitor/publications/measuring-performance-of-englands-strategic-roads-what-users-want>. Date Site Accessed: 31/10/2017

The concept of a delay to a journey includes two main components:

- The fastest achievable travel time if there is no delay; and
- The measured actual travel time achieved.

The total delay on a network is the difference between the travel time that could be achievable on the network and the actual time achieved, factored by the number of vehicles affected. The concept of congestion adds considerations of performance or expectation to the measures of delay introducing concepts such as traffic management, economic impact, experience, and other factors.

This report compares road delays using these metrics across the 13 countries and adds observations about congestion based on these comparisons.

Methodology

The work has been approached in five main stages:

- Defining comparable SRNs for each country
- Traffic flow data assembly
- Traffic Speed data assembly
- Calculating delay and congestion
- Understanding the economic effects

This section describes the approach taken for each stage.

Defining Comparable Strategic Road Networks

For the purposes of this analysis, the SRN for England was defined as the network that is managed by Highways England. This network is shown in Figure 1.

The approaches used by other countries to defining and managing SRNs were reviewed. SRNs link the major population centres within each country, and connect economic gateways such as ports and airports. Trunk road links including motorways dominate these networks in most countries, but other regional roads also make connections to more isolated towns which in England would be trunk roads, so these are also included. All of the countries covered manage many of these routes at a national or federal level, but many links are also managed by regional or local governments.

The European Union has also defined a supra-national network of routes to connect economies across Europe: The Trans-European Road Network (TEN). All of the TEN links in the 13 countries are part of their SRNs.

In order to define comparable networks in each country to the Highways England network, broadly the same approach was undertaken as had been used to define the major road network (MRN) in England in a study for the Rees Jeffreys Road Fund but allowing for the fact that that network includes some roads that are not on the SRN, so judgement was applied in selecting links seeking to match where possible the logic for including links in the English SRN². The English SRN possibly included some single carriageways that had been retained in the SRN for

² <http://www.reesjeffreys.co.uk/wp-content/uploads/2016/10/A-Major-Road-Network-for-England-David-Quarmby-and-Phil-Carey-Rees-Jeffreys-Road-Fund-October-2016.pdf>

historical reasons, but which were not essential for connecting major towns due to the presence of new motorways so the difficulty was in matching such roads. However overall the same network logic could be followed in all countries. This comprised:

- Selecting motorways and other similar major route categories designated for the purposes of strategic traffic in each country.
- Adding other roads to ensure that all towns of greater than 50,000 people, and peripheral towns or population clusters of more than 25,000 people were connected by the network.
- Adding other roads to ensure that ports with more than 2 million tonnes of freight, and the busiest airports by passenger traffic were connected to the network;
- Checking that the network offers choices of routes to provide resilience using a geographical inspection of alternative routes between major centres.



Figure 1 - England's Strategic Road Network

The MRN defined in England using these criteria was found to closely resemble the Highways England SRN. So using this approach enables a consistent approach across Europe using data on population centres, road networks and transport hubs available for all of the 13 countries.

Population by neighbourhood was sourced from Socio-Economic Data and Applications Centre (SEDAC)³ and plotted in GIS. This was overlaid with the road network from Open Street Map (OSM) to check that all clusters of population of more than 50,000 people, or 25,000 in peripheral areas were connected to the network. Major ports and airports by freight and passenger volume were then added to the maps using location data by volume for these facilities sourced from Eurostat. Nomenclature of Territorial Units for Statistics (NUTS3) boundaries were then added including population density data for each NUTS3 area.

Road links were then selected from OSM to define the SRN in each country as follows:

1. Selecting motorways and principal roads from the digital road network defined in OSM. This included a manual check that all links in the TEN were included.
2. Links to major ports and airports were then added.
3. Population clusters were identified from the maps of settlement data. In most cases the towns being connected were discrete settlements of over 50k (or 25k in peripheral areas) residents. However, where the maps showed cluster of towns of less than 25k all within a few miles of each other these locations were also connected.
4. Check the networks visually for coverage and resilience.

This resulting network for the countries (excluding Finland for clarity) is shown in Figure 2.

³ Center for International Earth Science Information Network - CIESIN - Columbia University, United Nations Food and Agriculture Programme - FAO, and Centro Internacional de Agricultura Tropical – CIAT (2005) *Gridded Population of the World, Version 3 (GPWv3): Population Count Grid*. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). <http://dx.doi.org/10.7927/H4639MPP>. Date Site Accessed: 22 August 2017.



Figure 2 – Overview of the Strategic Road Network Used for Benchmarking

Traffic Count Data Assembly

A review of available traffic count data for each country showed that it would not be possible to estimate traffic flows on each link of the SRN in each country from publicly available data. To estimate traffic flows at the locations where traffic delays were occurring, at a level of accuracy suitable for international benchmarking, estimated road capacities were used. There is an extensive literature on speed flow relationships on road networks which shows that averaged across entire networks two important thresholds can be identified: the points at which delays start to be observed by road type, and the maximum lane capacity by road type. The average flow where delays are observed is between these two thresholds.

Road categories and capacities from DfT Transport Appraisal Guidance⁴ were validated using a sample of traffic count data from the UK, Ireland, Finland and Germany. For these four countries automatic traffic counter (ATC) data was available for hourly segments throughout the day allowing the build-up of flow and delay throughout the day to be analysed.

The English data was available from MIDAS count sites across Highways England's network so sites in congested locations were selected to identify how flows and delays built up towards capacity. Figure 3 illustrates the curves for Motorways in the four countries. Delays build up on single carriageway roads from much lower flow levels when overtaking opportunities start to become limited and all vehicles are delayed to the speed of the slowest vehicle. Single carriageway traffic flows per lane rise to similar levels as for dual carriageways and motorways but only at vehicle speeds well below that sought by drivers.

Based on analysis and inspection of the many curves for the various road categories it was decided to use average hourly flows in the analysis as shown in Table 1. In selecting these values two important points are of note. There was no evidence from the limited data that lane capacities per hour were significantly different in any country. This reflects the international literature for speed flow relationships used in traffic models which transfer well from country to country.

⁴ Department for Transport (2017). *WebTAG: TAG Data Book July 2017*. Department for Transport.

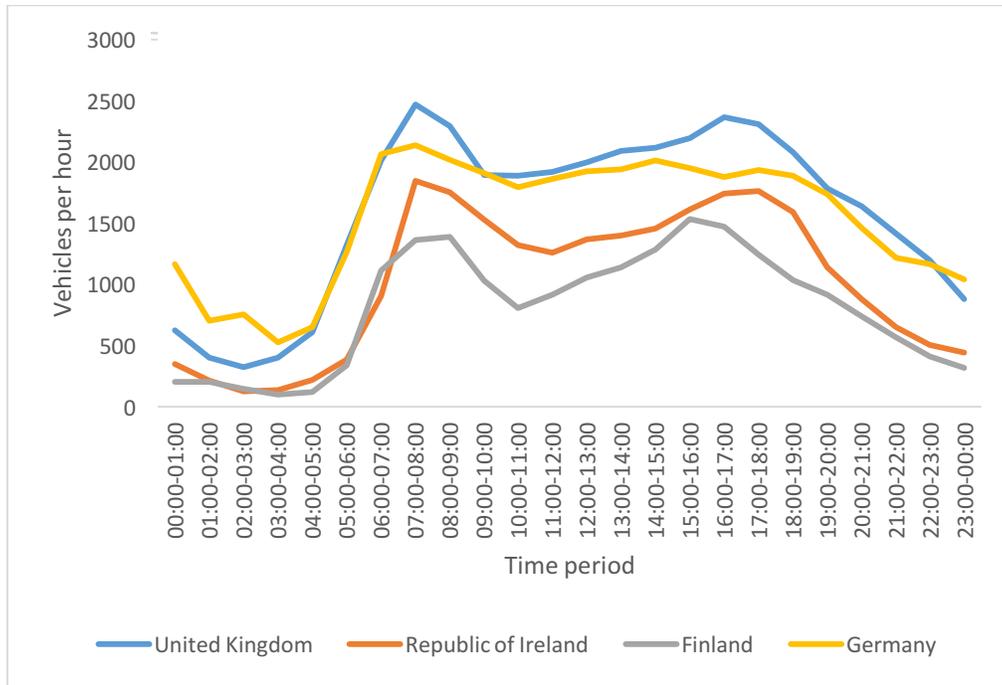


Figure 3 – Maximum vehicle flows per hour per motorway lane

Secondly, delays were evident on dual carriageways and motorways from 1500 vehicles per hour per lane upwards and there was no evidence of more than about 2500 vehicles per hour per lane being achieved. The curves demonstrate an average flattening of their tops at flows from 1900 vehicles per lane per hour. To represent a suitable value for average lane capacity at the point of delay somewhere between 1500 and 2500 vehicles per lane per hour an average of 2000 vehicles per lane per hour was chosen as a conservative average estimate. Some three and four lane motorways achieved the high end of this and some the low end so overall there was no reason to separate out 2 lane motorways from wider roads. For single carriageways 1000 vehicles per hour per lane was chosen, since at this level of flow delays to vehicles are building strongly even on roads with good overtaking opportunities.

