

# Delivering Demand and Utilisation

A comparative analysis of throughput between  
England and international operators

April 2016

## Document Control

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## 1 Executive Summary

This report aims to more accurately measure the contribution that the Strategic Road Network (SRN) makes to UK plc. This is achieved by determining the maximum sustainable throughput capacities of various road types and obtaining comparable data from international road operators to benchmark performance. The principle analysis focuses on flow throughput across different road types on the SRN. Data sources used were 5 minute traffic speed and flow profiles and average hourly classified flow counts gathered by the National Traffic Information Service. These were used to assess the maximum flow throughput before flow breakdown occurred across motorways and all-purpose trunk roads.

Analysis of maximum flow throughput across all road types showed that maximum flow is restricted to two periods of the day (06:30–09:30 and 15:30–19:00). There are many locations and time periods on the SRN that did not reach a point of maximum capacity. There is a correlation between increasing number of lanes and a lower hourly throughput per lane with higher flow throughput being achieved on roads with straight geometry and fewer junctions. The baseline flow figures on the SRN (in vehicles per hour per lane) were within the lower bounds of the ranges within the Design Manual for Roads and Bridges (DMRB<sup>1</sup>). This suggests that the DMRB quoted figures are a theoretical maximum that may be observed during extreme peaks of flow and are not sustainable. They do however provide validation of the outputs calculated. There was a correlation observed, between lower variability and roads with fewer lanes but with design features that prompt road users to consider their speed. Smart motorway schemes demonstrated reduced variability compared to standard D4M roads.

The International analysis found only limited data with which to make comparisons, but showed the SRN is comparable with roads in the Netherlands and Australia, in terms of both maximum sustainable flow throughput and variability in the maximum flow throughput on different roads of each type. The report also analysed the measurement of throughput of people and goods. People throughput in England is higher than in the Netherlands and Australia. The largest category of goods transported on the SRN during peak flows is food. The greatest HGV road usage type is three lane smart motorways closely followed by a standard three lane motorway. Freight movements are more prevalent on motorways as opposed to non-motorways.

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<sup>1</sup> DMRB Volume 5 Section 1 Part 3 TA 79/99 Amendment No 1

The report recommends that Highways England considers collecting more granular data at more network locations, focusing data collection on sections of the network that experience regular flow breakdown, and consideration to collate more detailed data on people and goods throughput.



## 2 Purpose of report

### 2.1 Objective

The objective of this task is to more accurately measure the contribution that the Strategic Road Network (SRN) makes to UK plc.

### 2.2 Scope

- Determine the maximum sustainable throughput capacities of the various road types that make up the SRN,
- Obtain comparable data from other international road operators,
- Benchmark the operational performance of strategic roads in England with those found in other countries.

### 2.3 Background

This report follows on from previous work undertaken examining the feasibility of measuring the throughput of people and goods<sup>2</sup>. It supports the Network Performance Group's objective of optimising road space, together with the Executive Milestone of measuring throughput of people and goods instead of vehicles.

The feasibility report examining the potential to measure the throughput of people and goods concluded that significant changes to the current methods of data collection and processing were required. Furthermore, it stated that there is currently no cost effective way of benchmarking the throughput of people and goods such that it can be measured and updated in a timely manner.

While Highways England considers the position on whether to invest in more detailed measures, it does have detailed data on flow with which to benchmark performance, both across the different road types found on the SRN and against other countries. This report uses this data to:

- Measure the flows achieved on examples of different types of road on the SRN,
- Consolidate results to determine 'typical' performance levels,

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<sup>2</sup> 20160226\_Feasibility of measuring the throughput of goods and people Summary Report\_v1 2

- Compare the range of throughput achieved with examples from different countries, to benchmark UK performance against international competitors.

### 3 Approach

In order to compare the throughput achieved on different road types, the analysis seeks to understand how the different features of these road types affect their capacity, and also to assess how the performance on the SRN compares with throughput achieved by similar road operators in other countries.

The following sections:

- give a definition of the different measures of throughput,
- set out how we have split the network into different road types, and,
- describe the data sources and data processing techniques that we have used throughout the report.

In summary, to find the maximum flow throughput actually achieved across the network, we examined the flow data profiles from November 2015, removing any locations affected by roadworks. We assessed data from Mondays, as these are most likely to experience maximum flows. We then extracted data from time periods where the network was operating at greater than 80% capacity and less than 45mph speed. We subsequently found the flow throughput achieved before flow break down occurred, as a measure of the maximum flow throughput that the different parts of the network can sustain when the demand is highest.

#### 3.1 Definitions

##### **Network Capacity**

*A theoretical (maximum) flow rate, expressed in vehicles per hour, describing the optimum conditions which can be reached prior to the onset of flow break down.*

##### **Flow Throughput**

*The measured maximum sustainable flow rate (in vehicles per hour) that can be maintained for a given carriageway in a given time period.*

- Vehicle flow is the total number of vehicles measured by traffic monitoring equipment that traverse a specific location in a specific time frame,

- Maximum sustainable flow rate is not the peak flow value, it is the highest measured throughput which can be achieved continuously given optimal conditions (eg no adverse weather, incidents etc).

### **People Throughput**

*Flow Throughput \* estimated average vehicle passenger occupancy figures.*

- Measured in terms of number of people on average that are transported past a specific location over a specific period of time. It is principally based upon flow throughput,
- Average vehicle occupancy figures are estimated from road user surveys and then extrapolated to national figures. Sample sizes are small and may not be totally representative.

### **Goods Throughput**

*Goods throughput = calculated flow throughput \* percentage of total flow that is classified flow greater than 6.6m (LGV/HGV) \* estimated percentage categorised goods transported per year by type of goods.*

- The output is an estimate of the number of vehicles transporting particular types of goods on particular road types.

*Weight of Goods = Flow Throughput \* percentage of total flow that is classified greater than 6.6m (LGV/HGV) \* estimated percentage of goods weights (tonnes) per goods type per year.*

- The output is estimate of the a tonnage value, per goods type, measured in terms of tonnes per hour.

As part of this task, values have been calculated for these different measures of throughput for eight different types of road, these are defined in the next section.

### 3.2 Types of Road

In order to compare the throughput on roads with similar characteristics, roads were grouped by the following criteria:

- Road classification, that is, motorway or APTR (all-purpose trunk road). Motorways were then subdivided into smart motorways i.e. roads with speed control, and “standard” motorways,
- Number of lanes.

For the comparison, only data from road section links that were between junctions (rather than slip roads or links within junctions) were selected. These sections are most likely to have flow monitoring in each selected country. Table 3.1 shows the eight groupings. There were too few examples of 5 lane motorways to provide meaningful statistics therefore they have been excluded.

**Table 3.1: Road Types**

Road Classification	Number of Lanes	Smart Motorways
Motorway*	5	Y
Motorway	4	Y
Motorway	4	N
Motorway	3	N
Motorway	2	N
A-road	3	N
A-road	2	N
A-road	1	N

The four lane smart motorways analysed were all hard shoulder running schemes. These are schemes where the hard shoulder, known as “lane below signal 1” is opened dynamically in response to increased flow. This design has been replaced by smart motorways all lanes

running. Presently, there aren't sufficient operational schemes to be able to draw robust conclusions about ALR performance in this analysis, therefore they have been excluded.

### **3.3 Data Sources**

The following data types have been used to derive throughput figures. Further details on the dataset sources can be found in appendix A.

1. NTIS 5 minute traffic speed, flow profiles were used to baseline the identified road types in England,
2. NTIS average hourly classified flow counts (vehicle counts categorised by vehicle lengths) were used to estimate the percentage of HGV traversing each network link to support the analysis of flow variations and goods throughput across England,
3. Country specific traffic speed and flow data in 15 minute time periods were used for the international comparison with the England baseline,
4. Eurostat vehicle passenger occupancy statistics from each country were used in combination with the collected flow data to support the identification of people throughput,
5. Eurostat types and tonnages of freight transported by road for each country were used in combination with the flow data to support the identification of goods throughput.

The data was processed by aggregating, filtering and visually extracting the maximum sustainable flow throughput for each road type (see section 3.2 for further details) and country. The outputs were then reduced to lane specific figures for comparison across road types and countries.

### **3.4 Methodology**

The analysis was focused on identifying the features of links that most regularly experience flow breakdown. The focus was on selecting data when stress is greater than 80% (indicating a high volume/capacity ratio, meaning the road is relatively busy) and when the average speed is lower than 45mph (low actual speeds being achieved on predominantly high speed roads is another indicator of congestion).

Data was eliminated from periods of roadworks, or when temporary speed restrictions were likely to be in place, except for the M1 J35-34 where we wanted to examine the achievable throughput during roadworks.

The next sections describe the data processing in more detail.

### **3.4.1 Aggregation**

Speed and flow traffic data from the National Traffic Information Service (NTIS) was aggregated from a 5 minute time period, per link, per day type to a 15 minute time period, per link, per day type to make it consistent with the time periods of the international datasets received. The classified flow data was also aggregated (vehicle counts by vehicle lengths) to identify an average hourly percentage of HGV traffic per link. This was performed by calculating the total number of vehicles, with a length greater than 6.6m and dividing this figure by the total hourly vehicle counts.

### **3.4.2 Filtering**

The data was filtered to extract locations where regular flow breakdown occurred and maximum throughput was achieved. For each location and 15 minute time period there was a selection of periods where:

1. network stress (see below) was greater than 80%, and
2. the average speed was less than 45mph for a 15 minute period.

Network stress is the flow divided by the capacity for each location and time period. The static capacity values used were those provided by NTIS. This set of filtering criteria gave a proxy for locations where routine flow breakdown occurs whilst providing a good sample of locations for more detailed analysis.

### **3.4.3 Data Cleansing and Outputs**

The NTIS data used in this analysis had already been validated. This validation is an involved process including a number of real-time and slow-time checks, comparing speeds and flows at specific sites, between nearby sites and across different data sources. Sites flagged as failing

validation are highlighted to NIS operators for detailed analysis and possible removal from the NTIS traffic dataset.<sup>3</sup>

Further data validation was undertaken which examined outliers in more detail. Where necessary, the road type categorisation was cross-referenced against Google Streetview (if the image capture data was recent). This enabled a potential understanding of the cause and subsequent exclusion of such outliers which were producing erroneous data.

For each road type there was an output of a speed flow graph and a visual inspection of the speed flow graph for each location was used to identify the maximum sustainable flow throughput.

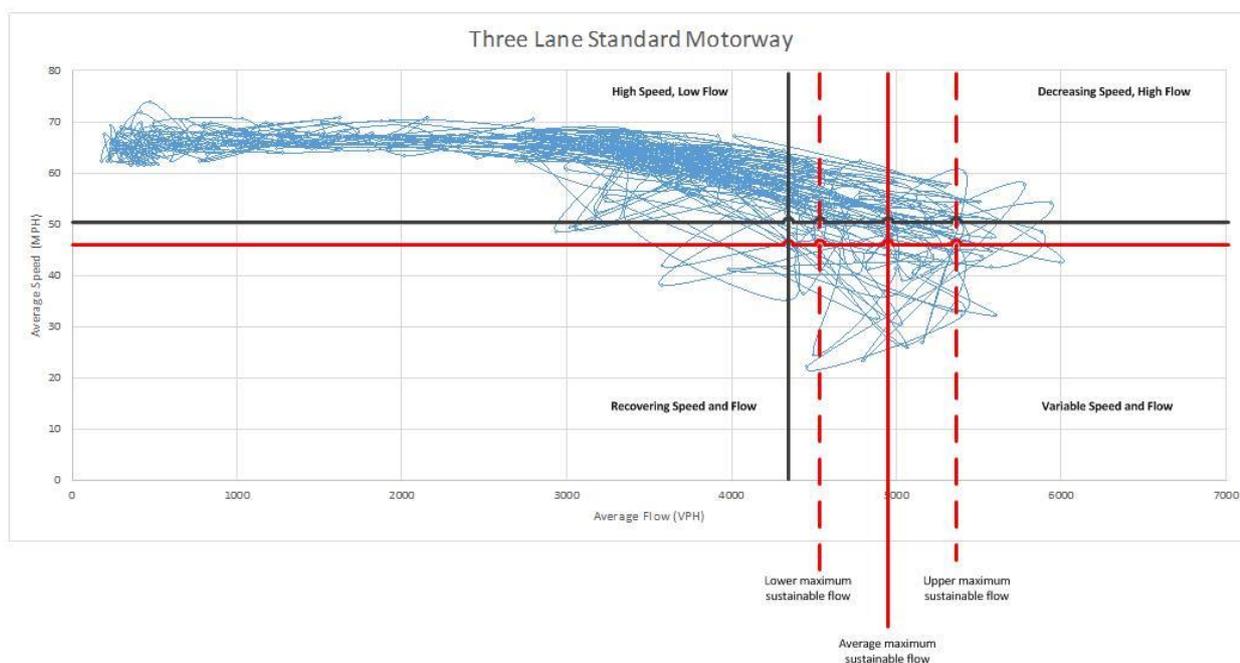
Graph 3.2 below shows how maximum throughput was visually identified by plotting lines on the speed flow graph, correlating with the maximum speed prior to flow becoming erratic. Upper and lower flow thresholds were then plotted along this line where the erratic flow behaviour begins to occur. This provides the level of variability of the maximum throughput, across the different locations, for each road type where maximum throughput occurred.

Speed/flow graphs are a standard way of analysing traffic on a road. Typically there are two speeds for a given flow. The top left quadrant of the graph indicates high speed, low flow conditions; the top right of the graph indicates reducing speed, high flow conditions just prior to flow break down. The bottom right of the graph indicates volatile speed and flow during flow breakdown and the bottom left of the graph indicates increasing speed and moderate flow, when traffic propagation is in recovery. The area of the graph used for this analysis was the top right region of the graph as this is where maximum throughput occurs.

