The future economic and environmental costs of gridlock in 2030

An assessment of the direct and indirect economic and environmental costs of idling in road traffic congestion to households in the UK, France, Germany and the USA

Report for INRIX, July 2014

Cebr

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London, August 2014

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Executive Summary

This report summarises the findings of a study of the future economic and environmental costs associated with road congestion in the UK, France, Germany and the USA, as well as in the most congested cities in these countries. The study focuses on the economic cost to households of congestion and assumes that households are affected by direct and indirect costs.

Methodological overview

Centre for Economics and Business Research (Cebr) was commissioned by INRIX in 2013 to evaluate the direct and indirect economic and environmental costs to British, French and German households as a result of congestion on their roads. This report provides a refresh of the original study, as well as an extension to the USA. Current costs are updated and forecasts are based on up-to-date data on the key economic drivers of congestion. Forecasts are undertaken out to 2030. We also evaluate costs for a selection of cities that are likely to bear a relatively high share of their respective national cost burdens. The cities covered in-depth in this study are London, Paris, Stuttgart and Los Angeles

The report analyses the costs imposed by gridlock on our roads for the years, 2013, 2020, 2025 and 2030, utilizing the INRIX Index which measurers delays caused by congestion. Direct costs are assumed to equal the value of the time and fuel wasted while sitting in congested traffic during peak periods. The indirect cost to households stems from the increased cost of doing business in congested conditions. For example, it is more costly to transport goods in and out of congested cities and more time-consuming to attend business meetings by road transport whilst the roads are congested. Such cost increases can be expected to be passed onto households through higher prices for final goods and services.

This study also examines the carbon footprint caused by stationary traffic or 'vehicle idling' resulting from gridlock across our advanced economies. The fuel that is consumed while stationary in traffic results in higher emission of greenhouse gases and pollutants, which leads to poorer air quality, particularly in urban areas.

A key input in our study was provided by TTI's 2012 Urban Mobility Report. This included, for the first time, the concept of 'planning time', that is, a measure of the amount of additional time that people need to allow to reach their destination on time. This essentially captures the unreliability of travelling in congested conditions – people know they will experience traffic jams with the need to plan arising because it is not possible to depend on how bad the traffic jams will be. The inclusion of this "extra" extra time that can end up wasted due to congestion is a new element in the analysis that did not feature in our previous report.

The findings of our study reveal that all three forms of costs, direct, indirect and environmental costs, are substantial and expected to increase over the time frame considered.

Key findings

The study reveals that road users spend, on average, 36 hours in gridlock every year in metropolitan areas across the four advanced economies analysed. This figure increases by threefold (111 hours) when account is taken of the additional planning time. This has significant implications for the economies of these nations, in particular the US where these urban areas generate 50% of US GDP, but only encompass 1.5% of the total landmass of the country.

Coupled with the return of growth to the western economies and the continual rise in urban populations, these findings have driven our expectation of significant increases in the demand for road travel, further increasing congestion and its associated costs due to increased delays and planning time requirements. The annual hours wasted across the advanced economies is, on average, predicted to increase by 6% between 2013 and 2030, therefore accounting for an additional 6.8 hours wasted in gridlock every year.

The key drivers of demand for road transport are identified to be population growth and higher living standards through higher GDP per capita, resulting in increases in the absolute numbers of vehicles on the road, even with car ownership rates expected to drop.

Our findings suggest that total economy-wide costs across all four advanced economies are forecast to rise from $200.7billion in 2013 to $293.1 billion by 2030 – a 46% increase in the costs imposed by congestion. The total cumulative costs over the 17 years, across all four countries, amounts to $4.4 trillion. This is likely attributable to a combination of an average increase of 19% in total passenger vehicle miles travelled and a 14% increase in freight miles travelled between 2013 and 2030, driving the aforementioned 6% increase in annual hours wasted due to congestion. Table E1 presents our estimates of the direct and indirect costs to households at the aggregate economy-wide level in 2013, 2020, 2025 and 2030, whilst E2 presents the cumulative costs between 2013 and 2030 (in which the sum of the totals across the four countries amounts to the $4.4 trillion).

Table E1: Country level economy-wide direct and indirect costs, millions of Dollars

Country	Sector	2013	2020	2025	2030	2013-30 % change
UK	Direct costs (value of fuel & time wasted)	12,649	15,865	18,264	20,937	66
	Indirect costs (increased cost of doing business)	7,883	9,565	10,928	12,473	58
	Total	**20,532**	**25,430**	**29,191**	**33,410**	**63**
France	Direct costs (value of fuel & time wasted)	12,881	14,780	15,984	17,158	33
	Indirect costs (increased cost of doing business)	9,630	10,668	11,517	12,430	29
	Total	**22,510**	**25,448**	**27,501**	**29,589**	**31**
Germany	Direct costs (value of fuel & time wasted)	21,684	24,224	25,929	27,702	28
	Indirect costs (increased cost of doing business)	11,796	13,116	14,517	16,137	37
	Total	**33,480**	**37,341**	**40,446**	**43,838**	**31**
USA	Direct costs (value of fuel & time wasted)	78,519	97,099	109,550	120,695	54
	Indirect costs (increased cost of doing business)	45,639	54,157	60,151	65,526	44
	Total	**124,158**	**151,257**	**169,701**	**186,221**	**50**

Source: Cebr analysis

Table E2: Country level economy-wide direct and indirect cumulative costs, millions of Dollars

Country	Sector	2013-2030 cumulative costs
UK	Direct costs (value of fuel & time wasted)	299,215
	Indirect costs (increased cost of doing business)	180,641
	Total	**479,859**
France	Direct costs (value of fuel & time wasted)	271,377
	Indirect costs (increased cost of doing business)	197,291
	Total	**468,671**
Germany	Direct costs (value of fuel & time wasted)	444,578
	Indirect costs (increased cost of doing business)	246,673
	Total	**691,261**
USA	Direct costs (value of fuel & time wasted)	1,803,225
	Indirect costs (increased cost of doing business)	1,003,564
	Total	**2,806,826**

Source: Cebr analysis

The aggregate costs across the four cities featured in this report on a city economy-wide basis are estimated to increase from $46.6bn in 2013 to $75.9bn by 2030 – a 63% increase in the cost imposed on households in these cities as a consequence of congestion. Table E3 presents these findings, whilst Table E4 presents the cumulative costs incurred by the four cities over the 17-year forecasting horizon. Households across all the four cities are estimated to incur cumulative costs amounting to $1.1 trillion over the period 2013 to 2030.

Table E3: City-level: economy-wide direct and indirect costs to households, millions of Dollars

City	Sector	2013	2020	2025	2030	2013-30 % change
London	Direct costs (value of fuel & time wasted)	4,310	5,602	6,669	7,741	80
	Indirect costs (increased cost of doing business)	4,203	5,088	5,943	6,779	61
	Total	**8,513**	**10,690**	**12,612**	**14,520**	**71**
Paris	Direct costs (value of fuel & time wasted)	6,282	7,558	8,688	10,008	59
	Indirect costs (increased cost of doing business)	5,410	6,404	7,479	8,693	61
	Total	**11,692**	**13,963**	**16,167**	**18,701**	**60**
Stuttgart	Direct costs (value of fuel & time wasted)	2,054	2,287	2,496	2,694	31
	Indirect costs (increased cost of doing business)	1,116	1,242	1,396	1,549	39
	Total	**3,170**	**3,529**	**3,892**	**4,242**	**34**
LA	Direct costs (value of fuel & time wasted)	13,213	17,305	20,074	22,294	69
	Indirect costs (increased cost of doing business)	9,987	12,610	14,573	16,061	61
	Total	**23,200**	**29,915**	**34,647**	**38,355**	**65**

Source: Cebr analysis

Table E4: City-level: economy-wide direct and indirect cumulative costs to households, millions of Dollars

City	Sector	2013-30 Cumulative costs
London	Direct costs (value of fuel & time wasted)	107,093
	Indirect costs (increased cost of doing business)	97,195
	Total	**204,295**
Paris	Direct costs (value of fuel & time wasted)	143,670
	Indirect costs (increased cost of doing business)	123,307
	Total	**266,977**
Stuttgart	Direct costs (value of fuel & time wasted)	42,075
	Indirect costs (increased cost of doing business)	23,231
	Total	**65,292**
LA	Direct costs (value of fuel & time wasted)	323,044
	Indirect costs (increased cost of doing business)	236,139
	Total	**559,188**

Source: Cebr analysis

Our estimates suggest that vehicle idling releases 15,434 kilotons of CO_2 equivalent into the atmosphere across the UK, France, Germany and the US every year. This is forecast to rise by 16% between 2013 and 2030 to reach 17,959 kilotons of CO_2 emissions.

The monetary valuations of the social costs of these environmental impacts are presented in Table E5 below. By 2030, the monetary valuation of the carbon emissions generated in the US as a result of vehicles idling in congestion is expected to reach $538 million by 2030, representing the largest cost across the countries examined. Similarly, Los Angeles also has the highest CO_2 emissions costs across the cities with $50.2m. This is also reflected in Table E6, which presents the cumulative costs associated with CO_2 emissions between 2013 and 2030. The four advanced economies are estimated to incur a cumulative social cost related to CO_2 emissions of $12.9bn, whilst the four cities are estimated to incur costs amounting to $2.7bn.

Table E5: CO_2 equivalent emissions in monetary terms, millions of Dollars

Country	2013	2030
UK	10.5	286.3
France	13.9	308.4
Germany	21.8	429.9
US	300.2	538.2
City	**2013**	**2030**
London	3.6	111.7
Paris	5.6	128.2
Stuttgart	1.8	36.9
Los Angeles	50.2	95.6

Source: INRIX, Cebr analysis

Table E6: CO_2 equivalent emissions in monetary terms, millions of Dollars

Country	2013 – 2030 cumulative costs
UK	1,461
France	1,606
Germany	2,300
US	7,574
City	**2013 – 2030 cumulative costs**
London	558
Paris	659
Stuttgart	196
Los Angeles	1,323

Source: INRIX, Cebr analysis

Conclusions

Governments across the four advanced economies can take public policy measures that could improve the situation and minimise these costs and their drain on the economy.

The continual improvement and expansion of public transport infrastructure can provide travellers with more options, thus encouraging people to use their car less. But the extent to which public transport can ever be deemed to be substitutable for the car will always be debatable and sensitive to the cost of public transport and the perceived quality of the public transport 'experience'. Given the perceived convenience of the car, public transport can be a hard sell, especially when it can also be costly and subject to delays.

Other pragmatic schemes like car-pooling have emerged and the more widespread introduction of car-pooling lanes should help stem the growth in the numbers of cars on their roads in peak periods. The encouragement of increases in telecommuting, primarily by ensuring the provision of higher speed internet connectivity, can also be expected to help alleviate the situation.

Neither can technology-based demand management solutions be overlooked, especially if one accepts that traffic will continue to grow and congestion to increase, even though car ownership rates are showing signs of decline. Technological innovations like multi-modal routing and real-time traffic management have been made possible by big data analytics and the growth of the Internet of Things, using road capacity more intelligently and, thus, creating 'smarter' cities.

Finally, as in all such cases, the optimal solution is likely to be some blend of or balance between all these measures, depending on the particular circumstances of the urban area under examination.

1 Introduction and background

Centre for Economics and Business Research (Cebr) was commissioned by INRIX in 2013 to evaluate the direct and indirect economic and environmental costs to British, French and German households as a result of congestion on their roads. This report provides a refresh of the original study, as well as an extension to the USA. Current costs are updated and forecasts are based on up-to-date data on the key economic drivers of congestion. Forecasts are undertaken out to 2030. We also evaluate costs for a selection of cities that are likely to bear a relatively high share of their respective national cost burdens. The cities covered in-depth in this study are London, Paris, Stuttgart and Los Angeles.

1.1 Aim of the study

The study aims to establish the cost imposed on households by peak traffic congestion. We consider three sources of **direct cost**:

1. The opportunity cost of the time wasted whilst delayed in congested traffic;
2. The cost of the fuel wasted whilst delayed in congested traffic;
3. The social cost of the negative impact of traffic congestion on the environment.

The largest of the three is undoubtedly the first – the cost of wasted time in delays. Estimating this cost first requires data on the quantities of the time being wasted in congested traffic in the countries and cities of interest. For this purpose, INRIX provided counts of the hours wasted in 173 urban areas, where time wasted measures delay, or the additional time spent commuting over and above the journey time in free flow traffic conditions.

However, in establishing the amount of time wasted due to congestion, we have also incorporated 'planning time', that is, a measure of the amount of additional time that people need to allow to reach their destination on time. This essentially captures the unreliability of travelling in congested conditions – people know they will experience traffic jams with the need to plan arising because it is not possible to depend on how bad the traffic jams will be. This was motivated by the inclusion of this additional planning time by TTI its 2012 Urban Mobility Report for the first time.[1] This is a new element in the analysis that did not feature in our previous report.

The task then is to establish how the different people affected by traffic congestion value their time – in other words, what is the return to the next best use or opportunity cost of a person's time? This varies by purpose of travel and mode of transport but our analysis is restricted in the direct context to commuters travelling by car.

But we also consider **indirect costs** to households. While the sources of indirect costs are the same three as identified above in the direct context, the subjects of the estimates of these indirect costs of congestion are people travelling for business purposes, but also those transporting freight. The costs imposed on these users ultimately increase the cost of doing business, which can, at least to some extent, be expected to be passed through to households in the form of higher prices for consumer goods and services.

[1] Texas A&M Transportation Institute (TTI), INRIX and South West University Transportation Centre, "Urban Mobility Report 2012", December.

We consider what these costs are currently or, more accurately, what they were in the period for which the most recent data are available, 2013 in this case. But another key aim of the study is to estimate how these costs are likely to grow in the future. We provide forecasts for each of the years 2020, 2025 and 2030 in this report.

1.2 Approach and methodology

Quantifying the ***current*** cost to households arising from congestion involved a number of steps, as follows:

- **Step 1** involved using INRIX delay data for each of 18, 33, 22 and 100 metropolitan areas in the UK, France, Germany and the USA, respectively, to estimate the average amounts of time wasted per vehicle per annum whilst delayed by congestion.[2] INRIX analyses and assigns index scores to major motorways and arterial streets in each metropolitan area. The **index score** is designed to represent average delay so that, for instance, a score of 1.20 indicates that the typical commuter trip takes 20% longer in peak congested conditions relative to travel under free-flow (uncongested) traffic conditions. INRIX then converts the index score into 'annual hours wasted' per vehicle based on the typical length of time taken to make a commuting trip during peak periods and the total number of commuting trips taken in a given year.

  Step 2 involved the quantification of the direct cost to households through the impact of congestion on commuters. Wasted time is valued according to officially recognised commuter valuations of time for the UK and US, and by reasonable approximations for France and Germany. Specifically, we used a proportion of hourly wages corresponding to how commuter values of time and hourly wages compare in the UK and US. Wasted fuel is valued at national fuel prices from the European Commission Oil Bulletin and the US Energy Information Administration. Estimates of the amounts of fuel wasted in congested traffic are based TTI's Urban Mobility Report[3] estimate of 1.7969 litres (or 0.4747 US gallons) per hour for the average medium-sized car.

- **Step 3** required extrapolation to the national or city economy-wide level. This was achieved by applying the individual commuter costs developed in step 2 to that share of the total workforce that commutes to work by car.

- **Step 4** involved repeating Steps 1-3 for those travelling by car on business purposes and for those required to transport freight by road. The costs imposed on these users are costs to the businesses that employ them. These increased costs of doing business are assumed to be passed on to households through higher prices for the goods and services purchased by them. Wasted time in this case is based on official valuations of working time by mode produced by the UK Department for Transport for the UK. Distinct values are provided for those travelling by car and those driving goods vehicles. For the other countries, we examined the relationship between GDP per hour and working time values (business users) and between average hourly salaries and working time values (goods transportation users) inherent in the UK data. We then applied these relationships to the corresponding hourly GDP and wage estimates for France and Germany. For the USA, we used the values of time used in TTI's Urban Mobility Report (2012).

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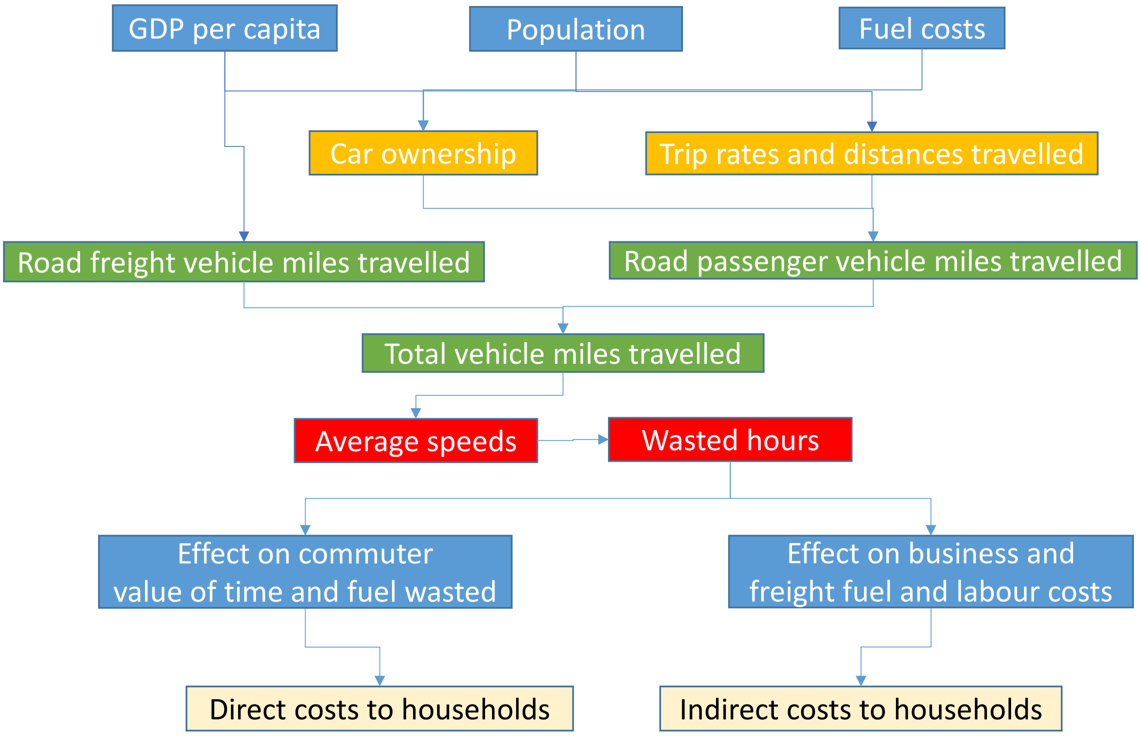
[2] In the United States, metropolitan areas are defined by the US Census Bureau's definition of Core- Based Statistical Areas (CBSAs). A current map of CBSAs by state from the US Census Bureau is available here: http://www.census.gov/population/metro/files/metro_micro_Feb2013.pdf. In Europe, they are defined by Eurostat's definition of Larger Urban Zones (LUZ).

