# Enhancement of transport safety through Cross Modal Switching

**Patel, T.**

# Enhancement of transport safety through Cross Modal Switching

## Toral Patel

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# Abstract

Transport safety has a direct impact on people's lives despite considerable improvements in recent decades. By treating transport modes independently and not taking full account of modal options available, policymakers have overlooked potentially important and low cost contributions to overall passenger safety.

This thesis investigates the extent to which Cross Modal Switching (CMS), encouraging users to transfer to safer modes of transport, can be deployed as an instrument of transport safety policy.

Research was conducted to establish the safety differences between modes on specific journeys, taking account of composite risks including all transport modes used. Primary research used surveys and qualitative interviews to target three different groups to understand their views on transport safety, willingness to switch modes, reasons that would cause them to switch and modal perceptions on risk and travel behaviour. The feasibility of promoting CMS was assessed by measuring substitutability between modes and calculating cross-elasticities using data from the empirical surveys conducted and previously published work.

Cost benefit calculations were made using monetised risk and the cost of fares subsidies to assess the net safety benefits for three selected journeys.

This analysis shows that there is a marginal justification for CMS as a tool within an overall integrated transport policy that considers safety in all modes simultaneously. This must recognise that the absolute safety benefits are not very large relative to other benefits, although the relative size depends on the manner in which changes of consumer surplus are treated in the CBA. CMS can be demonstrated to be cost effective in low risk modes, relative to larger infrastructure investments only yielding marginal safety improvements. Further research, using a larger sample of journey net benefit calculations, is thus required to validate the case robustly for CMS, identifying beneficial opportunities for modal switching on specific routes and target modes.

# Dedication

Dedicated to the memory of my Father

# Table of contents

# List of figures

# List of tables

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# Declaration of authorship

I declare that all the material contained in this thesis is my own work.

# Definitions and list of abbreviations

| | |
|---|---|
| ALARP | As Low As Reasonably Practicable |
| ATP | Automatic Train Protection |
| ATSB | Australian Transport Safety Bureau |
| BA | British Airways |
| BCR | Benefit to Cost Ratio |
| CAA | Civil Aviation Authority |
| CAP | CAA Publication |
| CBA | Cost Benefit Analysis |
| CCIS | Co-Operative Crash Injury Study |
| CD | Consumer Data |
| CEA | Cost Effectiveness Analysis |
| CMS | Cross Modal Switching |
| CPE | Cross-Price Elasticity |
| DETR | Department of Environment, Transport and the Regions |
| DfT | Department for Transport |
| DoT | Department of Transport |
| EASA | European Aviation Safety Agency |
| EC | European Commission |
| EIB | European Investment Bank |
| ERA | European Railway Agency |
| ERTMS | European Railway Traffic Management System |

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|---|---|
| ETCS | European Train Control System |
| ETSC | European Transport Safety Council |
| EU | European Union |
| FCS | Finished Consultant Episode |
| FSA | Formal Safety Analysis |
| FWI | Fatalities and Weighted Injuries |
| HES | Hospital Episode Statistics |
| HGVs | Heavy Goods Vehicles |
| HMT | Her Majesty's Treasury |
| HSC | Health and Social Care |
| HSE | Health and Safety Executive |
| HST | High Speed Train |
| ICAO | International Civil Aviation Organisation |
| IMO | International Maritime Organisation |
| IRTAD | International Road Accident Database |
| ITC | Independent Transport Commission |
| K | Killed<br>This is defined by the UK Department of Transport as "*Human casualties who sustained injuries which caused death less than 30 days (before 1954, about two months) after the accident. Confirmed suicides are excluded*" See Section 7.1 for more details. |
| km | Kilometres |
| LAD | Local Authority District |
| LCC | Low Cost Carrier |
| LDR | Long Distance Rail |
| LHD | Left Hand Drive |

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|---|---|
| **M** | Million |
| MB | Marginal Benefit |
| MC | Marginal Cost |
| MCA | Multi Criteria Analysis |
| NAO | National Audit Office |
| NGO | Non-Governmental Organisation |
| NPV | Net Present Value |
| NTS | National Travel Survey |
| OECD | Organisation for Economic Co-operation and Development |
| ORR | Office of Rail Regulation |
| PACTS | Parliamentary Advisory Council for Transport Safety |
| PAYD | Pay As You Drive |
| PCT | Primary Care Trust |
| PFI | Public Finance Initiative |
| PPI | Potential Pareto Improvement |
| PSC | Port State Control |
| RHD | Right Hand Drive |
| RIDDOR | Reporting of Injuries, Diseases and Dangerous Occurrences Regulations |
| RSSB | Rail Safety and Standards Board |
| SCB | Statistiska Centralbyran (Statistics Sweden) |
| SHIPS | Scottish Hospital In-Patient System |
| SI | Seriously Injured<br>(There are various definitions of this according to mode and country. The UK Department for Transport definition is: "*an injury for which a person is detained in hospital as an "in-patient", or any of the following injuries whether or not they are detained in hospital: fractures, concussion, internal* |

