RAND EUROPE

Road traffic demand elasticities

A rapid evidence assessment

Fay Dunkerley, Charlene Rohr, Andrew Daly

For more information on this publication, visit www.rand.org/t/rr888

Published by the RAND Corporation, Santa Monica, Calif., and Cambridge, UK

RAND Europe is an independent, not-for-profit policy research organisation that aims to improve policy and decisionmaking in the public interest through research and analysis. RAND's publications do not necessarily reflect the opinions of its research clients and sponsors.

www.rand.org
www.rand.org/randeurope

Preface

This report has been produced for the UK Department for Transport. It presents findings of a rapid evidence assessment review of peer-reviewed papers, reports and other 'grey' literature to understand what estimates have been made of the elasticity of road traffic with respect to key economic and demographic factors – with particular reference to (i) population growth, (ii) income growth and (iii) fuel cost changes (but not restricted to these if other factors are found or considered to be important) and, where possible, to gain an understanding of how these relationships have changed over time.

While the primary audience for the document is the UK Department for Transport, it may be of wider interest for transport researchers and transport planners involved in transport demand forecasting and strategic planning.

RAND Europe is an independent not-for-profit policy research organisation that serves the public interest by improving policymaking and informing public debate. Our clients are European governments, institutions and companies with a need for rigorous, impartial, multidisciplinary analysis. This report has been peer-reviewed in accordance with RAND's quality assurance standards (see http://www.rand.org/about/standards/) and therefore may be represented as a RAND Europe product.

For more information about RAND Europe or this document, please contact:

Charlene Rohr

RAND Europe

Westbrook Centre

Milton Road

Cambridge CB4 1YG

United Kingdom

Tel. +44 (1223) 353 329

crohr@rand.org

Table of Contents

Tables

Summary

Aims of the review

The aim of this review was to gain a better understanding of the factors driving road transport demand for both passengers and freight by reviewing the literature on elasticity of road traffic demand, with a particular focus on key economic and demographic factors: namely, population growth, income growth and changes in fuel costs. The primary aim was to identify what elasticity estimates were available in the literature with respect to these variables and, where evidence exists, how these elasticity values have changed over time, if indeed they have changed at all.

A rapid evidence assessment of literature was employed

A rapid evidence assessment (REA) review aims to be a comprehensive, systematic and critical assessment of the scope and quality of available evidence from the literature. The REA focused on studies that used UK evidence, or relevant international studies, particularly those that used UK evidence alongside evidence from other countries. Only publications from 1990 or later were included. The review included both passenger and freight demand studies, as both are important in explaining growth in total traffic, but non-road modes were excluded.

The REA covered two main strands of literature: (i) articles published in peer-reviewed journals and conference proceedings; and (ii) 'grey' literature, which generally contains reports that have not been subject to a peer-review process. A longlist of 154 papers was obtained from the literature search, from which a shortlist of 23 studies was selected and agreed with the Department, based on additional criteria, for review. It was considered important that: a number of papers relating to fuel price, income and population were reviewed; the papers should provide long-run elasticity estimates; and they should represent recent academic thinking. Eight of the shortlisted papers covered freight transport.

Narrow ranges of fuel price elasticities are estimated for both passenger and freight transport

The range of estimated fuel price elasticity values reported in the studies in this review is quite small (-0.1 to -0.5), although a variety of data types and methodologies were used. Comparison between studies was made more difficult by the use of different measures of fuel price; in this report we differentiate between fuel price (in pence per litre or equivalent) and fuel cost (pence per kilometre or equivalent). In the long run, fuel efficiency effects will result in a smaller reduction in demand for a given price rise – the so-called rebound effect. This should be reflected in a lower fuel price elasticity. Otherwise, fuel price elasticities will be expected to vary by distance, area type and trip purpose.

Long-run income elasticities reflect a variety of calculation techniques

For passenger transport, reported income elasticity values are predominately in the range 0.5 to 1.4. The evidence indicates that car ownership has a strong, positive, indirect effect on the income elasticity of demand. Some studies, however, do not include this and only report the direct effect of income on demand. In addition, GDP, household income and expenditure are all used as proxies for income. These measures may have different impacts on demand (and elasticity measurement) due to the underlying factors they encompass.

For freight transport, elasticity estimates of economic activity are mainly in the range 0.5 to 1.5 for an aggregate commodity sector but there the evidence suggests a much greater variation between sectors. Economic activity is also measured by a number of variables: GDP, GFE and indices of industrial production.

There is limited evidence on changes over time

The evidence on changes in fuel price elasticities of car demand over time is limited. One multi-country study that includes the UK finds that fuel price elasticity was lower in 2000 to 2010 than in the previous decade. Other studies, limited to the US, suggest that a period of decreasing elasticity up to 2006 has been followed by an increase. However, fuel price elasticity is expected to increase with fuel price and decrease with increasing real income and these impacts could explain the changes observed. As noted earlier, fuel efficiency effects will also impact elasticity values (and should lead to decreases in values).

There is limited evidence that income elasticities of car demand have decreased over time; two studies find that GDP elasticity fell after the year 2000. This could be explained by saturation in car ownership levels.

For freight transport, the evidence appears to be mixed. For earlier periods, the estimates for freight demand elasticity with respect to economic activity are reasonably consistent, with the range 0.66 to 1.49, once functional form and the measure used for economic activity are accounted for. There is also some agreement on freight decoupling within the period 1997 to 2007 when freight demand grew at a lower rate than GDP.

The study has highlighted a number of important gaps in the evidence base

Much of the evidence for the UK on car traffic is rather old. This has implications for the use of elasticities in forecasting and strategic planning because of the mixed evidence on changes in elasticities over time. It therefore seems important that a study is undertaken using more recent data. In addition to fuel price and income, this should cover the impact of location (urban/rural) and demographic effects, for which few studies are available.

There is no information on population elasticities per se. However, a few studies include demographic explanatory variables such as urban density, population density, employment and age, from which it is possible to calculate a corresponding elasticity.

There has been little investigation of the factors that may be responsible for the decoupling of freight transport and economic activity seen in the 2000s. The relative size of different commodity sectors in terms of GDP, as well as supply chain efficiencies have been shown to play a role in one study. Although, the share of van use increased significantly over the same period, there appears to be no evidence on the impact of this on demand for freight transport. There are also too few data to provide an estimate of this elasticity for more recent periods.

Acknowledgements

We are grateful to Jeppe Rich (DTU), Gerard de Jong (Significance) and Maria Börjesson (KTH) for giving us the benefit of their expertise and taking the time to respond to our queries concerning the use of elasticity estimates in transport modelling and appraisal in Denmark, the Netherlands and Sweden.

We are also grateful to the RAND Europe Quality Assurance reviewers, Sunil Patil and Greg Erhardt, for their useful comments and insights.

Lastly, we are grateful for the valuable advice from the Department for Transport, who helped improve the quality of the final report.

Abbreviations

AT	Abbreviation Text
EGBDF	Every Good Boy Does Fine
XYZ	Xavier's Yellow Zylophone
DfT	Department for Transport
FES	Family Expenditure Survey
GDP	Gross Domestic Product
GVA	Gross Value Added
GFE	Gross Final Expenditure
LMS	Landelijk Model Systeem
OECD	Organisation for Economic Cooperation and Development
REA	Rapid Evidence Assessment
RP	Revealed Preference
RTI	Road Transport Intensity
SP	Stated Preference
tkm	tonne-kilometres
VFR	Visiting Friends and Relatives
vkm	vehicle kilometres
VMT	Vehicle Miles Travelled
wrt	with respect to
WS	Workstream(s)

1. Introduction

Background

DfT is interested in the factors that drive road transport demand, partly from the perspective of ensuring that their National Transport Model (NTM) forecasts are consistent with the latest literature and evidence. At a more general level, understanding the implications of projected changes in economic and demographic trends on future traffic levels is also important in informing strategic thinking within the Department. The aim of the review is therefore to understand what estimates have been made of the elasticity of road traffic demand with respect to key economic and demographic factors – with particular reference to (i) population growth, (ii) income growth and (iii) fuel cost changes (but not restricted to these if other factors are found or considered to be important) and, where possible, to gain an understanding of how these relationships have changed over time.