[3]

The approach to quantifying the ***future*** annual costs of time spent idling in congested traffic draws on economic forecasts at the country and city level. These feed into forecasts of car ownership and the demand for road usage. Figure 1 below provides a diagrammatical representation of the relationship between key economic and road transport variables used in the analysis.

The forecasts of the average annual hours wasted in traffic are driven by Cebr's forecasts of the key economic drivers of road traffic, including economic growth and increased prosperity (GDP per capita), population growth and the cost of motoring at the country and city level. These variables drive the forecasts of total vehicle miles travelled on roads by commuters, business and freight transportation users. Baseline road transport variables were projected out to 2030.

Figure 1: Illustration of methodology



Source: Cebr analysis

Higher levels of road traffic during peak hours cause reductions in the average speed of travel. The INRIX **index score** of average delay by metropolitan area provides, as already noted, the percentage increase in delay during peak periods when compared with free flow conditions. But the measure can also be interpreted as the average percentage reduction in speed from free flow levels during congested peak periods. Speed-flow curves are, therefore, used to determine how a percentage increase in traffic in future years results in an overall reduction in speed and an increase in the time wasted in congested traffic.

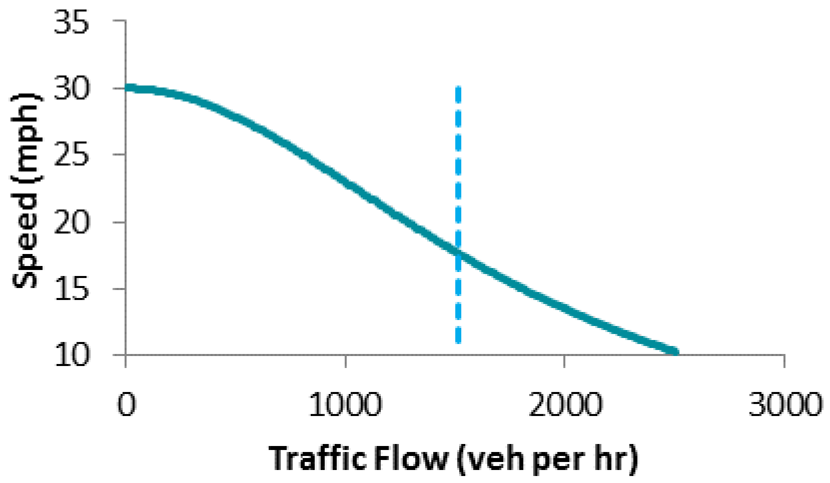
Figure 2 illustrates the relationship between average speed and traffic flow based on a free-flow speed[4] of 30 miles per hour (mph) and an average lane capacity of 1,515 vehicles per hour.[5] This is the typical

[4] The free-flow speed is the average speed of vehicles over an urban street, freeway or multilane highway segment under conditions of low volume (US Highway Capacity Manual, Transport Research Board, 2000).

capacity of urban roads that have speed limits of 30-40 mph, 2-3 lanes of traffic, a road width of 10 metres (32.8 feet) and carrying a mixture of local and through traffic.[6]

From this speed-flow curve, it can be seen that, as traffic flows increase, the reduction in average speed is gradual at first but is steeper as traffic flows approach the capacity of the road (marked at 1,500 vehicles per hour in this stylised illustration). Cebr has calibrated each country and city featured in the study to a speed-flow curve based on the INRIX Index.[7]

Figure 2: Speed-flow curve



Source: Cebr analysis

Using our projections of how traffic levels will grow in the future, we predict how each country and city is likely to shift down their respective speed-flow curves, thus enabling us to read off the changes in the average speed that would result from the increased traffic. To estimate the effect of higher future traffic levels on annual hours wasted, we assumed an inverse linear relationship between the drops in average speed and increased delays. At this point, it was possible to replicate the four step process used in the estimation of current costs for the estimation of future costs in 2020, 2025 and 2030.

1.3 Assumptions underlying the forecasts

Our future estimates of the direct and indirect costs of congestion to households are based on projected levels of traffic on the roads, as measured by total vehicle miles. Road usage (demand) is a function of a range of economic variables. This study considers the importance of GDP per capita, population, fuel costs and car ownership.

The key assumptions underlying the forecasting methodology are:

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[5] Road capacity is defined as the maximum sustainable flow rate at which vehicles reasonable can be expected to traverse a point or uniform segment of a lane or roadway during a specified period of time (US Highway Capacity Manual, Transport Research Board, 2000).

[6] Transport for London Roads Tasks Force – Technical Note 10.

[7] *Appendix A: Speed flow calibration* explains the specification of the speed-flow curve used in this study and the parameter values to which the model is calibrated to.

- Road capacity (supply) remains constant over the forecast period.[8]
- There is no significant shift in modal share from car to other forms of transport, such as rail, bus, cycling or walking over the forecast period.
- Potential developments like car-pooling or car-sharing are ignored.
- The proportion of hybrid vehicles that make up the vehicle fleet is assumed to be held constant.
- Telecommuting/homeworking does not displace a significant proportion of journeys that are currently made to the workplace.[9]
- There are no significant technological innovations that could alleviate congestion.

These assumptions reflect the kinds of changes that would be required to alleviate congestion and, for that reason, our projections capture how congestion and its associated costs are likely to increase if none of these alleviating measures are implemented.

Some of the assumptions relate to people's behaviour or 'habits', whilst others relate to technological developments that either alleviate congestion or reduce some element of the cost associated with congestion (as in the case of hybrid cars). While technological developments that could alleviate congestion likely will or already do exist, it was beyond the scope of this study to account for what their impact might be.

Nevertheless, we accept that technology has a large impact on all aspects of people's lives and that it constantly changes over time. Ongoing developments in ICT continue to improve the viability of 'working from home' for office and knowledge workers, which can reduce the number of people commuting to work and, thus, the number of cars on the roads at peak times. However, this factor cannot be overstated and will depend on the nature of the work involved. For management and client-facing employees, it is a less viable solution.

1.4 Structure of the report

The structure of this report is as follows:

- Section 2 examines the current levels of congestion within the four advanced economies and identifies the drivers of congestion.
- Section 3 forecasts the trends likely to be witnessed by the cost drivers of congestion and predicts their impacts on future levels of congestion.
- Section 4 presents the findings of our analysis on the country and city level economic costs of congestion to individual households and provides an explanation of the estimates.
- Section 5 reports the economy-wide costs of congestion, again at the country and city level.

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[8] See section 2.8 – What determines the level of congestion? This provides data on the length of the road network relative to demand (road vehicle miles) and the number of cars. Data on commuting modal share of car and cycling in selected geographies is also discussed in this section.

[9] Evidence from the US Bureau of Labor Statistics suggests that telecommuting has been 'instrumental in the general expansion of work hours' rather than displacing hours spent in the workplace – 'The hard truth about telecommuting' (Noonan and Glass 2012)

- Section 6 reports our findings and forecasts on the CO_2 emissions and provides estimates of the social costs of the environmental negative impacts on the environment produced whilst vehicles are in gridlock, both at the country and city level.
- Section 7 concludes the report by summarising the key findings and providing a brief outline of potential ways to reduce the impact upon the economy of the costs of congestion.

2 Current levels of congestion and its drivers

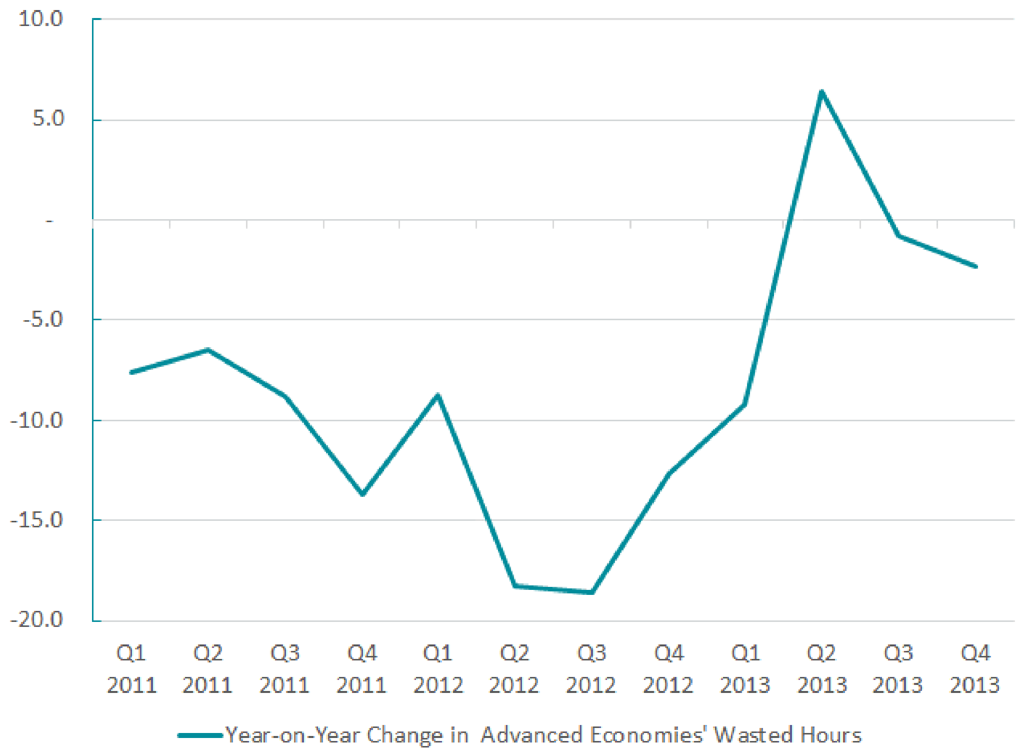
This section examines current levels of congestion in the UK, France, Germany and the US and, in doing so, highlights the cities in those countries that are most congested. Once congestion levels have been established, this section identifies and analyses the demand-side drivers of congestion, whilst simultaneously highlighting supply-side drivers, across the countries and cities. This section concludes by forecasting the movement of the key drivers of congestion up until 2030.

2.1 Indicators of current levels of congestion

Recent years have witnessed levels of congestion on urban roads in advanced economies falling due to historically high fuel prices and weak economic growth when compared to pre-credit crunch levels.

We estimate that, between Q1 2011 and Q4 2013, the amount of wasted time idling in congestion has seen an average annual decline of 8%. This trend is illustrated in Figure 3, in which the annual percentage change in wasted hours is illustrated. This shows Q2 2013 as the only quarter to see an increase in wasted time due to congestion and delays, after which further small declines are observed. The data represented in this illustration are based on weighted averages across the subset of advanced economies considered in our study.

Figure 3: Advanced economies: annual percentage change in advanced economies' wasted hours, 3-mth rolling average (monthly data confirms this illustration)



Source: INRIX, Cebr analysis

Figure 4 below presents the values of the INRIX index for each of the top five cities by population in France, Germany, the UK and the USA.[10] The index values are highest in London and Los Angeles. The gap between these cities and next largest cities in their corresponding countries, is also much greater than in either France or Germany.

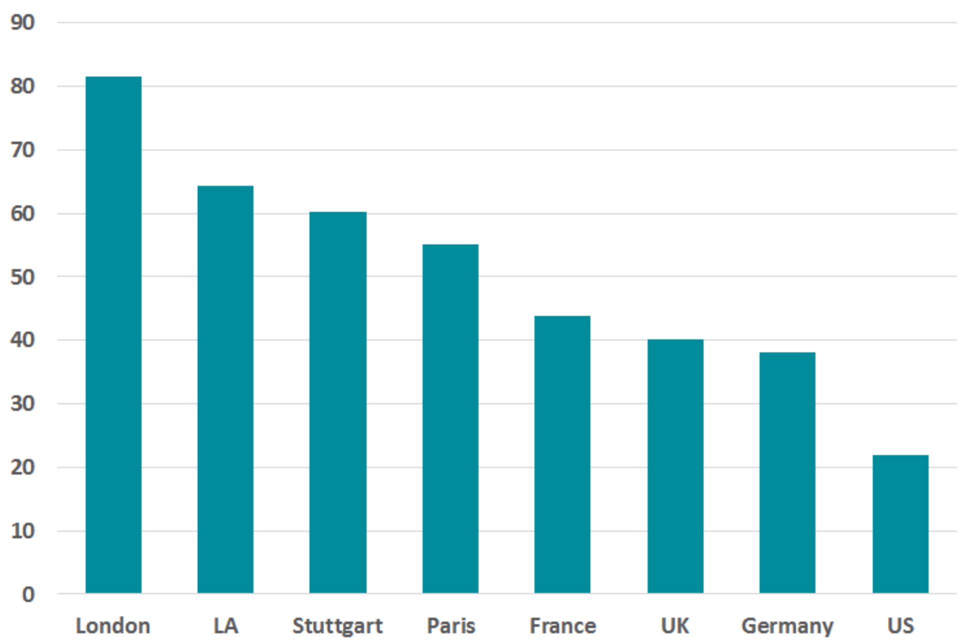
Figure 4: The INRIX index for the top five cities by population in each of France, Germany, the UK and the US, 2013

Source: INRIX

The average absolute levels of delay that correspond with these INRIX index values are presented in Figure 5 below for each of our four countries and the most congested city in each – Paris, Stuttgart, London and Los Angeles. Again, it is road users in the latter two that endure the most wasted time in congested traffic, but even the London average is significantly above the Los Angeles average which, although higher, is much closer to the Stuttgart and Paris averages.

[10] The one exception is Stuttgart, which is not in the top 5 German cities by population but is one of the most congested.

Figure 5: Absolute values of time wasted in congested traffic, number of hours



Source: INRIX, Cebr analysis

In the following sections, we explore the drivers of congestion.

2.2 Historical trends: concentration of economic activity

One of the major drivers of congestion and delay is the concentration of economic activity in and around major cities and towns. For this reason, these urban areas also tend to have the most pressing congestion problems. Figure 6 provides an illustration of the concentration of activities in urban areas of the USA. Half of US GDP is generated from areas that only account for approximately 1.5% of the total land area of the country.[11] Likewise, in the UK, urban areas make up just under 7% of the land area.[12] The top 25 most populated cities alone generate 39% of UK GDP. Figure 7 illustrates where these urban areas lie.

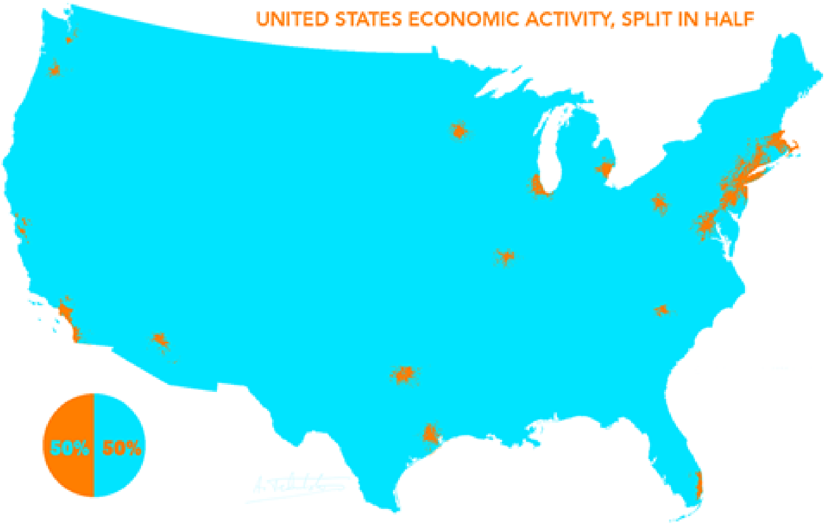
Road congestion is the result of the concentration of economic activities in this manner, imposing negative externalities[13] on commuters, business travellers and freighting companies who travel in and out of these urban areas.

[11] The data underlying the map is sourced from an IHS Global Insight report 'U.S. Metro Economies' prepared for the United States Conference of Mayors and Council on Metro Economies and the New American City. The map has been produced by a Reddit user and is published here: http://www.visualisingdata.com/index.php/2014/02/defending-the-incredible-gdp-map/

[12] UK National Ecosystem Assessment – understanding nature's value of society (2011)

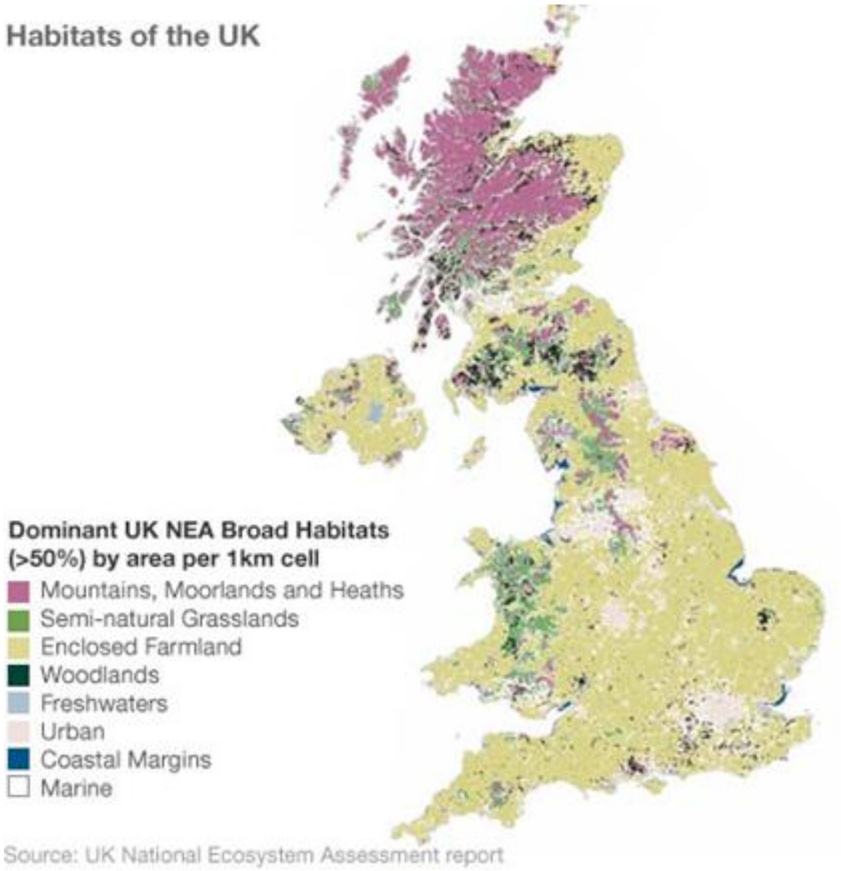
[13] A negative externality is a cost imposed on third-parties to the activities of others. For instance, poor air quality for pedestrians and cyclists due to traffic congestion in urban areas from motor vehicle users.