| | |
|---|---|
| | *injuries, crushings, burns (excluding friction burns), severe cuts, severe general shock requiring medical treatment and injuries causing death 30 or more days after the accident. An injured casualty is recorded as seriously or slightly injured by the police on the basis of information available within a short time of the accident. This generally will not reflect the results of a medical examination, but may be influenced according to whether the casualty is hospitalised or not”* See Section 7.1 for more details and discussion) |
| SIKA | Statens institut för kommunikationsanalys<br>(The Swedish Institute for Transport and Communications Analysis) |
| SMART | Specific, Measurable, Achievable, Realistic, and Time-bound |
| SPSS | Statistical Package for the Social Sciences |
| STPR | Social Time Preference Rate |
| TGV | Train à Grande Vitesse (French high-speed train) |
| TPWS | Train Protection and Warning System |
| TSGB | Transport Statistics Great Britain |
| VFR | Visiting Friends and Relatives |
| VSL/VPF/VSI | Value of Statistical Life/Value of Preventing a Fatality/Value of Serious Injury |
| WebTAG | Web Transport Analysis Guidance (provided by UK Government to support transport forecasting and evaluation, including safety aspects) |
| WHO | World Health Organisation |
| WTP | Willingness To Pay |

# 1 INTRODUCTION

## 1.1 OVERVIEW

Transport in developed or high income countries is safer today than it has ever been. Nevertheless transport risk still affects people every day and there are still demands from the public to improve transport safety further. Paradoxically, these public demands have a tendency to focus on safety improvements for safer modes and overlook the least safe. Savage (2013a) for example highlights this aspect of the debate on transport safety as follows:

*"A disproportionate part of the public debate concerns commercial transportation safety* [this could be attributed to actual versus perceived risks]. *The dramatic nature of crashes in commercial transportation, especially those that result in multiple fatalities or considerable environmental damage, engenders extensive press coverage and a public discussion as to the causes and what can be done to prevent a repetition. Yet highway crashes* [road accidents[1]] *represent the vast majority (95%) of the total transportation fatality risk. The motor vehicle must be the most dangerous machine that we interact with on a daily basis."*

Transport safety and policy have been intensely debated by the public (i.e. users), governments, decision/policy makers, transport operators and other interested stakeholders. Transport policy has generally been developed on a unimodal basis rather than in an integrated manner. Preston (2012) analyses why integrated policies where applied have had limited success within the UK and Europe. The factors that restrict the growth of integrated[2] policies are: problems in defining the integration concept, problems in 'operationalising' the concept, limited practical evidence to demonstrate integrated policy achievements and individual behavioural and institutional barriers to integration.

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[1] It should be acknowledged that there are differences in safety of the various modes that use the roads ranging from walking and cycling through private cars and taxis to bus, coach and tram travel.

[2] Preston adopts the NEA et al. (2003, p17) definition of transport integration: the organisational process through which the planning and delivery of elements of the transport system are brought together, across modes, sectors, operators and institutions, with the aim of increasing net social benefits.

In the UK, fragmentation in ownership of public transport and the non-strategic competition model used are particular barriers to the success of integrated policies.

Preston notes that integrated policies have had some success recently with supporting evidence emerging at a European level of the advantages of integrated policy (e.g. reduction of car use) and benefits in terms of "value for money" and cost effectiveness. Integration policy packages introduced at the lower rung of the integration ladder such as the promotion of active transport modes and public transport have been successful and there is a suggestion that schemes with an emphasis on integration across modes may represent good returns.

Although global transport casualties have reduced considerably, deaths and serious injuries on all transport modes are still a serious problem. The World Health Organisation (WHO, 2013) reports almost 1.24 million deaths every year as well as 20 to 50 million non-fatal injuries sustained as a consequence of road traffic accidents. "*Road traffic injuries*[3] *are estimated to be the eighth leading cause of death globally, with an impact similar to that caused by many communicable diseases, such as malaria*" (p1). As expected, there are a significant number of accidents attributable to road transport since it encompasses a number of different modes and users: cars/vans, buses, coaches, motorcycles, cycles and walking (i.e. a number of different motorised and non-motorised modes utilise the road infrastructure simultaneously). The average passenger casualty rates per 1000M person km from 2004-2013 (DfT, 2014c) indicate air and rail modes at 0.01, with sea demonstrating a higher risk rate at 0.4. Comparatively there are notable differences in safety (average casualty rate per 1000M person km) of modes that use roads: cars 1.9, buses and coaches 0.3, walking and cycling 29 and 27 respectively. Road accidents are estimated to cost low and middle-income countries between 1–2 % of their gross national product.

Transport safety, particularly a reduction in road casualties, is therefore an important issue for the European Union (EU) and the governments of its member states. In 2010, the EU committed to improving road safety by setting a target of reducing road deaths by 50% of the 2010 level by 2020. This goal followed an earlier target set in 2001 to halve road

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[3] WHO defines "a road traffic injury [as] a fatal or non-fatal injury incurred as a result of a collision on a public road involving at least one moving vehicle. Children, pedestrians, cyclists and the elderly are among the most vulnerable of road users".

deaths by 2010 (although considerable progress was made in terms of overall reduction in fatalities the full target was not achieved, suggesting further safety gains can be attained).