To do this, we aim to answer the following research questions:

1. What estimates are there of the elasticity of road traffic to population growth, income growth, fuel cost changes, and any other factors found in the literature to be important, such as employment, car ownership and location structure?[1]
2. Where evidence exists, how have these elasticity values changed over time, if indeed they have changed at all?

A rapid evidence assessment methodology is applied to find and review the evidence on these topics. This is described in the next section.

[1] By location structure we mean population and employment growth in specific locations such as cities, particularly London, which may have different implications for traffic than population and employment growth in suburban or rural areas.

2. Rapid Evidence Assessment Methodology

2.1. Search methodology

A rapid evidence assessment (REA) review aims to be a comprehensive, systematic and critical assessment of the scope and quality of available published evidence. REAs follow the same structure and are similarly replicable and transparent as systematic literature reviews, yet have the advantage of being less resource intensive. This is mainly achieved by restricting the search in terms of where the research was published, in which language it was conducted and during which time period it took place. For the purposes of this study, as the main requirement of DfT was for information relevant to road transport modelling and forecasting[2] in the UK this meant that the literature search could be restricted in several ways. Firstly, only English language studies from developed countries were considered, with a focus on evidence from the UK. Secondly, only publications from 1990 or later were included. This time period was considered sufficient to cover all major contributions to the literature in this field and capture studies that would provide evidence as to how road transport demand elasticities might be changing over time, while excluding elasticities derived in studies based on older data that may no longer be relevant in today's road transport setting. Finally, the review covered both passenger and freight demand studies, as both are important in explaining growth in total traffic[3] but non-road modes were excluded.

The REA covered two main strands of literature: (i) articles published in peer-reviewed journals and conference proceedings; and (ii) 'grey' literature, which generally contains reports that have not been subject to a peer-review process. The primary database for the search of journal papers and conference proceedings was the Transportation Research International Documentation (TRID) database, supplemented by Scopus and Web of Science.[4] These databases were searched by a trained librarian, using

[2] As noted in Section 1, DfT are also interested in forecasting from a strategic perspective, to understand the implications of trends in the factors driving demand on traffic levels, as well as the formal modelling sense.

[3] In 2013, cars were responsible for approximately 79 per cent of road vehicle miles travelled, the remainder being LGV (14 per cent), HGVs (5 per cent), buses (<1 per cent) and motorcycles (<1 per cent). Source: DfT Annual Road Traffic Estimates: GB 2013.

[4] The TRID database integrates the content of two major databases, the Organisation for Economic Co-operation and Development's (OECD's) Joint Transport Research Centre's International Transport Research Documentation (ITRD) Database and the US Transportation Research Board's (TRB's) Transportation Research Information Services (TRIS) Database. The TRID indexes over 900,000 records of transportation research worldwide.

Scopus is a large abstract and citation-based database of peer-reviewed literature with over 53 million records in the fields of science, technology, medicine, social sciences, arts and humanities.

strategies based on specific combinations of search terms, developed in conjunction with DfT. Abstracts for the resulting papers and reports were then screened by the review team to obtain a 'longlist' of relevant papers. There was inevitably some overlap in the types of reports and articles contained in the databases, which contained published peer-reviewed journal articles, reports and serials. The approach for unpublished studies was then to carry out a web search and contact experts and practitioners, once the database searches had been completed. Full details of the search methodology are found in Appendix A.

2.2. Selection of papers to review

Review of the databases, particularly abstracts of papers and reports within the databases, identified 154 studies from the published and grey literature, covering passenger and freight road transport relevant to the UK and internationally. From this, a shortlist was selected and agreed with DfT. A number of additional criteria were used to obtain the final selection:

- The three main drivers of road transport demand, for which DfT are interested in obtaining elasticities, are fuel price, income and population. It was agreed that the review should aim to have a reasonable coverage of each of these topic areas.
- The papers should provide elasticity estimates, so that, as far as possible, these could be compared between studies. Long run estimates were of greatest interest.
- Recent studies that represented current academic thinking in these areas were included.
- Studies that either tackled the issue of changes in elasticities over time directly or provided estimates for earlier and later time periods were judged to be important.
- The studies should provide elasticity estimates directly relevant to the UK.

The resulting shortlist consisted of 23 papers. Of these, 15 studies looked at passenger transport, five freight transport and three at both passenger and freight. There were 15 journal articles, four discussion papers or conference proceedings and four reports or unpublished material. Table 1 provides a summary of the shortlist. The full list is presented in the references.

Table 1: Summary information on the shortlisted studies for review

	Passenger	Freight
Paper type	12 journal, 3 conference, 3 reports	5 journal, 1 conference, 2 reports
Coverage	7 UK	4 UK
Elasticity	11 fuel price, 8 income, 4 population related	4 economic activity, 3 fuel price
Publication date	1998 to 2014	2004 to 2014

Web of Science is a citation index. The database covers 5,294 publications in 55 disciplines as well as 160,000 conference proceedings.

For each of the shortlisted papers, all information relevant to the review, including an assessment of quality of the material, was entered in a summary extraction table, recording information on elasticity values, geographical coverage, the basis and date of the evidence, sample sizes, identified segmentation as well as a quality assessment of the evidence. This was done separately for passenger and freight transport and these tables form the basis for the discussions in the following section.[5] Finally, in reviewing the papers, we assessed, as far as possible, the robustness and comparability of the different approaches and estimates with a view to recommending a reasonable range of elasticity values that could be used, based on the existing literature.

2.3. General findings regarding car demand elasticities

The main information from the review of papers on car demand elasticities has been further summarised in Table 2.[6] There are a number of general points that can be raised before each of the three main drivers is discussed separately.

Definition of demand

Firstly, throughout this report, the units of car demand are understood to be vehicle kilometres (usually annual) unless specified otherwise. While some studies also present elasticities of car trips, fuel consumption, car ownership or car use (km/vehicle), these are only discussed where they are relevant to the calculation of vehicle kilometre elasticities.

Coverage of elasticities

We found that several papers included both fuel price and income elasticities, even if only one of these was the real focus of the particular study. In order to understand the response of demand to population effects, more recent literature has concentrated on demographic explanatory factors such as urban density or employment. Moreover, some of these are not reported as elasticities, but rather as trip rates, etc. that vary by different population segments (e.g. those with different socioeconomic group or income, age, gender, etc.). These are then applied to future populations. Experts confirmed that this is also how population effects are accounted for in Sweden, Denmark and The Netherlands.

Date of elasticity estimates

Of the 11 papers on fuel price elasticities for example, five of the papers reviewed were more than ten years old. This was mainly to capture the two previous literature reviews of road transport demand elasticities in the UK commissioned by DfT (Goodwin et al. (2004), Graham and Glaister (2004)) and related literature. However, even some of the more recent papers (e.g. Dargay (2007) or Karathadorou et al. (2009)) use relatively old data, e.g. from 1995 or earlier.

---

[5] These tables are available from the authors on request as a separate spreadsheet document.

[6] Note that Giuliano and Narayan (2003), Jahanshahi et al. (2009) and Kenworthy (2013) do not appear in this table as they do not present elasticities and the relevant material from Litman (2012) is covered elsewhere.

Changes over time

There were two studies that directly addressed changes in elasticities over time. While the other papers provide elasticity estimates using data from different time periods, making inferences about how relationships have changed over time is not possible from this, since there were differences in approach or type of model or data that would make direct comparison difficult.