Figure 6: Concentration of economic activity in urban areas in the USA



Source: Visualisingdata.com

Figure 7: Concentration of economic activity in urban areas in the UK



2.3 Physical determinants of congestion

The level of congestion in any one country or city depends on a range of supply and demand factors. On the supply side, the principal factor is the size and capacity of the road network. Other supply side factors will inevitably include the level of investment in rail networks as better rail services will mean a greater likelihood that people will substitute away from car to rail travel. On the demand side, the principal drivers are the amount of travel that's typically undertaken by the population, the percentage of the workforce that commutes by car and population density.

Table 1 below presents a range of congestion indicators for each of the four countries examined – France, Germany, the UK and the US. Also included is the INRIX index, providing the relative measure of delay between the four markets.

Table 1: Country level: congestion indicators

Congestion Indicators					
	Country	UK	France	Germany	US
A1	Length of road network (thousands of miles)	261	654	400	4077
A2	Vehicle miles travelled (thousands of miles)	809	991	1218	8509
A3	% commuting by car	68%	73%	67%	69%
A4	Rail investment as % GDP	0.38%	0.28%	0.17%	0.16%
A5	Population Density (ppl for sq km)	263	34	231	120
A2/A1	Road intensity	3.1	1.5	3.0	2.1
	INRIX Index	18	19	13	11

Source: World Bank, OECD, INRIX, Cebr analysis

The INRIX index implies that France has the highest level of congestion and the US has the lowest. This is supported by the fact that France has the highest car modal share for commuters of 73%. This includes Paris, which pushes the congestion index upwards because 32% of French car commuters travel in and out of Paris. The UK has the second highest level of road congestion overall, as suggested by the INRIX index value, consistent with a higher road usage intensity (total vehicle miles travelled per mile of road network). The high population density in the UK is also likely to contribute to elevated congestion levels.

At the city level, the INRIX index implies that Los Angeles and London have the highest levels of congestion. This is consistent with, as presented in Table 2 below, Los Angeles having by far the largest car commuting modal share (67%) of all the four cities considered. However, the number of cars per mile of road (217) is modest compared to the other cities, which suggests that there are efficiency improvements to be made in the road network. Los Angeles is home to the second largest number of workers in the US after New York but only 1% of commuters cycle to work.[14]

Paris has a lower relative measure of congestion. This may in part be due to a bicycle-sharing scheme that promotes cycling to work. Specifically, Paris has the largest of these schemes outside China with more than 20,000 bikes and 1,800 stations. A total of 2.4% of Parisians cycle to work.[15] A similar scheme

[14] American Community Survey 2008-2012.

[15] http://www.reuters.com/article/2014/06/02/us-france-bicycles-idUSKBN0ED1O120140602

exists in London but, despite having only half the number of shared bicycles that there are in Paris and only 700 docking stations, 2.7% of commuters' in London cycle to work. This suggests that more people use their own bicycles (as opposed to the shared scheme) than in Paris.

Table 2: City level: congestion indicators

Congestion Indicators					
	City	London	Paris	Stuttgart	Los Angeles
A1	Length of road network (thousands of miles)	9.2	12.7	1.4	20.7
A2	Vehicle miles travelled (thousands of miles)	2549	3931	820	4487
A3	% commuting by car	32%	43%	47%	67%
A5	Population Density (ppl for sq km)	5100	2750	3550	3000
A2/A1	Road intensity	277	310	586	217
	INRIX Index	30	24	21	31

Source: World Bank, OECD, INRIX, Cebr analysis

There are plans to commence a similar shared bicycle scheme in Los Angeles but this has not yet been implemented. In Stuttgart in Germany, the 'call a bike' service has 60 stations and 450 bicycles and an annual subsidy means that the first half hour rental is provided free of charge. Stuttgart also has an extensive public transport network, including trains, trams and buses, so the need to commute to work by car is not as high. This probably explains why Stuttgart has the lowest INRIX index value of the four cities considered.

Furthermore, Los Angeles does not have the same amount of rail infrastructure relative to the other three cities– the length of the metro in LA is only 140.5km with 80 stations over six lines whereas the metro in Paris is 214km with 300 stations over 16 lines. Los Angeles is also much more geographically spread out than Paris, for instance, so it is natural to expect that large swathes of LA are not well connected by alternative modes of transport to the car. Consequently, commuting by car may be the easiest or the only option to get to work in LA. This is consistent with the high modal share of workers that commute by car.

Recent trends in telecommuting suggest that 9.6% of US workers in metropolitan areas worked from home on at least one full day a week in 2010, compared to around 7.0% in 1997. In Los Angeles, a total of 5.0% of workers spend at least one full day working from home. These trends should go some way to alleviate congestion.[16]

2.4 Closer examination of demand-side drivers of road usage

The key contributing demand-side drivers of road usage are:

- **Population** – population growth means more cars on the road if vehicle ownership rates remain constant. More people implies greater economic activity and more leisure and business trips.

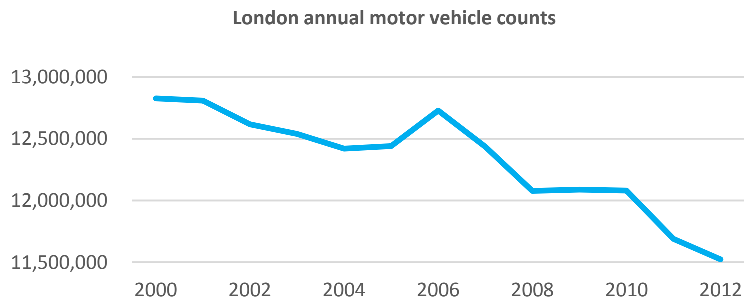
[16] Noteworthy is evidence from the US Bureau of Labor Statistics, which suggests that this activity is not displacing the commute, but rather, adding extra hours to the working week. See US Bureau of Labor Statistics - 'The hard truth about telecommuting' (Noonan and Glass 2012).

Population growth also increases the demand for goods which have to be transported in and out of cities, as well as the number of business meetings to attend.

- **GDP per capita** – growth in GDP per capita means higher standards of living and should result in increases in disposable income to spend on leisure activities. In such circumstances, the likelihood of greater distances being travelled to enjoy this leisure time is higher. During times of economic growth, employment is also likely to be higher, thus driving more commuter and business trips. With more disposable income, households will demand more goods, which increases the demands on freight services. These mechanisms serve to increase the propensity to travel more frequently and across greater distances.
- **Costs of motoring** – higher fuel prices can be expected to result in reduced car usage and lower car ownership rates as the cost of motoring is higher. However, more competition in the car manufacturing industry can result in lower prices for cars, which can counteract the effects of increasing fuel prices. Other important motoring costs include insurance, parking costs and the annual cost of servicing and repairs.
- **Car ownership** – car ownership is itself driven by the three factors above but increases also drive increases in the frequency of car usage. Higher standards of living and the reduced costs of motoring tend to spur greater car ownership. However, in the past decade, the trend between vehicle ownership and economic fundamentals has been broken due to demographic shifts in attitudes towards vehicle ownership and increasing investment in rail transport. This has led to theories of the so-called 'peak car' – stable or even declining rates of car usage and ownership in the West. Box 1 discusses the issue of the 'peak car' and discusses how ownership and usage rates are likely to develop in the future.

Box 1: 'Peak car' theory

'Peak car' theory is a hypothesis that total distances travelled by motor vehicle has peaked and will either remain constant or decline into the future. The theory gained strength after 2008 as declines in road passenger vehicle miles were seen in the US and UK. The same trends were observed in London between 2002 and 2012 where road traffic fell by around 8% over the period.



There are many possible factors which could affect a possible decline in car usage.

i) **Value of time** - as congestion increases and consumers become wealthier, higher valuations of the time wasted on congested roads will reduce the propensity to travel, at least by car.

ii) **Growth in public transport** – the use of urban transit systems may shift consumers towards rail. The change is particularly pronounced in urban areas where there is a premium on space associated with owning a car and where congestion is worse.

iii) **Demographic shifts** –driving license ownership rates testify that younger people are becoming less likely to learn to drive and own a vehicle compared to the previous decade.

iv) **Technological developments –**the rise in e-commerce and telecommuting through advances in ICT can be expected to contribute to less trips being taken.

Cebr's view is that the above factors have certainly played a part in reducing demand for road transport and we do indeed predict the number of vehicles per capita to fall in the US and UK. However, the underlying reason for reduced levels of congestion in recent years is attributable to the economic downturn and elevated fuel prices. This view is shared by the UK Department for Transport which predicts a 55% increase in road traffic in the UK between 2010 and 2040 in its central population and GDP per capita growth scenario. This equates to traffic growth of 32% between 2013 and 2030 which is broadly in line with the forecasts for the UK developed for this study.

Source: Cebr analysis, UK DfT Road traffic statistics, UK DfT Road Transport Forecasts, Cebr analysis

The remainder of this section considers recent and future trends in the first three of the four factors outlined above and how they are likely to affect the traffic forecasts that will drive our estimates of the future cost of congestion to households. Trends in car ownership are reserved for the next section of the report.

Population

According to the UK Department for Transport, the largest driver of road transport demand has been population growth. Figure 8 below illustrates the projected growth in population over the forecast period (2013-2030) for each nation and city under consideration. The US is predicted to have the highest population growth of 13% over the period, increasing from 316.3 million people to 356.7 million people.

London is predicted to be the city with the highest population growth of 20%, increasing from 8.4 million people in 2013 to 10.1 million by 2030. This is likely to place significant demands on the UK capital's road network. Underlying the projections is a 17% increase in the number of people between the ages of 24 and 65. This demographic has a higher tendency to travel by car than those over 65 or under 24. Trends amongst the younger demographics, particularly in the UK and the USA, suggest less people learning to drive and lower rates of car ownership.

Figure 8: Population Growth, 2013-2030

Source: World Bank, Destatis, DoF CA, ONS, Cebr analysis

The population of Germany, in contrast to other markets, is projected to fall by 3% due to an ageing population and a declining birth rate. This will have implications for our forecasts of road transport demand, accentuated by falling levels of car ownership and the fact that older people tend to make fewer trips. Therefore, we would expect to see a reduction in road transport demand in Germany if everything else is held constant.

GDP per capita

GDP per capita growth projections are shown in Figure 9 for the period 2013-2030. Over this period, France, Germany and the USA are forecast to achieve broadly similar growth rates, whilst the UK is expected to lag behind.

Paris and Los Angeles are projected to see the largest increase in GDP per capita, of 42% and 34% respectively. GDP per capita is highest in Paris and Los Angeles – both valued at around $71,000. These findings suggest that road transport demand will be stimulated by higher GDP per capita growth in Paris and Los Angeles, holding everything else constant.

Figure 9: Percentage growth in GDP per capita, 2013-2030

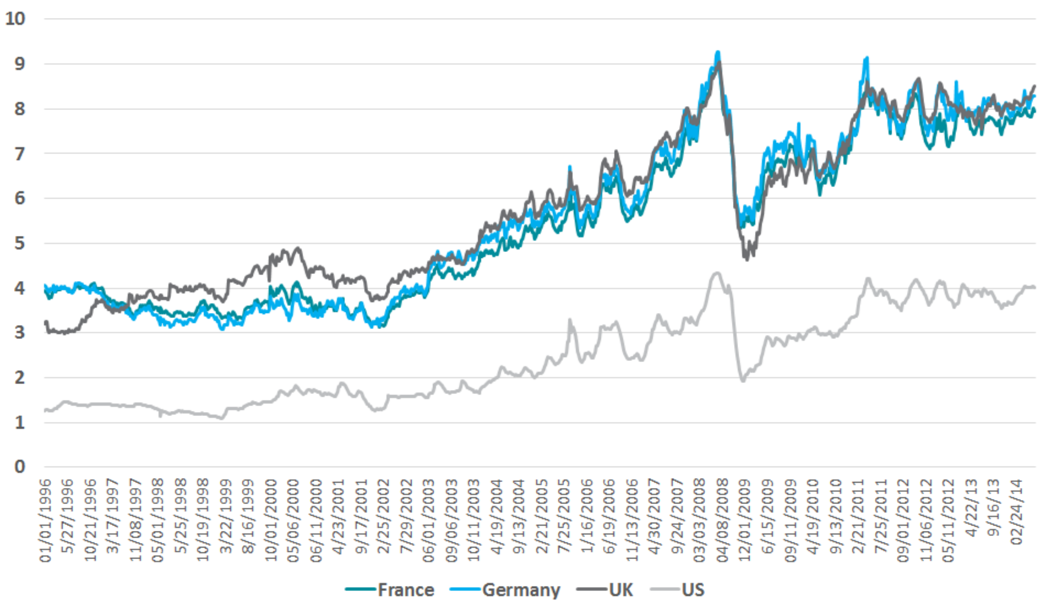
Source: IMF, DoT CA, Insee, ONS, Cebr analysis

The costs of motoring

Given its importance as an element in the total cost of motoring, fuel costs can be expected to influence vehicle ownership and the amount of travel by motor vehicle.

Figure 10 below illustrates the 20-year trend in average fuel prices in each of our four countries, which shows that fuel costs today are substantially more expensive than 10 or 20 years ago. Fuel price growth, such as that experienced over the past five years, which outpaced growth in overall inflation and household incomes, can be expected to have resulted in reduced car usage, traffic and congestion. Of course, the other key conclusion from Figure 10 is how much higher fuel prices are in Europe relative to the US.

Figure 10: Fuel prices in the USA



Source: Energy Information Administration (EIA)

The key driver of fuel prices is the price of oil. A time series of the spot oil price from the World Bank is shown in Figure 11 below. It can be seen how the trends in Figure 10 mirror the trend in Figure 11 pre-2013. Between 2001 and 2008, there was a steep upward trend in the price of oil. Following the decline in 2009, resulting from the financial crisis and the subsequent recession, oil prices increased again in 2010 and have since stabilised around the $100 per barrel mark. This more stable trend is, at present, forecast to continue out to 2030. This forecast feeds into our forecast of likely future fuel prices in each market.

Figure 12 shows the projected rates of growth in fuel prices for three different time periods; 2006-2014, 2014-2022 and 2022-2030. The growth rate is largest in the historical period 2006-2014 which, as already explained, mirrors the steep increase in the dollar price of oil over the same period. But note that exchange rate movements, as well as the price of oil itself, is also important for the UK, Germany and France because oil is generally traded in US dollars. During the period 2006-2014, the euro appreciated while the pound depreciated against the dollar.[17] This appreciation in the euro is at least partly reflected in the lower increase in fuel prices in Germany and France (expressed in their NCUs). Similar reasoning explains the highest increase in fuel prices in the UK.

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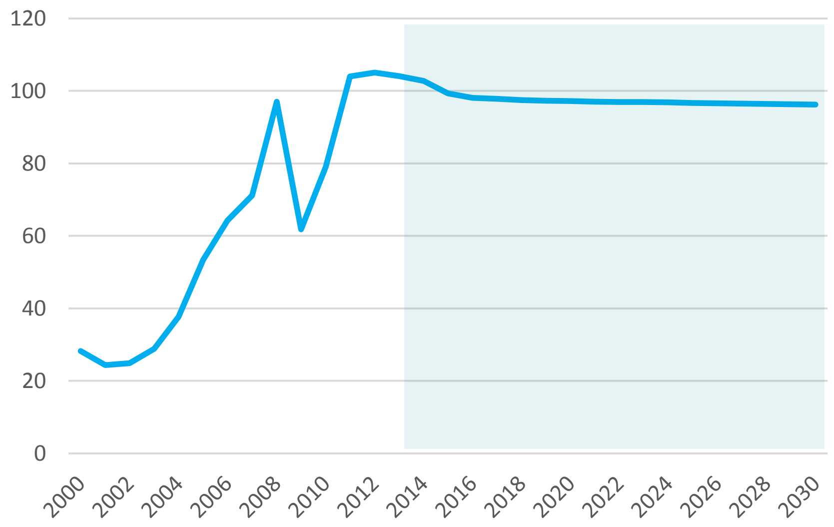
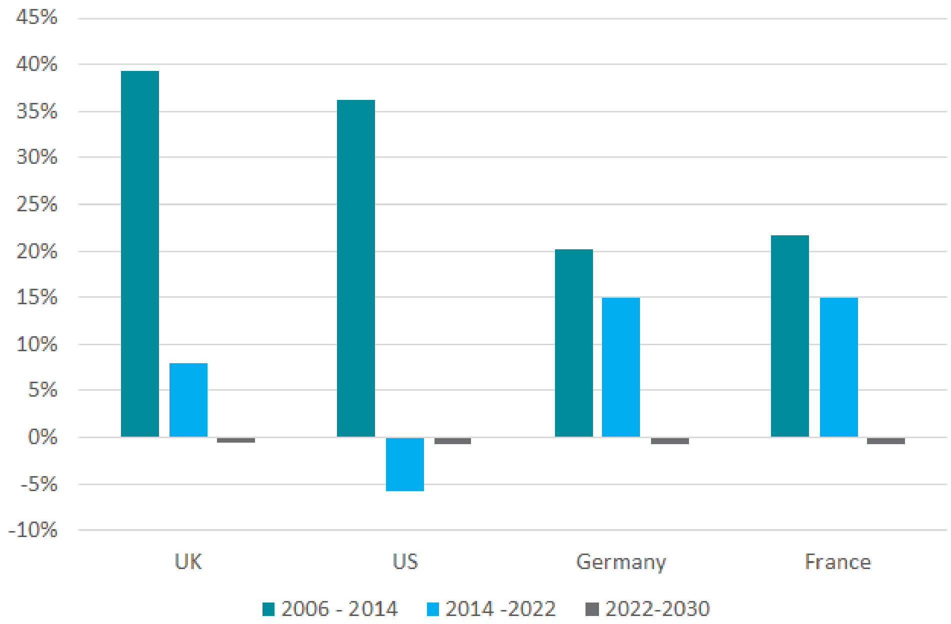
[17] An appreciation of the euro against the dollar means that you can get more dollars for one euro. For example in 2006 the dollar/euro exchange rate was €1=$0.9 and this increased to €1=$1.35, implying that a euro in 2014 was more expensive in dollars than a euro in 2006.