2014 was relatively not a good year for road safety. 25,845 people were killed in the EU28 as a consequence of road collisions compared to 26,009 in 2013, representing a below trend decrease of only 0.6%, compared with the annual decrease of 6.7% needed to reach the target for 2020 (Adminaite et al., 2015).

Investment devoted to safety measures has had a positive effect in preventing deaths and serious injuries on EU roads but the saving potential is far from exhausted. In 2014 more than 203,500 people were recorded as seriously injured by the police in the 23 EU countries that distinguish between seriously and slightly injured in their data.

The DfT 2014a) in their Reported Road Casualties Great Britain (RRCGB) indicated an increase in the number of reported road deaths at 1,775 (mainly pedestrians with a 12% increase from 2013). This represents a 4% (62 deaths) increase compared to 2013 (1,713). Relatively, this number of fatalities is the third lowest annual total on record after 2012 and 2013. Those seriously injured reported to the police increased by 5% (22,807), the first increase since 1994.

The reaction to the RRCGB report from David Davies, Executive Director of the Parliamentary Advisory Council for Transport Safety (PACTS, 2015) stated that: *"This level of death and injury represents personal tragedies…* [and] *huge costs to the health service and the British economy. Most of these deaths are preventable. They should not be seen as an acceptable cost of doing business. This should be a wake-up call for the Government and administrations across the UK to take action so that casualties go down, not up."*[4] The total value of prevention of all reported road accidents in 2012 was estimated to be £15.1 billion (including an estimate of the cost of damage-only accidents but not unreported injury accidents). An illustrative figure was also provided which allowed for accidents not reported to the police and thus increased the total value of prevention of road accidents to around £34.3 billion (DfT, 2012b).

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[4] Noted in PACTS Briefings, Featured, News & Publications. *Disappointing increase in GB deaths and serious injuries in Reported Road Casualties GB: 2014*. June 25, 2015.

The article by Savage (2013a) comparing fatality risks in United States transportation across modes and time (2000-2009) indicates that about 43,000 Americans die due to transport accidents annually. These deaths represent almost four out of every ten “unintentional injury deaths” in the United States. Unintentional injury deaths are those deaths that do not result from old age, disease, homicide or suicide. Transportation is the largest cause of unintentional injury deaths (38%) and is similar in size to the sum of the next two predominant causes of such deaths (which are falls and poisonings). Savage also notes that the recent reduction in transport related fatalities may be partially compensated by increased injuries[5].

One approach to reduce transport casualties is through Cross Modal Switching (CMS): that is, to reduce traveller risk by encouraging travellers to switch to safer transport modes. CMS could help reduce the need for some of the large infrastructure investments which seek to enhance transport safety.

The practicality of CMS, or modal transfer, depends on the degree of substitution possible and thus on the willingness and ability of transport users to change modes. Various studies have been undertaken to investigate mobility use and patterns. The segmentation of mobility patterns by modes and amounts of mobility have been examined by Diana and Mokhtarian (2009) with emphasis on the extent of multimodality in a person’s modal mix and preferred changes to that mix using a “multimodality index”. They aimed to define a new market segmentation approach by considering collectively an individual’s actual and perceived mobility levels according to different transport modes and their desire to alter them. In effect this provides a generic framework to investigate these “intermodal effects”.

Their analysis considers that modal transfer is influenced by physical constraints (e.g. the transport network) as well as individual preferences and perceptions, and therefore looks at actual trips grouped on the grounds of suitability for modal switching. Their findings highlight the significance of multimodal behaviour so that the direction and size of potential modal shift can be better understood and the segmentation can be useful in assisting policy. For example, groups of car users who wish to increase use of public

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[5] Vehicle safety has improved in the last decades and the focus has been on “crashworthiness” where design changes have been implemented to increase the chances of survival and reduce the severity of injuries in road accidents.

transport and reduce car dependency can be identified and compared with those who are satisfied with their current modal use. The willingness to change transport modes has been explored by them in the context of encouraging use of public transport to reduce environmental impacts and rationalise the use of resources.

Recent work in this area has been provided by Heinen and Chatterjee (2015) who analysed the variation in weekly transport modes used by individuals in Great Britain using data from the National Travel Survey (NTS). They examined the variance in modal shares (i.e. primary and secondary and the total number of modes used). Their findings show that 69% of those who make at least one trip weekly use multiple modes, there is lower "modal variability" for people living in smaller communities and modal variation is strongly connected with mobility capabilities and resources. Thus it is suggested that more assistance should be given to encourage use of public transport and active transport modes (walking/cycling) in these communities. Overall, encouraging investment in non-car transport modes would facilitate users towards "more balanced mobility" (p281).

The difference between safety levels for road transport compared to other modes, the continuing economic burden of accidents and the literature supporting modal variability towards public transport and reduced car transport mode use collectively suggest that CMS is potentially a viable approach that could provide safety improvements.

## 1.2 RESEARCH OBJECTIVE AND QUESTIONS

This thesis examines the extent to which the effective promotion of CMS can enhance overall transport safety on urban and long distance passenger transport, considering the whole door-to-door passenger journey. The central research question arising from this is therefore:

- To what extent can CMS be used (explicitly or implicitly) as an instrument of transport safety policy to encourage users of less safe modes to move to safer modes of transport?