Transferability of findings

Seven of the passenger studies reviewed provided elasticity estimates based on data for the UK. Although Espey (1997) rejected the hypothesis of common elasticities across countries, few papers discuss the issue of transferability. Van Dender and Clever (2013) suggest that fuel price may not be a useful forecaster of transport demand as it is not sensitive enough to all the possible explanatory factors of car travel, which are increasingly heterogeneous.[7] In their study comparing trip rates in the US and GB, Giuliano and Narayan (2003) also note that the household income effect is not the same in the two countries and the country specific constant that captures differences in fuel price and transport supply is strongly significant. This evidence suggests that where fuel price and income elasticities alone are used to explain road transport demand, they are sensitive to country specific effects that are not well understood. This should be borne in mind when using estimates based on data for different countries or groups of countries.

Analytical approaches and functional forms

The papers in this review can be divided into three broad categories:

- Literature review papers that both report elasticities from other empirical or modelling studies directly and also *combine* these to provide aggregate values. Meta-analyses, from which implied elasticities can be generated, are also included in this category.
- Empirical studies based on observations.
- Transport models, from which elasticities are obtained by changing income and price levels.

Empirical studies use models with different functional forms to derive elasticities from observations (e.g. double log, log-linear). In their review Goodwin et al. (2004) conclude that there is no strong consistent pattern of effect of model form. Dargay (2007) obtains similar values with various functional forms, while Espey (1997) finds that the most commonly used double log form cannot be rejected compared with other specifications. The advantage of this form is that the resulting elasticity is a constant. The variables used to explain transport demand (model specification) also differ between studies. A long-run elasticity estimate can be obtained from a dynamic model specification using time series data. Car ownership is also considered to be an important, endogenous factor in determining transport demand, at least in the long run. However, some empirical approaches include lagged demand effects but omit car ownership (Van Dender and Clever (2013)) and vice versa (Bradburn and Hyman (2002). Moreover, transport models (Rohr et al. (2013), de Jong and Gunn (2001)) generally do not adjust for vehicle stock in elasticity

[7] This conclusion is also echoed in the OECD ‘Long Run Trends in Car Use’, which is reviewed as part of Rohr and Fox (forthcoming).

calculations for model validation but allow mode and destination choice to change.[8] The effect of the different model specifications is difficult to assess without detailed analysis. However, lagged terms and car ownership effects both increase the magnitude of the elasticity compared with short run values.

In Table 2, studies are also classified by data type: aggregate or disaggregate. Aggregate data reflect average values across the population and disaggregate values are based on analysis at the individual (or household) level. Moreover, transport models can be developed using disaggregate stated preference (SP) or cross sectional revealed preference (RP) data, while aggregate empirical datasets are generally longitudinal but may rely on constructed variables.

[8] Vehicle stock changes may be incorporated in the ultimate model implementation, but in validating mode and destination choice models, such effects are usually not incorporated.

Table 2: Summary of car demand elasticity data as a function of fuel price/cost, income and population for shortlisted papers[9]

Paper	Geography	Data period	Data type	Fuel price or cost		Income measure	Population	Comments
Bradburn and Hyman 2002	UK	1950–2000	aggregate	-0.13 (price) -0.3 (km cost)		1.14		Income effect largely due to changes in vehicle stock.
Dargay 2007	GB	1970–1995 (FES)	aggregate	-0.14 (semi-log) -0.11 to -0.18 (various functional forms)		0.86 : 1.09 (semi-log: first value is for income reductions and the second for income increases)		Fuel cost elasticity Considers asymmetry in income elasticity values, which is not found to be important for transport demand in contrast to car ownership. Household expenditure proxy for income.
Dargay 2010	GB	1995–2006	Income elasticities derived from aggregate/ time series analysis; fuel price/cost elasticities derived from disaggregate data collected for the study	Elasticity by journey type and distance > 150 miles: business -0.34 commute -0.65 holiday -0.79 leisure -0.61 VFR -0.60	Elasticity by journey type and distance <150 miles: business -0.34 commute -0.62 holiday -0.72 leisure -0.41 VFR -0.49	0.69	Employment: 0.5 (business), 0.6 (commute) Elasticity of leisure and VFR trips with respect to (wrt) proportion over 60 years is negative.	Long-distance journeys only (> 50 miles). Demand is in passenger miles and motor fuel price index 'collated from the Office of National

9 Where standard errors or t-statistics for elasticities are provided, these have been reproduced in Table 2

Paper	Geography	Data period	Data type	Fuel price or cost		Income measure	Population	Comments
							Proportion of single adult households small negative impact on leisure travel and small positive impact on VFR.	Statistics and the Department for Transport'. Note: VFR denotes Visiting Friends and Relatives.
De Jong and Gunn (TRACE) 2001	EU	1985–1998 (assumed)	aggregate (from review) and disaggregate (from models?)	Literature review (by journey type): -0.23 commute -0.20 home business -0.26 non-home business -0.41 education -0.29 other **-0.26** total	From Dutch mode (by journey type) -0.22 commute -0.25 home business -0.16 non-home business -0.35 education -0.65 other **-0.36** total	N/A		Fuel price elasticities at constant fuel efficiency. No information on whether car ownership effects included. Brussels more indicative of metropolitan area (-0.31 commute).
Espey 1997	8 OECD countries including UK	1975–1990	aggregate	UK: -0.1 (t-statistic -2.89)		UK: 0.21 (t-statistic 1.77)	population density: -ve, significant urbanisation: +ve, significant	Fuel cost elasticities, population density and % population in urban areas are (linear) explanatory variables, so elasticities could be constructed (but they are not).
Goodwin et al. 2004	International (29 studies	1929–1991 (lit review)	various	-0.3 (0.22) Based on 22 static studies		0.49 (0.42)15 static studies 0.73 (0.48) 7		Includes studies using household income and GDP

Paper	Geography	Data period	Data type	Fuel price or cost	Income measure	Population	Comments
	from UK)			-0.29 from 3 dynamic studies	dynamic studies		and models with various functional forms.
Graham and Glaister 2004	International Including UK	up to 2000 (lit review)	TRACE (disaggregate model) + other	-0.26 (TRACE) -0.31 (Goodwin 1992)		0.73 from Hanly et al. 2002	Study not clear about units (see also TRACE).
Hymel et al. 2010	US	1966–2004	State level data	-0.246 (0.024) evaluated at 1966–2004 mean levels of interacting variables -0.135 (0.035) evaluated at 2004 levels of interacting variables	0.5	% share in metropolitan area: -ve, significant State population/adult: +ve, significant	Fuel cost elasticities. These are results without congestion. VMT wrt per mile fuel cost. Direct income elasticity reported but not the focus of the study.
Karathodorou et al. 2009	42 cities in US, Canada, Europe (including UK) and Asia	1995	aggregate	-0.2 (0.09)	0.163 (0.10))	urban density: -0.22 (0.09)	Costs appear to be per unit of energy. Currency units used also not clear. Based on cross sectional data.
Rohr et al. 2013	GB	2002–2006 (NTS)	disaggregate model	-0.23 commute -0.10 business -0.12 other	0.55 commute 0.63 business 0.27 other		Long-distance journeys only (>50 miles). Fuel cost elasticities. RP data but elasticities do not incorporate car ownership effects.