### **Graph 3.2: Speed Flow Curve**

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<sup>3</sup> Further details can be found in NIS TP NTIS 011 Traffic Data Validation (WA119-08-007-009-07)



For each road link passing the filtering and cleansing process, 15 minute aggregated flow and average speed data was used for a minimum of 1 month across 2015, from “typical” Mondays. A 15 minute time period gives a good balance between keeping data sizes manageable while allowing trends to appear. Monday was chosen as one of the busiest days of the week, where we would expect flow breakdown to occur frequently. This allowed us to measure the maximum throughput and to produce typical values for flow and speed across each road type, together with upper and lower bounds for the ranges that might be expected. These values calculated for the SRN were then compared with values calculated from flow and speed data from other countries, to benchmark the performance of the SRN.

The outputs produced for analysis included tables, graphs and charts of the following:

1. Lower, upper and mean speeds and flows across each road type, for the chosen day type, for each country. This is to allow for comparisons of variability across roads and countries.
2. Lane specific values for each road type and country to support more direct comparison.
3. The hourly HGV percentage of vehicles per road type to identify a potential cause of variations in flow throughput.

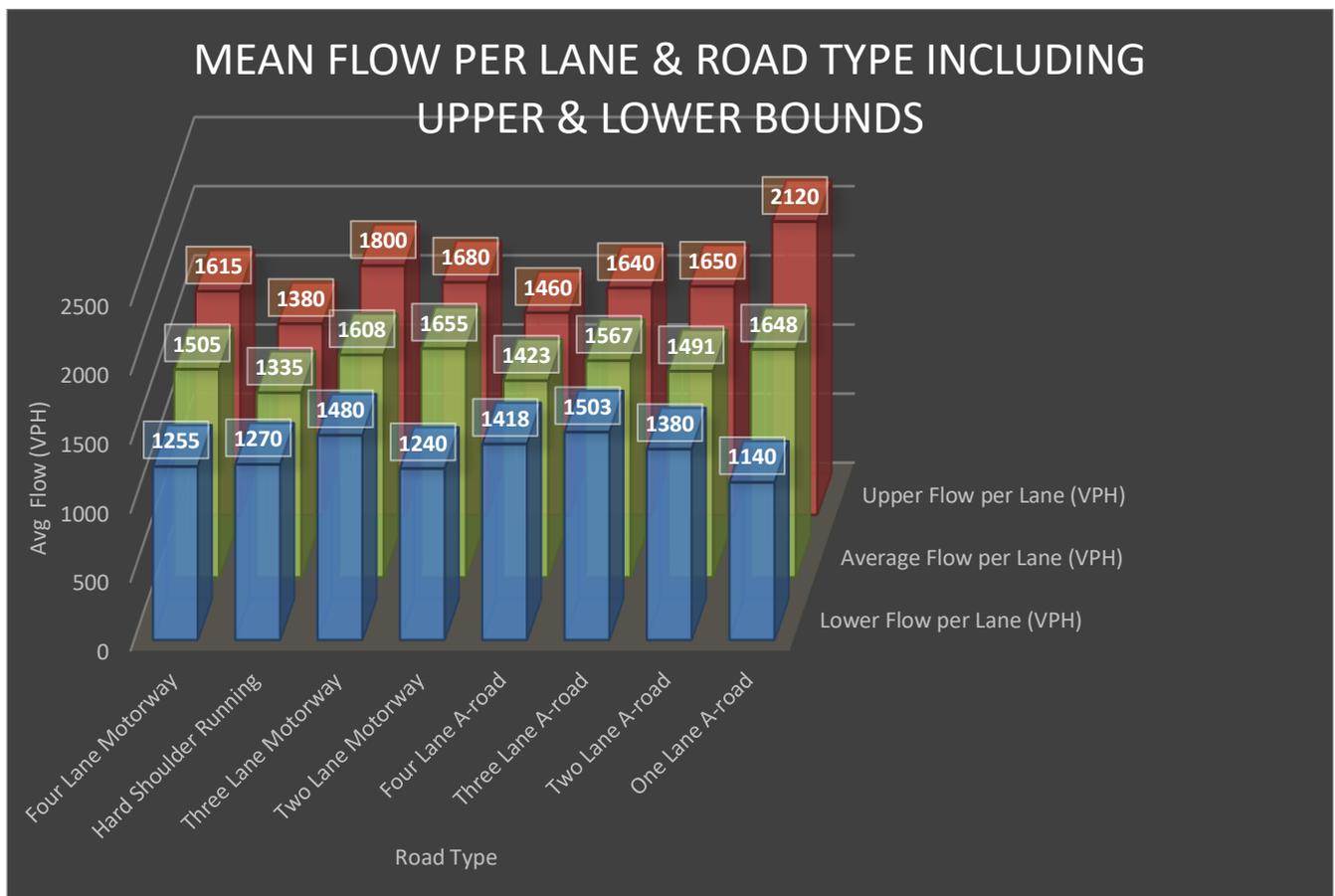


## 4 England SRN Baseline

### 4.1 Baseline Flow

Chart 4.2 shows the baselined flow throughput per road type including the mean, highest and lowest maximum flow throughput observed on the various sites analysed (mean, upper and lower bounds). This provides an indication of the level of variance for flow throughput for the same road type. Although the data required to analyse actual flow, in each lane, on any section of carriageway wasn't obtained, we divided the total flow by the number of lanes allowing for comparison of the equivalent, i.e throughput per lane.

**Chart 4.2: England Maximum Sustainable Flow per Lane and Road Type**



Examining the throughput values calculated for the different road types, the highest average throughput was 1655 vehicles per hour per lane for a two lane motorway. In contrast, the lowest average value, 1335 vehicles per hour per lane, is for a four lane smart motorway with Hard Shoulder Running. This is discussed further in the section on Hard Shoulder Running schemes.

Table 4.2 presents this data in tabular format and additionally shows the variability across all road types. The percentage variability was calculated using the following formula:

$$((\text{highest lane flow value} - \text{lowest lane flow value}) / \text{highest lane flow value}) * 100$$

**Table 4.2: Baselined Flow Throughput per Road Type Including Upper and Lower Bounds**

Road Category Description	Lower Flow per Lane (VPH)	Upper Flow per Lane (VPH)	Average Flow per Lane (VPH)	Average Daily HGV Percentage (%)	Number of link locations analysed in detail i.e. flow breakdown criteria met	Flow Throughput Variability compared to max value (%)
Four Lane Motorway	1255	1615	1505	0.14	9	22.29
Hard Shoulder Running	1270	1380	1335	0.20	6	7.97
Three Lane Motorway	1480	1800	1608	0.15	10	17.78
Two Lane Motorway	1240	1680	1655	0.13	8	26.19
Four Lane A-road	1418	1460	1423	0.13	4	2.91
Three Lane A-road	1503	1640	1567	0.09	3	8.33
Two Lane A-road	1380	1650	1491	0.13	21	16.36
One Lane A-road	1140	2120	1648	0.11	5	46.23

\*Note the average daily HGV % figures are variable most likely as a result of the low sample sizes.

The table also shows how many locations met the defined criteria for flow breakdown in each road category. For most road types this is a small number, less than ten sites. Many places across the network never experience flow breakdown. Of those which do, most usually only experience one or two periods of flow breakdown typically morning (06:30 – 09:30) and evening (15:30 – 19:00).

#### 4.1.1 Upper, Lower and Mean Speeds and Flows for Road Types

The graphs in the following sections show plots of speed and flow data analysed for each road type, over the last six weeks, for each location, based on 15 minute speed and flow data. The bold lines represent the mean values across all locations analysed. The vertical lines through the mean values show the range of values for that time period for each of the locations analysed. The longer these lines are, the greater the variability within the sample size.

Typically the flow line (axis on the right hand side) shows low overnight flow, increasing to a peak in the morning, reducing slightly in the middle of the day and increasing again to another peak in the evening, before dropping away again overnight. Simultaneously, the speed profile is steady when flow is low, as drivers do not have their speed impacted by the number of vehicles (unless long term speed enforced roadworks are lowering the average speed profiles). As the

flow increases, the speed that drivers can travel at is reduced, until “flow breakdown” occurs and the throughput is no longer “sustainable”.

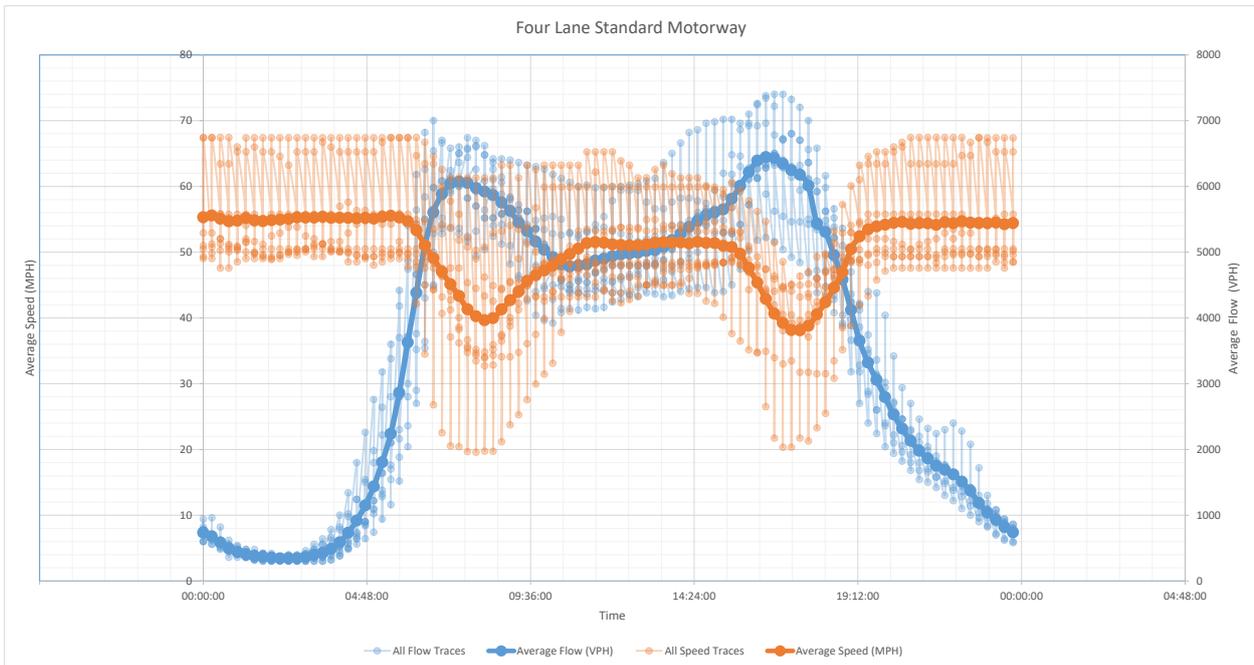
For each road type we have commented on the mean value of maximum throughput, and looked specifically at those locations with the lowest and highest values of maximum throughput, in order to identify trends in low and high maximum throughput.

As an additional validation check of the results, comparisons were made to the Design Manual for Roads and Bridges (DMRB) values for theoretical capacity where applicable (note there are no DMRB values for smart motorways).

### **D4M**

Graph 4.2.1 shows the speeds and flows for the data points for “standard” four lane motorways.

**Graph 4.2.1: D4M Flow Baseline**



Of the nine D4M sites that achieved flow breakdown, the M1 Southbound (D4M) J21A to 21 has the lowest throughput with 1255 vehicles per hour per lane. This is most likely because the link downstream has been impacted by roadworks, leading into Junction 19 (with the M6) creating a distortion in the figures. M1 Northbound J21 to 21A showed the greatest throughput (1615 vehicles per hour per lane). This section of 4 lane Motorway is uniform with wide junction

spacing and straight geometry. The lowest and highest performing sections here are the two opposite carriageways of the same motorway, something worthy of further investigation.

#### **Four Lane Hard Shoulder Running (HSR) Smart Motorway**

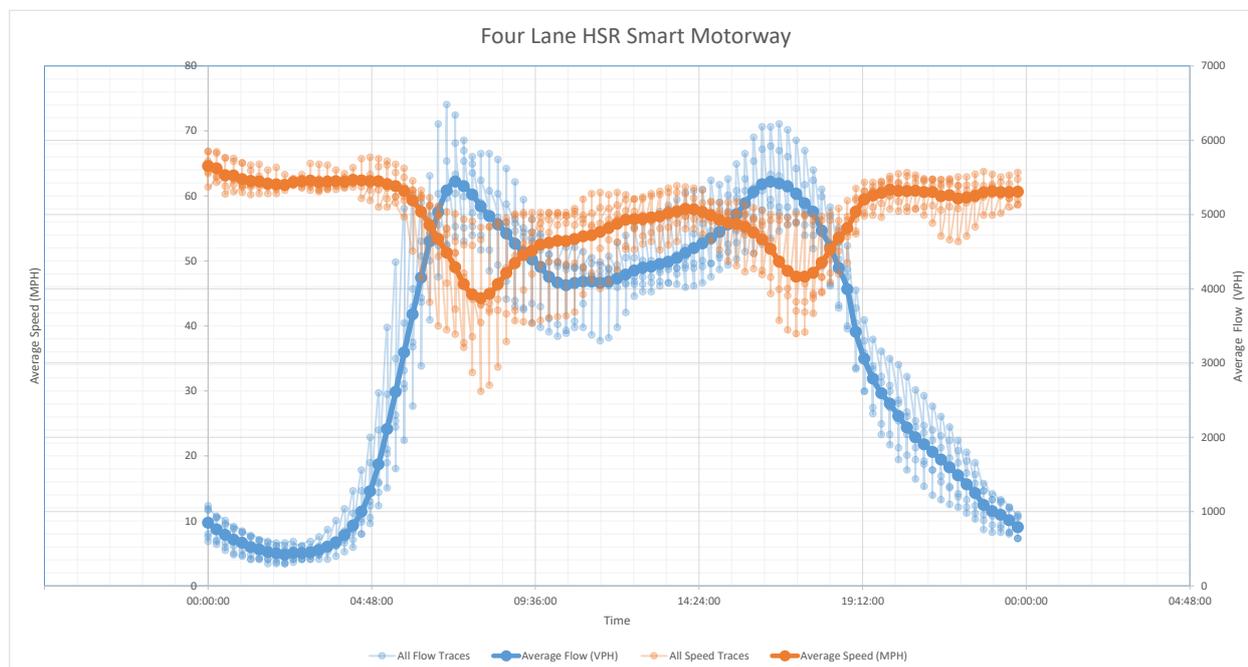
Graph 4.2.2 represents speed and flows for four lane smart motorways with hard shoulder running (HSR). The mean flow throughput results are lower than a D4M motorway (1335 compared to 1505 vehicles per hour per lane). Operational variables such as the timing of hard shoulder openings, maintenance performance and optimisation of congestion algorithms are all areas of known impact, now quantified by this analysis. We have recently reviewed the performance of HSR schemes for the smart motorway operations team<sup>4</sup> and have found that at times, the dynamic hard shoulder is turned on too late and left on too long, resulting in the kind of shockwave patterns that smart motorways should prevent, with prolonged traffic flow recovery. Furthermore the smart motorways operations team discovered potential issues with the through junction running approach to junction 11. Flow levels rise very quickly approaching the morning peak. This, together with unrealistic flow thresholds, means that at times flows are breaking down before the hard shoulder is opened.