To answer this question some sub-questions will be addressed:

- What methods of appraisal and tools should be used for the assessment of the safety policy initiatives and CMS in particular?
- Is the level of substitutability between modes and the cross-price elasticity (CPE) of demand sufficient to allow for CMS as a practical measure?

- What policies/instruments can be deployed to achieve CMS in practice (e.g. subsidisation)?
- Do the monetised benefits of CMS outweigh the cost of implementing the approach?
- If possible and beneficial, to which routes and modes should CMS be applied?

The rationale for the thesis is underpinned by two standpoints. The first is that transport safety policy gains from a rational approach, taking a long term perspective rather than short term reactions to specific incidents. Secondly, transport safety policies have previously been developed largely with reference to single modes in a compartmentalised manner. Although some work has been undertaken at the multimodal level which recognises that safety should be considered as part of the overall evaluation of multimodal projects, much of this seems to be at a cursory level. The European Commission (EC, 2013) passenger transport thematic looks at safety considerations but is focused mainly on road safety. Most studies on multimodal transport focus on time savings, reducing congestion and environmental benefits with limited emphasis on safety aspects.

By treating modes independently and not taking full account of the options within a specific journey, policy has hitherto overlooked a potentially important contribution to overall passenger safety, a contribution which, for many journeys, could be achieved at relatively low cost.

## 1.3 APPROACH

Based on the premises set out above, the thesis sets out to consider whether CMS is worth promoting as a means of yielding safety benefits. The overall approach showing links to subjects addressed in the thesis is set out in Figure 1-1.

This highlights the two main strands of the work, namely:

- to assess the case for CMS in terms of the safety differences between modes; and
- assuming that modal safety differences are sufficiently large, to consider the practicality of promoting CMS.

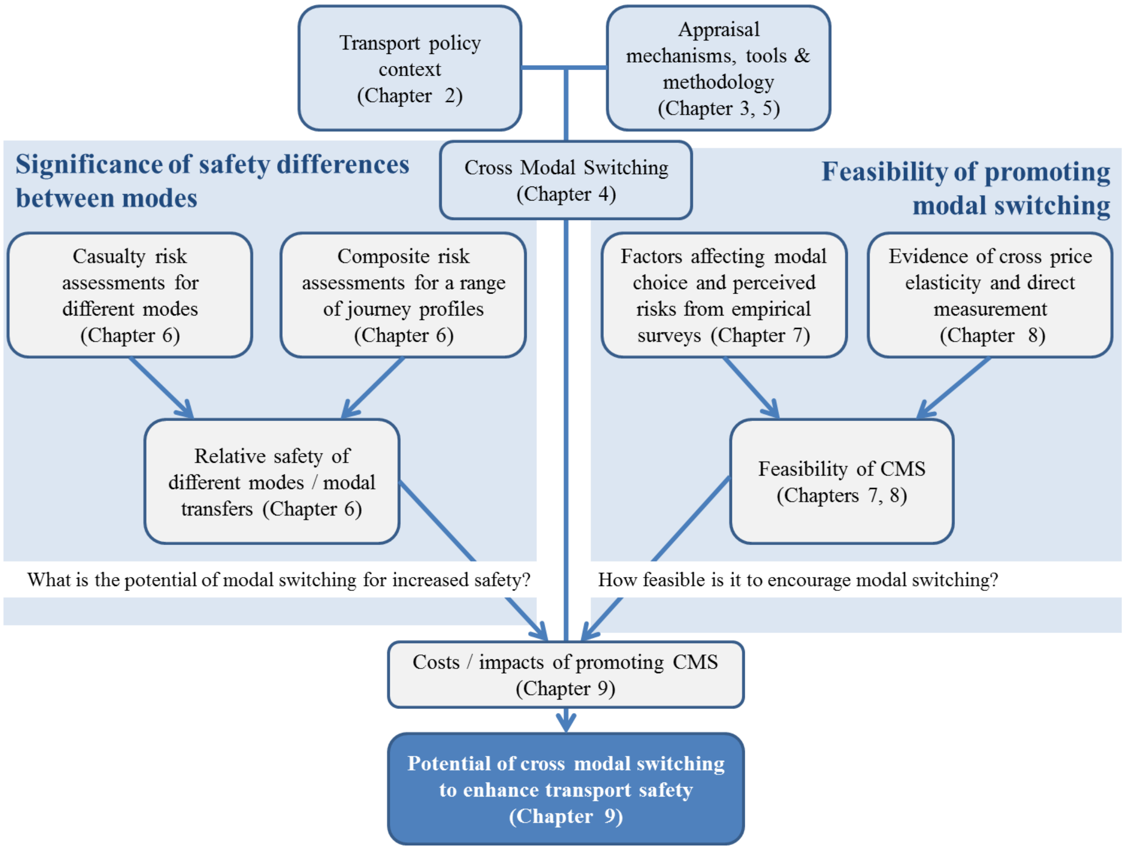

*Figure 1-1: Overview of approach*

If these two elements both give a positive result, the work can proceed to consider the benefits from CMS and the policy implications of how it might best be implemented. The overall approach is therefore as follows.