Paper	Geography	Data period	Data type	Fuel price or cost	Income measure	Population	Comments
							Largely cross sectional data.
SDG 2014	UK	1991–2011	aggregate	N/A	Motorway 0.99 (1993–2000) 0.55 (2000–2007) 0.04 (2007–2010) Rural major 0.65 (1993–2000) 0.58 (2000–2007) -0.07 (2007–2010)		Slide pack only available for review. Insufficient information on data and calculation methodology.
Van Dender and Clever 2013	5 OECD countries including UK	1990–2010	aggregate	M1 -0.37 M2 -0.46(before 2000) -0.19 (after 2000)	M1 1.43 (before break) 1.38 (after break) M2 1.31 (before 2000) 0.38 (after 2000)	% urban population significant, negative effect.	M1: Additional model (with country specific time dummy). M2: Structural break model Fuel price index used. No population elasticities.
Wang and Chen 2014	US	2009 (NTS)	aggregate	<$25000 -0.237* <$50000 -0.125 <$75000 -0.094 <$100000 -0.406* ≥$100000 -0.345*			Fuel price elasticity by income quintile. RP data but no car ownership or lag. *Variables significant at 0.05

Paper	Geography	Data period	Data type	Fuel price or cost		Income measure	Population	Comments
								level.
Wardman 2014	UK	1968–2010	various	Urban (by journey type) -0.21 commute -0.12 business -0.23 leisure	Inter-urban (by journey type) -0.36 commute -0.21 business -0.41 leisure			Only 5% of studies were for car, so focus is on public transport and rail. Assume fuel cost elasticities (wrt /km costs). These are implied elasticities from meta-analysis. Reported elasticities from Table 1 not reproduced here.

2.3.1. Fuel Price Elasticities

Overall, the fuel price and cost elasticities obtained from the studies we reviewed were mostly in the range -0.1 to -0.5, with the largest values (up to -0.79) for long distance holiday travel.

In the wider literature, fuel price elasticities refer to fuel costs measured in two ways: one calculated per unit of consumption (e.g. £/litre); and one calculated per unit of distance travelled (e.g. £/km). For the purposes of this study, we will designate the former a 'fuel price elasticity' (£/l) and the latter a 'fuel cost elasticity' (£/km). Where elasticities are extracted from models, fuel cost is the natural choice (e.g. Rohr et al. (2013); Dargay (2010)), whereas in empirical work, fuel costs have to be constructed from fuel prices alongside estimates of fuel efficiency (e.g. Bradburn and Hyman (2002); Dargay (2007)). Other authors (Van Dender and Clever (2013); Espey (1997)) use fuel prices directly to determine elasticities. In de Jong and Gunn (2001), fuel price elasticities are presented at constant fuel efficiency, so that fuel price and fuel cost elasticity are effectively the same; these results are from both a literature review and a modelling exercise (TRACE). Graham and Glaister (2004) also present the TRACE result, while the fuel price elasticity in Goodwin et al. (2004) is based on 22 studies from a large international survey.

The relationship between fuel price and fuel cost is determined by fuel efficiency. If an increase in fuel price leads to greater fuel efficiency through car usage[10] or technological advances, the reduction in car travel for a given increase in fuel price may be lower than expected as the (per km) fuel cost is lower. This is referred to as the 'rebound effect'[11] and should result in a lower fuel price elasticity in the long run. Bradburn and Hyman (2002) do report this but Goodwin et al. (2004) indicate in their analysis that there is some weak evidence that fuel cost elasticities are smaller than fuel price elasticities. Wang and Chen (2014) calculate a direct fuel efficiency effect but this is only significant for the lowest income group. In Table 2, the fuel cost elasticity values are generally smaller than the fuel price elasticities but, again, this evidence is very weak, given the range of type of study, segmentation, geography, etc.

Although there is substantial evidence on fuel price elasticities for Great Britain,[12] it is somewhat dated. Most of the data used in empirical work predates 2000 (Espey (1997), Bradburn and Hyman (2002), Dargay (2007), Karathadorou et al. (2009)) and the literature reviews are also based on earlier studies. The Wardman (2014) work on fuel price elasticities is recent; however, car studies account for a small proportion of the studies in the meta-analysis (5 per cent of the studies are focused on car). Although the study by Van Dender and Clever (2013) uses data from the UK, alongside data from other countries, a country-specific elasticity is not calculated.

There is some evidence in the literature on changes in fuel price elasticity over time. The studies that do attempt to quantify this generally find that it has been declining, but remains important. Only one study

[10] e.g. driver behaviour such as speed choice, overtaking, etc.

[11] See e.g. Hymel et al. (2010) for a discussion.

[12] Note that while we are specific in the tables about geographical coverage, for simplicity, GB and UK are used somewhat interchangeably in the text.

explicitly addresses the change in the long run fuel price elasticity of car demand. Using a model with a structural break for five OECD countries, Van Dender and Clever (2013) found a smaller fuel price elasticity for 2000 to 2010 than for the previous decade. The reported elasticities for car travel in Wardman (2014), showed a decrease over each decade from 1980 to 2010. Hymel et al. (2010) calculate fuel cost elasticities using data from 1966 to 2004. They find that elasticity declines over the period and attribute most of this to an increase in real incomes, which they incorporate in the model by interacting fuel cost and income terms. From the grey literature, Litman (2012) refers to various North American studies (particularly Congressional Budget Office 2008) to show that fuel price elasticities declined from 1980 to 2005 and to Litman (2012a) and Williams-Derry (2010) for evidence that since 2006 they are increasing. This could be attributed to increasing fuel price levels, as fuel price elasticity is expected to rise and fall in line with real price changes, as well as decrease with increasing real incomes. In the US, fuel prices rose much more rapidly than GDP from 2005 – a trend not seen in the UK, however.

Wang and Chen (2014) study the effect of income on fuel price elasticities in more detail using cross-sectional data. They calculate an elasticity for each income quintile. The values for the lowest and two highest quintiles are significant and appear to show that fuel price elasticities increase with increasing income. However, the values for the 2nd and 3rd quintiles are not significant, so the results are not conclusive. Although it would appear somewhat counter-intuitive that higher income groups are more sensitive to fuel price changes, the argument put forward by the authors is that those on higher incomes make more discretionary trips and also have more substitution possibilities than other income groups.

Only one paper in the review focuses on the drivers of car demand in urban areas (Karathodorou et al. (2009)). The fuel elasticity of -0.2 they obtain is based on cross-sectional data from 42 metropolitan areas worldwide. For the UK, Wardman (2014) distinguishes urban and inter-urban trips, although this approach is perhaps most suited to rail journeys, which form the majority of the studies in his meta-analysis, while both Rohr et al. (2013) and Dargay (2010) present elasticities for long distance trips only. As is shown in Table 2, the urban commute and leisure values obtained by Wardman (2014) are comparable with the Karathodorou et al. study. The inter-urban values, on the other hand, are larger than the long distance model values of Rohr et al. (2013) but smaller than those calculated by Dargay (2010). One possible explanation for this is the type of data used in the analysis. The long distance model developed by Rohr et al. (2013) is based on cross-sectional revealed preference (RP) data, while the Wardman (2014) meta-analysis may involve a number of different data types, including stated preference (SP) data and/or time series. Cross-sectional values are usually smaller than values obtained from time series (Daly and Fox (2012)) and estimates from SP data, which involve responses to hypothetical questions on travel cost, can be expected to be larger than estimates from RP data.[13] The elasticities from Dargay (2010) are based on transfer costs, which the authors acknowledge may lead to questionable absolute values.

Dargay (2010), Rohr et al. (2013) and Wardman (2014) also segment fuel cost elasticities by trip purpose, as does the Dutch National Model, which was an important component of the TRACE project (de Jong and Gunn (2001)). While not directly comparable, these studies indicate that fuel price (cost)

[13] The meta-analysis in Wardman (2014) contains an SP dummy variable with positive coefficient.

elasticities depend on the reason for travel, with fuel cost elasticities being lower for business travel, than for commute or leisure travel.

Based on the evidence reviewed in this study, it is reasonable to assume the fuel cost (price) elasticity falls within a fairly narrow range of -0.1 to -0.5, but will vary by distance, area type, trip purpose etc. However, most of the UK evidence is derived from data more than ten years old, whereas other international studies suggest more recent changes in elasticities.