There is much less variability within in the HSR figures in comparison to other road types such as D4M motorways, as illustrated by the shorter “bars” above and below the mean figures. This is principally due to the more controlled environment on a smart motorway compared to a standard motorway, as we would expect from the smart motorways design. There is no obvious step change to the graph representing when VMSL are turned on/off. It appears when the average speed on a 4 lane SM drops during the morning peak, it then stays at the 50mph mark. Speed limits are maintained during the inter-peak with traffic held below the national limit. As can be observed, the line never quite makes it back to the initial starting speed.

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<sup>4</sup> WP6 004 Scheme Assessment Report Issue C 221015 Establishing common performance metrics and targets to identify whether or not a Dynamic Hard Shoulder (DHS) scheme is achieving optimal performance Scheme Assessment Report

**Graph 4.2.2: Four Lane Smart Motorway Flow Baseline**



The M1 Southbound J11 to 10 showed the lowest throughput within this road type, 1270 vehicles per hour per lane. As mentioned in the previous paragraph and endorsed by the M1 scheme assessment reports, this section is subject to poor operation, with inaccurate settings of flow thresholds for opening and closing of the hard shoulder. This is the likely cause of the poor performance in this location.

The M62 Eastbound J26 to J27 shows the highest throughput within this type at 1380 vehicles per hour per lane. Long dual lane exit slips staggering the egress for Bradford and Leeds reduce the impact of junctions on traffic flow. Upstream and downstream speed control is smoothing flow entering and exiting the link supporting higher throughput.

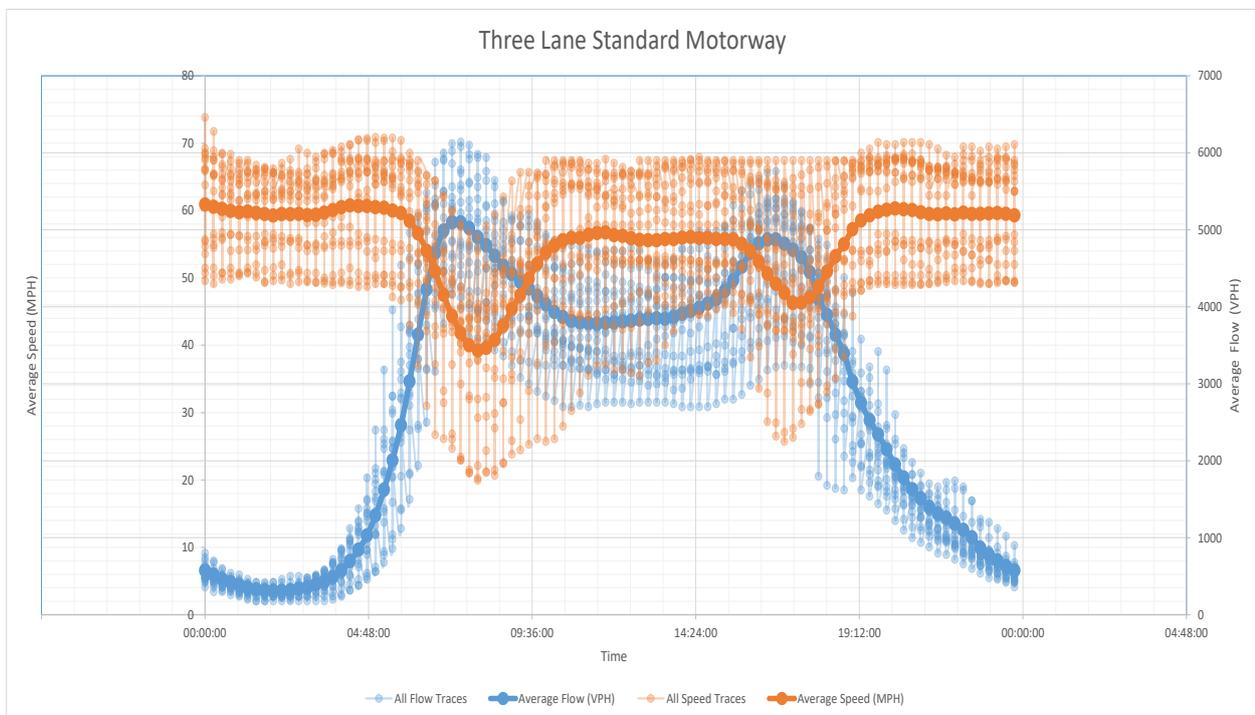
The controlled environment of smart motorways means vehicles can safely travel more closely together at the sacrifice of lowering the prevailing speed slightly, but subsequently achieve more throughput of people/goods.

<sup>5</sup> WP6 004 Scheme Assessment Report Issue C 221015 Establishing common performance metrics and targets to identify whether or not a Dynamic Hard Shoulder (DHS) scheme is achieving optimal performance Scheme Assessment Report

### D3M

Graph 4.2.3 shows the speed and flows for a standard D3M motorway. The calculated mean flow is lower than the stated capacity in the DMRB, at 4823 vs 5600 vehicles per hour, suggesting that on average across the D3M roads observed, flow breakdown starts to occur above 4823 vehicles per hour. However, there is high variability in the maximum flow figures calculated for this particular road type. This type of motorway is the most common, which lends itself to the possibility of many different variables which could impact upon throughput. The upper flow throughput figure of 5400 (seen on M1 J35-46 southbound) is 96% of the theoretical DMRB figure.

**Graph 4.2.3: D3M Flow Baseline**



The M3 Westbound J10 to11 presents the lowest flow of the locations analysed at 1480 vehicles per hour per lane. This link is particularly short with junction 10 and 11 less than 2 km apart from entry to exit slip. In addition, this link has a curved geometry and is on the crest of hill. Both factors have the potential to influence the throughput.

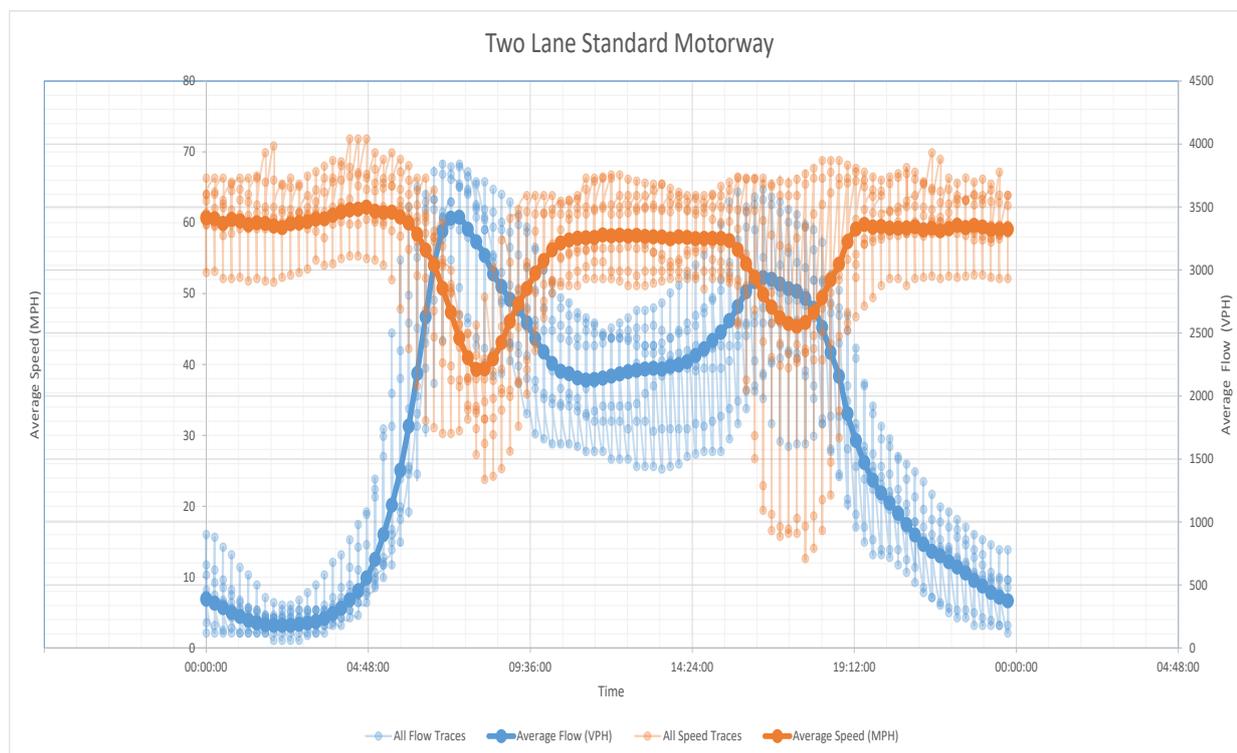
The M1 southbound J35 to J34 shows the highest throughput at 1800 vehicles per hour per lane. It is understood that 50mph enforced speed limits exist on this link due to smart motorways upgrade road works, this is also applicable to the upstream and downstream links. Additionally, this stretch of roadworks are part of the "making roadworks simpler and clearer" project. It is possible that this project is influencing driver behaviour positively and therefore

enhancing throughput, however it is more likely the enforced speed restrictions are having the greater impact on throughput.

## **D2M**

Graph 4.2.4 shows the mean sustainable flow throughput for a D2M motorway at 3309 vehicles per hour. The figure represented, whilst not at the DMRB quoted maximum value of 4000 vehicles per hour (which is an extreme maximum), is within 17% of the DMRB quoted value for this road type. The 3309 vehicles per hour calculated value includes various locations of D2M roads, such as urban and inter-urban stretches with various geometry and junction spacing configurations, hence providing the reason for a lower throughput than the DMRB quoted figures. This suggests that the DMRB quoted figures are a theoretical maximum that may be observed during extreme peaks of flow and are not sustainable. They do however provide validation of the outputs calculated.

**Graph 4.2.4: D2M Flow Baseline**



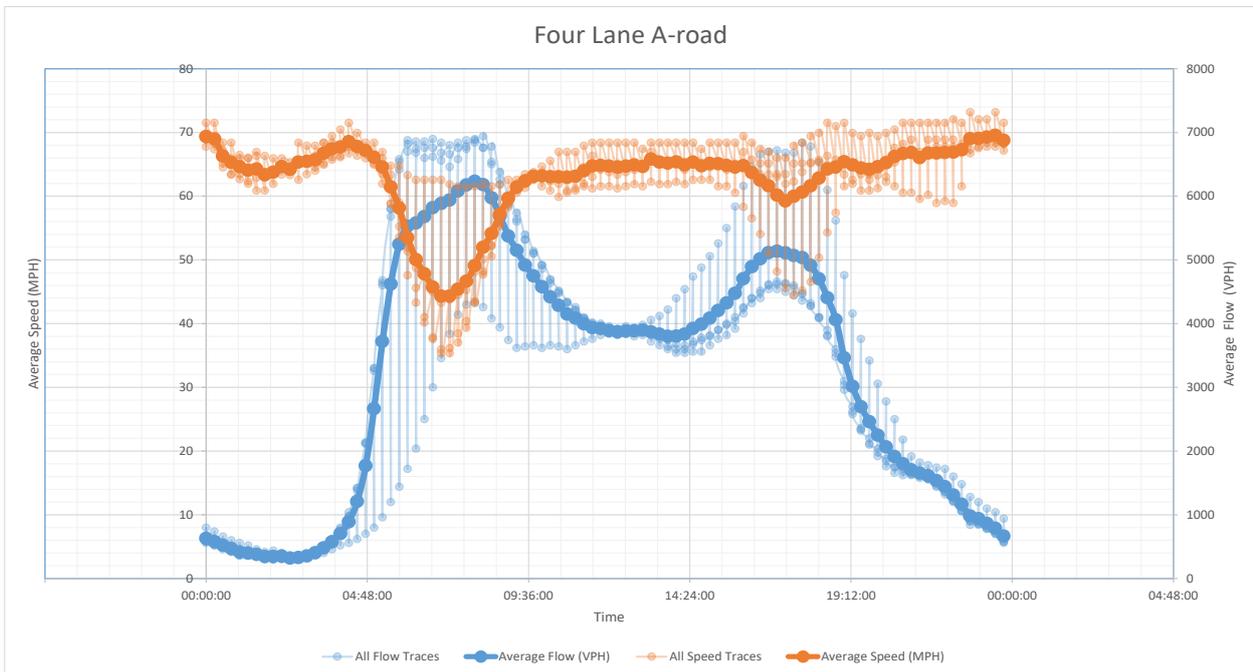
The M56 Eastbound J3 to 2 has the lowest flow throughput at 1240 vehicles per hour per lane. This link has a low flow throughput due to the close proximity of junctions i.e. less than 1.5km apart, has significant curvature at this location and serves as the link road to the M60.