Figure 11: Spot Oil Price ($/bbl)



Source: World Bank, Cebr analysis

Figure 12: Growth in fuel price in NCU



Source: World Bank, EC, US EIA, Cebr analysis

To compare fuel prices in common currency terms, we converted the fuel price data reflected in Figure 12 above into dollars. This is shown in Table 3 below, which suggests that fuel prices are cheapest in the US – around 50% of the prevailing price in Europe. In dollar terms, the fuel price is forecast to fall in all countries with Germany and France seeing the greatest percentage reductions in price.

Table 3: Fuel prices in dollars

	Fuel Prices ($)			
	Germany	UK	France	US
2013	2.13	2.10	2.04	0.94
2030	1.90	1.91	1.85	0.88

Source: EX, US EIA, Cebr analysis

However, expenditure on fuel can be reduced by vehicle modifications that improve the efficiency of fuel consumption. Fuel efficiency improvements, such as clutch-activated engine rest and restart, will offset increases in the price of fuel because more miles can be travelled per gallon. Future fuel efficiency improvements must, therefore, be taken into account when estimating levels of wasted fuel resulting from traffic congestion.

Governments have introduced policies that include future targets for improving the fuel economy of vehicles in order to reduce carbon emissions. Current policy targets in the EU are predicted to reduce the carbon emission impacts of fuel use by 47% by 2040 according to the EU's CO_2 regulation on new cars manufactured.[18] The USA has introduced a Corporate Average Fuel Economy (CAFE) initiative, which places a minimum mpg requirement on new cars manufactured. According to forecasts, the CAFE Standard results in 54.5 mpg in 2030, suggesting an increase of 50% in fuel efficiency between now and 2030 for new vehicles.[19] Historical and future trends in new car fuel efficiency in the EU and the US, as measured in mpg, are shown in Figure 13, where the forecasted data are shown in the shaded area.

The trend in both the EU and the US are upwards. Cars are, in other words, becoming more fuel efficient over time. But the US has historically lagged behind the EU in terms of fuel efficiency. One reason for this could be that Americans are more likely to purchase larger less fuel efficient vehicles. Sales of diesel cars in the US, for instance, are much lower than sales in the EU, with a lower proportion of owned cars being diesel in the US. The lack of availability of diesel engines partly explains the significant difference in fuel economy according to Achatespower.[20] The fuel price is historically lower in the US and so fuel efficiency may not have been as pressing a concern as in Europe.

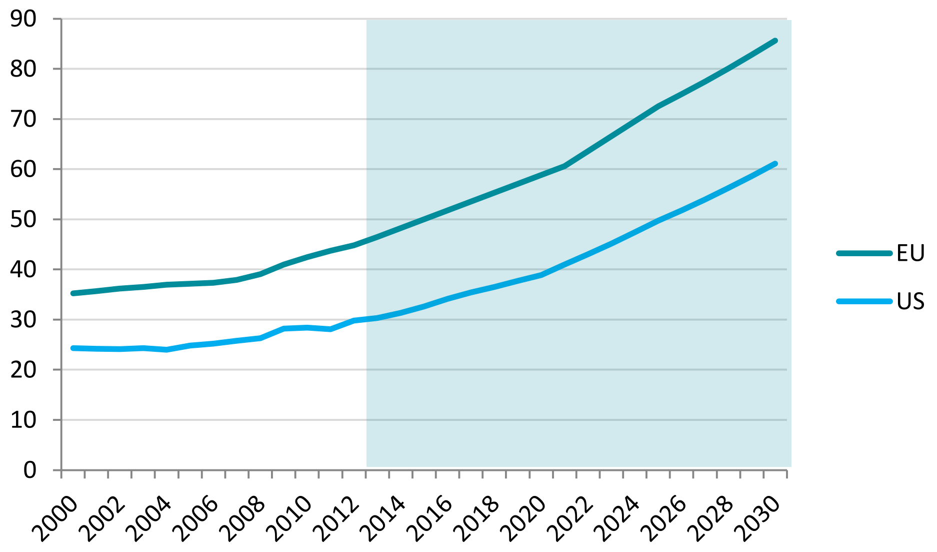
The noughties saw the introduction of hybrid electric vehicles that use alternative sources to power a car. These are becoming more popular and demand for them is increasing, which is a contributing factor towards improving a country's overall vehicle fuel efficiency. We have forecasted fuel efficiency enhancements, taking account of current policy targets in the EU and the US. The US projections show a steeper increase as fuel economy catches up with advanced EU economies.

[18] UK Department for Transport 'Road Transport Forecasts 2013' Results from the Department for Transport's National Transport Model.

[19] US Energy Information Administration 'Monthly Energy Review'.

[20] A blog named 'Under the hood' by the president and CEO of www.abatespower.com .

Figure 13: Fuel Efficiency of new vehicle fleet, mpg



Source: Centre for Climate and Energy Solutions, Cebr analysis

We have used these forecasts of fuel efficiency improvements and the future trends in fuel prices to estimate an overall impact on the effective cost of fuel over time. This is reflected in Figure 14, which illustrates the forecasted reductions in the effective cost of fuel over the period 2013 to 2030. According to this analysis, all four countries are expected to experience a drop in the effective fuel cost of motoring. The predicted fuel efficiency improvements are an important driver of these predictions. The US is predicted to see the largest fall in the effective cost of fuel, driven by the reduction in the price of fuel by 7% over the period. Germany and France still show a fall in the cost of driving even though the price of fuel is predicted to increase by 13% and 15% respectively. However, the fuel efficiency improvements offset these rises, so the overall result is still a decrease in the effective fuel cost of driving.

Figure 14: Change in effective fuel costs, 2013-30

Source: World Bank, EC, UK DfT, US EIA, Cebr analysis

3 Future levels of congestion and delay

This section presents our findings on the economic costs of congestion in the UK, France, Germany and the USA. We outline current trends in congestion based on the latest available data in these advanced economies and INRIX delay data for 173 metropolitan areas in the studied countries between January 2010 and the present day. As already noted, in the United States, metropolitan areas are defined by the US Census Bureau's definition of Core- Based Statistical Areas (CBSAs), whereas in Europe, they are defined by Eurostat's definition of Larger Urban Zones (LUZ).

The key underlying economic drivers that determine our forecasted levels of road traffic demand are then discussed. Finally, our estimates of current and forecasted amounts of time wasted in congestion between now and 2030 are presented.

3.1 The economic outlook

With an improving economic situation, congestion and delay can be expected to increase – more economic activity means higher employment and more people on the roads to and from urban centres of economic activity, especially at peak times. Although emerging economies have hit a bump, Cebr expects advanced economies to drive acceleration in global GDP growth this year following more than half a decade of very low growth.

Germany

The emergence of the Eurozone from recession is expected to help Germany's export-oriented economy. Cebr's forecasts suggest GDP expansion of 1.6% this year, accelerating further to 1.8% in 2015. Beyond that, our expectation is of stable but modest growth of 1.5% on average in the period 2016-2019, chiefly driven by domestic consumption and investment. Our forecasts are motivated by this rebalancing of the German economy from exports to domestic activity due to rising competition from emerging markets, especially China, and also due to higher government spending by the ruling grand coalition compared to previous regimes.

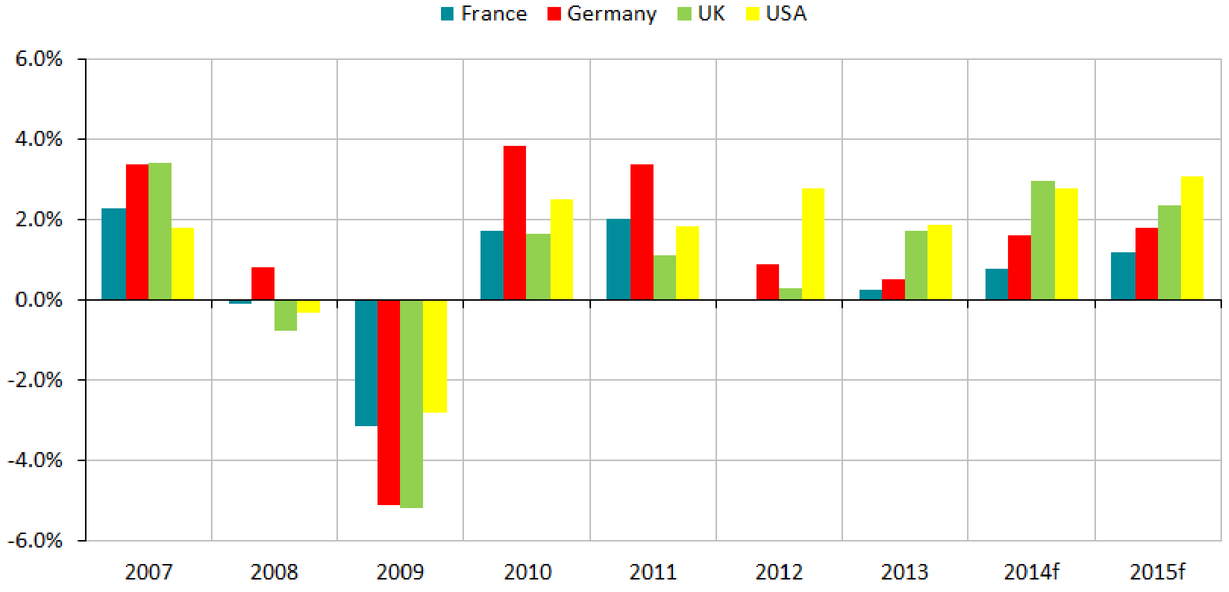
These forecasts would be sensitive to risks such as an escalation of current tensions between Europe and Russia over the crisis in Ukraine, which would weigh on German firms exporting to Russia, or a sharp slowdown in emerging markets, which remains a downside risk to our growth forecast for Germany's export economy.

France

The French economy continues to be held back by government spending cuts, not to mention the weight of high unemployment on household consumption. GDP growth is expected to accelerate only marginally from an anaemic 0.3% to 0.8% in 2014. We expect growth to pick up but to remain close to the Eurozone average, well below 2.0% until 2019.

The French budget deficit stood at 4.3% of GDP in 2013, so the EU continues to put pressure on France to lower its budget deficit to meet its limit of 3.0%. While this position is unsustainable, fiscal consolidation at this stage could derail entirely any prospect of economic recovery.

Figure 15: Percentage growth in GDP, 2007-2014



Source: ONS (UK), IMF (France, Germany, USA), Cebr forecasts for 2014

United Kingdom

The UK economy is predicted see the highest level of growth this year relative to the other three nations at 3.0%, before falling back to 2.4% in 2015. Despite weak earnings growth, British business and consumer confidence have been rising throughout 2013 and the initial months of 2014. This has driven an expansion in business investment of 10.9%, making economic growth more balanced in 2014.

However, there have been recent signs of consumer and business confidence reaching a turning point, raising suspicion that underlying growth in the UK economy may already be starting to decline. While the Bank of England can be expected to maintain a loose monetary policy, increasing government spending cuts in 2016 and 2017 to address the fiscal deficit are expected to burden economic growth prospects. This leads us to believe that the UK economy will witness a long-run growth rate of about 2%.

United States of America

The US finds itself in a rather different position to the Eurozone, posting annual average growth of 2.25% between 2010 and 2013. Growth in 2013 was relatively subdued at 1.9% and is expected to reach similar levels in 2014. The extremely weak start to 2014, largely caused by an unusually tough winter, and less rosy expectations about the rest of the year has caused us to revise down our 2014 forecast from 3.0% to 1.9%. All will depend on whether the strengthening labour market and increasing domestic consumption will sustain itself.

Stronger growth, perhaps reaching 3.0% is anticipated in 2015 with households spending less of their incomes on debt repayments and more in the shops. However, we would anticipate growth slowing as the Federal Reserve exits the phase of loose monetary policy that steered the economy out of the worst recession in over half a century. Higher interest rates from 2015 onwards will act as a headwind to growth, which is forecast to average 2.7% between 2017 and 2019.

3.2 Car ownership forecasts

This section discusses the forecasted car ownership in each of the country and city markets. Car ownership is an important factor as it influences the amount of cars on the roads and therefore the level of congestion. In absolute terms, levels of car ownership are influenced by population growth. Rates of car ownership (a relative measure) can be expected to be driven by growth in GDP per capita and the overall cost of motoring, which itself has several elements as outlined in section 2.

Table 4 presents the number of passenger vehicles per 1,000 people in each of the countries and cities that are the focus of this study.

Table 4: Passenger vehicles per thousand persons, 2013

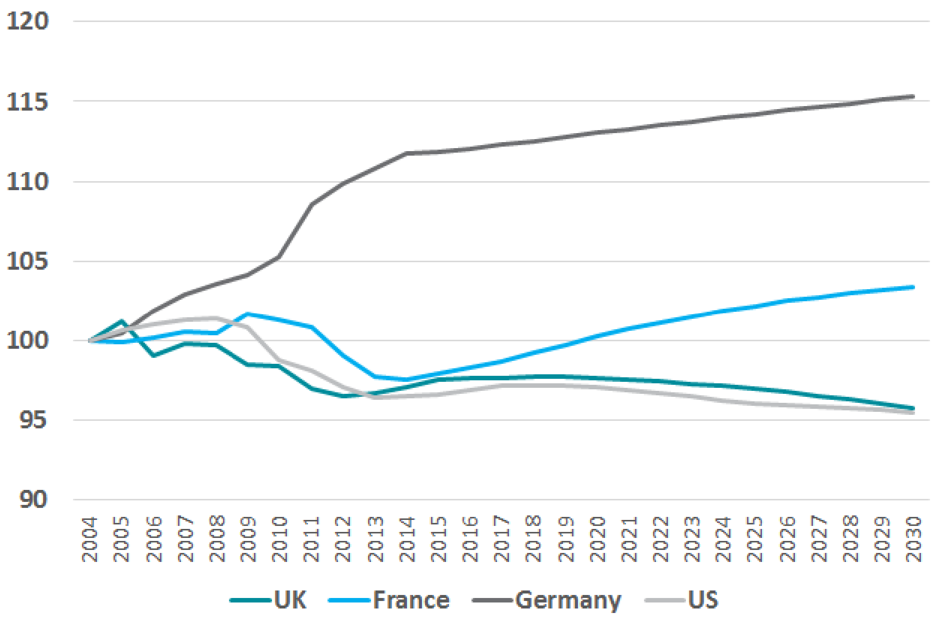
Country	Vehicles per Capita (000s)
US[23]	787
Germany	538
France	483
UK	448
City	**Vehicles per capita (000s)**
Los Angeles[24]	342
Paris[25]	330
London[26]	303
Stuttgart[27]	423

Source: World Bank, DfT, US Census Bureau, Cebr analysis

The US has by far the highest number of passenger vehicles per capita at 787 vehicles per thousand persons and the UK has the lowest at 448 vehicles per thousand persons – 75% lower than in the US. At the city level Stuttgart has the highest number of vehicles per capita whilst London has the lowest. We have predicted the future trends in these statistics as part of the overall forecast methodology. Figure 16 provides an **indexed** forecast of vehicles per capita in each country which enables us to chart trends in vehicle ownership on a comparative basis between countries.

This illustrates our prediction of a decline in vehicle ownership rates in the US and UK from 2019-2020 onwards, after a brief boost supported by more favourable economic conditions in the short-term. Significantly, although ownership rates are anticipated to fall, **the absolute number of vehicles on the roads is still expected to be higher by 2030 in all countries as a result of population growth**. By contrast, French and German markets are not forecast to reach saturation over the forecast period – seeing vehicle ownership rates continuing to rise until at least 2030. The significant increase in vehicles per capita in Germany is a function of the car market not having reached saturation and a declining population over the forecast period.

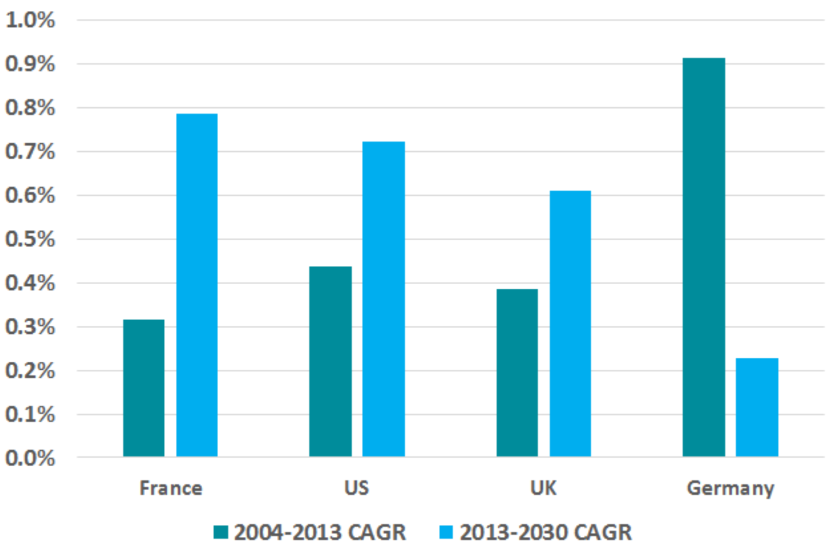
Figure 16: Passenger vehicles per capita, 2004-2013 historic, 2014-2030 forecast (2004=100)



Source: World Bank, DfT, US Census Bureau, Germany VDA, Cebr analysis

Figure 17 illustrates that France and the US are forecast to have the highest annualised growth in the absolute number of passenger vehicles on the road even though ownership rates are expected to fall. Increasing numbers of households owning more than one car can also be expected to be an important driver.

Figure 17: Average annual growth rate in total passenger cars



Source: World Bank, DfT, US Census Bureau, Germany VDA, Cebr analysis

Passenger vehicles on French roads are expected to grow by 14% between 2013 and 2030, compared to 13% in US, 11% in UK and 4% in Germany. There are forecast to be 281 million vehicles on the road in the

USA, 45 million in Germany, 35 million in France and 32 million in UK by 2030. Table 5 summarises these findings.