Putting these in a wider European context, according to the experts we consulted, no official elasticity values are used for model validation or transport analysis in Denmark, the Netherlands or Sweden (where detailed national models tend to be used). In Sweden, elasticities from the National Model (Sampers) of -0.3 for regional travel and -0.14 for long distance travel are commonly applied and fuel cost elasticities for car-km implied by the Dutch National Model (LMS/NRM) are expected to be in the range -0.1 to -0.2.[14]

2.3.2. Income elasticities

In contrast to fuel price elasticities, a much broader range of values for income elasticity of car demand are reported in the literature we surveyed. Almost all the evidence suggests that income elasticity is greater than zero (SDG (2014) is a partial exception here) with some studies reporting values as high as 1.4. However, there may be a broad consensus, once all the differences in calculation methodologies are taken into account. These are discussed below.

Changes in income can affect car demand (total vehicle-km driven) directly through changes in the number of trips taken or distance travelled by an individual. Total car demand also depends on the number of vehicles on the roads and car stock is responsive to income, mainly through changes in car ownership levels. The impact of car ownership on overall income elasticity seems to be important, and is taken into account differently in different models. According to Bradburn and Hyman (2002), for example, the indirect impact of GDP on car traffic from its impact on car ownership is much larger than the direct effect. While many empirical studies control for car ownership, if the indirect car ownership income effect is not in the reported income elasticity value,[15] the elasticities will underestimate the full effect of income on car demand. For example, although Espey (1997) controls for vehicle stock in her regression equation for demand, obtaining a coefficient of 1.11,[16] she only reports a direct demand elasticity of 0.2 for the UK. Van Dender and Clever (2013) on the other hand, do not control for car

[14] The Danish National Transport Model is expected to generate a number of elasticities but these are not yet published.

[15] It is difficult to make a judgement on the size of the car ownership effect. Although some authors report the income elasticity of car ownership (see appendices), this cannot be simply added to the direct income effect unless the direct effect of car ownership on demand has also been calculated, as the two terms need to be multiplied. So, two simultaneous equations are effectively required. Furthermore, Dargay (2007) provides evidence that the income elasticity of car ownership is asymmetric, so that there is a more elastic response to an increase in income than to a decrease, at least for household income.

[16] The effect of income on vehicle stock is not calculated, however, and the indirect contribution of vehicle stock to the income elasticity of demand cannot therefore be imputed.

ownership, so that the reported income elasticities, which are generally greater than one, contain both direct and indirect effects.

An interesting question arises from the role of car ownership in income elasticity. If car ownership rates are nearing saturation, does this mean that we would expect GDP/income elasticities to fall? Two studies consider changes over time directly (SDG (2014); Van Dender and Clever (2013)) and both find a decrease in income elasticity after the year 2000. SDG find a further fall for the period 2007–2010, although this is based on limited data. These authors find similar effects pertain on motorways and major rural roads but find that traffic on major urban roads has remained relatively unchanged. The explanation put forward is that rising income has not affected traffic in urban areas because these have already reached capacity. While it would be possible to include congestion effects, although none of the studies reviewed do this in the context of income elasticity, there may be other explanatory factors that cannot be accounted for through income elasticity, such as changes in company car ownership, increasing immigration levels in urban areas, etc. These are discussed in more detail in RAND Report 'Evidence Review of Car Traffic Levels: A Rapid Evidence Assessment', which is being produced in parallel to this report (Rohr and Fox, forthcoming). That report reviews the evidence on the recent levelling off of total miles driven in the UK and the factors that may contribute to this.

In some studies income elasticity is calculated from GDP (Bradburn and Hyman (2002), Van Dender and Clever (2013), Espey (1997), SDG (2014)) and in others household income (Rohr et al. (2013), Dargay (2010)) or household expenditure (Dargay (2007)). It appears that income elasticities based on household incomes are generally smaller than those obtained from GDP; this is not unreasonable as GDP, as a measure of national income, encompasses a wider range of factors than average household income, while numbers of households change, separately from the total population. However, it should be noted that studies using GDP and household income may also differ in terms of data type and functional form that may also have an impact on the calculated elasticity values.

Again, in contrast to studies on fuel price elasticities, there is little discussion of the effect of income on car demand by journey type or distance. Only Rohr et al. (2013) consider elasticity by trip purpose (commute, business, VFR) in their model of long distance passenger travel. Their results are similar in magnitude to those of the SDG study (2014) over a similar period and indicate that VFR journeys are the most inelastic and business trips the most elastic.

Based on the discussions above, the data presented in Table 2 appear compatible with long-run elasticities in the range 0.5 to 1.4, which take adjustments in car ownership into account. There is insufficient evidence from the UK to support using a lower value, although recent studies indicate that income elasticity may have decreased.

Finally, we note here that Bastian and Börjesson (2014) use an elasticity estimate of 0.5,[17] taken from Goodwin et al. (2004) in their paper explaining the peak car phenomenon in Sweden.[18] There does not appear to be evidence of official use of other income elasticity values.

[17] This is equivalent to the 0.49 reported in Table 2, based on static studies only.

[18] This paper is reviewed in Rohr and Fox (forthcoming).

2.3.3. Population Elasticities

There is no information in the literature reviewed on population elasticities in the formal sense. However, a number of studies include demographic explanatory variables such as urban density, population density, employment and age, to explain transport demand. For some of these, an elasticity is reported (or could be provided with additional data and analysis).

Karathodorou et al. (2009) calculate an elasticity of metropolitan car demand with respect to urban density of -0.229, which is statistically significant. Urban population (as a proportion of total population) has also been found to have a negative influence by other authors (Hymel et al. (2010), Van Dender and Clever (2013)). Espey 1997, on the other hand, finds that the percentage of the population living in urban areas has a significant, positive effect on car transport demand and that population density has a significant negative one. The employment rate of the population and their age are also found to be important for different journey purposes in one study. Dargay (2010) provides employment elasticities of demand for long-distance car travel of 0.5 for business travellers and 0.6 for commuters. Further, the elasticity of leisure and visiting friends and relatives (VFR) trips with respect to the proportion over 60 years is negative.

Litman (2012) also notes that 'Per capita vehicle ownership and travel tend to be higher in rural and automobile-dependent suburban areas, while walking, cycling and public transit travel tend to be higher in urban areas', although these are not quantified.

There are two further studies of relevance in this area, but which focus on trip rates and cover all modes rather than road alone. Giuliano and Narayan (2003) find that population density has a different effect on trip rates in the US and GB, in terms of explanatory power, but that age has a similar effect. The study by Jahanshahi et al. (2009) also differentiates trip rates by trip purpose and investigates some quite complex interaction of variables, some of which are categorical. For example, area type is used in preference to population density. Their models may provide more evidence on how total trip rates or travel vary with population segments but this would require a more detailed examination of the full report and, preferably, runs of the model under different scenarios. One interesting finding from their work is that socio-economic class and income are not highly correlated and, in general, including both improves the model fit. Evidence from the experts we consulted indicates that a similar approach is being applied by institutions in other European countries.

2.4. Freight elasticities

There were far fewer studies on freight elasticities compared with passenger road transport. The two literature reviews (Goodwin et al. (2004); Graham and Glaister (2004)) presented in Table 2 above covered freight as well as passenger transport.[19] The literature search identified six further studies that were published in the last five years and concentrated on economic activity and fuel price to explain

[19] However, Goodwin et al. did not provide any elasticity estimates for freight and this paper is not included in Table 3.

freight transport demand. In all cases the studies focus on HGV transport. A summary of the results is presented in Table 3.