The M32 Northbound J2 to 1 has the highest flow throughput at 1680 vehicles per hour per lane. This link is long (3.5km) minimising junction interruption of flow and this is a typical feature of roads demonstrating high throughput. Additionally, this section has a 2 lane off slip, reducing the potential for traffic to influence the mainline.

### Four Lane A-road

Graph 4.2.5 shows the output for four lane A-roads. There are not many four lane A-roads, therefore the sample had only four suitable sections. Other four lane A-roads that did not demonstrate flow breakdown were: westbound A227 to B262 and eastbound M25/A282 to B255. They had similar upper (1460 vehicles per hour per lane) and lower flow thresholds (1418 vehicles per hour per lane). Both of these carriageways are notably straight and have few potential driver distractions, signage, junctions etc. This is the likely cause of the throughput on these roads being high.

**Graph 4.2.5: Four Lane A-road Flow Baseline**



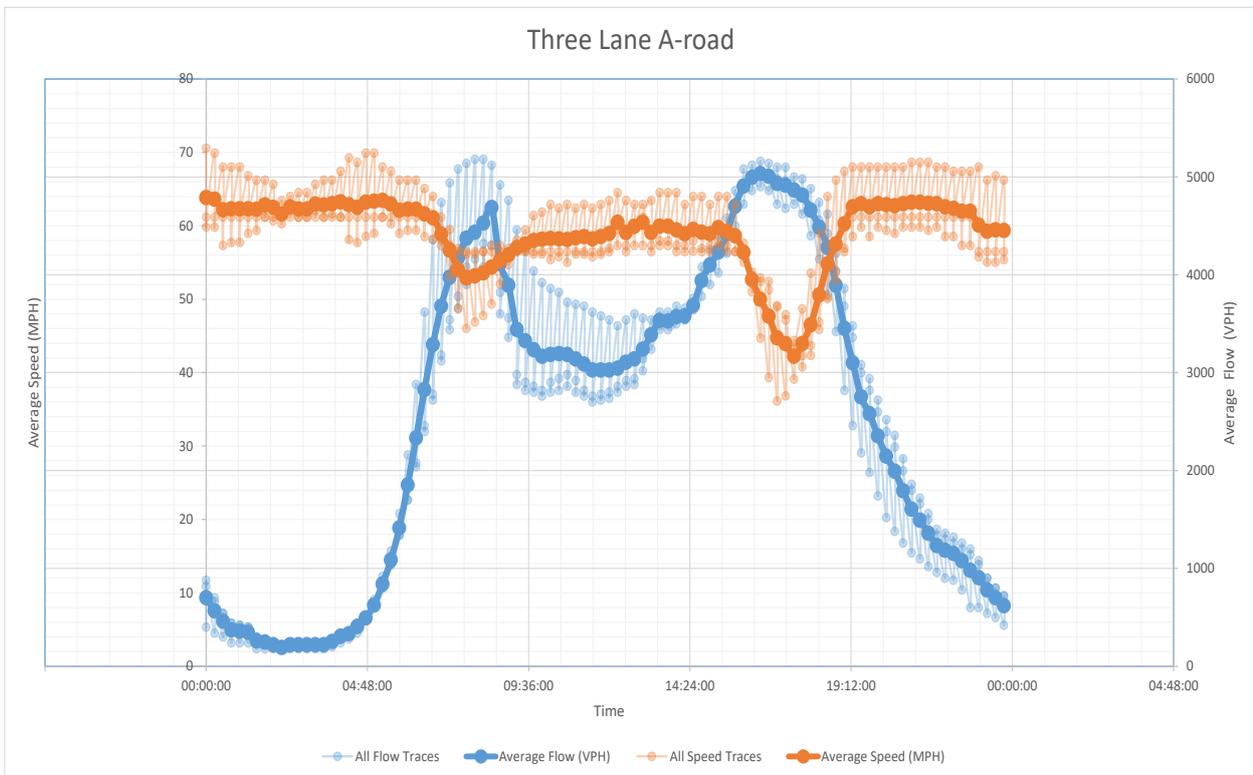
### Three Lane A-road

Graph 4.2.6 overleaf shows the plot for three lane A-roads. There were only three, three lane A-roads that met the flow breakdown criteria on a routine basis.

The A27 westbound A2030 to M27/M275 has the lowest flow throughput at 1503 vehicles per hour per lane. This link bypasses the northern outskirts of Portsmouth and has a short distance between junctions (approximately 1km).

The A2 eastbound A223 to A2018 has the highest flow throughput at 1640 vehicles per hour per lane. This link is relatively long and is the start of a 3 lane section so demand is constrained by the upstream link which has only two lanes.

**Graph 4.2.6: Three Lane A-road Flow Baseline**



## **Two Lane A-road**

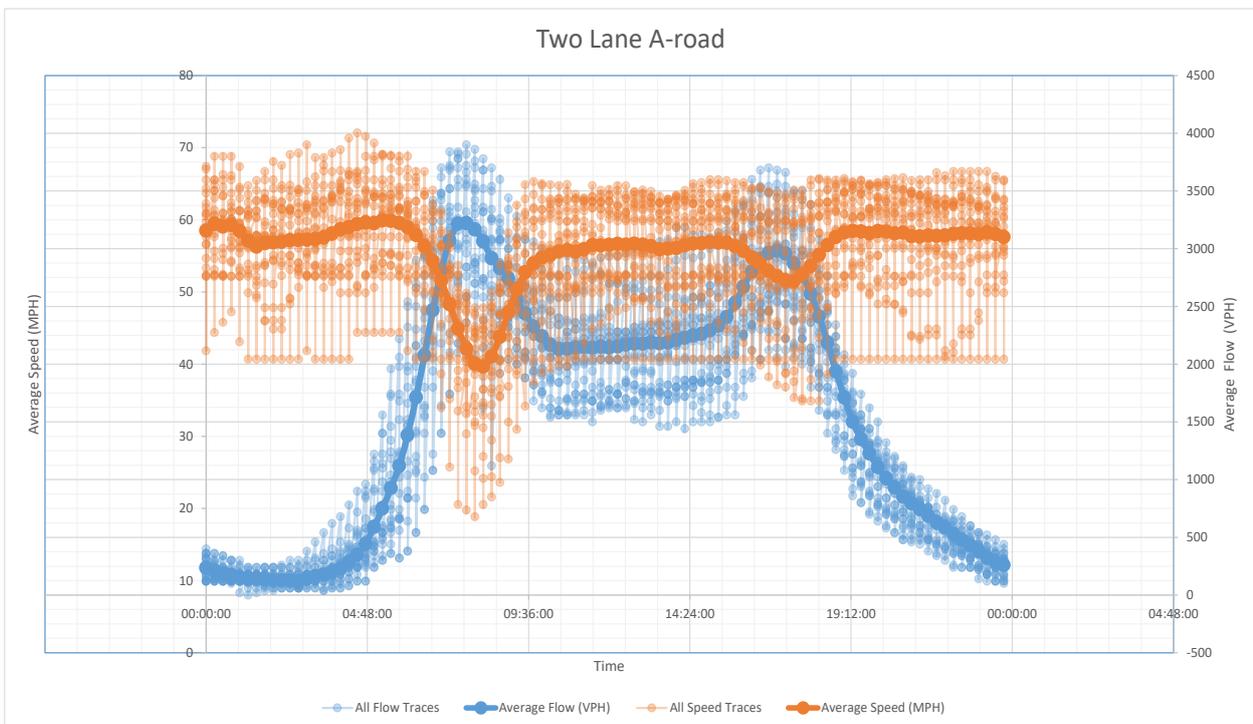
Graph 4.2.7 overleaf shows the plot for two Lane A-roads, for which we calculated a mean flow of 2981 vehicles per hour. The significant variability in the configuration of two lane A-roads is the likely cause for this result. Also note the significant drop in afternoon peak speeds to less than 40mph from 60mph average. This significant variability is vastly different when compared to the morning peak speeds.

The A1 southbound A1(M) J40 to B6474 has the lowest flow throughput of 1380 vehicles per hour per lane. This two lane link has a daily average LGV/HGV percentage, 12% of total flow,

hence possibly attributing the reduced flow to a reduction in throughput caused by slow moving/speed restricted vehicles overtaking. This this is also a main north/south route for freight.

The A500 southbound A527 (south) to A53 has the highest flow throughput at 1650 vehicles per hour per lane. This link, whilst short, has full barrier both sides of the roads providing a consistent driving experience. Noteworthy, is the daily average LGV/HGV percentage is 7%, supporting the suggestion that higher percentages of HGVs negatively impact traffic flow.

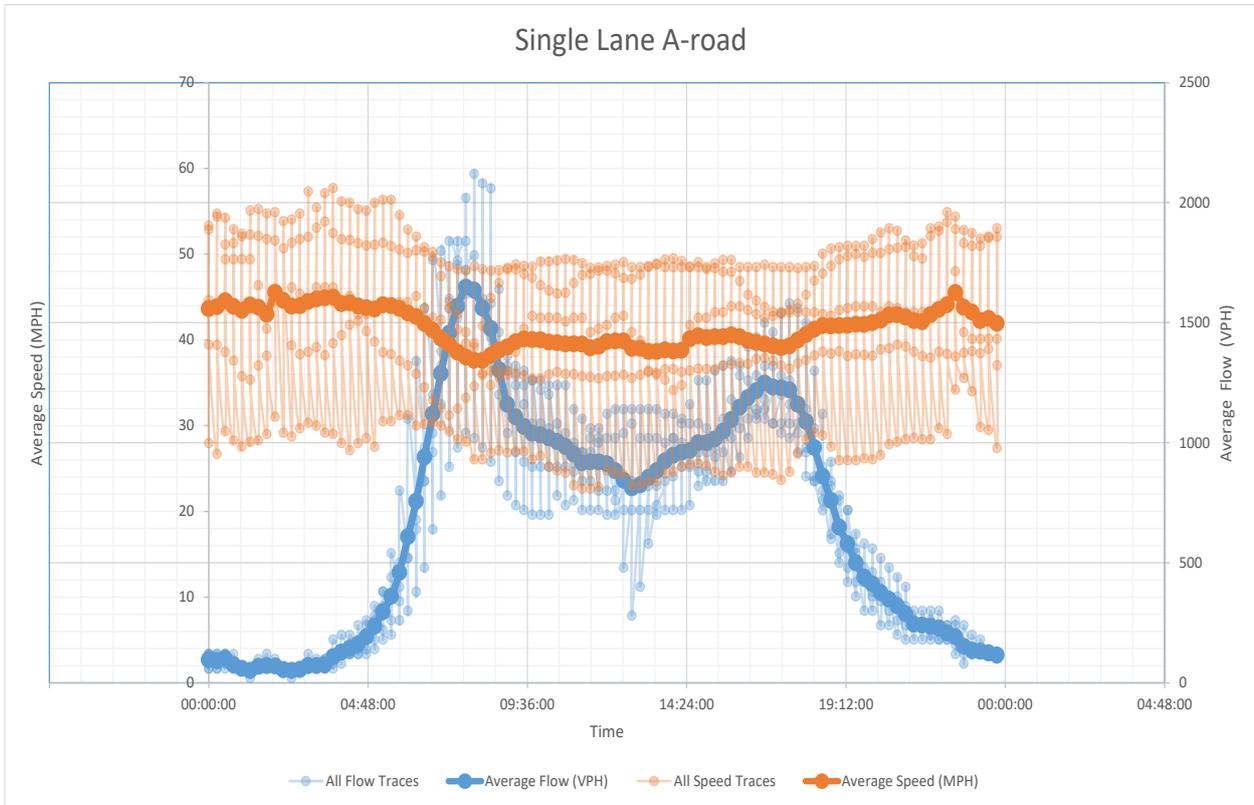
**Graph 4.2.7: Two Lane A-road Flow Baseline**



**Single Lane A-road**

Graph 4.2.8 below depicts a one lane flow baseline. The breakdown point wasn't quite reached on any road in the measured dataset for single lane A-road. This is due to flow measurement site locations and low density on these road types compared to the link data extracted. There was significant variability between the minimum and maximum flow throughput figures on one lane A-roads (46.23% - see table 4.2) which was much greater than any other road type. This could be due to the limited ability to overtake slower moving vehicles on a single lane APTR.

**Graph 4.2.8: One Lane A-road Flow Baseline**



## 4.2 Baseline People

This section extrapolates the hourly vehicle flow throughput figures (presented in section 4.1) into hourly people throughput figures using mean vehicle occupancy figures, giving a baseline for people throughput in England.

The vehicle passenger occupancy figures in table 4.2.1 show England having an occupancy rate of 1.62.

**Table 4.2.1: Vehicle Passenger Occupancy Figures**

	Vehicle Passenger Occupancy % (Average Annualised figures - All vehicles)
England (2008)	1.62

Typically, developing countries have higher passenger occupancy rates than developed countries as a result of reduced car ownership and more people requiring public transport.

Chart 4.4.2 below presents the throughput in terms of people per road type for England. This is calculated by multiplying the flow throughput by the mean occupancy values. The use of average occupancy rates and multiplication of typical volumes of traffic is a coarse method of comparison, but it is a method that is readily available. This methodology is also endorsed in a report conducted by the Texas Department of Transportation<sup>6</sup>.