Table 1 – Average hourly flows at the places in strategic road networks where delay is observed (per lane, by type of road)

	Average Hourly Flows Under Congested Conditions (per lane)
Urban roads with speed limits of 50kph or less	2000
Rural single carriageway roads	1000
Dual carriageways and motorways	2000

In practice it is often junction capacity and road context rather than lane capacity that constrains maximum flows, and the delays experienced on the network.

For the purposes of benchmarking, the average values in Table 1 represent an acceptable level of accuracy for comparing average levels of delay. To achieve a higher level of accuracy the actual traffic flows would need to be estimated across all countries using real traffic flows at frequent intervals along every road which would demand a coverage of traffic counts well beyond that available. Using a common value of 2000 should deliver fairly robust benchmarking results for dual carriageways and motorways. Greater caution is needed when comparing single carriageways as their flow and delay characteristics are more variable.

Journey Time Data Assembly

There are many potential sources of link speed data, but the source most widely used by the public is journey times from Google Maps. Google's Android system operates about half of the mobile phones in the UK and 90% of smartphones globally. These phones are precisely located and tracked on the road network when travellers have activated location services (roughly 85-90% of travellers). The Google data therefore represents by far the world's largest source of data showing the journey times on the road network. Given the multiple occupancies of many road vehicles more than half of all vehicles on the strategic road network are being tracked by Google.

Google themselves process this data and share it openly for public use, principally for journey planning and route navigation. The data is made available in real time showing not just speeds but disruption and other delays on the network and supports navigation using Google's mapping systems and many third party applications which use the Google API under Google terms and conditions. Journey times can be accessed on Google's servers for any date and time, so the data can be sampled under Google's terms and conditions for the purposes of calculating road delays. If the public use and trust these journey times it is appropriate that ORR, acting on behalf of the public, should benchmark congestion using data which the public already trusts. A license was purchased to access the Google data via their web-servers.

Data on journey times was repeatedly accessed through the Google Application Program Interface (API) until the journey times at 15 minute intervals had been obtained across the SRNs for the 13 countries. The sampling method used all journey times for 10th October 2017. Weekly expansion factors were derived from data for the full week commencing 8th October

2017. The data was then expanded from weekly to annual values using comparable data for the second Tuesday of each month. These expansion factors allowed the 10th October journey times to be factored to annual averages.

To extract the data from Google, origin and destination points were identified at junctions on the SRN for each country using co-ordinates for these junctions defined using OSM networks. The SRN was then built up as a series of nodes and waypoints by road number. This process was not without challenges. Initial attempts to match co-ordinates resulted in a number of errors where diversions off the intended route were observed. However, these issues were overcome with manual checking of the routes built by Google in each country. Routing errors were resolved by amending waypoints as required to specify the network accurately using the standard Google waypoint input format. The route was then specified as a set of RouteIDs made up of LegIDs and BaseIDs consistent with the Google format for connecting nodes and waypoints.

Calculating the Delay and Congestion Metrics

To calculate delay, the free flow speeds were estimated as the best average travel time achieved in any 15 minute period on any Leg. To avoid confusing road delays with small variations in journey times (for example travel time of 10 minutes across a link at 2am, compared to 9 minutes at 3am), only delays to the free flow time of more than 15% of the minimum value were included. The minutes of delay on each LegID were then aggregated across the network based on estimated traffic flows on each Leg to calculate the total travel time delay for the defined network.

The total delay metric used by DfT on the English SRN is:

- $(\text{The larger of (Journey Time – Free-flow journey time) or zero}] * \text{Expected Flow}) / \text{Total Vehicle km on the SRN (1)}^5$

As discussed above, only limited data is available about traffic flows on the SRNs across Europe. The errors that would have been associated with estimating traffic flows across Europe

⁵ Note that the Journey Time on any link of the network is the lower of the measured travel time or the speed limit. Speed limit data for each LegID was extracted from Google. This data is based on automatic recognition of speed limit signs in Google Streetview and Google note that there can be errors in this data. To ensure that accurate speed limits were used, on legs where the average of the observed speeds between 1am and 4am exceeded the speed limit from Google for the LegID, the Google LegID speed limit was replaced with the national speed limit for that type of road in each country.

would potentially be greater than any differences in congestion. To ensure a consistent approximation to the vehicle flows across the European Countries at the points in the network where delay was observed an average lane capacity at congested locations was used to estimate the volume of traffic delayed.⁶

Where delays are observed, the actual flow on the road may be slightly above or below the estimated flow based on road capacity, but averaged across a large area, these lane capacity estimates offer a consistent way to ensure that delay could be benchmarked in a consistent way in all countries with acceptable accuracy.

Since the total traffic flow on the SRN is not known for countries other than England, equation (1) was modified to show the delay per mile of road to ensure a comparable metric for each country:

- (The larger of (Journey Time – Free-flow journey time) or zero] * Estimated Road Capacity)/Miles of SRN (2)

To ensure that the benchmarking delay metric accurately reflected the Highways England metric the congestion in England was also calculated using equation (1). The analysis was undertaken separately in each direction for each part of the SRN. Table 2 compares the Highways England calculation approach with the benchmarking calculation approach used in this work.

Table 2 – Comparing The Highways England KPI approach and the ORR Approach

Highways England	ORR Approach
Expected flow is taken from MIDAS counting sites associating each site with a road link and where necessary combined data to obtain an average or sum of multiple sites to estimate the flow on each link. Expected Flow is calculated as a combination of flows measured in the given 15-minute and similar time periods. Time periods without observed data are infilled with data from time periods either side of the period required. Flows without data after this process are infilled with the monthly average values for the link by day and night	Expected flow is taken from associating each LegID with an estimate of traffic from the best available data for that link or if none is available a default flow for the link type assuming that the link is running near capacity estimated from the capacity of that type of road as showing in Table 1.
Road speeds are extracted from the Trafficmaster data on sampled days in each	Travel times were extracted from the Google database based on their “best-guess” of the

⁶ Where there is no delay at a location, the traffic flow is not used since zero delay delivers a zero result from equation (1).

Highways England	ORR Approach
<p>month are calculated for each 15 minute period as the sum over all 15 minute periods of (Delay) / sum over all 15 minute periods of ([Expected Flow] * [Length of link]). Using the Trafficmaster data journey times are calculated from data for cars only. These are car speeds from long term historical data capped at the recorded speed limit. The speed limit is used as the basis for free flow journey times.</p> <p>Delay is presented per vehicle/mile and calculated as the total delay divided by the total vehicle miles from UK traffic count data.</p>	<p>journey time on any link at any time of day. The representative daily delays for 10th October 2017 were calculated for each 15 minute period as the sum over all 15 minute periods of (Delay) / sum over all 15 minute periods of ([Expected Flow] * [Length of link]) To eliminate the effect of random variation during periods of no delay, delays of less than 15% to the travel time were ignored. Travel times were capped at the value which would be achieved when travelling at the speed limit.</p> <p>Delay is presented per vehicle/mile by taking the total delay and dividing this by the estimated total vehicle miles on the strategic road network from DfT statistics for the Highways England network (91.9 billion vehicle miles in total).</p>

As noted above, traffic flow data is not available for all of the SRN in each country so for the purposes of international benchmarking different delay metrics were needed. The three measures of delay used for the benchmarking are described in Table 3.