2.4.1. Fuel price elasticity

The sensitivity of freight transport demand to price is the focus of two literature reviews. Graham and Glaister (2004) calculate an elasticity of -1.07 (standard error 0.84) using 143 elasticity estimates from seven international papers that mainly used data from before 1988. The review by de Jong et al. (2010) expands on the literature of Graham and Glaister (2004), to include several more recent studies; two of these are based on UK data. They are also more specific in terms of the units of both the freight demand and fuel price. Assuming, among other things, that 25 per cent of vehicle-km costs are due to fuel cost, the authors derive consistent 'best-guess' estimates of long run demand elasticities in both tonne-km and vehicle-km with respect to both fuel price and vehicle-km cost.[20] Their calculations allow for effects of fuel efficiency, transport efficiency and modal shift in addition to a direct demand effect. Improving transport efficiency (e.g. vehicle routing, shipment size) and changing transport volumes by shifting mode or changing production technology, for example, are found to have a greater impact on costs, so that demand is more elastic with respect to the km cost than to fuel price. These values are shown in Table 3. Comparing these results with two other empirical studies in our review, Agnolucci and Bonilla (2009) and Rizet and Bougerra (2013),[21] the elasticity estimates are reasonably consistent, in the range 0.1 to -0.2 for the fuel price elasticity of demand in tonne-km and in the range -0.25 to -0.4 for the fuel price elasticity of demand in vehicle-km.[22] Indeed these values are also in line with the range of elasticity estimates for the fuel price elasticity of passenger demand. Although based on French data, the Rizet and Bougerra (2013) study is interesting for two reasons; firstly, it finds that the fuel price effect accounts for almost 50 per cent of vehicle-km costs; and secondly, they obtain a much better fit to the data when the elasticity explicitly increases as a function of time, resulting in a corresponding long run average value of -0.33.

[20] The authors also provide tonne-km cost demand elasticities.

[21] Note, this study is in French.

[22] We should also note here that the overall long run estimates of de Jong et al. (2010) are much larger than the elasticity estimates of the two cross-sectional UK studies they include in their review (but not reviewed by us). Yin et al. (2005) find a tonne-km price elasticity of demand (in tonne-km) of -0.2 using 2001 data and Maurer et al. (2008) use 1998 data obtain a vehicle-km price elasticity of demand (in vkm) of -014.

Table 3: Summary of freight demand elasticities for shortlisted papers

Paper	Geography	Date of data	Type of data	Fuel price /cost		GDP or other income measure	Comments
Alises et al. 2014	UK, Spain	1999–2007	11 commodity sectors including service (aggregate).	not included in model			Considers changes in RTI=freight tkm/GDP. Finds change of 57% from 1999–2007 but most of this before 2003.
Agnolucci and Bonilla 2009	UK	1957–2003	one aggregate sector	-0.2		0.66	Fuel price used (output from macro-economic model).
de Jong et al. 2010	International	Studies pre-2010	literature review	Fuel price -0.1 -0.2 (veh-km)	Fuel km cost -0.6 -0.9 (veh-km)		Consistent set of best guess estimates derived by authors. Allow for change in mode, fuel efficiency, transport efficiency.
Graham and Glaister (2004)	Mainly US, Canada, Belgium.	Mostly before 1988	literature review. 143 elasticity estimates from 7 papers	-1.07 (0.84)		Not included	Based on 143 elasticity estimates. Units of demand and price are not clear.
Rizet and Bougerra (2013)	France	1998–2010	aggregate	lag vkm: -0.3 time trend: -0.25 (1998) to -0.40 (2010) with LR average -0.33.		Lag vkm: 1.3 Time trend: 2.89	Demand in vehicle-km (tonne-km in abstract only). Fuel price (also considered km cost in short run). Lag vkm poor fit R2=0.23).
Shen et al. (2009)	UK	1974–2006	road and rail freight combined. 6 sectors.	Discussed but not included in model		0.72 to 1.485 (all sectors) lagged OLS 3.289 (Agricultural, food and drink) to 0.108 (coal and coke)	Used index of industrial production as measure of economic activity. Six models used.
SDG (2014)	UK	1971–2011	aggregate			1.14 (0.000) 1971–1991 0.88 (0.006) 1991–2000 0.52 (0.146) 2000–2007 1.54 (0.006) 2007–2010	GDP (p-values in parentheses).

2.4.2. Elasticity with respect to economic activity (GDP)

Before discussing its relationship with economic activity, it is useful to consider HGV transport in the context of statistics on goods transport by road in the UK. According to DfT (2013a), demand for road transport in tonne-km grew only gradually from 1999 to 2007, followed by a steep decline in 2008 and 2009, which was accompanied by a fall in real GDP/capita. The share of rail freight has not changed significantly over this period. On the other hand, while the share of car transport in road vehicle-km still dominates and has remained fairly constant over the last decade at around 70 per cent, the share of LGV-km has increased by almost 20 per cent to make up 14 per cent of the total (DfT 2013b). HGV-km have fallen by 11 per cent over the same period.

The relationship between road freight transport and GDP is often considered in the context of road freight 'decoupling', in which economic activity continues to grow without a corresponding increase in road freight demand and its contingent externalities. McKinnon (2007)[23] listed 12 possible reasons for the observed decoupling in the UK between 1997 and 2004. Of these, the change in the composition of GDP and the erosion of industrial activity abroad, both of which relate to the type of commodities that contribute to the economy and therefore ought to be country specific, are considered significant. The paper also cites the increase in the real costs of road freight transport, the increased penetration of the market by foreign hauliers and the declining share of road freight transport as important factors.[24] However, McKinnon (2007) attaches little importance to more efficient supply chains, vehicle routing or switching from trucks to vans.

Most of the papers in our review express freight demand in tonne-km, rather than vehicle-km, although measures other than GDP are often used for economic activity (e.g. Gross Value Added (GVA), Gross Final Expenditure (GFE), index of industrial production). Two studies calculate elasticities using data for a long time period. Agnolucci and Bonilla (2009) calculate an elasticity of demand of 0.66 with respect to GFE for one aggregate commodity sector, controlling for price. In their study, Shen et al. (2009) consider the effect of index of industrial production on combined road and rail freight, with demand for rail freight remaining relatively constant over the period of interest. They distinguish seven commodity sectors and find quite different results by commodity and model type used. While the aggregate result for all sectors is in the range 0.72 to 1.485, the lowest value of 0.72 is obtained using a similar model to Agnolucci and Bonilla (2009). The range of elasticity estimates Shen et al. (2009) obtain results from the functional form used, with static and dynamic OLS techniques generating higher values.

Changes in the relationship between road freight transport demand and GDP/economic activity over time in the UK are explicitly explored in two studies. SDG (2014) use some form of regression analysis to explain HGV-km in terms of GDP over four periods from 1971 to 2011. For the earlier periods, their results are reasonably consistent with Shen et al. (2009), given the methodology used. They do, however, calculate a much smaller elasticity (0.52) for the period 2000 to 2007, compared with previous years,

[23] Not reviewed as part of this study.

[24] McKinnon (2007) also notes that data on road freight transport in the UK by foreign hauliers are not readily available. We have no information as to whether DfT statistics include these.

which is indicative of freight decoupling, although this is not statistically significant. Interestingly, the largest elasticity value is found for the period 2007 to 2011, which coincided with the recession. Alises et al. (2014) on the other hand focus on the change in road transport intensity (RFTI)[25] from 1999 to 2007 and show a decline in RFTI of 57 per cent over this period, although most of this occurs before 2003. They also highlight the importance of the share of a sector in GDP. In the UK, the food sector had the most significant effect on the decline in RTI due to supply chain improvements but the service sector also contributed strongly because of its high share of GDP. Neither of these papers includes price effects.

Overall, the evidence appears to be mixed. For earlier periods, the estimates for freight demand elasticity with respect to economic activity are reasonably consistent, with the range 0.66 to 1.49, once functional form and the measure used for economic activity are accounted for. There is some agreement on freight decoupling within the period 1997 to 2007. However, there has been little investigation of the factors that may be responsible. The composition of GDP and supply chain efficiencies have been shown to play a role in one study (Alises et al. (2014)). Although, the share of van use increased significantly over the same period, there appears to be no evidence on the impact of this. The impact of transport costs is also not consistently accounted for. Finally, there are too few data after 2007 to make a judgement on how elasticity estimates would relate to the preceding periods.