Table 5: Passenger vehicles on road, 2013 and 2030, millions

Country	Pax vehicles 2013	Pax vehicles 2030	% change 2013-2030
US	248.8	281.2	13.0
Germany	43.4	45.1	3.9
France	30.8	35.1	14
UK	28.7	31.9	11

Source: World Bank, DfT, US Census Bureau, Cebr analysis

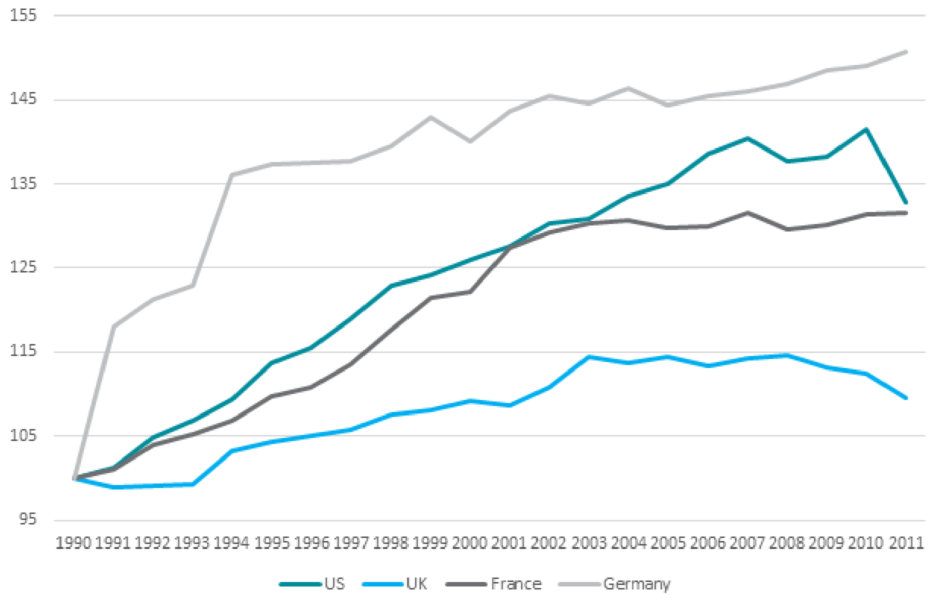
3.3 Demand (road usage) forecasts

This section presents our demand or road usage forecasts for each of France, Germany, the UK and the US. We consider passenger and freight miles travelled, which are driven by the economic outlook and the impact that this has on our forecasts of the key drivers of road usage – population growth, GDP per capita and the cost of motoring (as outlined in subsection 2.4 above) and car ownership rates and levels (as outlined in the previous subsection 3.2).

Figure 18 illustrates the total number of passenger vehicle miles travelled on roads in France, Germany, the UK and the US respectively. The trends show significant growth in passenger road usage across all four economies, with the exception of the period 2009-2011 in the UK. These trends inform us that road transport demand increased by 51%, 32%, 31% and 10% in Germany, the US, France and the UK, respectively, between 1990 and 2011.

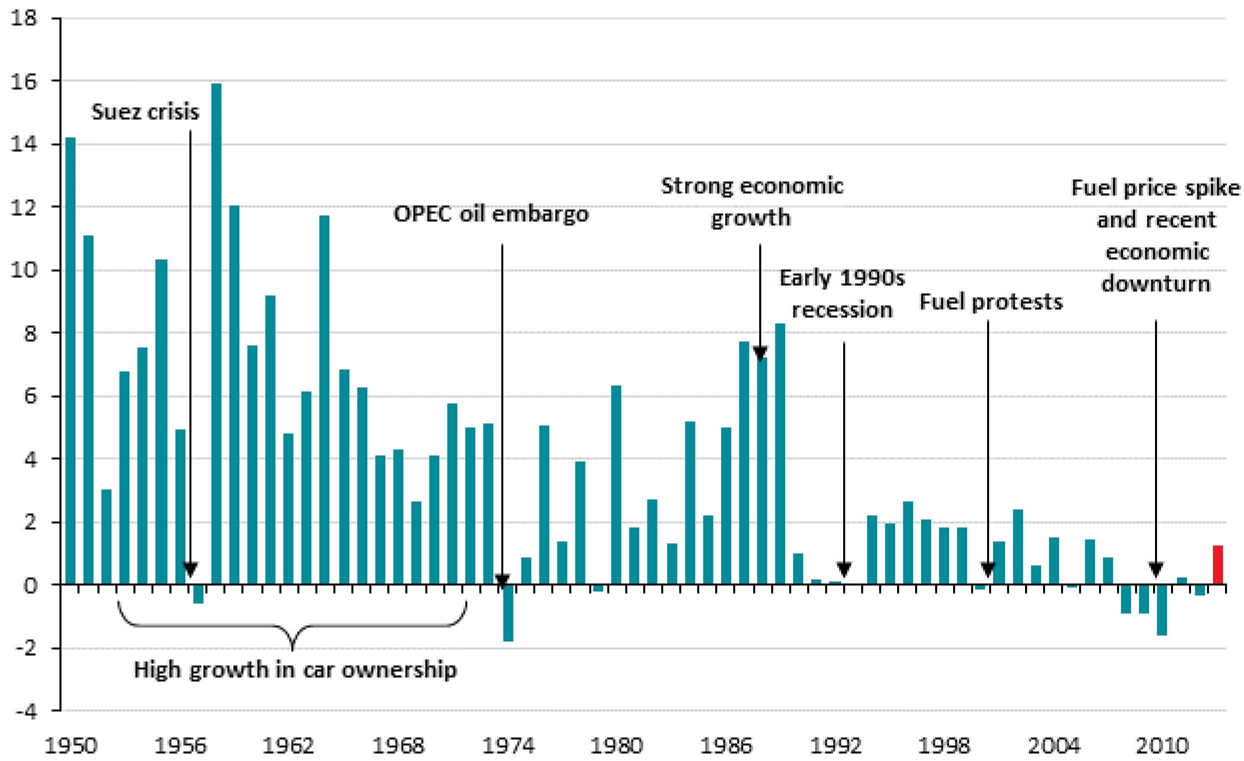
Since 2008, most countries have experienced either stalling or significantly weaker growth in road usage. This can be explained by tougher economic conditions and higher fuel prices. Indeed, the UK largely saw declines in total motor traffic vehicle miles travelled 2008 and 2012 as result of these effects as Figure 19 illustrates.

Figure 18: Index of total road passenger vehicle miles travelled, 1990=100



Source: UK DfT, US EIA, OECD International Transport Forum, Cebr analysis

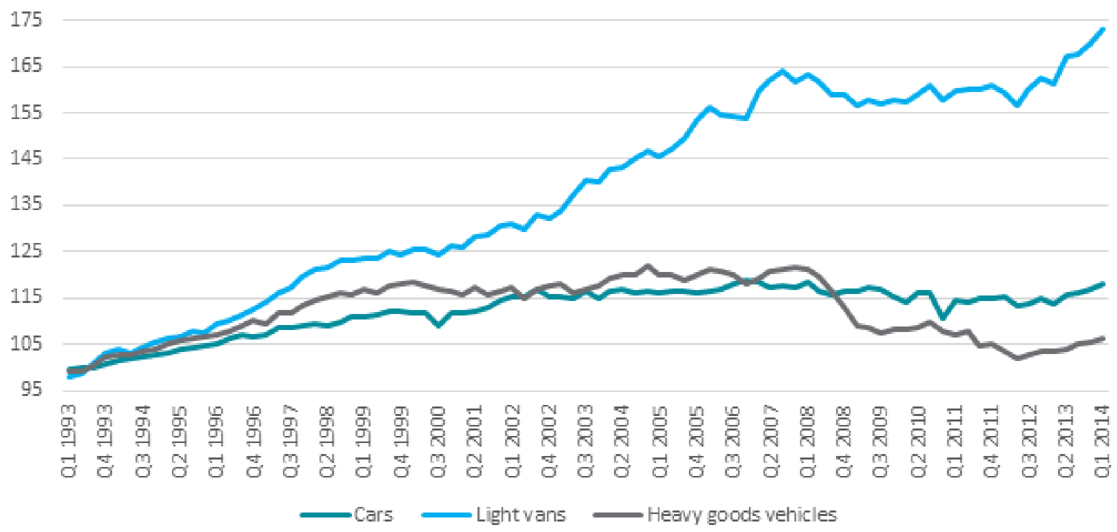
Figure 19: Growth in UK motor vehicle traffic vehicle miles, 1950-2013



Source: UK DfT, Cebr analysis

However, the UK Department for Transport estimated a pick-up in road usage from 2013 as economic conditions improve. This improvement is illustrated by more recent data across both the passenger and freight traffic sectors in Figure 20 below.

Figure 20: Indexed road traffic vehicle miles by vehicle type (100= 1993)



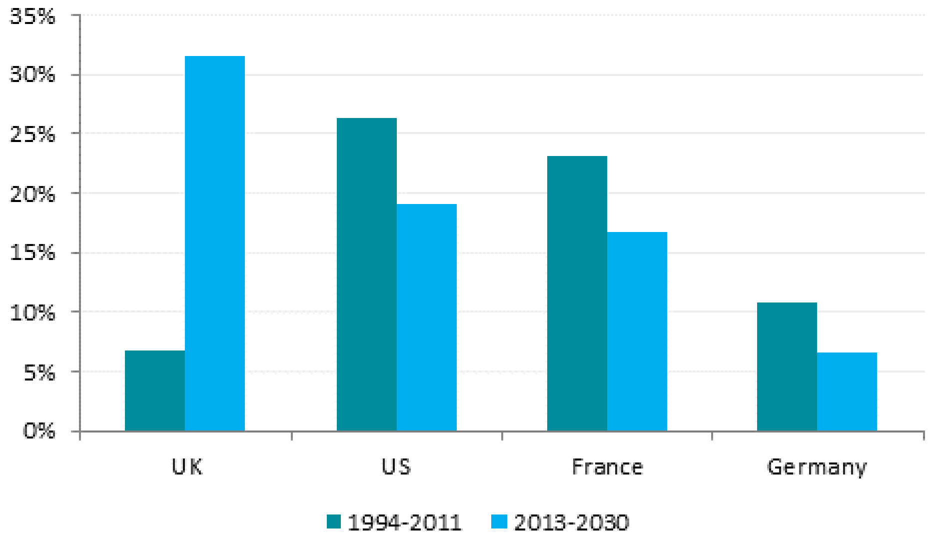
Source: UK DfT, Cebr analysis

This illustrates the recovery in UK car traffic in Q1 2014 (as measured in vehicle miles) to its highest levels since Q1 2007 – increasing by 3.9% over the year. There has also been a significant pick up in light van traffic whilst heavy goods traffic is still markedly below 2007 levels. Overall, the picture for road traffic demand across all countries has been subdued in recent years, but the more positive economic outlook for 2014 and beyond would appear to be driving renewed increases.

Cebr's forecasts of car passenger volumes at the city and country levels, presented in Figure 21 below are based on our forecasts of GDP per capita, population, the costs of motoring, car ownership. We have road passenger and freight volume elasticities from published by the UK Department for Transport and US Energy Information Administration.[21]

[21] See Appendix B below - road passenger and freight volume elasticities.

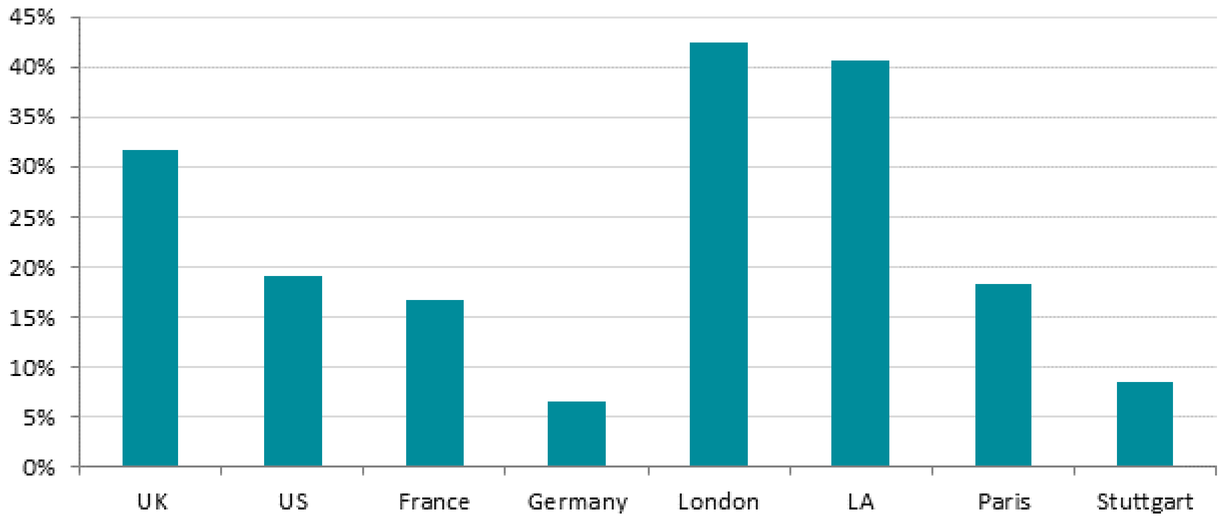
Figure 21: Growth in car passenger vehicle-miles, historic 1994-2011 and forecast 2013-30



Source: UK DfT, US EIA, OECD International Transport Forum, Cebr analysis

According to these forecasts, the UK is the only market which has a higher forecasted growth in car passenger miles than the historical growth rate. This can be explained, at least in part, by the UK encountering two recessions (in 1992 and 2008) and high resulting fuel prices, as well as the undertaking of significant investments in rail over this time period. Between 2013 and 2030, total passenger vehicle miles are expected to increase by 32% in the UK compared to 17% in the US. The country values are presented alongside the city-level forecasts in Figure 22.

Figure 22: Growth in total car passenger vehicle miles, forecast 2013-2030

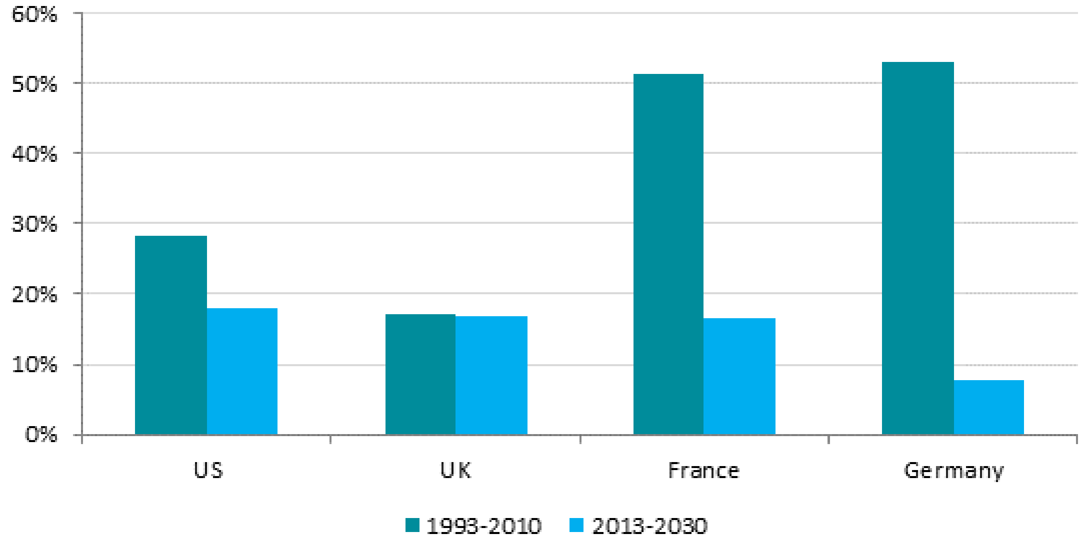


Source: UK DfT, US EIA, OECD International Transport Forum, Cebr analysis

London is forecast to have the highest increase in car passenger traffic, driven by strong population growth, stable fuel costs and strong economic fundamentals – a 43% increase in passenger vehicle miles is expected between 2013 and 2030, compared to 41% in Los Angeles. This is despite the fact that vehicles per capita are expected to fall in London as demographic trends and spatial constraints – particularly in Central London due to ownership reaching saturation. Paris and Stuttgart are expected to experience weaker growth in road usage, stemming from slow population growth and rising fuel costs in these markets.

Turning to freight vehicle miles travelled, Cebr's freight forecasts are based on forecasted GDP growth at the city and country level, and the freight volumes-to-GDP elasticities for each country, as detailed in Appendix B. We have also estimated the increase in road freight tonne-miles in each city between 2013 and 2030. Figure 23 illustrates country-level forecasts for freight volumes between 2013 and 2030.