Table 3 – Benchmarking Delay

Delay Measure	Calculation Method
Delay by vehicle miles by road length	Travel times were extracted from Google based on their “best-guess” of the journey time. Tuesday 10 th October was sampled at 15 minute interval periods and these results were annualised using weekly and monthly expansion factors. The time delays greater than 15% of the free flow time were factored by the number of lanes of congested traffic and the average flow per lane in congested traffic to estimate the total vehicle delay on the SRN. The delay metric was then presented as the number of hours of delay per mile per day.
The average number of hours when traffic is delayed	Where traffic is delayed by more than 15% of the free flow journey time on a link, the length of the road link was factored by the number of 15 minute time periods affected, and summed across the country. The total was then divided by the total length of the network to calculate the average number of hours of delay on the SRN.
Effects of delay on connections between the population and the largest cities, and the largest airports in each country	<p>The travel time from each NUTS3 population centroid to the point on the SRN closest to strategic cities, ports and airports was calculated at 15 minute intervals as for the delay by vehicle miles and resident population measure.</p> <p>The population catchment for the free flow times was compared with the population catchment during peak hours of the day as follows:</p> <ul style="list-style-type: none"> • Population of NUTS3 area within 30, 60 and 120 minutes of each strategic destination • Peak hour travel times were the average of journey times at 8am, 9am, 5pm and 6pm. • Free flow journey times were the minimum journey times achieved.

These measures of delay have been used to compare the SRN in England with traffic delays in the 12 other countries. The value of these delays to each country will depend on many factors such as effects on productivity based on the character of the local economy. It is beyond the scope of this work to benchmark the economies of the countries, but the above measures of delay could be combined with other economic indicators as part of a broad benchmarking study if required.

The Strategic Road Networks

Figure 4 shows that England's SRN has a higher proportion of rural single carriageways than other densely populated countries. Whereas long distance routes to towns on the periphery of countries like Italy, France and Spain are connected by dual carriageways, England still relies on single carriageways for parts of long distance routes. Only Finland, Scotland, Wales and Ireland rely more heavily than England on single carriageways to connect their main population settlements.

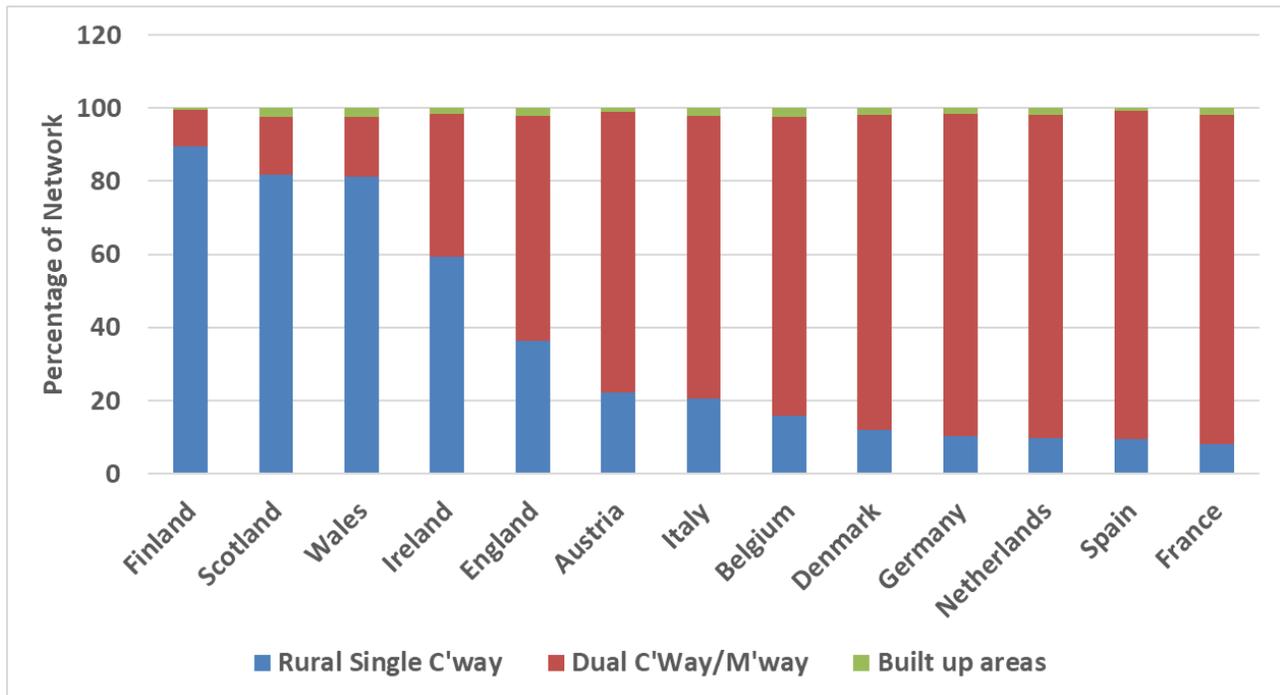


Figure 4 – Proportion of SRN by Road Type

Road congestion is often seen as mainly an urban problem. The SRNs are defined as the routes between urban areas with built up areas, such as trunk roads passing through towns, accounting for less than 2% of the length of the SRNs in all countries.

Only Belgium and the Netherlands have more of their SRN passing through areas with population densities exceeding 500 people per square km as defined by the European NUTS3 geography population density classification.

Figure 5 shows that England, the Netherlands, Italy and Belgium are the four countries with more than 30% of the SRN passing through areas with medium population densities of between 251 and 500 people per square km.

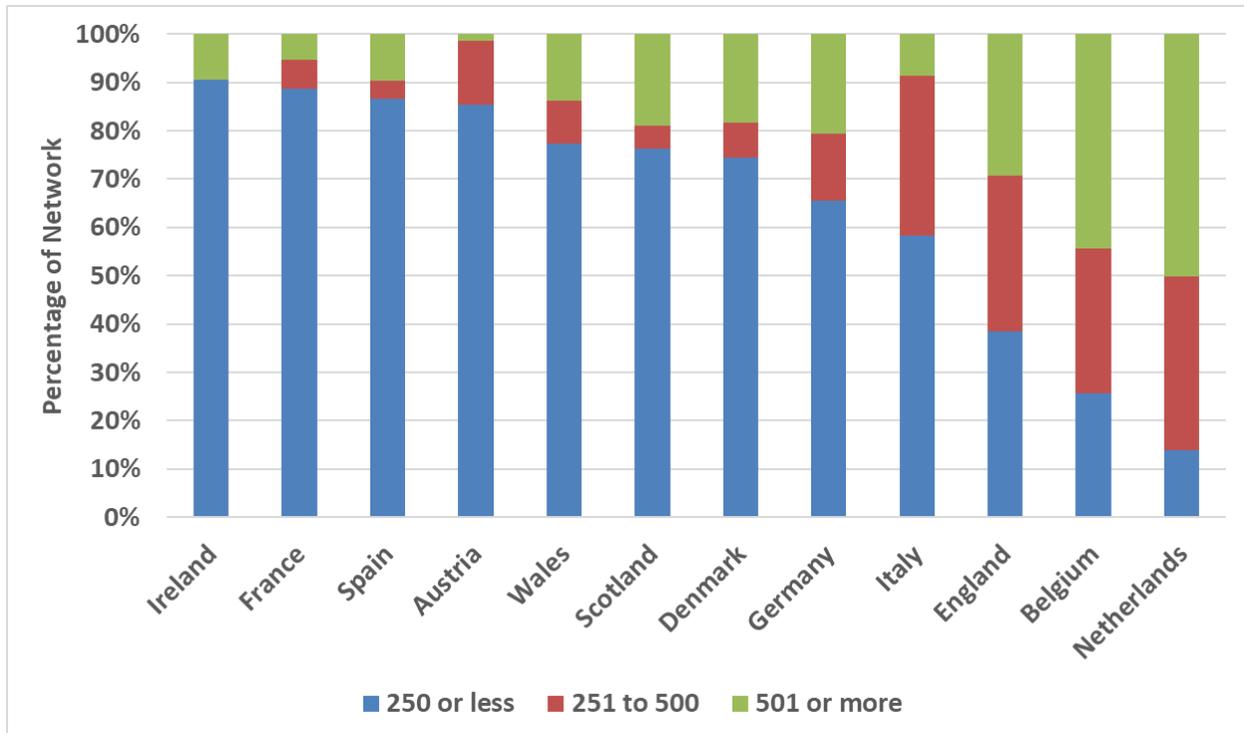


Figure 5 – Proportion of SRN by density of NUTS3 area through which routes pass

Comparing the Highways England Delay Measure with the ORR Benchmarking Approach

Delays on the English SRN were calculated using the methodology described in Table 2. This method differs from the DfT approach in two important respects:

- The travel times are extracted from Google rather than from Trafficmaster as in the DfT approach.
- The vehicle flows where the delay occurs use average lane flows from Table 1 rather than the actual measured flows on each part of the network as in the DfT approach.