As the average vehicle passenger occupancy figures are not broken down by road type, the highest per lane figures are for a two lane motorway, this is heavily skewed by this road type having the greatest flow throughput. On a four lane motorway the estimated maximum people throughput per hour for the whole carriageway is nearly 10000 people per hour. This is shown in Chart 4.2.2.

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<sup>6</sup> “monitoring and evaluating managed lane facility performance”

<http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/0-4160-23.pdf>

**Chart 4.2.2: Maximum Sustainable People Throughput (people per hour)**

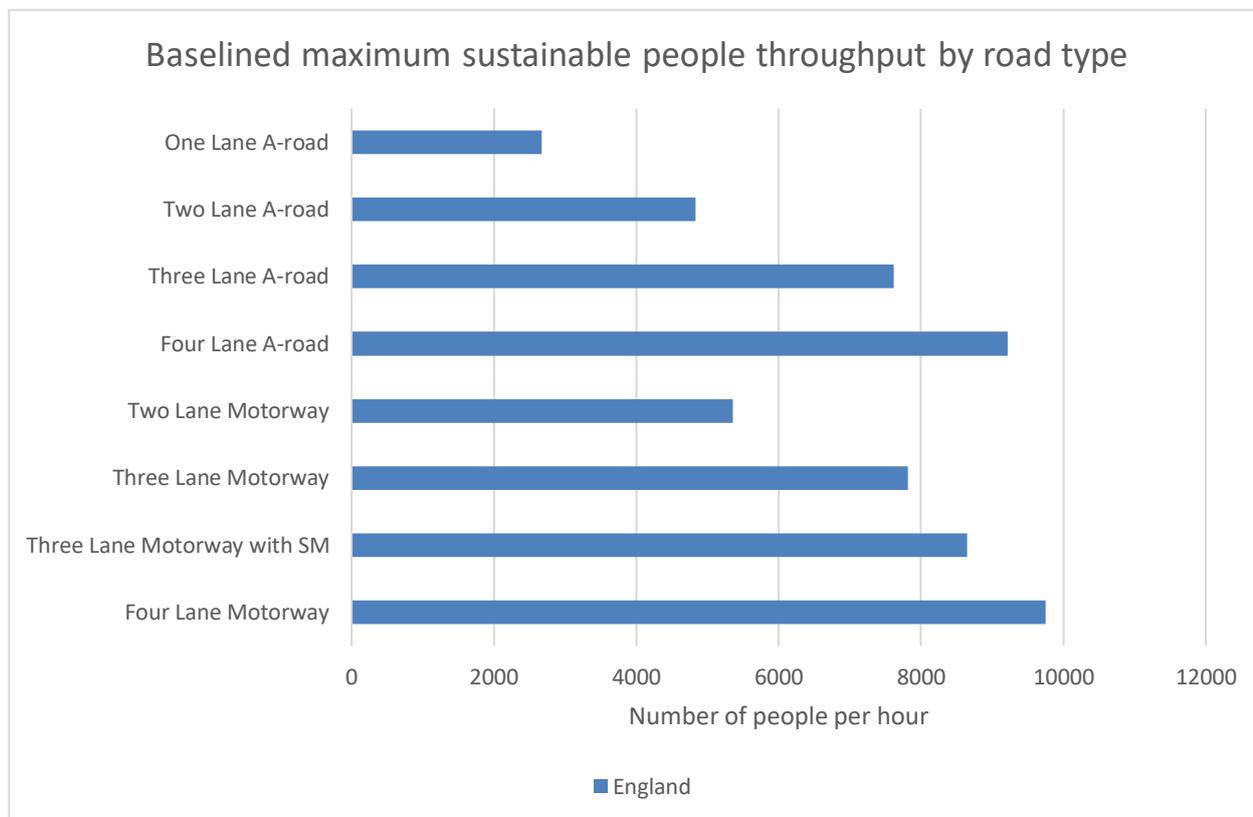


Table 4.2.2 shows the per lane people throughput per road type. It is worth pointing out that while maximum sustainable flows have resulted on these road types the people throughput is significantly less, than the maximum potential. For example, assuming a vehicles average capacity is 4 persons, an occupancy figure of 1.62 is only just over 40%. Also noteworthy, interventions such as High Occupancy Vehicle lanes have been shown to achieve similar benchmarks per lane with fewer vehicles.<sup>7</sup> However, this is usually in combination with other measures such as enforcement.

<sup>7</sup> "monitoring and evaluating managed lane facility performance" <http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/0-4160-23.pdf>

**Table 4.2.2: People Throughput per Lane per Hour**

Road Category Description	Average Flow per Lane (VPH)	Average Vehicle Person Occupancy (%)	Assumed maximum vehicle passenger capacity	Maximum People Throughput per lane per hour
Four Lane Motorway	1505	1.62	4.00	2437
Hard Shoulder Running	1335	1.62	4.00	2163
Three Lane Motorway	1608	1.62	4.00	2604
Two Lane Motorway	1655	1.62	4.00	2680
Four Lane A-road	1423	1.62	4.00	2304
Three Lane A-road	1567	1.62	4.00	2538
Two Lane A-road	1491	1.62	4.00	2415
One Lane A-road	1648	1.62	4.00	2670

### 4.3 England Baseline Goods

Chart 4.3.1 presents an extrapolated output showing the hourly throughput of goods type, by road type, using the maximum sustainable flow figures (for freight vehicles only) calculated in section 4, using the formula:

$$\text{Goods throughput} = \text{calculated flow throughput} * \text{percentage of total flow that is classified flow greater than 6.6m (LGV/HGV)} * \text{estimated percentage categorised goods transported per year by type of goods.}$$

The output is an estimate of the number of vehicles transporting particular types of goods on particular road types.

The caveat to this method is that it assumes that the national averages of goods type across the network are broadly replicated on each road type and apply equally across each hourly period in the day. The data is generated from a small sample, which records less than 1% of UK HGV movement data. There is a risk of introducing inaccuracies when scaling up to the whole network. Therefore, this data can at best provides an indication of the types of goods carried across the network and the road types used. Chart 4.3.1 shows an estimation of the a tonnage value, per goods type, measured in terms of tonnes per hour, concluding that the largest category of goods transported during maximum sustainable flow is food, closely followed by mining and waste. The greatest road type usage for freight is a three lane smart motorway, closely followed by standard three lane motorways.

**Chart 4.3.1: Baseline Goods Throughput by Type**

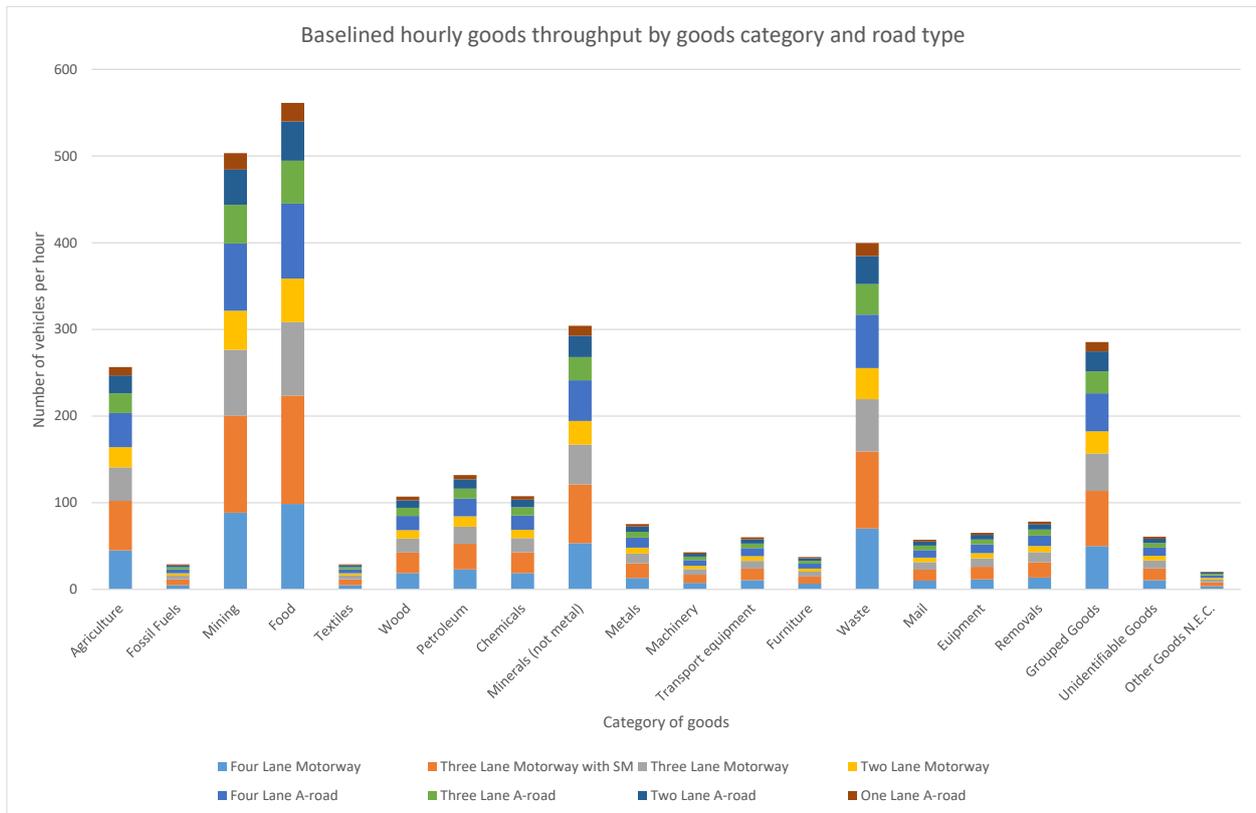
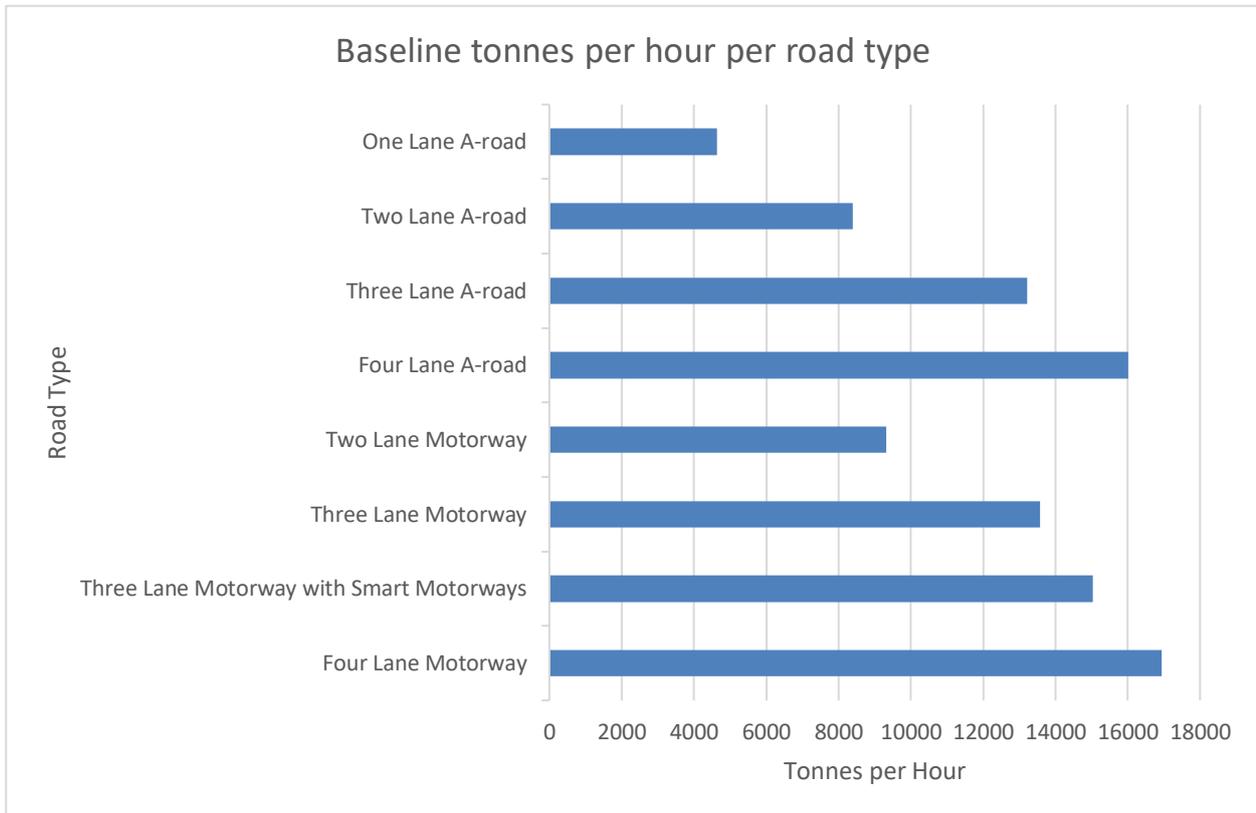


Chart 4.3.2 below summarises throughput by road type, weight and type of goods transported using the formula:

$$\text{Weight of Goods} = \text{Flow Throughput} * \text{percentage of total flow that is classified greater than 6.6m (LGV/HGV)} * \text{estimated percentage of goods weights (tonnes) per goods type per year.}$$

As can be seen, the results follow a pattern similar to the results for people throughput, with larger capacity roads having a greater throughput in terms of vehicles and weight. This is expected, as the figures are based on annualised mean values compared to 15 minute flow data. The same limitations apply here as described above for chart 4.3.1.