Firstly, two initial premises are considered:

**Transport safety policy:** The overall approaches to transport safety are examined as context. The logic is that a rational response to transport safety, of the type typified by CMS, is a more effective one than being driven by major events, even if these events are prominent to the general public and other stakeholders.

**Appraisal mechanisms for CMS:** A second preparatory section is needed to examine and select the most appropriate appraisal tools with which to evaluate CMS approaches.

The potential value of CMS depends on there being sufficient safety differences between modes. The thesis therefore investigates the safety gains on specific journey types which can be achieved by modal switching or by changing the modal mix. This process is undertaken for a wide range of possible journey types and different modal combinations within each of these types. By comparing the risk of death and serious injury per passenger km in composite journeys, the work addresses the potential value of CMS. If significant differences in safety between exchangeable modes are established, then overall transport safety can be improved by encouraging consumers to switch to safer modes for at least part of their journey.

To support the overall appraisal and allow the benefits of reducing risk to be assessed objectively, methods and tools for measuring and comparing risk need to be considered. The cost element of the comparison is addressed later in the context of CMS promotion.

The next stage in the assessment is to consider whether CMS is viable and how this can best be achieved. Factors here include the levels of substitutability between modes and the CPE of demand when switching between modes. These are addressed through two questionnaire surveys targeted at mainly leisure and business travellers for a range of mode/journey type combinations, together with one expert survey linked to follow up qualitative interviews with experts and users. The results of this data gathering are combined with reviews of the literature to test the validity of the approach.

Having established the potential value of CMS and the practicality of implementing it, CBA is applied to determine the net benefit of CMS in a variety of scenarios. In addition to testing the value of CMS this analysis also provides valuable insights into the priorities and promotional incentives needed to make the approach work in practice.

If a valid basis for CMS, and an optimal way to apply it, can be established, the final stage is to consider the implications for overall transport safety policy. The work has significant implications for a wide range of transport types from road and rail travel through to the more recent efforts to promote urban cycling as a way to reduce emissions and congestion.

## 1.4 STRUCTURE OF THE THESIS

The thesis is arranged to answer the research question stated above and provides theoretical background, theory to practice, empirical assessment and analysis. It is organised into ten chapters including an introduction and conclusion.

Chapter 2 aims to put into context the main policies and principles that underpin this thesis: namely, examining the potential of CMS to improve overall transport safety. It considers the rational basis for transport safety policy in terms of setting objectives and guiding practical implementation and highlights the importance of a rational approach for the uptake of CMS.

The economic case for state intervention in transport safety is outlined and is developed here as a platform for the promotion of CMS. Chapter 2 therefore provides the definition of an optimal transport safety policy across various modes and how policy outcomes can be evaluated.

Chapter 3 considers appraisal methods for transport safety. It describes and provides a critique of CBA in the context of alternative appraisal techniques and shows why it is the preferred approach for the appraisal of CMS in this thesis. Issues associated with the application of CBA, safety output/benefit measurement, actual and perceived risk and valuation of safety are important factors that are closely investigated.

Chapter 4 introduces the essential innovative conceptual framework of the work: the use of CMS as an instrument of transport safety policy. An overview of CMS is provided in the context of policy and modal behaviour with examples. This is followed by a review of the literature on CMS as applied to various transport objectives and specifically with respect to safety improvements.

Chapter 5 sets out the analysis methodology for the thesis, describes the approach and details the methods used to test its hypotheses.

Chapter 6 considers composite journey risk as a means to determine the full end to end travel risk for a variety of journey types. It presents the approach and calculates the risks of death or serious injury for a range of journey types. The door to door journey risk is analysed taking full account of the risks of the different modes used for each journey and the modal transfer risks are also considered. The aim of this analysis overall is to determine the significance of the safety differences between different modal combinations for typical journeys of different lengths.

Chapter 7 aims to understand the risk perceptions and other decision making criteria of travellers making modal choices. It presents the analysis of the primary research undertaken using questionnaires targeting different user groups. Specific objectives were to understand their views on transport safety, willingness to switch modes and the reasons that would cause them to do this, modal perceptions on risk and travel behaviour.

Chapter 8 provides evidence on CPEs from the published literature and the inferences of CPEs and perceived importance of price in consumer decisions (findings from the empirical survey analysis in Chapter 7). This chapter therefore reviews the impacts of price as identified by the surveys and in particular aims to directly measure CPE of demand which relates price to the mode selection process. It also provides a basis to understand the extent of subsidies that would be required to promote CMS.

Chapter 9 applies the CBA appraisal approach to determine the net benefit of applying CMS promoted by public subsidy. Initially the chapter evaluates the significance of the comparisons of perceived (from Chapter 7) and actual (Chapter 6) risks and their implications for CMS. The main part of the chapter then concentrates on applying CBA to provide net benefit assessments. These compare the monetised safety benefits and related economic benefits of modal shifts on given journeys to the cost of realising these shifts through subsidies. These assessments determine the net value of CMS for a range of selected point to point and regional journeys of different distances.