Table 4 summarises the key statistics from the calculation of the Highways England KPI using the ORR methodology

Table 4 – Delay on the English SRN using the Highways England Delay Measure

Item	Value
Seconds of vehicle delay on the SRN	841 billion
Total vehicle miles on Highways England network ⁷	91.9 billion
Average delay per vehicle mile (seconds)	9.15

An average level of delay of around 9 seconds per vehicle mile has been consistently reported annually for the English network⁸. The averaging approach used in this project for benchmarking delays using internationally available data delivers a value of 9.15 is consistent with this.

⁷ Department for Transport (2017) *Road Traffic Statistics*. URL: <https://www.gov.uk/government/collections/road-traffic-statistics>. Date Site Accessed: 23/10/2017

⁸ Department for Transport (2017) *Travel Time Measure for the Strategic Road Network and Local A Roads: July 2016 to July 2017*. URL: <https://www.gov.uk/government/statistics/travel-time-measures-for-the-strategic-road-network-and-local-a-roads-july-2016-to-june-2017>. Date Site Accessed: 2/10/2017

Benchmarking Delays on the SRN

There are 74 hours of vehicle delay per mile of English SRN per day. Only Germany has more hours of delay per vehicle mile on its SRN per day. Figure 6 shows that most countries have levels of delay less than half of the English level but Denmark, the Netherlands and Belgium also have higher than average levels.

Figure 6 – Hours of vehicle delay per mile of SRN per day

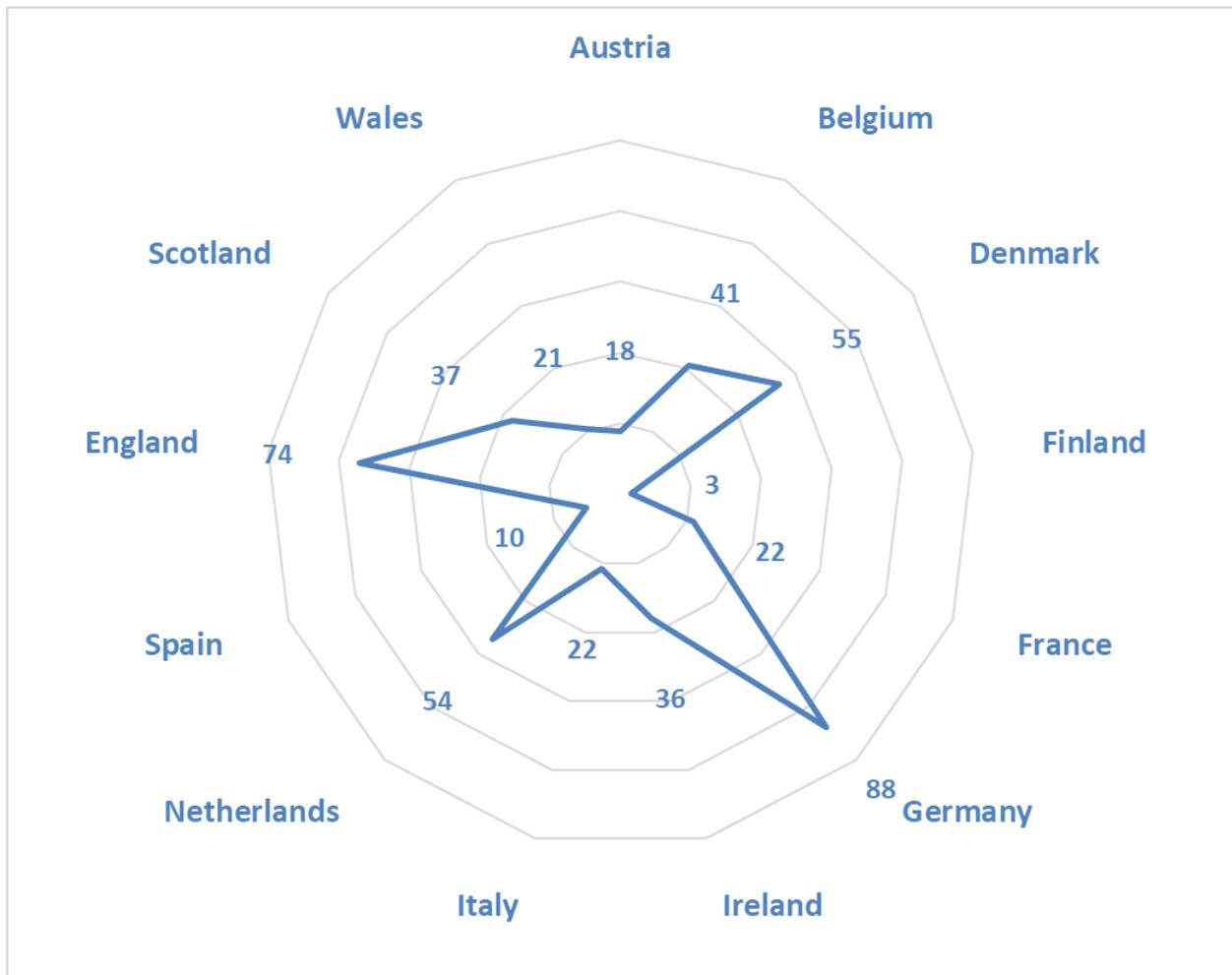
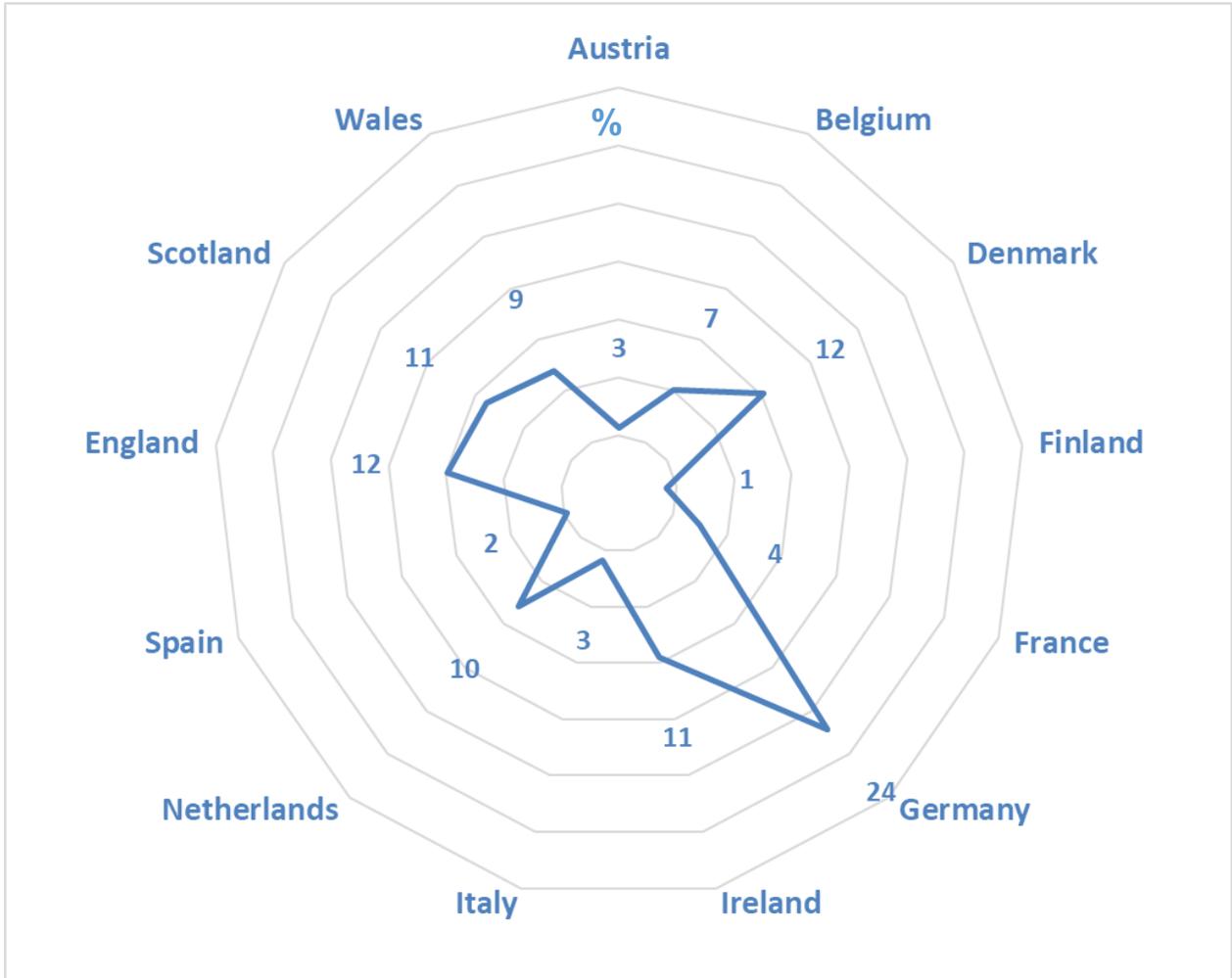