2.5. Quality assessment

Most of the studies considered in this review were published in peer-reviewed journals or written by authors with a track record in the field. Most of the studies use quantitative (econometric) analysis of time-series data, or model outputs, which are judged to be of high quality. Other studies have undertaken literature review analysis, incorporating a wide range of evidence. However, in some cases it was found that terminology was assumed and not explicit, leading to potential inconsistencies across the literature. A further limitation of journal articles for this type of review is that sometimes it is not possible to include sufficient detail of all aspects of the study in the requisite number of pages. On the other hand, extracting relevant data can also be difficult when elasticities, the focus of this review, are not the main focus of the study.

Although we have provided ranges of elasticity estimates, based on the evidence from the studies reviewed, as being the best available, these are subject to the caveats discussed in previous sections; particularly, the age of some of the studies and lack of data transferability.

[25] RFTI measures the amount of goods (commodity in tonne-kms) moved by road for a particular industry per unit of its GDP.

3. Conclusions and recommendations

Below we set out the key conclusions from our review on fuel price, income and population elasticities.

Fuel price elasticities

- Based on the evidence reviewed, it is reasonable to assume the fuel cost (price) elasticity falls within a fairly narrow range of -0.1 to -0.5, but some trips may be more elastic, depending on distance and trip purpose.
- Although there is substantial information on fuel price elasticities for Great Britain, it is getting old. The Wardman (2014) work on fuel price elasticities is recent; however, car studies account for a small proportion of the studies in the meta-analysis (5 per cent of the studies are focused on car).
- Are fuel price elasticities changing over time? The evidence is limited.
  - According to a calculation by Van Dender and Clever (2013) for five OECD countries including the UK, the elasticity for the period 2000 to 2010 was smaller than for the preceding decade.
  - In his review, Litman (2012) references studies that show that elasticities decreased from 1980 to 2005 and have since been increasing again. This may be a US-specific phenomenon, because of differences in fuel price levels between the US and other European countries.
- There is little evidence on differences in fuel price elasticities for urban and non-urban journeys. Studies are either purely urban, long distance or make no distinction. Wardman (2014) distinguishes urban and inter-urban trips but this is perhaps most suited to rail (see above).

GDP / Income elasticities

- The evidence suggests that income elasticity is positive and may be as large as 1.4. However, the evidence is also compatible with long-run elasticities in the range 0.5 to 1.4 if we take into account that the impact of including car ownership on income elasticity seems to be important, and is determined differently in different models.
- Cross-sectional values are usually smaller than values obtained from time series (Daly and Fox (2012)).

- Some studies use household income or expenditure rather than GDP, and it is not clear what differences these may have on the elasticity estimates.
- There is limited evidence that income elasticities have decreased over time; two studies find that GDP elasticity fell after the year 2000. This could be explained by saturation in car ownership levels.

Population elasticities

- There is no information on population elasticities per se. However, a few studies include demographic explanatory variables such as urban density, population density, employment and age, from which an elasticity is calculated (or could be with additional data).
- More evidence may exist on how trip rates or travel vary with population segments, but the outputs are not converted to elasticities (often these are categorical variables, e.g. gender, car ownership, SEG, area type, age, etc.).

Freight elasticities

- The focus of the freight literature is on HGV transport.
- There is some consistency in the price elasticity of freight demand, with values in the range -0.1 to -0.6.
- For the elasticity of freight demand with respect to economic activity:
    a. A range of values from 0.52 to 1.49 were found for an aggregate commodity sector, depending on the time period and functional form used.
    b. There is some evidence that this varies considerably across commodities.
    c. There is some evidence on the decoupling of freight demand from GDP from 1997 to 2007 but little evidence on the factors explaining this.
    d. There is insufficient evidence to suggest a different value for the period after 2007.

Other

- Transferability is an issue. There are few studies using only UK data but at least one that indicates that elasticities are not constant across countries (Espey (1997)). Van Dender and Clever (2013) also suggest many other variables should be taken into account in explaining transport demand that may differ between countries.
- The functional form used to determine elasticities does not appear to be particularly important for passenger transport. The evidence is less clear for freight.

On the basis of our study, we conclude that there is insufficient evidence for DfT to change the income and price elasticity values of passenger and freight road transport demand from those that are currently implied in NTM or for other forecasting purposes. In view of the available evidence on how these elasticities may have changed over the period since most of the empirical work using UK data was carried out, we would recommend that a detailed study of elasticities be undertaken to quantify fuel price and income elasticities using recent data. For passengers, this should take explicit account of the impact of car ownership, fuel price, fuel efficiency, income and geographical differences, e.g. rural and urban areas.

Demographic effects should also be considered and the analysis should explicitly test for changes in values over time. For freight, further work is required to incorporate LGVs, as well as to understand differences in current approaches to quantifying HGV elasticities and additional explanatory factors that may be relevant.

References

Reviewed documents on fuel price, income and population elasticities

Alises, A., J.M. Vassallo & A.F. Guzmán (2014). 'Road Freight Transport Decoupling: A Comparative Analysis Between the United Kingdom and Spain.' Transport Policy 32: 186–193.

Agnolucci, P. & D. Bonilla (2009). 'UK Freight Demand: Elasticities and Decoupling.' Journal of Transport Economics and Policy 43 (3): 317–344.

Bradburn, P. & G. Hyman (2002). An Economic Investigation of Car Use in the National Transport Model for Great Britain. Association for European Transport.

Dargay, J. (2007). 'The Effect of Prices and Income on Car Travel in the UK.' Transportation Research Part A: Policy and Practice 41A (10): 949–960.

Dargay, J. (2010). The prospects for longer distance domestic coach, rail, air and car travel in Great Britain. ITC Report.

De Jong et al. (2010). 'Price Sensitivity of European Freight Transport Demand – Towards a Better Understanding of Existing Results.' Report by Significance and CE Delft

De Jong, G. & H. Gunn (2001). 'Recent Evidence on Car Cost and Time Elasticities of Travel Demand in Europe.' Journal of Transport Economics and Policy 35 (2): 137–160.

Espey, M. (1997). 'Traffic Jam: An International Study of Automobile Travel Demand.' Papers in Regional Science 76 (3): 343–356.

Goodwin, P., J. Dargay & M. Hanly (2004). 'Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review.' Transport Reviews 24 (3): 275–292.

Graham, D.J. & S. Glaister (2004). 'Road Traffic Demand Elasticity Estimates: A Review.' Transport Reviews 24 (3): 261–274.

Giuliano, G. & D. Narayan (2003). 'Another Look at Travel Patterns and Urban Form: The US and Great Britain.' Urban Studies 40 (11): 2295–2312.

Hymel, K.M., K.A. Small & K. Van Dender (2010). 'Induced Demand and Rebound Effects in Road Transport.' Transportation Research Part B: Methodological 44 (10): 1220–1241.

Jahanshahi, J., I. Williams & X. Hao (2009). 'Understanding Travel Behaviour and Factors Affecting Trip Rates, etc. ETC Conference Proceedings.

Johnson, C. & J. Bull (2014). 'An Analysis of the Variation in UK Road Traffic Levels Since 1970 and the Key Economic Drivers for This Change.' SDG slide set by John Swanson. Referenced in text as SDG (2014).

Karathodorou, N., D.J. Graham & R.B. Noland (2009). 'Estimating the Effect of Urban Density on Fuel Demand.' 88th Annual Meeting of the Transportation Research Board

Kenworthy, J. (2013). 'Decoupling Urban Car Use and Metropolitan GDP Growth.' World Transport Policy & Practice 19 (4): 8–21.

Litman, T. (2012). Understanding Transport Demands and Elasticities: How Prices and Other Factors Affect Travel Behavior. Victoria Transport Policy Institute.