**Chart 4.3.2: Baseline Goods Throughput by Weight**



As we have sought to identify opportunities and methodologies to measure throughput of goods and people we have approached partner organisations and different departments within our own organisations. The AECOM Freight and Logistics team has existing freight measurement work undertaken to identify quantities of freight transported for commercial clients. The team have attempted to bridge the issue of small sample size through the development of a ‘specialised goods vehicle count’ application/model. This model can access a snapshot of HGV movements on any specific day with the capability to refine and allocate commodity group movements on any road type within the UK and potentially abroad. Having access to this level of detail would be helpful to Highways England and would support the aspiration of the ‘Concept of Operations’ which intellectual property for this model sits with commercial clients and it is not possible to simply borrow it in its current form. However, going forward, the vested knowledge within the AECOM freight team would enable us to develop something very similar for Highways England to provide a more robust, granular and ultimately usable measure

## 5 International Benchmark

### 5.1 Countries

After reviewing the data and information available via other road authorities and online, we have been able to compare data from the following countries against the England baseline data:

- **Netherlands (data from Rijkswaterstaat)**
- **Australia – Victoria, (data from Vic roads)**

Our rationale for choosing these countries is as follows; they provide good spatial diversity, have developed economies, have a reasonably dense traffic monitoring infrastructure, they provide a consistent comparison and data was available for analysis. All countries considered for the analysis and the rationale for inclusion and exclusion are shown in appendix G.

### 5.2 Flow

The data available from Australia and the Netherlands allowed the same methodology to be applied as described in section 3 enabling the calculation of the maximum throughput for two, three and four lane motorways.

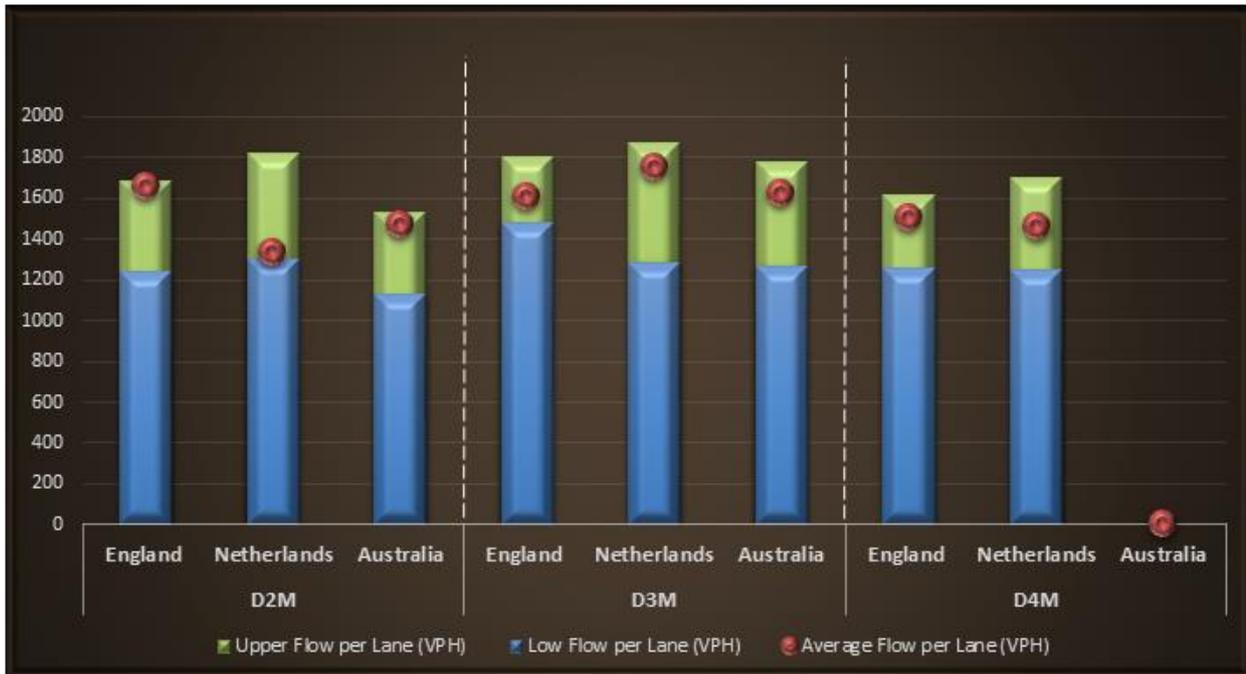
Table 5.2.1 shows the lowest, highest and mean values for the maximum sustainable throughput in terms of flow (VPH) per country per lane. The England values were within expected ranges of Australia and Netherlands values.

Chart 5.2.2 illustrates that for D2M roads, the SRN mean throughput figure is higher than both the Netherlands and Australia. The Netherlands has a higher value than the SRN for both the lowest and highest maximum throughputs seen at specific sites. Australia has a lower value for both. For D3M roads, the SRN mean throughput figure is the lowest of the three countries, but both Australia and the Netherlands' lowest values at a specific site are lower than those seen on the SRN. For D4M sites, the SRN has a higher mean and higher lowest specific site value than the Netherlands, but the highest flow at a specific site is in the Netherlands. The D4M data for Australia was not available at the time of writing.

**Table 5.2.1: Flow Throughput – International Comparison**

		Road Type		
		D2M	D3M	D4M
England	England Lower Flow per Lane (VPH)	1240	1480	1255
	England Average Flow per Lane (VPH)	1655	1608	1505
	England Upper Flow per Lane (VPH)	1680	1800	1615
	England Variability (%)	26.19	17.78	22.29
	Number of Sampled Locations	21	10	8
Netherlands	Dutch Lower Flow per Lane (VPH)	1297	1283	1246
	Dutch Average Flow per Lane (VPH)	1336	1748	1461
	Dutch Upper Flow per Lane (VPH)	1823	1868	1700
	Dutch Variability (%)	28.85	31.33	26.71
	Number of Sampled Locations	9	12	7
Australia	Australia Lower Flow per Lane (VPH)	1126	1268	-
	Australia Average Flow per Lane (VPH)	1467	1621	-
	Australia Upper Flow per Lane (VPH)	1530	1780	-
	Australian Variability (%)	26.41	28.76	-
	Number of Sampled Locations	5	5	-

**Chart 5.2.2: Flow Throughput – International Comparison**



### 5.3 People

The same methodology applied in section 4.2 is applied here. An extrapolation of the hourly vehicle flow throughput figures into hourly people throughput figures, based on mean vehicle

occupancy figures by country. Subsequently, this gives an indication of the different levels of people throughput that could be achieved if occupancy rates can be influenced.

The vehicle passenger occupancy figures given in table 5.3.1 show some variation between countries, with England having an occupancy rate of 1.62 compared to 1.32 for the Netherlands.

**Table 5.3.1: Vehicle Passenger Occupancy Figures<sup>8</sup>**

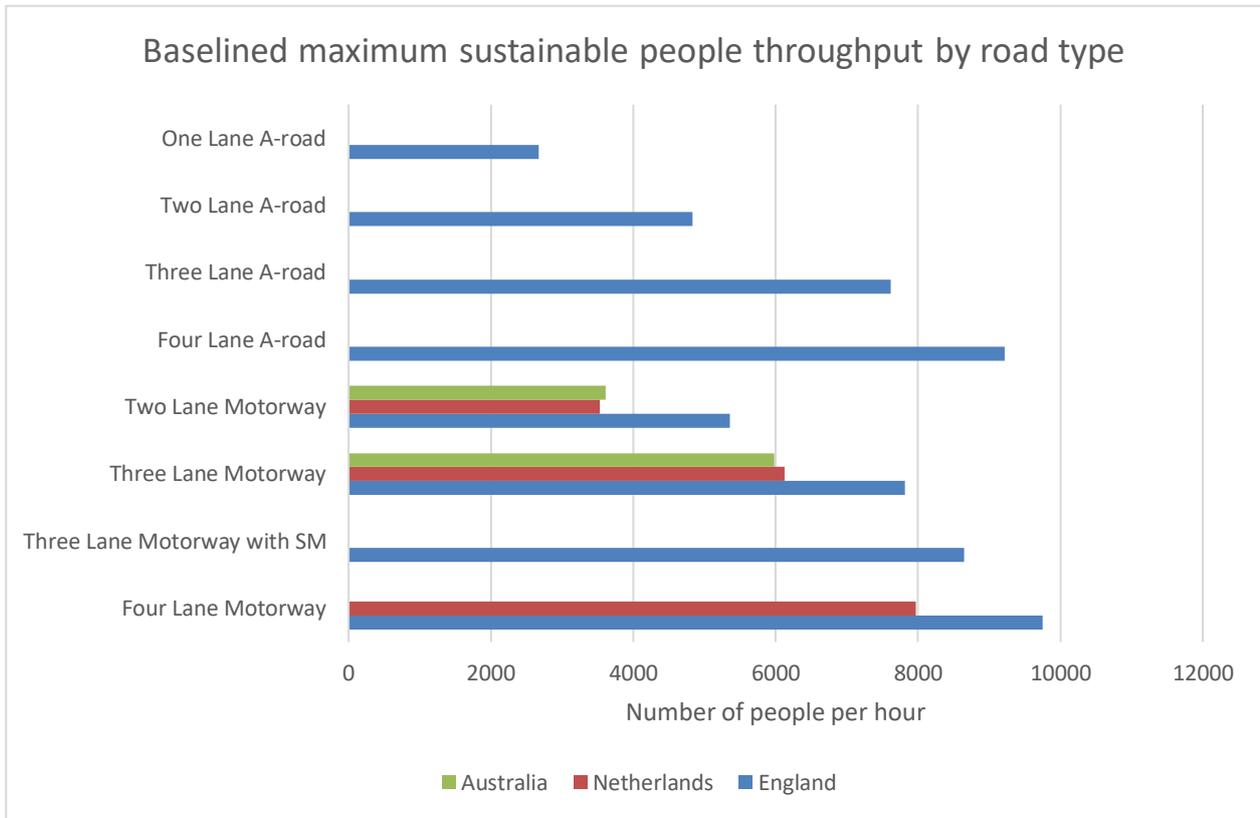
	Vehicle Passenger Occupancy % ( Average Annualised figures - All vehicles)
England (2008)	1.62
Netherlands (2007)	1.32
Australia (2009)	1.23
US (2012)	1.55

All countries used in this analysis were all developed and there is no obvious reason for the difference in the occupancy figures. Chart 5.3.2 presents the throughput in terms of people per road type by country, calculated by multiplying the flow throughput by the mean occupancy values.

The results demonstrate England having a higher throughput, nearly 9,749 people an hour for a four lane motorway. The flow throughput and the average occupancy rate are both higher for England than they are for the Netherlands.

<sup>8</sup> Eurostat European Statistics (<http://ec.europa.eu/eurostat>) – See appendix A for list of data sources

**Chart 5.3.2: Maximum Sustainable People Throughput (people per hour)**



## 5.4 Goods

The data available for baselining the throughput of goods was limited just to England. Therefore, no data is available to make an international comparison.

## 6 Conclusions

### 6.1 Summary

The following conclusions have resulted from the analysis:

The Maximum flow throughput is only achieved for two short periods of the day – morning peak (06:30 – 09:30) and evening peak (15:30 – 19:00) on all road types. There are numerous locations that do not suffer regular flow breakdown on the network.

When examining the different roads types, the highest average throughput was 1655 vehicles per hour per lane for a two lane motorway and in contrast, the lowest average value was 1335 vehicles per hour per lane for a four lane smart motorway with Hard Shoulder Running (HSR). There are known issues with the operation of HSR schemes, which have been investigated by the smart motorway operations team. If the dynamic hard shoulder cannot be opened for operational reasons, this will reduce the maximum flow throughput, which was one of the reasons that Highways England have moved away from the use of a dynamic hard shoulder for smart motorway schemes.

The England baseline flow (VPH) per lanes figures were in the ranges suggested by the Design Manual for Roads and Bridges, however the values calculated are generally at the lower end of the range. This suggests that the DMRB<sup>9</sup> quoted figures are a theoretical maximum that may be observed during extreme peaks of flow and are not sustainable. They do however provide validation of the outputs calculated.

Road types with fewer lanes appear to have higher lane specific throughput, for example; single lane APTR and D2M. This could be attributable to weaving traffic and higher HGV percentages on road types with a greater number of lanes. However, when comparing the variability within a given road type the situation is significantly different with single lane APTR performing by far the worst in terms of consistency of flow throughput, with a variability of 46.3%. One of the main factors for this is the variability in design of, for example, single lane APTR roads in comparison with the standardised design of HSR.

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<sup>9</sup> DMRB Volume 5 Section 1 Part 3 TA 79/99 Amendment No 1

There was a trend of flow variability reduction with roads that have fewer lanes and design features, but make users conscious of the speed they are travelling. This is apparent with both infrastructure aspects e.g. increased barrier provision and technical aspects e.g. smart motorways technology. Smart motorways schemes were observed to have a reduced flow variability in comparison to standard D4M roads.

More throughput is achieved on roads where a straight geometry and fewer junctions are present.

The vehicle passenger occupancy figures show some variation between countries, with England having an occupancy rate of 1.62 compared to 1.32 for the Netherlands, 1.23 for Australia and 1.55 for the US. Typically, developing countries have higher passenger occupancy rates than developed countries as a result of reduced car ownership and more people requiring public transport. However, the countries used in this analysis were all developed and there is no obvious reason for the difference in the occupancy figures.

The use of average occupancy rates and multiplication of typical volumes demonstrated England having a higher throughput, nearly 9,749 people an hour for a four lane motorway. The flow throughput and the average occupancy rate were both higher for England than they were for the Netherlands.

The largest category of goods transported during maximum sustainable flow is food, closely followed by mining and waste. The greatest road usage type for goods is a three lane smart motorway, closely followed by standard three lane motorways. Goods follow a similar pattern to the results for people throughput, with larger capacity roads having greater throughput in terms of vehicles and weight.