Figure 7 shows that the higher levels of delay in Germany are at least partly due to traffic congestion lasting for longer across more of the network in Germany than elsewhere.

Figure 7 – Percentage (%) of the available hours on the SRN by network length experiencing vehicle delay



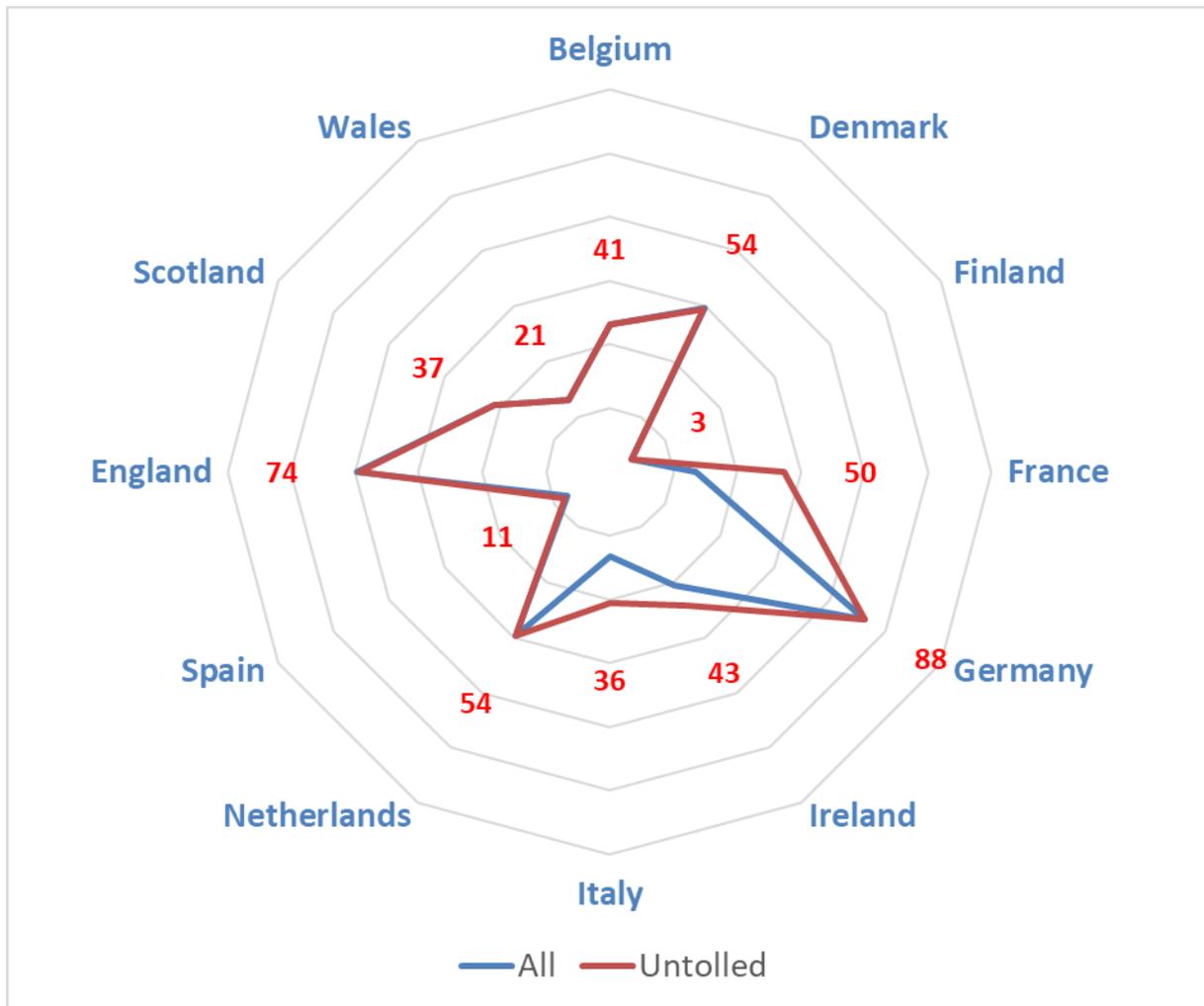
Nearly a quarter of available hours by length of SRN are delayed in Germany. This compares to 9-12% of hours by road length in England, Scotland, the Netherlands, Denmark and Wales. This also means that the delay of 74 hours per mile on the English SRN is twice as concentrated by network hours and length as the 88 hours per mile on the German SRN.

Further analysis gives some insight into why some countries have less delay than others.

Some countries use tolled roads to relieve the pressure on untolled roads and to offer vehicle users a choice of a premium network. Others like England largely use tolls more sparingly predominantly as part of funding for expensive assets such as estuarial crossings. Figure 8 compares the delay for untolled roads with the average for all roads. France, Italy and Ireland have higher levels of delay on the untolled routes with the effect being particularly marked for

France, where there are 50 hours of delay per mile on the untolled network, more than twice the average of 22 for all roads. Tolled roads in these nations form a comparatively higher proportion of the strategic road network compared to other nations.