These CBA calculations test the concept of promoting modal switching and hence help to draw the analytical elements of the thesis towards a conclusion. This is provided in Chapter 10 together with practical recommendations based on the findings of the work.

# 2 POLICY AND PRINCIPLES

This chapter aims to put into context the main policies and principles that underpin this thesis: namely, examining the potential of CMS to improve overall transport safety.

The chapter initially examines the way in which decision-makers approach, determine and implement transport safety policy with an emphasis on rational methods. The main approaches and threats are outlined and analysed to identify the most appropriate entry points for the methodological developments proposed.

The value of CMS can only be fully achieved if it is implemented as part of a rational approach to transport safety policy. If the policy context is skewed by a combination of vested interests, a lack of understanding of the statistics and disproportionate responses to specific accidents driven by media coverage, then the value of CMS may not be fully realised. Understanding how to achieve a rational approach to transport safety is therefore an important aspect of this thesis.

In this work there is a strong emphasis on the need for rationality in policy-making. It is recognised that transport safety policy-making is part of the political process and is subject to trade-offs against other priorities as well as media scrutiny which may be irrational from a transport safety perspective. Within these constraints however, it must still be argued that policy-making should aim to be rationally based. In this context the task of the scientist or academic critic is to develop a rational understanding of issues and possible solutions and to bring this to bear on the policy development to help ensure the formation of well-informed, practical and balanced policies.

Following the discussion on the approaches to transport safety the chapter explores optimal policies (safety), the applicable norms (efficiency and equity) and the rationality of goals and goal setting in transport safety. The remainder of the chapter focuses on the arguments for public sector intervention in transport safety and how transport safety can be optimised.

The economic case for state intervention and transport safety policy is developed as a platform for the promotion of CMS. In some countries the transport infrastructure itself is nationally or regionally in public ownership and here the role of the state is clear. Even with privately operated systems however there is a strong case for intervention at some levels. The chapter concludes by focusing on the definition of an optimal safety policy across various modes and how policy outcomes can be evaluated.

## 2.1 RATIONALITY APPROACHES

### 2.1.1 Overview

The Oxford English Dictionary defines rationality as something based on or in accordance with logic. A rational approach to safety assessment is simply one based on reason, which is to say on a clear and logical thinking process. The ultimate goal of rational thinking is the discovery of truth and the consequent dissipation of unfounded opinion and illusion. A policy based on such thinking will therefore most likely achieve the greatest improvement for a given investment.

There is an important distinction between knowledge-based rationality of thought or thought processes as might be expressed in mathematical formulae, versus practical rationality of actions or decisions as may be expressed in policy decisions. This distinction approximates to the distinction of epistemic versus practical rationality. Epistemic rationality according to Benn and Mortimore (1976) refers to whether or not a proposition can be proved conclusively true. It is an epistemological notion and epistemically rational propositions are epitomised by mathematical truths/equations. O'Sullivan (2011) further states: *"If…we speak of an epistemically rational agent we can only mean one who has reached a state of perfect knowledge – an agent all of whose beliefs are held with absolute certainty…" (p114).* According to Benn and Mortimore practical rationality refers to the relation between an individual's/agent's declared goals and the actions taken to attain those goals. For practical rationality the actions taken must be effective for achieving the goals.

A science based approach is often regarded as an essential ingredient of a rational process. The European Transport Safety Council (ETSC) is an independent non-profit organisation, (ETSC, 2003a) intended to promote transport safety across Europe using a science based approach that does not represent a single party or industry. The ETSC was formed in 1993 in response to the persistent and unacceptably high European road casualty toll and public concern about individual transport tragedies. Cutting across national and sectoral interests, ETSC aimed to provide an impartial source of advice on transport safety matters to the European Commission, the European Parliament and, where appropriate, to national governments and organisations concerned with safety throughout Europe (ETSC, 2015)[6]. The Council asserts that emphasis on transport safety is furthermore based on the three pillars of Engineering, Education and Enforcing. The ETSC also advocates the identification and promotion of best practice, for example EU guidelines on effective engineering, education, and enforcement. They consider this a basis for effective transport legislation that will help overcome limitations emanating from disparities in perception and philosophical approach across Europe. In this context, the ‘scientific’ label is being used partly to counter the perception that safety policy may be unduly influenced by vested interests. The application of scientific methods is considered to remove any inherent bias.

A science based decision-making model is often used in the transport planning process. This could be described as a rational planning model with the following features which relate to rationality of goal setting and practical rationality:

- Rationality of goal setting:
    - Identify objectives;
- Practical rationality:
    - Identify the possible courses of action to meet the objectives;
    - Predict consequences of these actions;
    - Evaluate the consequences;
    - Select the most appropriate alternative in accord with efficiency criteria.

This approach is rational and scientific but it can be too limited if the mechanisms are applied only to aspects of the problem readily amenable to science and engineering solutions. There are a number of social and economic factors that must also be addressed effectively including the individual behaviour patterns of the travelling public and their response to any proposed measures. It is certainly true that the objectivity of a scientific approach is important, though there are cases where psychological, cultural or other social issues cannot be overlooked.