Figure 23: Growth in road freight million tonne-miles, historic 1993-2010 and forecast 2013-2030



Source: OECD International Transport Forum, Cebr analysis

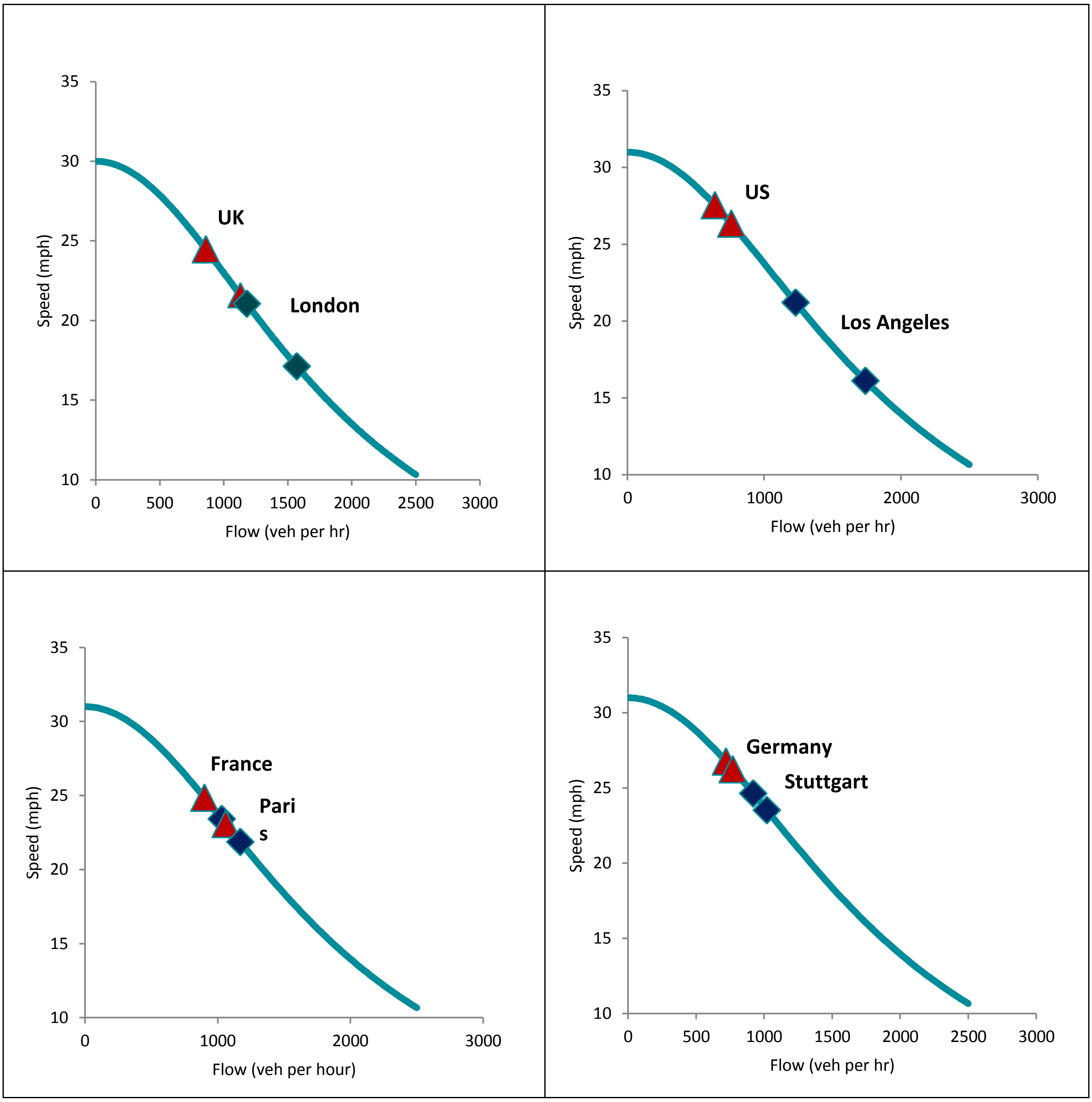
The forecasts suggest road freight growing by around 17-18% in the UK, France and Germany between 2013 and 2030. This is a lower rate of growth than what was experienced in the period between 1993 and 2010. A report by the European Commission confirms that freight vehicle traffic is anticipated to grow at a slower rate when compared against passenger vehicle miles due to a trend in globalisation which means components are more likely to be produced abroad and so the chosen mode of transportation, which means a greater reliance on other modes, such as air, maritime and rail.[22]

3.4 Road congestion forecast

To forecast future levels of congestion and delay, we used the actual delay estimates provided by the INRIX Index and combined these with the estimated changes in road usage (demand) presented in the previous section. Using the country-specific speed-flow curves, we estimated the reductions in the speed of travel as a result of this increased usage. Figure 24 shows the speed-flow curves for the UK, US, Germany and France and where each country and city is currently on the curve and where it will be in 2030 given the predicted increase in road usage.

[22] EU Transport GHG: Routes to 2050? Freight trends and forecasts:- http://www.eutransportghg2050.eu/cms/assets/ISIS-Freight-trends-and-forecasts.pdf

Figure 24: Speed flow curves, 2013 and 2030 positions

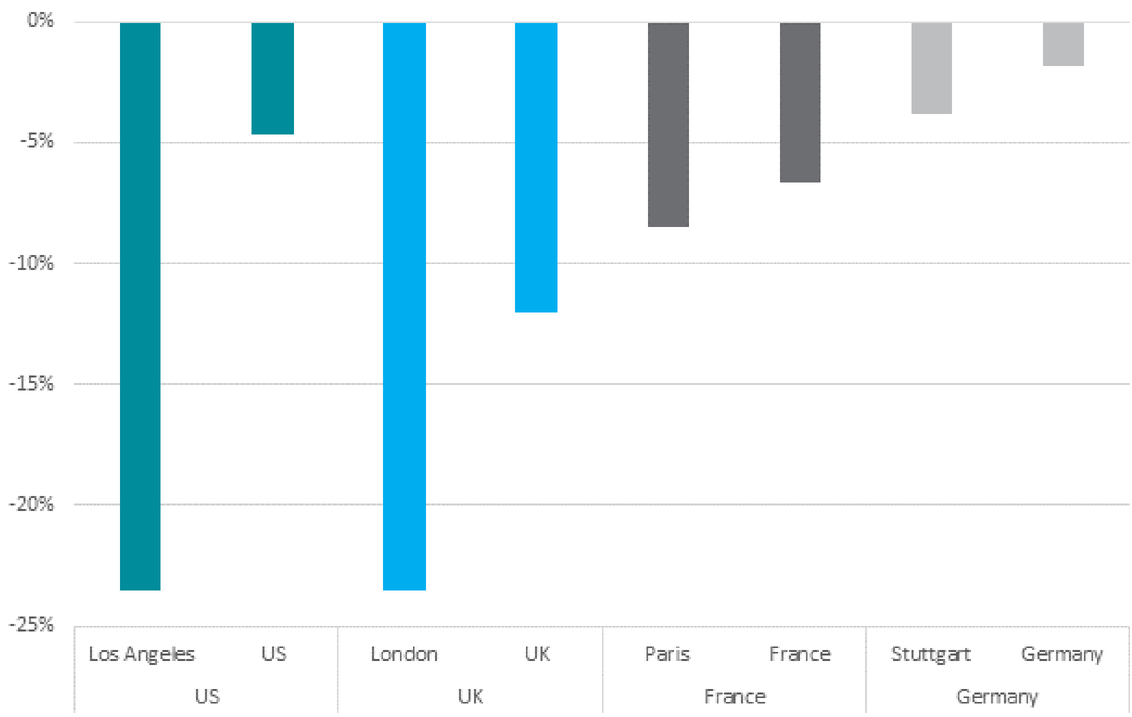


Key: Country is shown in red and the city in blue for 2013 and 2030

Source: INRIX, Cebr analysis

This analysis suggests that London has the slowest congested speed of 21mph in 2013, which is forecasted to drop to 16mph by 2030. However, Los Angeles is forecast to suffer the largest drop, also to 16mph by 2030. Stuttgart is further along the curve than Germany as a whole, but both markets are forecast to move down the curve by similar amounts by 2030. France as a whole is expected to be more congested by 2030 than Paris is today. While Paris is expected to move down the curve, the reduction in average speed is nowhere near as significant as expected in London and Los Angeles. Figure 25 summarises the predicted total percentage reductions in average congested speeds in each of these countries and cities between now and 2030.

Figure 25: Reduction in average congested speeds between 2013 and 2020



Source: INRIX, Cebr analysis

It is these percentage reductions in speed that drive our forecasts of the likely increases in time wasted through congestion and delays. Given the value (or opportunity cost) of this additional wasted time, as well as the additional fuel wastage and social costs associated with more environmental impacts, it will come as no surprise that we expect increases in the costs imposed on households by road congestion throughout the period to 2030.

3.5 Estimated average time wasted as a result of congestion

Time wasted due to delays

Our estimates of the average amounts of time wasted due to congestion number of hours wasted per are based directly on the INRIX index score.

Table 6: Country-level: average annual hours wasted (excluding the Planning Time Index) in congested traffic

Country	2013	2030	2013-2030 % change
UK	40.1	44.0	10
France	43.9	46.5	6
Germany	38.2	39.0	2
US	22.0	23.4	7
Advanced Economy Average	36.1	38.2	6

Source: INRIX, Cebr analysis

Table 7: City-level: average annual hours wasted (excluding the Planning Time Index) in congested traffic

City	2013	2030	2013-2030 % change
London	81.6	96.9	19
Paris	55.1	59.8	9
Stuttgart	60.2	62.2	3
Los Angeles	64.3	74.4	16
City Average	65.3	73.3	12

Source: INRIX, Cebr analysis

Time wasted as a result of planning time to counteract unreliability

But this INRIX-based measure does not take account of the additional time that commuters and other road users allocate to their journey to ensure that they arrive on time. This is called planning time and is described in the following terms: trips take longer in rush hour but when people really need to be somewhere at a specific time, they need/tend to plan for the possibility of a longer trip. They know they will experience traffic jams, but the need to plan arises because it is not possible to depend on how bad the traffic jams will be. TTI's *Urban Mobility Report* calls it the "extra" extra travel time, with the 2012 version incorporating the concept for the first time.

The Planning Time Index (PTI) tries to capture this idea. In technical terms, this is a travel time reliability measure that represents the total travel time that should be planned for a trip. It is computed with the 95th percentile travel time and represents the amount of time that should be planned to be late for only 1 day per month (assuming on average 20 working days in a month).

Exhibit 7 on page 8 of the 2012 Urban Mobility Report illustrates the idea of planning time. We have used the 'All 498 Area Average' of 3.09 in Table 3 on page 35 of this report. This is now built into the results of our analysis by applying this planning time multiple to the average hours wasted in congestion and delays derived from the INRIX delay data, as presented in Table 6 and Table 7 above. Table 8 and Table 9 below present these national and city level estimates of average time wasted in congestion including planning time.

Table 8: Country-level: average annual hours wasted (including the Planning Time Index) in congested traffic

Country	2013	2030	2013-2030 % change
UK	123.9	136.1	10
France	135.8	143.6	6
Germany	118.0	120.6	2
US	68	72.7	7
Advanced Economy Average	111.4	118.2	6

Source: INRIX, Cebr analysis

Table 9: City-level: average annual hours wasted (including the Planning Time Index) in congested traffic

City	2013	2030	2013-2030 % change
London	252.1	299.4	19
Paris	170.3	184.8	9
Stuttgart	186.0	192.3	3
Los Angeles	198.7	229.7	16
City Average	201.8	226.6	12

Source: INRIX, Cebr analysis

It should be noted that this report utilises the annual hours wasted without the PTI for calculations fuel wastage estimates while a vehicle is idle in traffic. It was not deemed appropriate as the commuter or other road user is unlikely to spend much of this “extra” extra time stuck in traffic, except of course when circumstances are such as to worsen congestion and increase delays. We do use time wasted including planning time, however, when valuing the cost of time wasted as a result of congestion.

Expected trends in time wasted due to congestion

The UK is expected to see the largest percentage increase in average annual hours wasted of 10% between 2013 and 2030. Across all advanced economies, an average rise of 6% is expected, amounting to an estimated additional 6.8 hours wasted in congestion every year.

At the city level, London’s average annual hours wasted (including planning time) are forecast to rise from 252.1 hours to 299.4 hours. London is expected to see the largest percentage increase of 19% between 2013 and 2030. Across all the cities, an average increase of 24.8 hours is expected by 2030.

4 Cost of congestion to individual households

The findings presented so far suggest that road usage, measured as the total passenger vehicle miles travelled per annum, is expected to increase on average by 19% across the four countries studied. This is expected to result in a 6% decrease in the average congested speed during peak periods, thereby increasing the time wasted in traffic congestion. Table 10 illustrates the direct and indirect costs to household resulting from the increased demands on road networks in 2013, 2020, 2025 and 2030.

Table 10: Country-level: average direct and indirect costs of congestion per individual car commuting household, Dollars[23]

Country	Sector	2013	2020	2025	2030	2013-30 % change
UK	Direct costs (value of fuel & time wasted)	1,519	1,788	2,007	2,251	48
	Indirect costs (increased cost of doing business)	711	807	883	966	36
	Total	**2,230**	**2,596**	**2,891**	**3,217**	**44**
France	Direct costs (value of fuel & time wasted)	1,711	1,883	2,012	2,148	26
	Indirect costs (increased cost of doing business)	870	921	965	1,015	17
	Total	**2,580**	**2,804**	**2,977**	**3,163**	**23**
Germany	Direct costs (value of fuel & time wasted)	1,588	1,755	1,920	2,110	33
	Indirect costs (increased cost of doing business)	599	656	729	817	36
	Total	**2,187**	**2,412**	**2,649**	**2,927**	**34**
USA	Direct costs (value of fuel & time wasted)	1,179	1,368	1,500	1,617	37
	Indirect costs (increased cost of doing business)	557	617	655	684	23
	Total	**1,736**	**1,985**	**2,155**	**2,301**	**33**

Source: Cebr analysis

Our findings suggest that British households are likely to incur the highest cost of congestion per car commuting household at $3,217 by 2030.Whilst US households are expected to have the lowest forecasted cost at $2,301 per annum, growth in the cost to American households is expected to be high at 33% on 2013 levels by 2030. This can be attributed to the US having the lowest average annual hours wasted due to traffic congestion throughout the time period analysed. An individual living in and using road transport on average is estimated to waste 68 hours stuck in traffic annually in 2013 and 72.3 hours per annum by 2030, compared to a person travelling in France who is expected to waste 135.8 hours in 2013 and 143.6 hours in 2030. The forecasted decline in fuel prices between 2013 and 2030 for the US is another factor resulting in the lowest cost estimated costs of traffic congestion for US households.

British households are expected to incur the largest percentage increase in per household cost of congestion of 44% between 2013 and 2030. This is consistent with the findings presented earlier in this report indicating the largest percentage increase in annual hours wasted at 10%. Coupled with the

[23] For country and city level tables in national currency units (NCU) and Euros please refer to Appendix C.

highest estimated growth in car passenger vehicle miles travelled between 2013 and 2030 (32%), this implies a substantial increase in demand for the UK's already congested road network.

Our findings at the city level suggest an average increase of 21% in total passenger vehicle miles travelled between 2013 and 2030 across the cities studied. As a result, the average congested speed during peak periods is expected to decline by 11%, thereby increasing the number of hours wasted annually by commuters. Table 11 presents our estimates of the costs imposed on the average household in each of these cities in 2013, 2020, 2025 and 2030.

Table 11: City-level: average direct and indirect costs of congestion to individual households, Dollars

City	Sector	2013	2020	2025	2030	2013-30 % change
London	Direct costs (value of fuel & time wasted)	3,091	3,643	4,170	4,659	51
	Indirect costs (increased cost of doing business)	1,235	1,348	1,480	1,599	30
	Total	**4,325**	**4,991**	**5,650**	**6,259**	**45**
Paris	Direct costs (value of fuel & time wasted)	2,597	3,031	3,474	3,965	53
	Indirect costs (increased cost of doing business)	1,058	1,209	1,376	1,560	47
	Total	**3,655**	**4,240**	**4,851**	**5,525**	**51**
Stuttgart	Direct costs (value of fuel & time wasted)	2,825	3,123	3,468	3,804	35
	Indirect costs (increased cost of doing business)	1,282	1,408	1,576	1,748	36
	Total	**4,107**	**4,531**	**5,044**	**5,552**	**35**
LA	Direct costs (value of fuel & time wasted)	3,448	4,270	4,882	5,336	55
	Indirect costs (increased cost of doing business)	2,282	2,709	3,017	3,219	41
	Total	**5,730**	**6,979**	**7,899**	**8,555**	**49**

Source: Cebr analysis

These findings suggest that Parisian households will experience the largest percentage increase in costs of 51% between 2013 and 2030. But Los Angeles households are expected to incur the highest costs due to congestion at $8,555 per car commuting household by 2030. The application of the planning time uplift also has a marked impact on the estimates for LA households. However, it is also likely to have been influenced by LA having the largest percentage of people commuting by car at 67% (in contrast to London, for example, at 32%). LA also has the largest absolute numbers of cars than any other city examined at 4.5 million. The confluence of these factors contributes to an expected 16% increase in annual hours wasted between 2013 and 2030.

5 Economy-wide costs of congestion to all households

Our findings show that total economy-wide costs across all four advanced economies are forecast to rise from $200.7billion in 2013 to $293.1 billion by 2030 – a 46% increase in the costs of congestion. This is likely attributable to a combination of an average increase of 19% in total passenger vehicle miles travelled and a 14% increase in freight miles travelled between 2013 and 2030, aiding a rise of 6% in annual hours wasted on average across all four economies. Table 12 presents our estimates of the direct and indirect costs to households at the aggregate economy-wide level in 2013, 2020, 2025 and 2030.

Table 12: Country-level: economy-wide direct and indirect costs to households, millions of Dollars

Country	Sector	2013	2020	2025	2030	2013-30 % change
UK	Direct costs (value of fuel & time wasted)	12,649	15,865	18,264	20,937	66
	Indirect costs (increased cost of doing business)	7,883	9,565	10,928	12,473	58
	Total	**20,532**	**25,430**	**29,191**	**33,410**	**63**
France	Direct costs (value of fuel & time wasted)	12,881	14,780	15,984	17,158	33
	Indirect costs (increased cost of doing business)	9,630	10,668	11,517	12,430	29
	Total	**22,510**	**25,448**	**27,501**	**29,589**	**31**
Germany	Direct costs (value of fuel & time wasted)	21,684	24,224	25,929	27,702	28
	Indirect costs (increased cost of doing business)	11,796	13,116	14,517	16,137	37
	Total	**33,480**	**37,341**	**40,446**	**43,838**	**31**
USA	Direct costs (value of fuel & time wasted)	78,519	97,099	109,550	120,695	54
	Indirect costs (increased cost of doing business)	45,639	54,157	60,151	65,526	44
	Total	**124,158**	**151,257**	**169,701**	**186,221**	**50**

Source: Cebr analysis

In 2013, the US had the highest cost of congestion at $124.2 billion followed by Germany ($33.5 billion), France ($22.5 billion) and the UK ($20.5 billion). The US is expected to see a 50% increase which can be attributed to the key drivers of increased road usage (demand for roads), particularly GDP per capita, which has been estimated to grow by 33% between 2013 and 2030. This would be expected to increase living standards of US households and, coupled with the US being estimated to have the highest population growth at 13% from 2013 to 2030, to drive substantial increases US road usage.

The UK currently has the lowest aggregate absolute cost of congestion at $20.5 billion but this is expected to overtake France in 2030, reaching $33.4bn representing the largest percentage increase at 63%. This is an expected result from earlier findings, which showed that the UK is estimated to have the largest reduction in average congested speeds between 2013 and 2030 of -10%, compared to Germany with a drop of only -2% over the same time frame. The UK also has the highest rate of road usage intensity at 3.1, in comparison to France at 1.5, and a higher population growth of 12% over France's population growth of 7%.

The cumulative costs, over the 17 years (2013 to 2030), is estimated to reach $2.8 trillion for the US alone. The European nations are expected to see relatively lower cumulative costs compared to the US, with Germany estimated to incur the highest cost amongst the European economies at $691 billion – Table 13 presents our findings.