Figure 8 – Hours of vehicle delay per mile on SRNs by tolled and untolled roads⁹

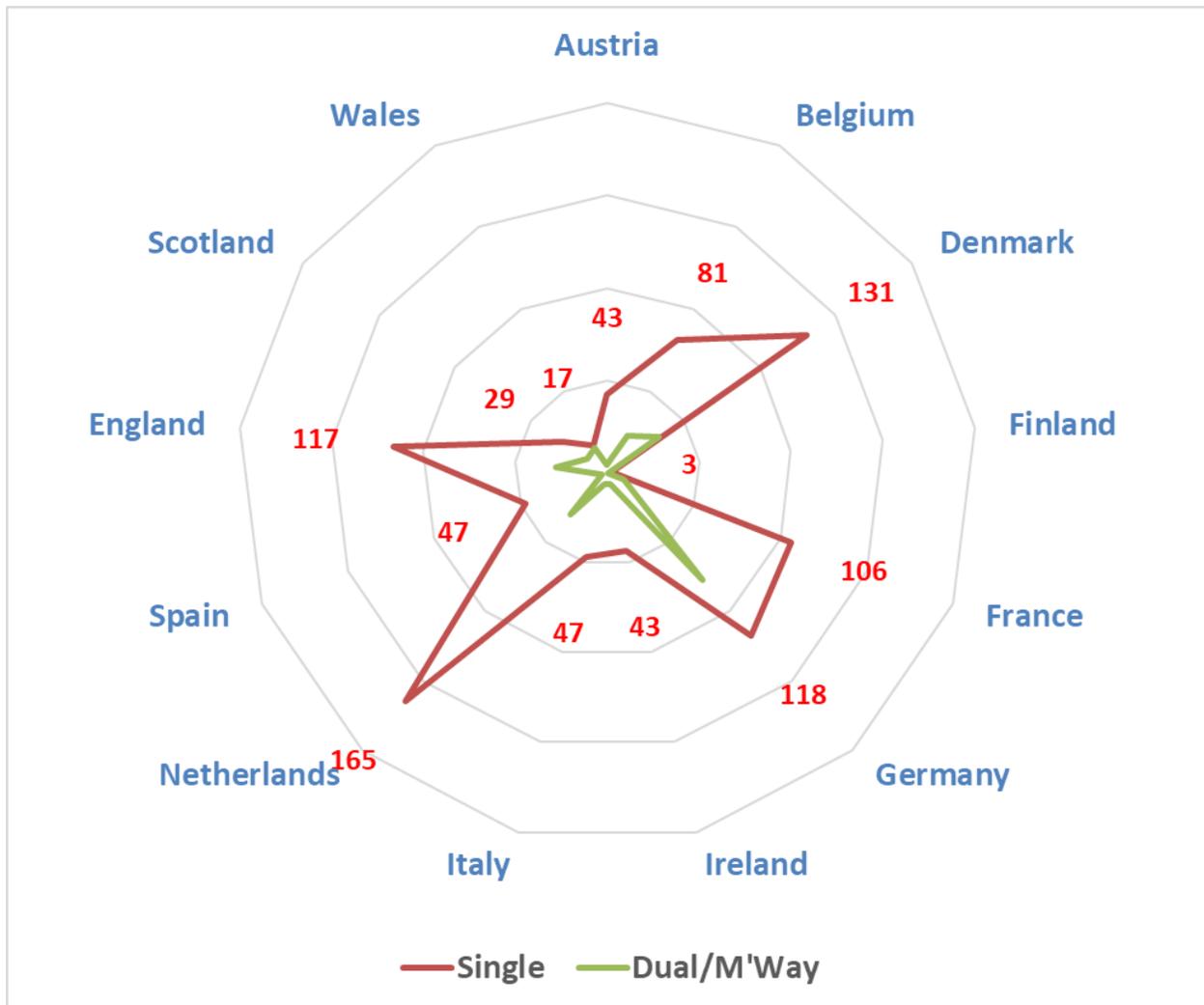


There are much greater delays per mile on single than dual carriageways and motorways, particularly in more densely populated countries. Although England may be more dependent on single carriageways for strategic network connections to towns and ports it has less delay per mile on these roads than the Netherlands, Denmark and Germany. Perhaps more significantly English dual carriageways and motorways have only 28 hours of delay per mile which is less

⁹ Note that Austria is not included in this comparison since the vignette applied to major Austrian roads by time of day does not allow toll roads to be classed separately

than 30 in the Netherlands, 34 in Denmark and 77 in Germany. Despite some roads in Germany having no speed limit, there are few instances of higher average speeds on road links in Germany than elsewhere so this is not a factor in this higher level of delay.

Figure 9 – Hours of Vehicle delay per Mile on SRNs for Single and Dual Carriageways

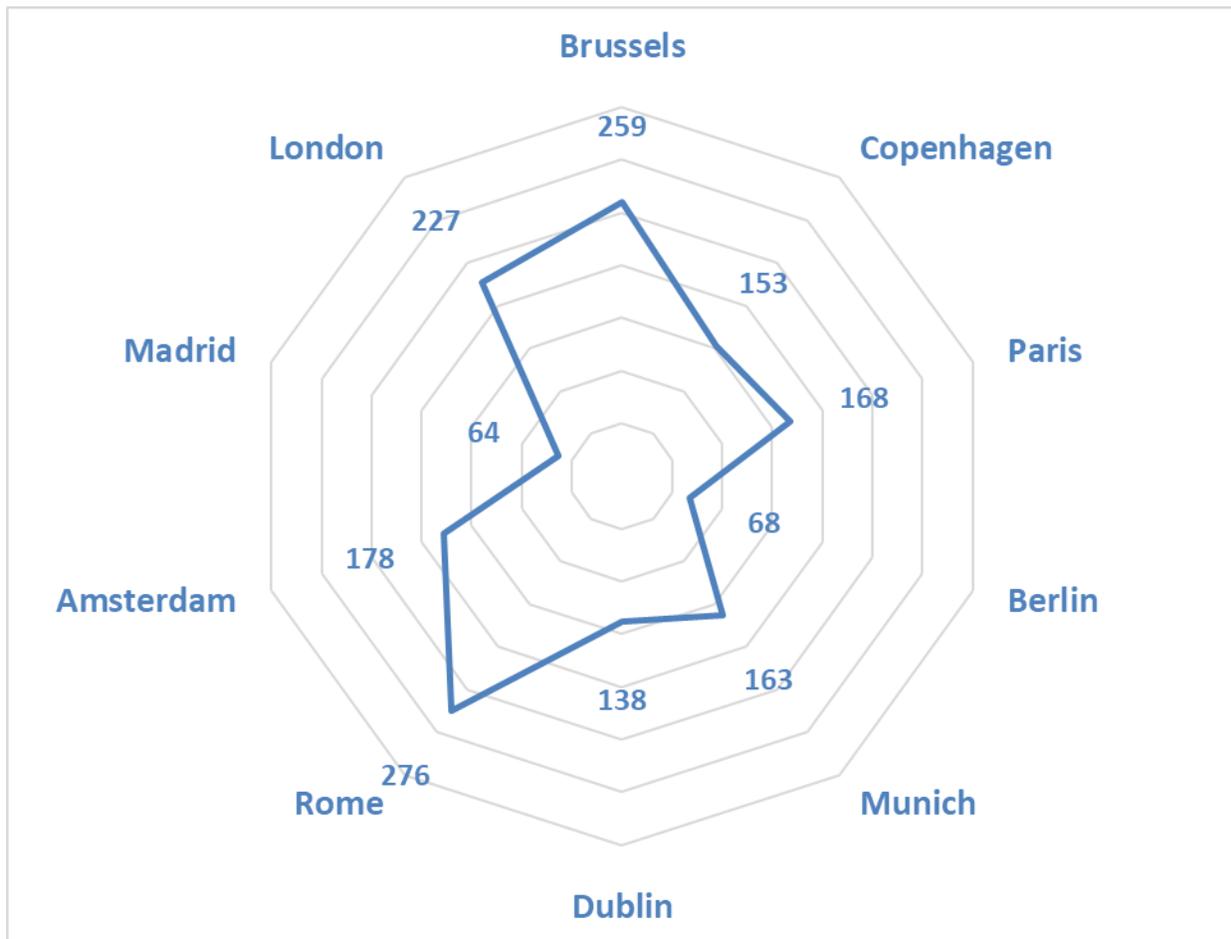


The motorways around major cities have amongst the highest levels of delay. Many cities have circular or semi-circular motorways round them and Figure 10 compares the hours of delay per mile for these routes. Both the inner and outer orbital motorways for Madrid have been included in this analysis which perhaps contributes to the lower level of delay seen there. The outer

orbital is more remote from the city. In contrast for Brussels, the semi-circular motorway is well within the urban fringe.

Rome's orbital motorway forms a close boundary around the city and has 276 hours of delay per mile with delays affecting 22% of the routes hours by length. In contrast the M25 around London experiences delays for 20% of hours by network length accounting for 227 hours of vehicle delay per mile.