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[6] When interviewed on March 6th 2015, ETSC confirmed that in its present form it purely focuses on road safety as it considers that 98% of fatalities arise from road related accidents. It also acknowledges as a result over time that there is presently a gap for an overall organisation that considers the safety aspects of all transport modes collectively. (ETSC 2015, pers. comm., March 6th).

### 2.1.2 Threats to rationality

Goss (1989) points out that decisions relating to maritime safety, *"…could be made a good deal more rational or scientific, so as to rely less upon judgement and emotional reactions to major tragedies*." This idea may be expanded to cover other modes of transport and when referring to safety assessment in general.

Following any major transport accident there is often political and public demand to achieve an unrealistically low level of risk on the particular mode of transport affected. This is understandable, but there is a danger that if the initial reactions are not tempered by rational assessment of the issues, budgets will be redirected to the affected mode of transport at the expense of other areas where the same resources could yield far greater benefits.

Two examples of such situations following UK accidents are:

- The ground fire on a BA Boeing 737 at Manchester International Airport on August 22 1985, which resulted in 55 fatalities. This initially led to a proposal to require smoke hoods to be carried in all public transport aircraft. Two years later, rational evaluations found that this was not a cost effective proposal and concluded that mandatory use of smoke hoods on aircraft would not eliminate the risk of death or serious injury in the event of fire on board the aircraft (CAA, 1987). This contrasts with the effectiveness of low level lighting in aircraft gangways to guide passengers to evacuate more rapidly and removal of seats near emergency exits to facilitate evacuation, both of which have been introduced as practical measures in response to this specific event.
- The Ladbroke Grove rail crash in 1999, which led to calls for the immediate installation of Automatic Train Protection Systems, ATP (auto stop at red signals) on the UK rail network at a cost of £3.1 billion over 20 years (1999 estimates). This compared to the Train Protection and Warning System, TPWS (warning only at red signals) being installed at the time at a cost of £450 million. The joint inquiry into Train Protection Systems after the Southall and Ladbroke Grove accidents (Uff and Cullen, 2001) acknowledges that the TPWS was a "stop gap" solution and that over time ATP would be implemented as a permanent solution since this was already being trialled at the time of the Ladbroke Grove accident on specific routes. The report states that TPWS was approximately 55-60%

> effective in saving ATP preventable fatalities valued at £13.9 million for fitment to all signals and £7 million for partial fitment. It also notes its reservations on the effectiveness of TPWS and noted that the Ladbroke Grove accident could have been prevented if the ATP system had been in use.

In some cases, short term (rolling stock has a relatively short remaining life) measures have been implemented retrospectively, such as the introduction of central automatic locking of passenger-operated hinged doors on older stock (Mk 3 coaches) while the train is in motion to prevent falls from moving trains. Central locking on Mk 3 meant that trains did not move until all doors were shut and locked and passengers could not open them on moving trains. This was a measure for the limited period of some years for which this rolling stock remained in use (e.g. transfer of HSTs to Scotland) and was a mandatory requirement from January 1 2006 (Connor, 2011).

In the aftermath of a major disaster, the public wish to see action and politicians ignore this desire at their peril. Nevertheless, the ‘optimal’ solution, considered across all transport modes, may be substantially different from the ‘obvious’ solution at the time of the disaster. In the UK, the Health and Safety Executive have advocated a system of what can be achieved that is “reasonably practicable” across all sectors, including transport. ALARP (“As Low As Reasonably Practicable”) is about ensuring that when considering reductions in risk these are weighed proportionately to the benefits of risk reduction achieved. For example, investing £2m to avoid minor injuries for three people is disproportionate, compared to investing £2m in the reduction of 150 fatalities (which can be considered to be reasonable).

The solution to this problem is the availability of rational, scientific, objective and clearly expressed analyses that show the advantages of a balanced approach which (subsequently) directs resources most effectively.

## 2.2 OTHER PERSPECTIVES

### 2.2.1 Considerations from other perspectives

Research in this area suggests that there are a number of other possible perspectives that are consistent with the rational approaches considered above. King (1995) discusses psychological, cultural, economic and political perspectives on the issue of transport safety. These are not alternatives to rational safety policy; rather they represent different discipline-based perspectives on questions of transport safety which may be adopted either within the framework of a rational or a non-rational approach. Thus, in evolving a rational approach to transport safety, it is important to take account of such perspectives.

### 2.2.2 Psychological

Psychological perspectives are useful in the delineation of practical measures to promote safety. Many transport accidents are attributable to human errors and, in seeking to avoid such incidents, it is vital to understand how human beings interact with each other and their environment. These issues/findings must then be taken into account in decisions relating to operational procedures and rules as well as in vehicle and infrastructure design.

The public perception of risk and how people act on these perceptions is also an important determinant of the effectiveness of safety policies. This is because such policies, including the promotion of modal switching, rely on the public response to measures designed to change behaviour. This psychological aspect will therefore be important when considering the implementation of measures to promote safety including CMS.