Table 13: Country-level: economy-wide direct and indirect cumulative costs to households, millions of Dollars

Country	Sector	2013-2030 cumulative costs
UK	Direct costs (value of fuel & time wasted)	299,215
	Indirect costs (increased cost of doing business)	180,641
	Total	**479,859**
France	Direct costs (value of fuel & time wasted)	271,377
	Indirect costs (increased cost of doing business)	197,291
	Total	**468,671**
Germany	Direct costs (value of fuel & time wasted)	444,578
	Indirect costs (increased cost of doing business)	246,673
	Total	**691,261**
USA	Direct costs (value of fuel & time wasted)	1,803,225
	Indirect costs (increased cost of doing business)	1,003,564
	Total	**2,806,826**

Source: Cebr analysis

The aggregate costs across the four cities featured in this report that total economy-wide costs across all four cities are forecast to rise from $46.6bn in 2013 to $75.8bn by 2030 – a 63% increase in the costs of congestion. Table 14 presents our findings.

Table 14: City-level: economy-wide direct and indirect costs to households, millions of Dollars

City	Sector	2013	2020	2025	2030	2013-30 % change
London	Direct costs (value of fuel & time wasted)	4,310	5,602	6,669	7,741	80
	Indirect costs (increased cost of doing business)	4,203	5,088	5,943	6,779	61
	Total	**8,513**	**10,690**	**12,612**	**14,520**	**71**
Paris	Direct costs (value of fuel & time wasted)	6,282	7,558	8,688	10,008	59
	Indirect costs (increased cost of doing business)	5,410	6,404	7,479	8,693	61
	Total	**11,692**	**13,963**	**16,167**	**18,701**	**60**
Stuttgart	Direct costs (value of fuel & time wasted)	2,054	2,287	2,496	2,694	31
	Indirect costs (increased cost of doing business)	1,116	1,242	1,396	1,549	39
	Total	**3,170**	**3,529**	**3,892**	**4,242**	**34**
LA	Direct costs (value of fuel & time wasted)	13,213	17,305	20,074	22,294	69
	Indirect costs (increased cost of doing business)	9,987	12,610	14,573	16,061	61
	Total	**23,200**	**29,915**	**34,647**	**38,355**	**65**

Source: Cebr analysis

These findings suggest that, in 2013, Los Angeles has the highest overall costs of congestion at $23.2bn followed by Paris ($11.7bn) and London ($8.5bn). Los Angeles is forecast to have the highest congestion costs by 2030 at $38.4bn, representing the second largest increase (65%) after London at 71%.

The large increases forecasted for both Los Angeles and London can be attributed to the underlying key drivers of increased road usage (road demand). Both these cities have the highest projected population growth rates, with London expected to see population growth of 20% and Los Angeles an increase of 10% over the forecast period. Combined with the largest expected growth in total car passenger vehicle miles travelled in the time frame analysed, London with 34% and Los Angeles with 26%, have meant that these two cities are expected to witness the largest declines in average congested speeds of -19% in London and -16% in Los Angeles. These characteristics of the cities are the likely reasons for the large expected increases in congestion costs going forward.

The findings of our study suggest that Los Angeles accounts for 19% of the total US cost of traffic congestion. This compares with TTI's Urban Mobility Report 2012, which attributes 9% of total US cost to LA. The discrepancy between the two estimates can be attributed to two principal factors. First, this report is based on an analysis 80 areas compared to the 498 areas the UMR study includes. The 80 urban areas analysed in this report all have a population over 500,000, with 15 urban areas having more than 3 million inhabitants (one of them being LA). As our dataset has a larger proportion of metropolitan areas than the UMR data, our country-wide analysis will inevitably attribute a larger share of the total estimated costs to the largest urban areas, such as Los Angeles.

Secondly, Los Angeles has one of the largest proportions of population that commute to work across the US, with 50% of the population placed under the commuting bracket. This report's methodology assigns a larger weight on commuters than the UMR report. This creates a multiplier effect on the estimation of Los Angeles's costs due to the large proportion of commuters within the city.

Table 15: City-level: economy-wide direct and indirect cumulative costs to households, millions of Dollars

City	Sector	2013-30 Cumulative costs
London	Direct costs (value of fuel & time wasted)	107,093
	Indirect costs (increased cost of doing business)	97,195
	Total	**204,295**
Paris	Direct costs (value of fuel & time wasted)	143,670
	Indirect costs (increased cost of doing business)	123,307
	Total	**266,977**
Stuttgart	Direct costs (value of fuel & time wasted)	42,075
	Indirect costs (increased cost of doing business)	23,231
	Total	**65,292**
LA	Direct costs (value of fuel & time wasted)	323,044
	Indirect costs (increased cost of doing business)	236,139
	Total	**559,188**

Source: Cebr analysis

Table 15 presents the cumulative direct and indirect costs of congestion that cities are estimated to incur between 2013 and 2030. Households in Los Angeles, on aggregate are expected to incur the largest costs of $559bn, more than double the cost estimated for Paris ($267bn).

6 Social cost of environmental damage

This study also examines the carbon footprint caused by stationary traffic or 'vehicle idling' resulting from gridlock across our advanced economies. The fuel that is consumed while stationary in traffic results in higher emission of greenhouse gases and pollutants, which leads to poorer air quality, particularly in urban areas. Our estimates suggest that vehicle idling releases 15,434 kilotons of CO_2 equivalent into the atmosphere across the UK, France, Germany and the US every year. This is forecast to rise by 16% between 2013 and 2030 to reach 17,959 kilotons of CO_2 emissions. Table 16 illustrates the fuel consumed per vehicle and annual hours wasted in each market.

Table 16: Annual hours wasted (excl. PTI) and fuel consumed per vehicle whilst idling, 2013

Country	Annual hours wasted (2013)	Fuel consumed in litres per vehicle (2013)
UK	40.1	72.06
France	43.9	78.95
Germany	38.2	68.62
US	22.0	39.53
City	**Annual hours wasted (2013)**	**Fuel consumed in litres per vehicle (2013)**
London	81.6	146.59
Paris	55.1	99.01
Stuttgart	60.2	108.19
Los Angeles	64.3	115.58

Source: INRIX, Cebr analysis

These findings suggest that French car commuters currently waste the most fuel per year at 79 litres per vehicle. This can be clearly linked to France having the highest annual hours wasted in congested traffic in 2013.

At the city level, London car commuters waste the most fuel at 147 litres per vehicle. This again is driven by the fact that the average London households spend the longest amount of time stuck in traffic congestion at 81.6 hours in 2013.

It can be seen from the above table that there is a positive and proportional relationship between the annual hours wasted and the fuel wasted in litres per vehicle. Average fuel consumed per vehicle when idle is assumed to be 1.79 litres per hour for the average medium-sized car. Table 17 illustrates that in total, 5.95 billion litres of fuel is wasted across the advanced economies by vehicles idling in congested traffic.

Table 17: Fuel wasted during vehicle idling whilst driving on congested roads, millions of litres

Country	Fuel Wasted (2013)
UK	747
France	740
Germany	1,166
US	3,297
Advanced Economies	5,950
City	**Fuel Wasted (2013)**
London	113
Paris	83
Stuttgart	27
Los Angeles	153
Cities	377

Source: INRIX, Cebr analysis

On an economy-wide basis, the US wastes nearly three times more fuel (3,297m litres) than Germany, the next highest with annual wasted fuel of 1,166 million litres in 2013. Los Angeles suffers the greatest fuel wastage at the city-level. These results are driven by a number of factors. First, the US, Germany and Los Angeles have the highest number of vehicle miles travelled at 8.5 million, 1.2 million and 4.5 million respectively. Second, they all have the highest number of passenger vehicles per thousand persons (787, 538 and 342 respectively). These factors drive high levels of congestion, thereby increasing the chances of vehicles getting stuck in congested traffic, idling and wasting fuel. Table 18 illustrates the total CO_2 emissions released through vehicle idling as a consequence of the fuel burned.

Table 18: CO_2 equivalent emissions from fuel wasted as a result of congestion, kilotons of CO_2 equivalent

Country	2013	2030	2013-30 % change
UK	1,931	2,401	24
France	1,917	2,175	13
Germany	3,010	3,032	1
US	8,576	10,351	21
Advanced Economies	15,434	17,959	16
City	**2013**	**2030**	**2013-30 % change**
London	658	937	42
Paris	773	904	17
Stuttgart	253	260	3
Los Angeles	1,433	1,838	28
Cities	3,117	3,939	26

Source: INRIX, Cebr analysis

A total of 15,434 kilotons of CO_2 equivalent emissions were released across our sample of advanced economies in 2013, which is forecasted to rise by 16% to 17,959 kilotons of CO_2 by 2030. Our findings suggest that emissions in the UK are expected to grow at the fastest rate between 2013 and 2030 – by 24%, followed by the US at 21%.

Once again, this is driven by the higher annual hours wasted in congested traffic in the UK (40.1 hours annually) than in most of the other countries. The US, in contrast, has the lowest annual hours wasted (estimated at 22 hours) but, due to the very high numbers of vehicles on the road in the US (4.5 million vehicle miles travelled and 787 vehicles per thousand people), combined with estimated population growth of 13% between 2013 and 2030 and GDP per capita growth of 33% in the same time frame, the US is estimated to produce 10,350 kilotons of CO_2 from vehicle idling due to congestion. The monetary valuation of these carbon emissions is presented in Table 19 below.[24]

The monetary valuations of the social costs of these environmental impacts are presented in Table 19 below. By 2030, the monetary valuation of the carbon emissions generated in the US as a result of vehicles idling in congestion is expected to reach $538 million by 2030, representing the largest cost across the countries examined. Similarly, Los Angeles also has the highest CO_2 emissions costs across the cities with $50.2m.

Table 19: CO_2 equivalent emissions in monetary terms, millions of Dollars[25]

Country	2013	2030
UK	10.5	286.3
France	13.9	308.4
Germany	21.8	429.9
US	300.2	538.2
City	**2013**	**2030**
London	3.6	111.7
Paris	5.6	128.2
Stuttgart	1.8	36.9
Los Angeles	50.2	95.6

Source: INRIX, Cebr analysis

The UK is predicted to witness the largest percentage increase of 2616% in the cost of CO_2 emission from car idling. This is not only due to UK emissions being forecasted to grow at the fastest rate but also due to the European social cost of carbon increasing at a substantially faster rate than that of the US. Table 20 presents the differences in the social cost of CO_2 emissions per metric ton in Europe versus the US. The European rate is predicted to be $67 more than the US cost estimate by 2030.

[24] European estimates for carbon prices are based on short-term traded carbon values used by the UK Department for Energy and Climate Change for public policy appraisal (September 2013). US carbon value estimates are based on a technical update of the social cost of carbon for regulatory impact analysis by the Interagency Working Group on Social Cost of Carbon, United States Government (November 2013).

[25] For CO2 equivalent emissions in monetary terms in NCU and Euros please refer to Appendix C.

Table 20: Social cost of CO2 emissions in Europe and US, $/per metric ton of CO2

Year	European Cost	US Cost
2013	6	33
2020	8	43
2025	63	47
2030	119	52

Source: DECC, Interagency Working Group US Government

Table 21 presents the cumulative CO_2 emission costs for both the countries and cities examined. The cumulative CO_2 emissions from congestion are estimated to cost the US economy $7.6bn by 2030, whilst the European nations are estimated to incur between 60% and 80% less.

Table 21: CO_2 equivalent cumulative emissions in monetary terms, millions of Dollars

Country	2013 – 2030 cumulative costs
UK	1,461
France	1,606
Germany	2,300
US	7,574
City	**2013 – 2030 cumulative costs**
London	558
Paris	659
Stuttgart	196
Los Angeles	1,323

Source: Cebr analysis

7 Conclusions

The future costs imposed on households by congestion are expected to rise for the UK, France, Germany and the US. These advanced economies are, on average, expected to witness increases in these costs of up to 50% between 2013 and 2030. The US is predicted to have the highest cost of congestion on an economy-wide scale both in 2013 and 2030 at $124.2 billion and $186.2 billion respectively. The cumulative costs imposed by congestion are expected to amount to $4.4 trillion across the four economies, with the US accounting for $2.8 trillion alone over the 17-year forecasting horizon.

The three European nations are also forecasted to see their costs due to gridlock rise, on average by $25.5 billion to $35.6 billion. But they still, given the relative size of their populations, face lower costs than the US by almost $100 billion, in absolute terms.

A similar picture is portrayed at the city level where households in European cities are estimated to incur lower costs (on average $4,029 in 2013 and $5,779 in 2030) compared to their US counterparts. Specifically, Los Angeles is expected to see an increase of 49% between 2013 and 2030 to $8,555 per individual car commuting household. This is also reflected in the cumulative costs, estimated to amount to $559 billion by 2030.

The different expected increases across the advanced economies featured in this study can be explained by the different mix of changes in the demand-side drivers of road usage, which has different impacts on the amount of wasted time spent in congested traffic. The key drivers of demand (road usage) are population growth, GDP per capita growth, changes in the cost of motoring and in car ownership. Stuttgart, for instance, has the highest number of vehicles per thousand people, at 423, while London has the lowest with 303 vehicles per thousand people. This would naturally lead to the expectation that households in Stuttgart would have higher costs imposed on them by congestion. But, due to London's higher population growth of 20% (Stuttgart expected to see a population decline of -2%), greater increases in the absolute numbers of vehicles on the road are expected. This has led to estimated increases in annual hours wasted in congested traffic of 19% in London between 2013 and 2030, whereas Stuttgart is expected to see only a 3% increase. This filters through to higher forecasted economic costs to households in London than in Stuttgart but also higher environmental costs from CO_2 emissions.

CO2 emissions from vehicle idling in gridlock are expected to rise sharply in all four advanced economies, with the US predicted to see the largest cost burden in 2030 of $538.2 million. However, the US is forecasted to incur a cumulative cost of $7.6 billion due to CO_2 emissions over the 17 years. CO2 emissions are determined predominately by the sheer number of vehicles on the road, the fuel efficiency levels of the vehicles and the number of annual hours wasted in congested traffic. Generally, there is a positive relationship between, on the one hand, the amount of time wasted and the number of vehicles on the road and, on the other, the amount of CO_2 emissions produced whilst vehicles idling in gridlock. An inverse relationship exists with fuel efficiency increases.

Governments across the four advanced economies can take public policy measures that could improve the situation and minimise these costs and their drain on the economy.

The continual improvement and expansion of public transport infrastructure can provide travellers with more options, thus encouraging people to use their car less. But the extent to which public transport can ever be deemed to be substitutable for the car will always be debatable and sensitive to the cost of public transport and the perceived quality of the public transport 'experience'. Given the perceived convenience of the car, public transport can be a hard sell, especially when it can also be costly and subject to delays.

Other pragmatic schemes like car-pooling have emerged and the more widespread introduction of car-pooling lanes should help stem the growth in the numbers of cars on their roads in peak periods. The encouragement of increases in telecommuting, primarily by ensuring the provision of higher speed internet connectivity, can also be expected to help alleviate the situation.

Neither can technology-based demand management solutions be overlooked, especially if one accepts that traffic will continue to grow and congestion to increase, even though car ownership rates are showing signs of decline. Technological innovations like multi-modal routing and real-time traffic management have been made possible by big data analytics and the growth of the Internet of Things, using road capacity more intelligently and, thus, creating ‘smarter’ cities.

Finally, as in all such cases, the optimal solution is likely to be some blend of or balance between all these measures, depending on the particular circumstances of the urban area under examination.

Appendix A: Speed-flow calibration

In order to calculate a forecast for the flow of road traffic, we calculated the overall elasticity of the three key drivers on road traffic demand for each year. We were provided with data from INRIX that allowed us to calculate the average speed in 2013 and data from the UK Department for Transport[26] provided us with the current (2013) flow of traffic on urban roads during peak hours. Using this and a speed flow relationship was required to estimate a road traffic and average speed forecast.

The most common speed flow curve used in the literature for transport demand modelling is the BPR (Bureau of Public Roads) function, which provides a relation between the average speed and the volume of traffic on a given road.

The equation is shown below:

$$S = \frac{S_0}{\left[1 + a\left(\frac{V}{C}\right)^b\right]}$$

Where S = average speed

S_0 = Free flow speed

$\frac{V}{C}$ = volume to capacity ratio

a = coefficient[27]

b = Exponent[28]

In order to estimate this equation, some assumptions were required for the values of the four unknown parameters; S_0, C, a, and b. The assumed values for these parameters are shown in the table below.

Parameter	Value
S_0	30
C	1515
a	0.7
b	2

A strong assumption for the free flow speed, S_0, is 30 mph as this is the most common speed limit on arterials in dense urban areas. The road capacity, C, is assumed to be 1515 vehicles per hour. This is the typical capacity of urban roads with a speed limit of between 30 and 40 mph that have an average of 2-3 lanes with a road width of 10m as defined by the Transport for London Road Tasks Force. In order to estimate the parameters a and b, we calibrated the equation to traffic data for London at peak hours, which was obtained from the UK Department for Transport. This resulted in a=0.7 and b=2, which were

[26] Table TRA0302 from the Department for Transport Statistics Great Britain bulletin.

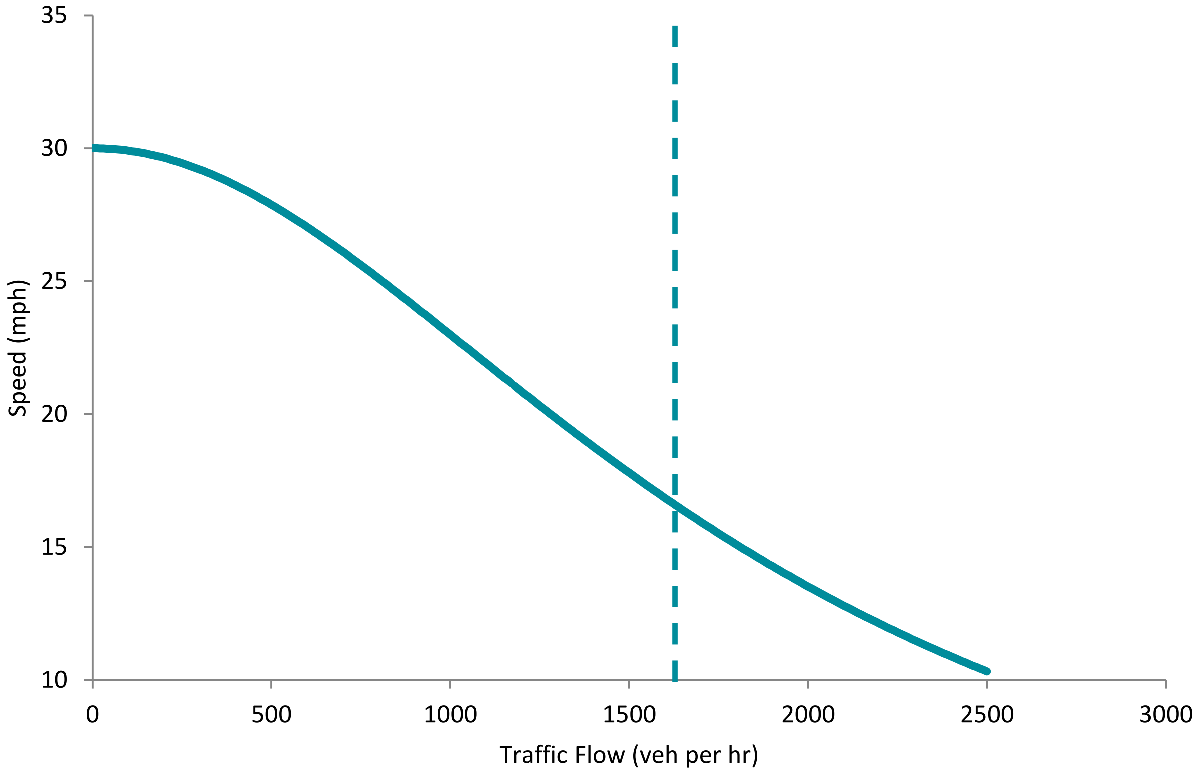
[27] This parameter determines the ratio of free-flow speed to the speed at capacity.