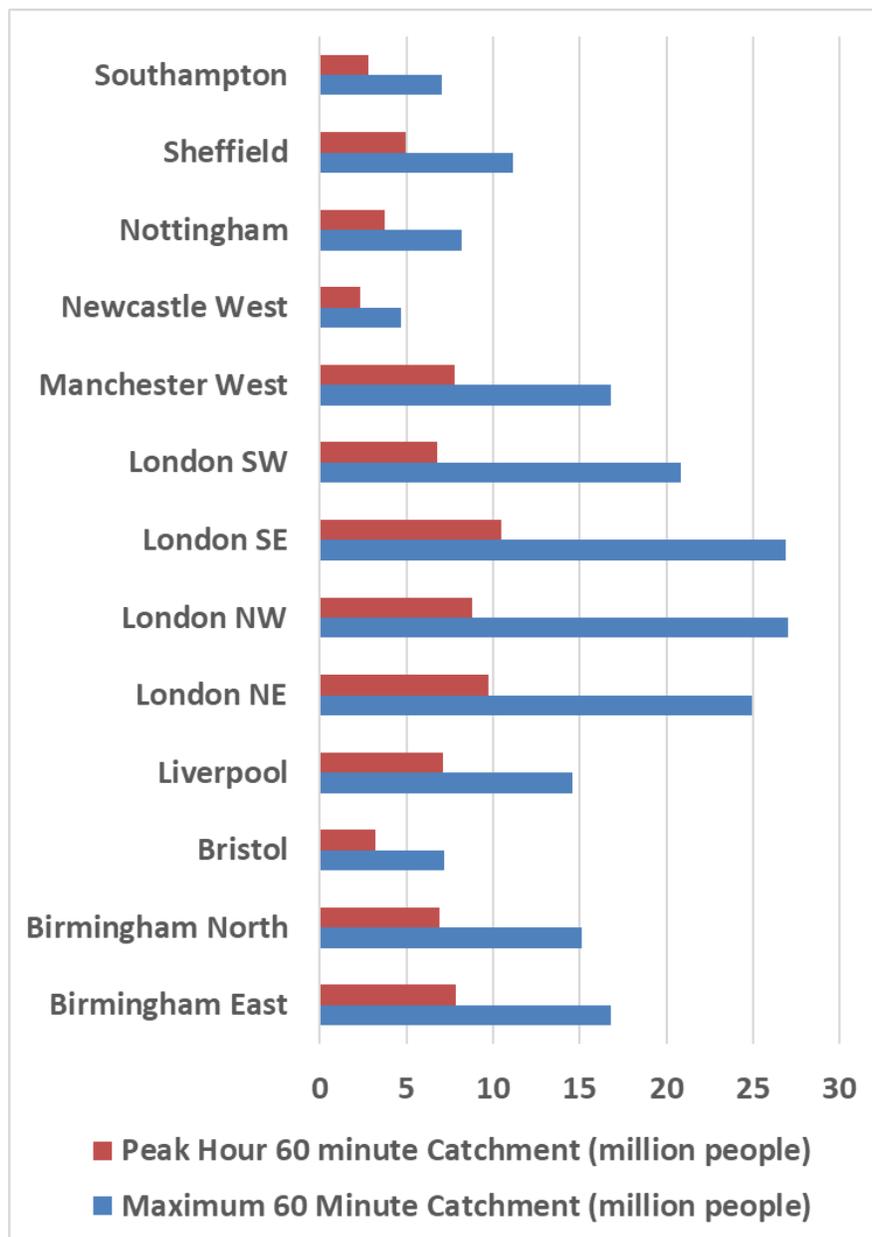
Figure 10 – Hours of Vehicle delay per Mile on SRNs for Orbital Motorways



Benchmarking Travel times to Key Nodes

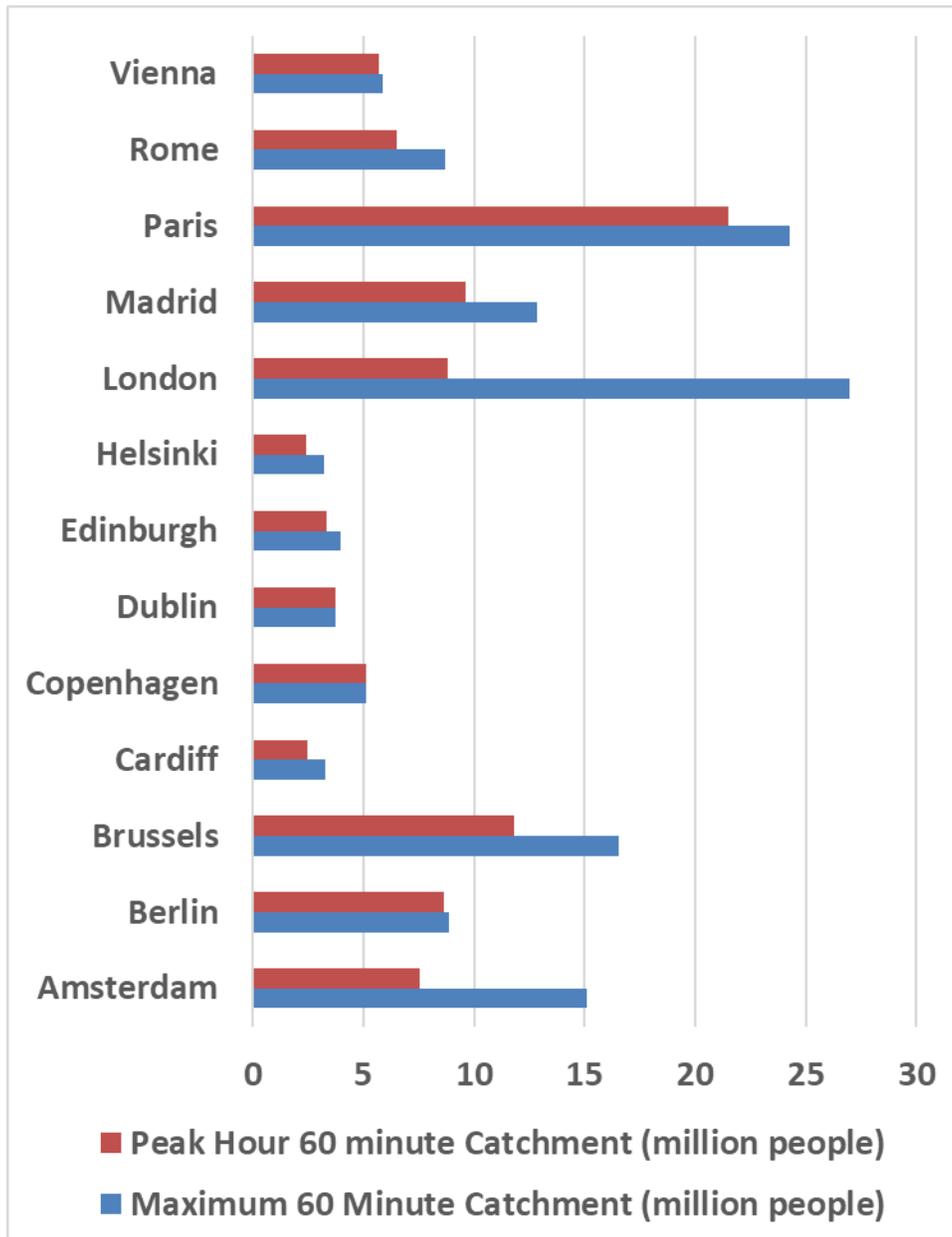
Reliable travel times to reach key destinations can be particularly important for economic competitiveness. Figure 11 shows one-hour population catchments in the peak and off-peak periods to Major Cities in England.