## 6.2 Recommendations

Cowen (2016)<sup>10</sup>, concluded that in order to start accurately measuring the throughput of people and goods using the road network, investment will be needed to gain the required granularity in terms of temporal and spatial measurement. This report has concluded that although the SRN

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<sup>10</sup> Cowen (2016) *The feasibility of measuring the throughput of goods and people*, Woking: Mouchel

achieves similar flow throughput levels to those observed in the Netherlands and Australia, the network does not manage throughput and capacity optimally, with disparity in performance between roads of the same type and even the same design, presenting opportunity for improvements in the interim.

The steps described below, identify opportunities for further analysis, which could enhance the conclusions and make improvements/changes to road design which we observed in this report, thus enabling better throughput.

### **Recommendation 1:**

*Collecting more granular data at more network locations looking at regional trends.*

For example, 1 minute site specific flows vs 15 minute average link flow. This level of temporal data would provide more detail at each location as to when throughput is maximised, and how long for, prior to flow breakdown occurring. The benefit of this would be to allow a pin pointing of specific disparities within and between road types and their different designs across regions (possibly due to differences in driver behaviour). This would facilitate interventions which could either increase or maintain maximum throughput for longer. Data could also be collected via other methods, such as mobile phone counts, and by collating “local intelligence” from (for example) route managers or the traffic officer service, to understand the factors that may cause two identical looking roads to perform in a different way. In addition, this approach could be developed further by comparing this more granular data, with international operator datasets (where data availability permits).

### **Recommendation 2:**

*Focus data collection on those sections of the network that experience regular flow breakdown.*

The analysis has shown that there are relatively few sites that are regularly experiencing flow breakdown. More detailed analysis of this smaller sample set would allow site specific measures to improve flow throughput to be investigated and implemented, in a similar way to the specific investigation into performance of the HSR sections undertaken by the smart motorway operations team. This would have the benefit of improving throughput at these most “stressed” sites. Comparing the UK with international operators brought to the fore a number of observations highlighting the differences in design features that may improve throughput. Examples include, coordinated ramp metering, which is widely used in Australia and helps

smooth traffic flow across a wide area, covering multiple consecutive junctions by controlling access. Other observations include reduced roadside driver distractions and the uniformity of design. For example; types of technical equipment and infrastructure safety features such as barrier and removal of outdated equipment to reduce driver distractions, subsequently leading to improvement of the drivers understanding of the road environment, improved driver behaviour and better throughput

### **Recommendation 3:**

*Consider collation of more detailed data on people and goods throughput.*

Our previous research examined the potential to measure the throughput of people and goods, concluding that significant changes to the current methods of data collection and processing were required. Highways England is already considering the position on whether to invest in more detailed measures.

Finally, as mentioned within the section on goods throughput, there is an opportunity to measure throughput of goods more robustly than is presently possible. Highways England could consider use or development of a 'specialised goods vehicle count' application/model similar to that being developed by AECOM's freight team, which can access a snapshot of HGV movements on any specific day. Having access to this level of detail would support the aspiration of the 'Concept of Operations' which has a desire to develop a capability to influence such measures as the throughput of goods.

## 7 Appendices

### Appendix A – Datasets

Dataset Name	What is it?	Reason for Use
Road Operator Traffic Flow and Speed statistics (all countries)	Categorised flow data and average speeds aggregated to 15 minute time periods for a minimum of 1 month across 2015. This dataset was distributed across multiple locations. The day type used for the analysis was a typical Monday	The definition of throughput was based on flow data, a 15 minute time period was believed to be a good balance, keeping data sizes reasonable while giving the potential to show trends. Monday was chosen as being one of the busiest days of the week as it was assumed to incur flow breakdown more frequently hence maximum throughput was measured
Vehicle Passenger Occupancy Rates – National Travel Survey (DfT)	Average annualised percentage of people travelling in vehicles for each country (note this is not broken down by vehicle type although some countries distinguish different times of day)	To be multiplied against the traffic flow and speed datasets for each country to provide a summary view of maximum passenger throughput
Continuing Survey of Road Goods Transport (CSRGT) freight managers surveys	Continuous surveys that transport managers are mandated to complete and forward to the DfT. It includes information on the type and weight of goods from freight operators elected to be in the sample	To support analysis of findings with respect to freight throughput

National Transport User Satisfaction Survey	Annualised summary of freight goods types and tonnage in the UK	To support analysis of findings with respect to freight throughput
Eurostat European Statistics ( <a href="http://ec.europa.eu/eurostat">http://ec.europa.eu/eurostat</a> )	Annualised summary of types and tonnage of Goods across EU countries	To support analysis of findings with respect to freight throughput

## Appendix B – England Throughput in Terms of Flow (VPH) by Road Type

Road Category ID	Road Category Description	Number of Lanes	Smart Motorways	Lower Flow Throughput (VPH) when breakdown occurs	Lower Flow per Lane (VPH)	Lower Flow Threshold Location	Upper Flow Throughput (VPH) when breakdown occurs	Upper Flow per Lane (VPH)	Upper Flow Threshold Location	Average Flow Throughput (VPH) when breakdown occurs	Average Flow per Lane (VPH)	Flow Throughput Variability compared to max value (%)	Average Daily HGV Percentage (%)	2008 Passenger Occupancy Figures (Avg annualised figure)	Passenger Throughput per lane per hour	Passenger Throughput per road per hour
3	Four Lane Motorway	4	No	5020	1255	M1 southbound between J21A and J21	6460	1615	M1 northbound between J21 and J21A	6018	1505	22.29	0.14	1.62	2437	9749
4	Hard Shoulder Running	4	Yes	5080	1270	M1 southbound between J11 and J10	5520	1380	M62 eastbound between J26 and J27	5340	1335	7.97	0.20	1.62	2163	8651
5	Three Lane Motorway	3	No	4440	1480	M3 westbound between J10 and J11	5400	1800	M1 southbound between J35 and J34	4823	1608	17.78	0.15	1.62	2604	7813
6	Two Lane Motorway	2	No	2480	1240	M56 eastbound between J3 and J2	3360	1680	M32 northbound between J2 and J1	3309	1655	26.19	0.13	1.62	2680	5361
7	Four Lane A-road	4	No	5670	1418	A2 westbound between A227 and B262	5840	1460	A2 eastbound between M25/A282 and B255	5690	1423	2.91	0.13	1.62	2304	9218
8	Three Lane A-road	3	No	4510	1503	A27 westbound between A2030 and M27/M275	4920	1640	A2 eastbound between A223 and A2018	4700	1567	8.33	0.09	1.62	2538	7614
9	Two Lane A-road	2	No	2760	1380	A1 southbound between A1(M) J40 and B6474	3300	1650	A500 southbound between A527 (south) and A53	2981	1491	16.36	0.13	1.62	2415	4829
10	One Lane A-road	1	No	1140	1140	A47 westbound between A1074 and B1110	2120	2120	A47 westbound between A1064 and A1042	1648	1648	46.23	0.11	1.62	2670	2670

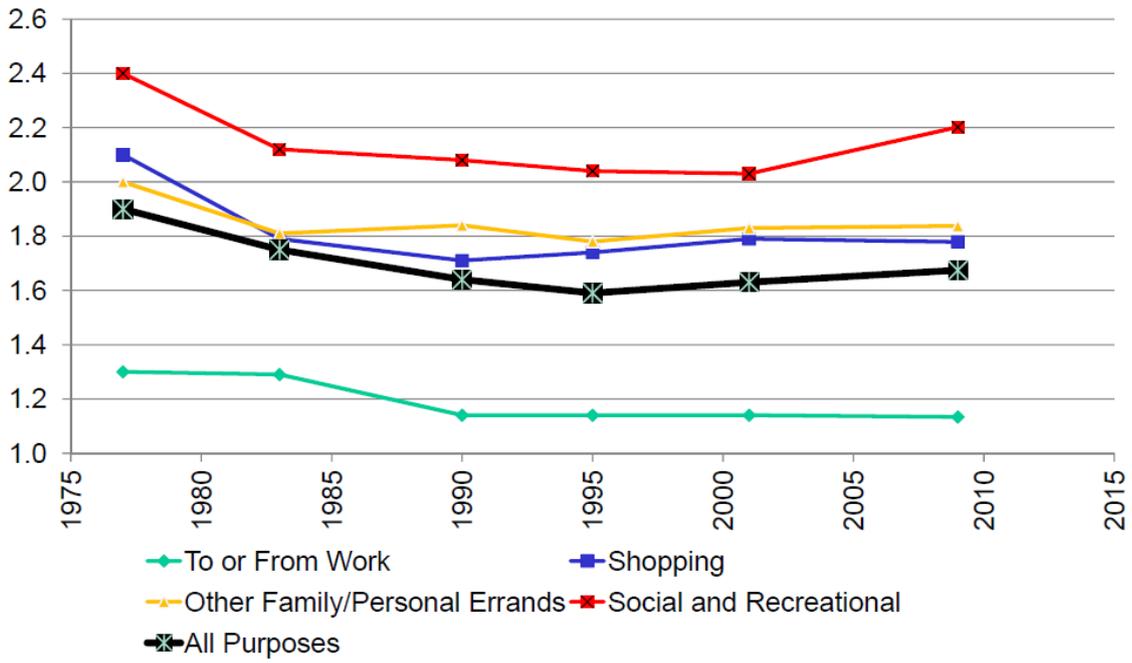
## Appendix C - England Throughput in Terms of Number of People and Number of Good Vehicles by Road Type

Road Category ID	Road Category Description	Hourly people throughput based on max sustainable flow rate			Hourly goods vehicle throughput based on max sustainable flow rate					General Comment
		Baseline maximum sustainable hourly flow throughput (all vehicle types)	Average 2008 passenger occupancy figures (people per trip)	Baseline hourly passenger throughput (people)	Average week day cat3 & 4 vehicle types compared to all vehicles (%)	Baseline hourly cat3 & 4 flow throughput (number of goods vehicles)	Empty Haulage i.e. available space (%)	Full Haulage i.e. space used (number of vehicles)	Total Weight in Tonnes (based on Avg 35 tonne per vehicle)	
1	Five Lane Motorway	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Dataset too limited for 5 lane roads
2	Four Lane Motorway with Smart Motorways	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Dataset too limited for 5 lane roads
3	Four Lane Motorway	6018	1.62	9749	14	843	33	564	19757	Small Sample Size for 4 lane motorways skews figures, hence they appear to have low throughput compared to 3 lane motorway
4	Three Lane Motorway with Smart Motorways	5340	1.62	8651	20	1068	33	716	25045	
5	Three Lane Motorway	4823	1.62	7813	15	723	33	485	16965	
6	Two Lane Motorway	3309	1.62	5361	13	430	33	288	10087	
7	Four Lane A-road	5690	1.62	9218	13	740	33	496	17346	
8	Three Lane A-road	4700	1.62	7614	9	423	33	283	9919	
9	Two Lane A-road	2981	1.62	4829	13	388	33	260	9088	
10	One Lane A-road	1648	1.62	2670	11	181	33	121	4251	Flow breakdown not quite reached in dataset - hence additional small increase in throughput likely to be possible

## Appendix D – England Throughput in Terms of Number of Vehicles by Goods Type and Road Type

				Hourly number of loaded goods vehicles by road type based on maximum sustainable flow																	
Category ID	NST07 Categories Description	Tonnes (2014) in 000's	Tonnes % of Total	Four Lane Motorway		Three Lane Motorway with SM		Three Lane Motorway		Two Lane Motorway		Four Lane A-road		Three Lane A-road		Two Lane A-road		One Lane A-road		Average across All Road Types	
				No. of vehicles	Weight in Tonnes (based on 35 Tonne Avg load)	No. of vehicles	Weight in Tonnes (based on 35 Tonne Avg)	No. of vehicles	Weight in Tonnes (based on 35 Tonne Avg)	No. of vehicles	Weight in Tonnes (based on 35 Tonne Avg)	No. of vehicles	Weight in Tonnes (based on 35 Tonne Avg)	No. of vehicles	Weight in Tonnes (based on 35 Tonne Avg)	No. of vehicles	Weight in Tonnes (based on 35 Tonne Avg)	No. of vehicles	Weight in Tonnes (based on 35 Tonne Avg)	No. of vehicles	Weight in Tonnes (based on 35 Tonne Avg)
				564	19757	716	25045	485	16965	288	10087	496	17346	283	9919	260	9088	121	4251	402	14057
Agriculture	Products of agriculture, hunting, and forestry; fish and other fishing products	120384	7.99%	45	1578	57	2000	39	1355	23	806	40	1385	23	792	21	726	10	340	32	1123
Fossil Fuels	Coal and lignite; crude petroleum and natural gas	13594	0.90%	5	178	6	226	4	153	3	91	4	156	3	89	2	82	1	38	4	127
Mining	Metal ores and other mining and quarrying products; peat; uranium and thorium	236120	15.67%	88	3095	112	3923	76	2658	45	1580	78	2717	44	1554	41	1424	19	666	63	2202
Food	Food products, beverages and tobacco	263300	17.47%	99	3451	125	4375	85	2964	50	1762	87	3030	50	1733	45	1587	21	743	70	2456
Textiles	Textiles and textile products; leather and leather products	13613	0.90%	5	178	6	226	4	153	3	91	4	157	3	90	2	82	1	38	4	127
Wood	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and...	50172	3.33%	19	658	24	834	16	565	10	336	16	577	9	330	9	302	4	142	13	468
Petroleum	Coke and refined petroleum products	61884	4.11%	23	811	29	1028	20	697	12	414	20	712	12	407	11	373	5	175	16	577
Chemicals	Chemicals, chemical products, and man-made fibers; rubber and plastic products; nuclear fuel	50468	3.35%	19	662	24	839	16	568	10	338	17	581	9	332	9	304	4	142	13	471
Minerals (not metals)	Other non metallic mineral products	142707	9.47%	53	1871	68	2371	46	1606	27	955	47	1642	27	939	25	860	11	402	38	1331
Metals	Basic metals; fabricated metal products, except machinery and equipment	35330	2.34%	13	463	17	587	11	398	7	236	12	407	7	233	6	213	3	100	9	329
Machinery	Machinery and equipment n.e.c.; office machinery and computers; electrical machinery and apparatus n.e.c.; radio, television and communication equipment	20089	1.33%	8	263	10	334	6	226	4	134	7	231	4	132	3	121	2	57	5	187
Transport equipment	Transport equipment	28176	1.87%	11	369	13	468	9	317	5	189	9	324	5	185	5	170	2	79	8	263
Furniture	Furniture; other manufactured goods n.e.c.	17585	1.17%	7	231	8	292	6	198	3	118	6	202	3	116	3	106	1	50	5	164
Waste	Secondary raw materials; municipal wastes and other wastes	187528	12.44%	70	2458	89	3116	60	2111	36	1255	62	2158	35	1234	32	1131	15	529	50	1749
Mail	Mail, parcels	26882	1.78%	10	352	13	447	9	303	5	180	9	309	5	177	5	162	2	76	7	251
Equipment	Equipment and material utilized in the transport of goods	30662	2.03%	11	402	15	509	10	345	6	205	10	353	6	202	5	185	2	86	8	286
Removals	Goods moved in the course of household and office removals; baggage and articles accompanying travellers; motor vehicles being moved for repair; ot...	36702	2.44%	14	481	17	610	12	413	7	246	12	422	7	242	6	221	3	104	10	342
Grouped Goods	Grouped goods: a mixture of types of goods which are transported together	133879	8.88%	50	1755	64	2225	43	1507	26	896	44	1541	25	881	23	807	11	378	36	1249
Unidentifiable Goods assigned to groups 01-16.	Unidentifiable goods: goods which for any reason cannot be identified and therefore cannot be assigned to groups 01-16.	28524	1.89%	11	374	14	474	9	321	5	191	9	328	5	188	5	172	2	80	8	266
Other Goods N.E.	Other goods n.e.c.	9665	0.64%	4	127	5	161	3	109	2	65	3	111	2	64	2	58	1	27	3	90
	<b>Combined</b>	<b>1507266</b>	<b>100.00%</b>	<b>564</b>	<b>19757</b>	<b>716</b>	<b>25045</b>	<b>485</b>	<b>16965</b>	<b>288</b>	<b>10087</b>	<b>496</b>	<b>17346</b>	<b>283</b>	<b>9919</b>	<b>260</b>	<b>9088</b>	<b>121</b>	<b>4251</b>	<b>402</b>	<b>14057</b>