[28] This parameter determines how quickly the curve drops from the free flow speed.

of a similar magnitude to values found in the literature that had calibrated the curve to their own data. These values are assumed to be the same for all eight markets.

The speed flow curve with the calibrated parameters is shown in Figure A1, where the dashed red line indicates the road capacity of 1515 vehicles per hour.

Figure A1 Speed flow relationship



This curve shows that as traffic flow increases, the average speed on the roads starts to fall below the free flow speed of 30 mph. The closer the traffic flow is to road capacity, the quicker the speed drops for a given change in traffic flow. Therefore, the extent to which average speed changes in response to changes in traffic flow depends on where the market is on the curve.

This relationship is then used to obtain the average speed the traffic is travelling at from the corresponding flow of traffic, which was estimated using the forecasts for the key drivers for each year over the forecast period 2013 to 2030.

Appendix B: Road passenger and freight volume elasticities

As part of the forecasting methodology, we used elasticities to calculate the impact of a change in the three key drivers on road transport demand. An elasticity measures the percentage change in a variable in response to a 1% change in another variable. Therefore, it provides us with a quantified relationship between the change in the value of the key driver and how this will change the level of car traffic. The implied elasticities used in our forecasting model are shown in Table B1.

Table B1 Population, GDP per capita and fuel cost elasticities

Impact of a 1% increase in Key Driver on traffic			
Road Passenger Elasticities			
	2010	2025	2035
Population	0.95%	0.94%	0.92%
GDP per Capita	0.28%	0.22%	0.19%
Fuel Cost	-0.30%	-0.21%	-0.17%
GDP Road Freight Elasticities			
	2010	2025	2035
UK	0.45	0.45	0.45
France	0.48	0.48	0.48
Germany	0.32	0.32	0.32
US	0.42	0.42	0.42

Source: UK Department for Transport, EC Freight Transport FORESIGHT 2050, US DoT, Cebr analysis

From this table we can infer that in 2010, a 1% increase in population lead to an increase of 0.95% in car passenger traffic. Therefore, according to the DfT's model, car traffic changes almost proportionately to a change in the population. Out of the three key drivers, population has the highest impact on car traffic and the fuel cost has the lowest impact in the forecast periods.

These elasticities were derived by the Department for Transport (DfT) from their own road transport forecasts[29], which forecast road transport demand to 2040. The table shows that the impact of the three key drivers on car traffic is falling over time. The report states that the reasons for this are that the market is close to maturity (many more people own a car today than they did in the 1960s), congestion impacts, public transport and more environmentally sustainable travel patterns.

Freight GDP elasticities for UK, France and Germany are derived from a report commissioned by the European Commission entitled 'Freightvision: freight transport FORESIGHT 2050'. US GDP freight elasticities are derived from econometric analysis of US Intercity truck ton miles data from the Department of Transportation against US economic growth.

[29] Report by the DfT: Road Transport Forecasts 2013 – Results from the Department for Transports National Transport Model

We applied the elasticities for 2010 and 2025 to our population, GDP per capita and fuel cost data for each of the years over the forecast period 2013-2030. This allowed us to obtain the percentage change in car traffic due to each of the three drivers individually for each forecast year up to 2030. From this, we could then calculate the total elasticity which combines the effect of each of the three key drivers and explains how much car traffic will change in response to a combined change in the three key drivers.

In order to estimate a traffic flow forecast, we applied these derived total elasticities to the traffic flow data.

Appendix C: Country and City Level Impacts in National Currency Units (NCUs) and Euros

Monthly average exchanged rates were averaged to give an annual average exchange rate for 2013.

Currency Exchange	Avg. Exchange Rate 2013
£/$	1.56
Euro/$	0.75

Source: Bank of England

Table C2: Country-level: average direct and indirect costs of congestion to individual car commuting households, NCU

Country	Sector	2013	2020	2025	2030	2013-30 % change
UK	Direct costs (value of fuel & time wasted)	971	1,143	1,283	1,439	48
	Indirect costs (increased cost of doing business)	455	516	565	618	36
	Total	**1,426**	**1,659**	**1,848**	**2,057**	**44**
France	Direct costs (value of fuel & time wasted)	1,288	1,418	1,514	1,617	26
	Indirect costs (increased cost of doing business)	655	693	726	764	17
	Total	**1,943**	**2,111**	**2,240**	**2,381**	**23**
Germany	Direct costs (value of fuel & time wasted)	1,196	1,321	1,445	1,588	33
	Indirect costs (increased cost of doing business)	451	494	549	615	36
	Total	**1,647**	**1,815**	**1,994**	**2,203**	**34**
USA	Direct costs (value of fuel & time wasted)	1,179	1,368	1,500	1,617	37
	Indirect costs (increased cost of doing business)	557	617	655	684	23
	Total	**1,736**	**1,985**	**2,155**	**2,301**	**33**

Source: Cebr analysis

Table C3: Country-level: average direct and indirect costs of congestion to individual car commuting households, Euros

Country	Sector	2013	2020	2025	2030	2013-30 % change
UK	Direct costs (value of fuel & time wasted)	1,144	1,346	1,511	1,695	48
	Indirect costs (increased cost of doing business)	535	608	665	727	36
	Total	**1,679**	**1,954**	**2,176**	**2,422**	**44**
France	Direct costs (value of fuel & time wasted)	1,288	1,418	1,514	1,617	26
	Indirect costs (increased cost of doing business)	655	693	726	764	17
	Total	**1,943**	**2,111**	**2,241**	**2,381**	**23**
Germany	Direct costs (value of fuel & time wasted)	1,196	1,321	1,445	1,588	33
	Indirect costs (increased cost of doing business)	451	494	549	615	36
	Total	**1,646**	**1,816**	**1,994**	**2,203**	**34**
USA	Direct costs (value of fuel & time wasted)	888	1,030	1,129	1,217	37
	Indirect costs (increased cost of doing business)	419	465	493	515	23
	Total	**1,307**	**1,494**	**1,622**	**1,732**	**33**

Source: Cebr analysis

Table C4: City-level: average direct and indirect costs of congestion to individual car commuting households, NCU

City	Sector	2013	2020	2025	2030	2013-30 % change
London	Direct costs (value of fuel & time wasted)	1,976	2,329	2,666	2,979	51
	Indirect costs (increased cost of doing business)	789	862	946	1,023	30
	Total	**2,765**	**3,191**	**3,612**	**4,002**	**45**
Paris	Direct costs (value of fuel & time wasted)	1,955	2,282	2,615	2,985	53
	Indirect costs (increased cost of doing business)	797	910	1,036	1,174	47
	Total	**2,752**	**3,192**	**3,651**	**4,159**	**51**
Stuttgart	Direct costs (value of fuel & time wasted)	2,127	2,351	2,611	2,864	35
	Indirect costs (increased cost of doing business)	965	1,060	1,186	1,316	36
	Total	**3,092**	**3,411**	**3,797**	**4,180**	**35**
LA	Direct costs (value of fuel & time wasted)	3,448	4,270	4,882	5,336	55
	Indirect costs (increased cost of doing business)	2,282	2,709	3,017	3,219	41
	Total	**5,730**	**6,979**	**7,899**	**8,555**	**49**

Source: Cebr analysis

Table C5: City-level: average direct and indirect costs of congestion to individual car commuting households, Euros

City	Sector	2013	2020	2025	2030	2013-30 % change
London	Direct costs (value of fuel & time wasted)	2,327	2,742	3,139	3,507	51
	Indirect costs (increased cost of doing business)	929	1,015	1,115	1,204	30
	Total	**3,256**	**3,757**	**4,253**	**4,712**	**45**
Paris	Direct costs (value of fuel & time wasted)	1,955	2,282	2,615	2,985	53
	Indirect costs (increased cost of doing business)	797	910	1,036	1,174	47
	Total	**2,752**	**3,192**	**3,652**	**4,159**	**51**
Stuttgart	Direct costs (value of fuel & time wasted)	2,127	2,351	2,611	2,864	35
	Indirect costs (increased cost of doing business)	965	1,060	1,186	1,316	36
	Total	**3,092**	**3,411**	**3,797**	**4,180**	**35**
LA	Direct costs (value of fuel & time wasted)	2,596	3,214	3,675	4,017	55
	Indirect costs (increased cost of doing business)	1,718	2,040	2,271	2,424	41
	Total	**4,313**	**5,254**	**5,946**	**6,440**	**49**

Source: Cebr analysis

Table C6: Country-level: economy-wide direct and indirect costs to households, millions of NCU

Country	Sector	2013	2020	2025	2030	2013-30 % change
UK	Direct costs (value of fuel & time wasted)	8,086	10,142	11,676	13,385	66
	Indirect costs (increased cost of doing business)	5,040	6,115	6,986	7,974	58
	Total	**13,126**	**16,257**	**18,662**	**21,359**	**63**
France	Direct costs (value of fuel & time wasted)	9,697	11,126	12,033	12,917	33
	Indirect costs (increased cost of doing business)	7,249	8,031	8,670	9,358	29
	Total	**16,946**	**19,158**	**20,703**	**22,275**	**31**
Germany	Direct costs (value of fuel & time wasted)	16,324	18,236	19,520	20,854	28
	Indirect costs (increased cost of doing business)	8,881	9,874	10,929	12,148	37
	Total	**25,204**	**28,111**	**30,449**	**33,002**	**31**
USA	Direct costs (value of fuel & time wasted)	78,519	97,099	109,550	120,695	54
	Indirect costs (increased cost of doing business)	45,639	54,157	60,151	65,526	44
	Total	**124,158**	**151,257**	**169,701**	**186,221**	**50**

Source: Cebr analysis

Table C7: Country-level: economy-wide direct and indirect costs to households, millions of Euros

Country	Sector	2013	2020	2025	2030	2013-30 % change
UK	Direct costs (value of fuel & time wasted)	9,522	11,943	13,749	15,762	66
	Indirect costs (increased cost of doing business)	5,935	7,201	8,226	9,390	58
	Total	**15,457**	**19,144**	**21,976**	**25,152**	**63**
France	Direct costs (value of fuel & time wasted)	9,697	11,126	12,033	12,917	33
	Indirect costs (increased cost of doing business)	7,249	8,031	8,670	9,358	29
	Total	**16,946**	**19,158**	**20,703**	**22,275**	**31**
Germany	Direct costs (value of fuel & time wasted)	16,324	18,236	19,520	20,854	28
	Indirect costs (increased cost of doing business)	8,881	9,874	10,929	12,148	37
	Total	**25,204**	**28,111**	**30,449**	**33,002**	**31**
USA	Direct costs (value of fuel & time wasted)	59,111	73,098	82,471	90,861	54
	Indirect costs (increased cost of doing business)	34,358	40,770	45,283	49,329	44
	Total	**93,469**	**113,869**	**127,754**	**140,190**	**50**

Source: Cebr analysis

Table C8: Country-level: economy-wide direct and indirect cumulative costs to households, millions of NCU

Country	Sector	2013-2030 cumulative costs
UK	Direct costs (value of fuel & time wasted)	191,286
	Indirect costs (increased cost of doing business)	115,483
	Total	**306,771**
France	Direct costs (value of fuel & time wasted)	204,297
	Indirect costs (increased cost of doing business)	148,524
	Total	**352,824**
Germany	Direct costs (value of fuel & time wasted)	334,686
	Indirect costs (increased cost of doing business)	185,699
	Total	**520,393**
USA	Direct costs (value of fuel & time wasted)	1,803,225
	Indirect costs (increased cost of doing business)	1,003,564
	Total	**2,806,826**

Source: Cebr analysis

Table C9: Country-level: economy-wide direct and indirect cumulative costs to households, millions of Euros

Country	Sector	2013-2030 cumulative costs
UK	Direct costs (value of fuel & time wasted)	225,254
	Indirect costs (increased cost of doing business)	135,989
	Total	**361,246**
France	Direct costs (value of fuel & time wasted)	204,297
	Indirect costs (increased cost of doing business)	148,524
	Total	**352,824**
Germany	Direct costs (value of fuel & time wasted)	334,686
	Indirect costs (increased cost of doing business)	185,699
	Total	**520,393**
USA	Direct costs (value of fuel & time wasted)	1,357,498
	Indirect costs (increased cost of doing business)	755,500
	Total	**2,113,026**

Source: Cebr analysis

Table C10: City-level: economy-wide direct and indirect costs to households, millions of NCU

City	Sector	2013	2020	2025	2030	2013-30 % change
London	Direct costs (value of fuel & time wasted)	2,756	3,582	4,263	4,949	80
	Indirect costs (increased cost of doing business)	2,687	3,253	3,799	4,334	61
	Total	**5,442**	**6,834**	**8,063**	**9,283**	**71**
Paris	Direct costs (value of fuel & time wasted)	4,729	5,690	6,541	7,534	59
	Indirect costs (increased cost of doing business)	4,073	4,821	5,630	6,545	61
	Total	**8,802**	**10,511**	**12,171**	**14,079**	**60**
Stuttgart	Direct costs (value of fuel & time wasted)	1,546	1,722	1,879	2,028	31
	Indirect costs (increased cost of doing business)	840	935	1,051	1,166	39
	Total	**2,387**	**2,656**	**2,930**	**3,194**	**34**
LA	Direct costs (value of fuel & time wasted)	13,213	17,305	20,074	22,294	69
	Indirect costs (increased cost of doing business)	9,987	12,610	14,573	16,061	61
	Total	**23,200**	**29,915**	**34,647**	**38,355**	**65**

Source: Cebr analysis

Table C11: City-level: economy-wide direct and indirect costs to households, millions of Euros

City	Sector	2013	2020	2025	2030	2013-30 % change
London	Direct costs (value of fuel & time wasted)	3,245	4,128	5,020	5,828	80
	Indirect costs (increased cost of doing business)	3,164	3,830	4,474	5,103	61
	Total	**6,409**	**8,048**	**9,495**	**10,931**	**71**
Paris	Direct costs (value of fuel & time wasted)	4,729	5,690	6,541	7,534	59
	Indirect costs (increased cost of doing business)	4,073	4,821	5,630	6,545	61
	Total	**8,802**	**10,511**	**12,171**	**14,079**	**60**
Stuttgart	Direct costs (value of fuel & time wasted)	1,546	1,722	1,879	2,028	31
	Indirect costs (increased cost of doing business)	840	935	1,051	1,166	39
	Total	**2,387**	**2,656**	**2,930**	**3,194**	**34**
LA	Direct costs (value of fuel & time wasted)	9,947	13,028	15,112	16,783	69
	Indirect costs (increased cost of doing business)	7,518	9,493	10,971	12,091	61
	Total	**17,465**	**22,521**	**26,083**	**28,874**	**65**

Source: Cebr analysis

Table C12: City-level: economy-wide direct and indirect cumulative costs to households, millions of NCU

City	Sector	2013-30 Cumulative costs
London	Direct costs (value of fuel & time wasted)	68,464
	Indirect costs (increased cost of doing business)	62,136
	Total	**130,605**
Paris	Direct costs (value of fuel & time wasted)	108,157
	Indirect costs (increased cost of doing business)	92,827
	Total	**200,985**
Stuttgart	Direct costs (value of fuel & time wasted)	31,674
	Indirect costs (increased cost of doing business)	17,489
	Total	**49,153**
LA	Direct costs (value of fuel & time wasted)	323,044
	Indirect costs (increased cost of doing business)	236,139
	Total	**559,188**

Source: Cebr analysis

Table C13: City-level: economy-wide direct and indirect cumulative costs to households, millions of Euros

City	Sector	2013-30 Cumulative costs
London	Direct costs (value of fuel & time wasted)	80,621
	Indirect costs (increased cost of doing business)	73,170
	Total	**153,797**
Paris	Direct costs (value of fuel & time wasted)	108,157
	Indirect costs (increased cost of doing business)	92,827
	Total	**200,985**
Stuttgart	Direct costs (value of fuel & time wasted)	31,674
	Indirect costs (increased cost of doing business)	17,489
	Total	**49,153**
LA	Direct costs (value of fuel & time wasted)	243,193
	Indirect costs (increased cost of doing business)	177,769
	Total	**420,967**

Source: Cebr analysis

Table C14: equivalent emissions in monetary terms, millions of NCU

Country	2013	2030
UK	6.7	183
France	10.0	232
Germany	16.0	324
US	300.2	538
City	**2013**	**2030**
London	2.3	71.4
Paris	4.2	96.5
Stuttgart	1.4	27.8
Los Angeles	50.2	95.6

Source: Cebr analysis

Table C15: equivalent emissions in monetary terms, millions of Euros

Country	2013	2030
UK	7.9	215.5
France	10.5	232.1
Germany	16.4	323.7
US	226.0	405.2
City	**2013**	**2030**
London	2.7	84.1
Paris	4.2	96.5
Stuttgart	1.4	27.8
Los Angeles	37.8	71.2

Source: Cebr analysis

Table C16: equivalent cumulative emissions in monetary terms, millions of NCU

Country	2013 – 2030 cumulative costs
UK	934
France	1,209
Germany	1,732
US	7,574
City	**2013 – 2030 cumulative costs**
London	357
Paris	496
Stuttgart	147
Los Angeles	1,323

Source: Cebr analysis

Table C17: equivalent cumulative emissions in monetary terms, millions of Euros

Country	2013 – 2030 cumulative costs
UK	1,100
France	1,209
Germany	1,732
US	5,702
City	**2013 – 2030 cumulative costs**
London	420
Paris	496
Stuttgart	147
Los Angeles	996

Source: Cebr analysis