Figure 11 – Peak and Off-Peak Catchments from City Nodes on the SRN in England



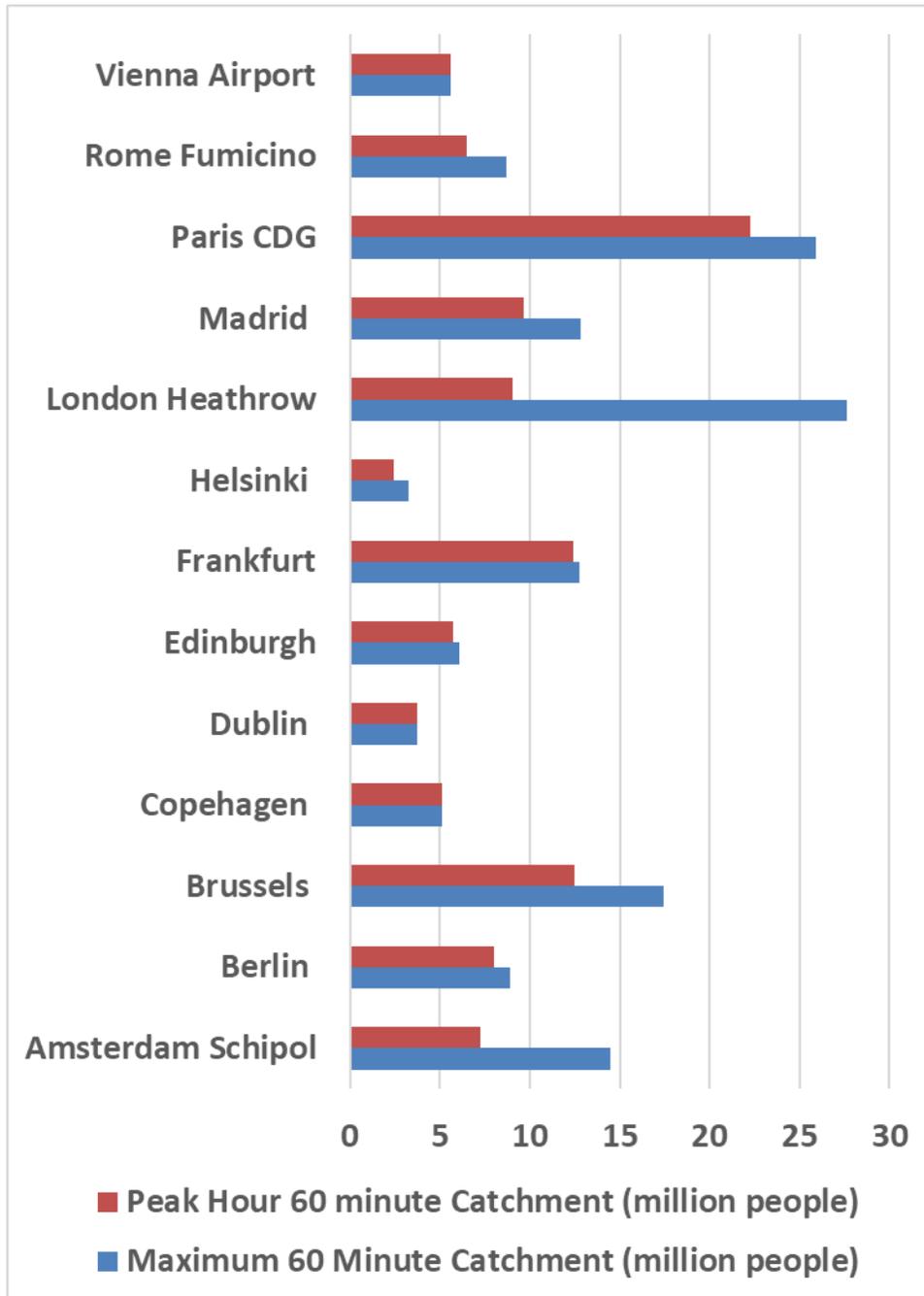
Making a similar comparison for the major cities in the 13 countries the effects of peak hour traffic on London can be seen to be particularly marked. London has the largest free flow catchment but this falls behind Paris, Brussels and Madrid in the peak period.

Figure 12 – Peak and Off-Peak Catchments from City Nodes on the SRNs



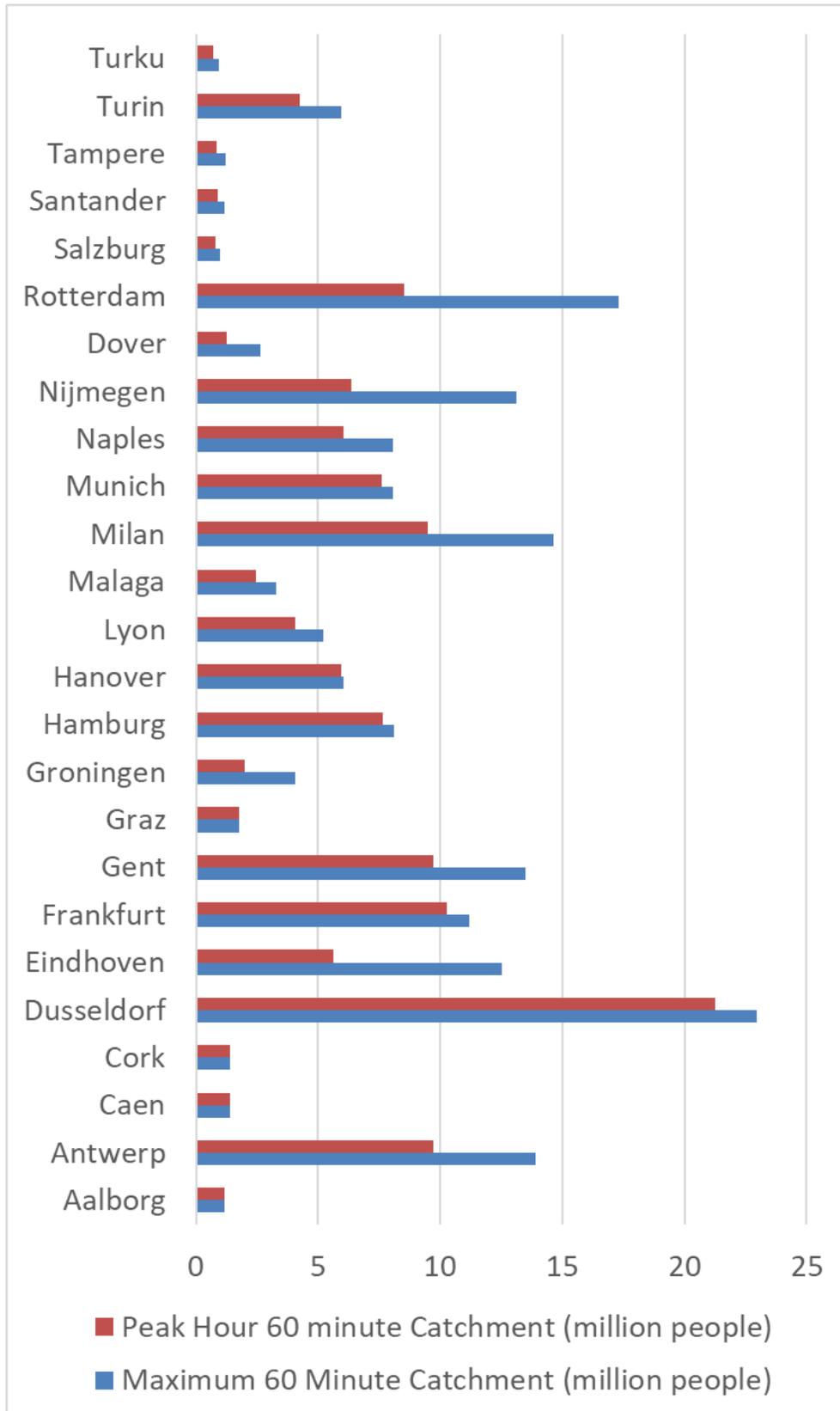
A similar picture is seen for the airports as key international gateways from each country.

Figure 13 – Peak and Off-Peak Catchments from Major Airports



Comparing a selection of less central towns including ports like Dover and Rotterdam shows that delays on the road network are not distributed evenly in the 13 countries.

Figure 14 – Peak and Off-Peak Catchments for Key Towns and Cities



Conclusions

This analysis has shown that delay on SRNs in 13 countries varies from 1% of hours by length of network in Finland to 24% of hours by length of network in Germany.

Although England's SRN experiences an average number of hours of delay by network length, this results in more hours of vehicle delay than all countries other than Germany. In Germany there are 88 hours of delay per mile of SRN compared to 74 hours of delay per mile in England, but the delays in England are far more concentrated geographically and temporarily than in Germany. The higher delays in England are partly related to the reliance on single carriageways, which typically experience higher delays, in England for some strategic roads. Towns of 20,000 people or more in most countries are largely served by dual carriageways.

There may also be some influence from the way the networks were defined, since the English SRN includes additional single carriageways which it is possible would not have been selected using the methodology described. Lower levels of delay are associated with less dependence on single carriageways for strategic links and the level of tolling on the network. In countries such as France and Italy with large tolled networks complementing the free networks the delays on the untolled SRN is more than three times the delay on the tolled network. For example, in France the 50 hours per day per mile for untolled roads compares with 13 hours per day per mile for tolled roads, and the equivalent figures for Italy are 35 for untolled roads and 15 for tolled roads.

The concentration of delays on the English network results in a greater peak to off-peak variance in journey times compared with other countries. It may be that there is less flexibility in England about the timing of economic activity leading to the more concentrated peaks.

The data collection for this work from public sources has shown how widely available consumer data can be used to benchmark the experience of users of the road network. There are many ways that the data assembled for this work could be further analysed to consider effects relating to economic links and connections. This analysis has considered these effects only from the perspective of the travel times to key nodes, but suggests that reductions in peak hour delays on the road network could enhance English competitiveness, particularly the labour market catchment for London.