## Appendix F – Results of International Comparison of Throughput

	Road Category ID	1	2	3	4	5	6	7	8
	Road Category Description	Four Lane Motorway	Three Lane Motorway with SM	Three Lane Motorway	Two Lane Motorway	Four Lane A-road	Three Lane A-road	Two Lane A-road	One Lane A-road
	Number of Lanes	4	3	3	2	4	3	2	1
	Smart Motorways	No	Yes	No	No	No	No	No	No
Flow Throughput (VPH) when breakdown occurs	England	6018	5340	4823	3309	5690	4700	2981	1648
	Netherlands	6040	0	4639	2672	0	0	0	0
	Australia	0	0	4863	2933	0	0	0	0
Latest Passenger Occupancy Figures (Avg annualised figure)	England (2008)	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62
	Netherlands (2007)	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32
	Australia (2009)	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23
	US (2012)	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55
Passenger Throughput Total	England	9749	8651	7813	5361	9218	7614	4829	2670
	Netherlands	7973	0	6123	3527	0	0	0	0
	Australia	0	0	5981	3608	0	0	0	0
Comment					Flow breakdown not quite shown in averaged Dutch and Australian dataset for this road category most likely due to 15min time period data smoothing - hence additional small increase in throughput likely to be possible				Flow breakdown not quite shown in averaged England dataset for this road category most likely due to 15min time period data smoothing - hence additional small increase in throughput likely to be possible

## Appendix G – International Operators and Data Considerations

Country	Road Operator	Contact Details	Data on People	Notes	Data on Goods	Notes	Result
England	Highways England (Traffic England Service)	<a href="mailto:info@highwaysengland.co.uk">info@highwaysengland.co.uk</a> <a href="tel:03001235000">0300 123 5000</a>	Traffic flows, speed, travel times, vehicle kilometres	This is done using sensors on the road and in vehicles	Goods lifted, goods moved and vehicle distance	These are derived from the Continuing Survey of Road Goods Transport Great Britain, which provides information on HGVs registered in Great Britain only	Flow, People & Goods
USA(California)	US Department of Transport (Bureau of Transportation Statistics) Maintained on state by state basis	Online contact form 202-366-4000	Traffic flow data by commodity type. Measured vehicle miles traveled by state	They have 4,000 continuous traffic counting locations nationwide. Can get access to data on vehicle miles and traffic flow through TMS through division offices.	Measure value of commodities moved, imports and exports	This is done through a survey (eg 2012 commodity flow survey) rather than measuring weighted volume of moving vehicles for example. This survey is done every 5 years as part of the Economic Census	People & Goods insufficient data provided
France	Autoroutes.fr- toll roads. Ministry of Transport	Online contact form for autoroutes.fr	Vehicle kilometres travelled (traffic volume), real time measurements of traffic flow, average speed, occupation rate on motorways. Paris: real time traffic information	Fuel main source of data collection method for calculating vehicle kilometres. This is supplemented by driver survey and road counts. Real time measurements only covers Strasbourg. The traffic data are collected every minute from 42 traffic recording stations by means of loop sensors placed every kilometre on the road. 50 video cameras have been installed on the road network in order to improve/ complete these measurements. These data are then released on the interactive map provided by the 'Direction Departementale du Bas Rhin' through their website. Paris: provided by Sytadin: interactive map shows current speed and travel time on the major roads around Paris. Data is calculated from inductive loops through the SIRIUS network	Weigh in Motion systems	30 systems installed on motorways and highways balanced by region. Most >200 trucks a day. Accuracy >/ C(15). (Data not from autoroutes.fr website. From an alternative source <a href="http://www.google.co.uk/url?sa=t&amp;rtct=j&amp;q=&amp;esrc=s&amp;frm=1&amp;source=web&amp;cd=2&amp;ved=0ahUKEWiE1PvhhNvJAhUBmBQKHd2ZCq0QFggoMAE&amp;url=http%3A%2F%2Fwww.euro-controle-route.eu%2Fsite%2Ffiles%2Fteksfotos%2FHans-van-Loo_Bernard-Jacob.ppt&amp;usg=AFQjCNGbO2V9MfNTf9zNMiGu6bSaxL9hXg&amp;sig2=og4gBMRFKAOqfWa-Pg08GQ">http://www.google.co.uk/url?sa=t&amp;rtct=j&amp;q=&amp;esrc=s&amp;frm=1&amp;source=web&amp;cd=2&amp;ved=0ahUKEWiE1PvhhNvJAhUBmBQKHd2ZCq0QFggoMAE&amp;url=http%3A%2F%2Fwww.euro-controle-route.eu%2Fsite%2Ffiles%2Fteksfotos%2FHans-van-Loo_Bernard-Jacob.ppt&amp;usg=AFQjCNGbO2V9MfNTf9zNMiGu6bSaxL9hXg&amp;sig2=og4gBMRFKAOqfWa-Pg08GQ</a> . Not used for this purpose at the moment- little else	No data received
Canada	Transport Canada	Motor vehicle safety: 1-800-333-0371 mvs-sa@tc.gc.ca General: 613-990-2309	Traffic count data by vehicle type, Vehicle speeds, traffic volume data, vehicle occupancy, vehicle speeds	Speed data obtained from a satellite vehicle tracking technology. Traffic volume data was provided in the annual average daily traffic (AADT) and some data given in Axle Count format, no data on how speeds and vehicle occupancy data is collected	Weigh in Motion systems, volume of heavy vehicles (goods vehicles)		No data received
Germany	The BAST (German Federal Highway Research Institute)	<a href="mailto:post@bast.de">post@bast.de</a> <a href="tel:00492204430">0049 2204 43-0</a>	Traffic volumes by vehicle type, motor vehicle population, vehicle classification, number of vehicles and speed tests on A4. Traffic Information System: current traffic situation and traffic forecasts including real time data on traffic speeds and traffic flow	Split by automatic, continuous counting stations and manual counts. There are 1345 counting stations (621 on motorways, 724 on main roads). Tests are with inductive loops on the A4 and video systems. For vehicle kilometres use mixture of driver survey, road counts and fuel. Traffic Information System one of most relevant and reliable source of road traffic forecasts in Europe		No data online at the moment	No data received
The Netherlands	Institute for road safety research (statistics Netherlands)	<a href="mailto:info@swov.nl">info@swov.nl</a> <a href="tel:+31703173333">+31-70-3173 333</a> <a href="mailto:cvb@cbs.nl">cvb@cbs.nl</a>	Vehicle kilometres travelled (traffic volume), road traffic flows, traffic congestion and traffic speeds	Mainly use odometer data to collect vehicle kilometers data. Passenger traffic statistics made available containing data on traffic volume (VKT) and much more. Density figures are given by Statistics Netherlands	Weight of goods transported on roads	Cannot find detail on how this is measured on statistics netherlands website	Flow, People, no goods

<b>Spain</b>	DGT (Dirección General de Trafico)	(+34 902 887 060 Contact form online	Real time traffic data since 2007 integrated into Google maps, hourly traffic flow, average speed, occupancy rate, traffic intensity	Facilitated by 4000 traffic sensors located over the Spanish road network- still in early stages of development. Hourly rates only on sensors located on some motorway links (A6, M40, M11)- still in early stages of development. Historic data are also available for different time periods. Said to be 'one of the best traffic information tools that are currently freely accessible on line in Europe'	Hourly percentage of light duty vehicles	Sensors only located on some motorway links- still in early stages of development	<b>No data received</b>
<b>Denmark</b>	The Danish Road Directorate (Statistics Denmark)	<a href="mailto:vd@vd.dk">vd@vd.dk</a> <a href="tel:+4572443333">+45 7244 3333</a> <a href="mailto:dst@dst.dk">dst@dst.dk</a> <a href="tel:+4539173917">+45 39 17 39 17</a>	Road traffic of Danish vehicles on Danish roads by vehicle type, and average daily traffic. Real time traffic data (GPS based), speed	First country to use real time traffic data across entire road network. More details on statistics etc on the Danish Road Directorate in Danish. English website is much more limited. Data on vehicles is based on traffic counts (doesn't cover whole road network) but use odometer readings and driver survey data		Could be some on the Danish Road Directorate Danish website. English website is much more limited	<b>No data received</b>
<b>Sweden</b>	Statistics Sweden	<a href="tel:+46850694801">(+ 46850694801</a>	Vehicle kilometres travelled (traffic volume), car occupants	Mainly use road counts to collect vehicle kilometers data but also use odometer data as a supplementary source. Car occupancy data through a survey		No data on the statistics sweden website at the moment	<b>No data received</b>
<b>Australia</b>	Government of South Australia: department of planning, transport and infrastructure (S Australia more dominant) Australian Bureau of Statistics	<a href="#">online forms</a> <a href="tel:+61292684909">+61 2 9268 4909</a>	Traffic volumes, lane occupancy rates, car occupancy rates	These figures are estimated. Measures are annual average daily traffic estimates and commercial (heavy) vehicle estimates	Commercial (heavy) vehicle estimates	Only estimates. No detail on how this is measured	<b>Flow, People, no goods</b>
<b>New Zealand</b>	New Zealand Transport Agency	(+64 6 953 6200	Journey times, queue wait times, real time traffic information, traffic count, monthly average daily traffic, vehicle occupancy done through a survey	BlipTrack system: detects vehicles carrying some form of Bluetooth enabled device. Network of sensors collect this data. Not fully rolled out yet. Traffic count data report done on a monthly basis	Percentage of light/ heavy vehicles	Could be used to measure data on goods but not clear whether that is its current use. Use a vehicle weigh in motion system and dual inductive loops to classify vehicles by length (collected continuously)	<b>No data received</b>
<b>Portugal</b>	Estradas de Portugal	<a href="mailto:duvidas.portagens@estradas.pt">duvidas.portagens@estradas.pt</a> <a href="tel:707500501">707 500 501</a>	Real time traffic data- traffic flow classified by vehicle category, average speed, vehicle weight	All the data are collected by more than 300 automatic count recorders installed on major Portugese roads. The results are also available in Excel format	Vehicle weight measured	Could be used to measure data on goods but not clear whether that is its current use. Data on website in Portugese so could be more detail	<b>No data received</b>
<b>Belgium</b>	Belgian Federal Government and Statistics Belgium	<a href="mailto:info.stat@economie.fgov.be">info.stat@economie.fgov.be</a> <a href="tel:080012033">0800 120 33</a>	START/SITTER System to collect real time traffic data such as flow of vehicles, average speed, occupancy rate	Covers whole of Belgian highway network and data imported each minute. Historical traffic data can also be downloaded from 1999. Note that you need to be registered before accessing the database and is mainly used by the staff of the federal police and by public radio stations		No data on the statistics belgium website at the moment	<b>No data received</b>
<b>Ireland</b>	Road Safety Authority and Transport Infrastructure Ireland	Research department: 096 25000/ 1890 40 60 40 <a href="mailto:researchdept@rsa.ie">researchdept@rsa.ie</a>	T11 Traffic Data Site giving data on traffic counts and traffic volume, speed	T11 Traffic Site allows you to access daily/ weekly/ monthly reports, speed done on a survey basis: 'free speed survey'		Ireland are heavily involved in WIM projects in Europe (funding etc) but no evidence of roll out of technology yet	<b>No data received</b>