Rizet, C. and H. Bouguerra (2013). 'Evolution of Fuel Price Elasticities of Road Freight Transport.' Cahiers scientifiques du transport, 64: 119–142.

Rohr, C. and J. Fox, (forthcoming). 'Evidence Review of Car Traffic Levels: A Rapid Evidence Assessment.' RAND Europe, Cambridge.

Rohr, C., J. Fox, A. Daly, B. Patruni, S. Patil & F. Tsang (2013). 'Modelling Long-Distance Travel in the UK.' Transportation Research Record 2344: 144–151.

Shen, S., T. Fowkes, T. Whiteing & D. Johnson (2009). 'Econometric Modelling and Forecasting of Freight Transport Demand in Great Britain.' ETC Conference Proceedings 2009.

Van Dender, K. & M. Clever (2013). 'Recent Trends in Car Usage in Advanced Economies – Slower Growth Ahead?: Summary and Conclusions.' ITF/OECD Roundtable on Long-run Trends in Car Use, Discussion Paper No. 2013–9.

Wang, T.T. & C. Chen (2014). 'Impact of Fuel Price on Vehicle Miles Traveled (VMT): Do the Poor Respond in the Same Way as the Rich?' Transportation 41 (1): 91–105.

Wardman, M. (2014). 'Price Elasticities of Surface Travel Demand.' Journal of Transport Economics and Policy, 48 (3): 367–384.

Other references

DfT (2013). Transport Statistics Great Britain 2013.

DfT (2013a). Annual Road Traffic Estimates: Great Britain 2013

Litman, T. (2012a). Todd Litman (2012), 'Changing North American Vehicle-Travel Price Sensitivities: Implications For Transport and Energy Policy.' *Transport Policy.* Note EndNote publication date is 2013.

McKinnon, A.C. (2007). 'Decoupling of Road Freight Transport and Economic Growth Trends in the UK: An Exploratory Analysis.' *Transport Reviews* 27 (1): 37–64.

Williams-Derry, C. (2010). 'Dude, Where Are My Cars?' Sightline Institute.

Appendix A: Search Protocol

The search protocol used for the study is attached below.

Inclusion and exclusion criteria

A rapid evidence assessment (REA) review aims to be a comprehensive, systematic and critical assessment of the scope and quality of available evidence. REAs follow the same structure and are similarly replicable and transparent as systematic literature reviews, yet have the advantage of being less resource intensive. This is achieved by formally constraining the types of research to be sourced on the basis of the location of the study, the language in which it was published, the date of publication and the type of demand considered. The proposed constraints are detailed below.

Location

To ensure that the elasticity values are relevant to the UK-context the review will be restricted to studies from developed countries, with a focus on UK studies.

Language

Given the available timescales the review will be restricted to English language material.

Date of publication

We propose to review evidence published since 1990, as changes over time are of interest.

Demand type

Both passenger and freight demand studies will be considered as both are important in explaining growth in total traffic.

Search strategy

The literature search will be conducted in a range of relevant databases and grey literature will be searched. The literature search will be undertaken by a trained librarian based in RAND's Santa Monica office in the US. The primary database for the search of journal papers and conference proceedings will be the Transportation Research International Documentation (TRID) database, supplemented if necessary by searches of other databases.

Unpublished studies will be sought by web search and by contacting experts and practitioners, who may include Gerard de Jong, Kenneth Small and Mark Wardman who are established researchers in this field.

A draft search strategy is presented in Table 4.

Table 4: Draft search terms

<u>Search 1 (passenger and freight combined – no TRID subject limits)</u> Road transport OR road traffic OR road transport demand OR car use OR car demand OR automobile demand OR automobile use OR car cost OR automobile cost OR road travel OR road freight OR freight traffic OR road transport model OR road travel demand

AND
Income OR fuel OR population OR GDP OR gross domestic product OR GNP OR gross national product OR
Elasticit* OR sensitiv*

<u>Search 2 (limit search to passenger transportation and freight transportation and economics</u>)

Transport model OR demand model OR transport demand OR freight transport

(NOT
Air OR rail OR sea OR)
AND
Income OR fuel OR population OR GDP OR gross domestic product OR GNP OR gross national product OR
Elasticit* OR sensitiv*

<u>Search 3 (passenger transportation only and economics</u>)
Road transport OR road traffic OR road transport demand OR car use OR car demand OR automobile demand OR automobile use OR car cost OR automobile cost OR road travel OR road transport model OR road travel demand

AND
Income OR fuel OR population OR GDP OR gross domestic product OR GNP OR gross national product OR
Elasticit* OR sensitiv*

<u>Search 4 (freight transportation only and economics</u>)
Road transport OR road traffic OR road transport demand OR road travel OR road transport model OR road travel demand

AND
Income OR fuel OR population OR GDP OR gross domestic product OR GNP OR gross national product OR
Elasticit* OR sensitiv*

<u>Search 5 (freight and passenger transportation and economics</u>)

Vehicle kilometres OR vehicle tonnes OR fuel consumption OR vehicle stock

AND
Income OR fuel OR population OR GDP OR gross domestic product OR GNP OR gross national product OR
Elasticit* OR sensitiv*

The search terms are designed to take account of the fact that elasticities may not be the main subject of a paper and may therefore not appear in the title, abstract or keywords. The search terms may be subject to modification as the search progresses and, particularly, after the pilot test, where we check that a number of relevant papers are captured by the search strategy. This may also be the case if the initial searches do not generate sufficient information relating to additional factors noted in Section 1.2.

A number of additional strategies will also be tried and carefully scrutinised. For example, the NOT term will be used to test whether other non-road modes can be excluded, as this could remove papers that consider several modes. Searches in the different databases can also be restricted in different ways, by category, subject index or journal type.[26] The above list outlines the searches that will be used first in TRID. A subset of these search strategies will then be applied in Web of Science under appropriate restrictions as this database is more general. All the databases used support truncation, denoted by *.

Study selection and data extraction

Study selection

For this REA, experienced staff will screen titles and abstracts of studies identified from the literature search and eliminate papers that are not relevant in order to come up with a 'longlist' of titles and abstracts for consideration.

The longlist will then be reviewed by senior staff members to identify a shortlist of 10–12 papers for review. A spreadsheet summarising both the longlist and the proposed shortlist will be circulated to the Department and their agreement sought before the data extraction stage commences.

Data extraction

An Excel spreadsheet will be used for the data extraction phase. A data extraction template will be developed and piloted using two or three studies. Data likely to be extracted from each study include:

- Study identification information – number, authors, date
- Study location/country
- Elasticity measure – population/income/fuel cost/other
- Comments (e.g. significant differences between study groups)

The final list of items for extraction will be agreed on the basis of what emerges from the literature and will be agreed with the Department once data has been extracted.

The first study will be reviewed by two reviewers as a check on the information extracted.

26 A brief summary of the search options for Scopus, TRID and Web of Science is available in Search Options by Databse.xlsx (attached).

Quality assessment

The quality of each study reviewed will be assessed according to the following criteria:

- Whether the source was peer reviewed – some are likely to be conference presentations.
- Is the research question clearly stated?
- Is the methodology appropriate to the analysis and clearly reported?
- Are the results clearly reported with appropriate confidence intervals/measures of statistical significance?

The quality assessment will not be used as a basis for determining which papers should be shortlisted for review. Rather, the quality assessment will be used in the review to assess evidence from the different sources. For example, if the review identifies an elasticity value for a particular factor from a single source, then the quality assessment will be used to provide an assessment of the reliability of that elasticity estimate.

Synthesising the evidence

We anticipate that for population, income and fuel cost elasticities ranges of values will be presented segmented by passenger and freight traffic, though it is anticipated that less detail will be available for freight traffic.

For any other drivers of traffic identified from the review, elasticity values will be presented if the evidence allows it, but it is possible that only a list of other relevant measures will be presented.