### 2.2.3 Cultural

How different cultures think about safety differs widely and should be considered when delineating safety policy. This may affect the level of acceptable risk, and also the approaches to achieve the accepted risk level. For example, whereas in some countries such as the Netherlands an entirely open plan design of infrastructures with few areas fenced off near rail infrastructures is considered fully consistent with safety, in others such as the UK a much more paternalistic approach is thought to be needed to achieve the same or desired level of safety. This highlights that the two cultures have different attitudes towards safety: one placing responsibility on the individual while the other places it on the rail infrastructure provider to prevent access to their assets. As with the psychological aspect, this will also be very important in considering measures to promote improved safety to the public. If the public consider that safety is already sufficient, it will be more difficult to encourage behavioural changes through promotion with safety as the main driver.

### 2.2.4 Economic

Economics studies the allocation of scarce resources among competing ends and reminds us when discussing safety to take account of the true opportunity cost of policy measures and to relate these to the expected benefits. This leads to the use of transport appraisal methods which trade monetised benefits against costs in evaluating safety measures.

Economic theory can thus be applied to help the analysis of proposed safety measures. For example, neo-classical economics rests on three basic assumptions which also help to provide a framework for this assessment:

- People have rational preferences among outcomes that can be identified and associated with a value;
- Individuals maximise utility and firms maximise profits;
- People act independently on the basis of full and relevant information.

All of these assumptions are important factors for the analysis and are taken up in more detail later in this chapter in Sections 2.3 and 2.5.

### 2.2.5 Political or power / "Machiavellian"

This perspective helps to identify what is politically feasible, affordable and practicable at a given time and this is certainly relevant to a rational discussion of safety policies.

The power/"Machiavellian" approach to understanding policy making is based on positive economics: that is, a description and explanation of actual economic phenomena working out in practice. This can be contrasted with the normative approaches outlined in previous sections. This approach emphasises the acquisition, perpetuation and use of political power, hence "Machiavellian". Flyvbjerg (1998) discusses this, drawing on the work of Machiavelli, Nietzsche and Foucault and using the case study of the Aalborg Project in Denmark to improve traffic safety and improve the environment in the centre of Aalborg. Flyvbjerg discards normativism (what should be done) and instead advocates "what is actually done" as an approach. His work focuses on the interaction between power and rationality (i.e. rationality is always mediated through power structures), fully admitting that an increase in power diminishes rationality. It focuses on four value-rational questions: where are we going with planning; who gains and who loses and by which mechanisms of power; is this development desirable; and what should be done?

However, in the context of this work, his analysis of the Aalborg case concludes that the project did not succeed: i.e. there was no improvement in traffic safety and no reduction in noise and air pollution. The project was considerably fragmented with only a few of the sub-projects actually being implemented. Flyvbjerg then concludes that the mistakes made in the project ought to be avoided elsewhere. Hence Flyvbjerg returns to a normative stance in his argument.

In summary, the power/”Machiavellian” perspective is interesting as a contrast to the normative approach, although it is not relevant in this thesis as observing what is done still does not provide policy guidance.

## 2.3 OPTIMAL POLICIES AND NORMS

The starting point of any discussion of policy must be an elucidation of the norms, which in moral or political philosophy are prescriptive statements against which an evaluation of good or bad policies can be made. Economists can in principle adopt many norms as a basis for normative policy judgments. It has traditionally been held that the state or regulatory bodies may wish to intervene under two main normative principles: the equity norm and the Pareto norm. It would be useful to examine how the equity and Pareto norms function in an economy and, subsequently, the reasons why the state would wish to regulate using these norms as outlined by Little (1970).

The equity norm (Arenson, 2007) is principally concerned with the fair distribution of wealth and resources in an economy. The Pareto norm, which will be central to this thesis (Kanbur, 2005), as with its derivative the Kaldor-Hicks compensation principle, also known as Potential Pareto Improvement (PPI) (Kaldor, 1939), evaluates the efficiency of allocation of resources within an economy.

Thus it is appropriate to examine Pareto optima and PPI conditions, instances where these conditions are not present in an economy and where intervention by the state or regulatory body could help ensure the attainment of these optima.

According to the strict Pareto criterion (Pareto norm), where a change results in an improvement making some people better off without making others worse off, the change is good and ought to be implemented. This is observed up to the point where another change implemented would make one person better off but another person worse off (Begg et al., 2003).[7] It suspends judgement on all other instances. It can be demonstrated that if the price of every good or service in an economy is set equal to the true marginal

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[7] An allocation is Pareto-optimal for a given set of consumer tastes, resources, and technology if it is impossible to move to another allocation that would make some people better off and nobody worse off.

cost of producing it[8], a Pareto optimal allocation of resources will be the result. Under conditions of perfect competition a firm's profit maximising price will equal long run marginal cost in the long run equilibrium position; hence goods or services are produced at Pareto optimal levels under perfect competition in all markets provided that there are no public non-excludable externalities and provided that all agents in the economy are adequately informed in matters relating to their choices (Gould and Ferguson, 1980).[9]

The Pareto norm, introduced by Pareto (1909), has been evolved further by economists including Pigou (1932), Kaldor (1939) and Mishan (1965) in the context of welfare economics. Considering the context of social policy, it is useful to examine the Pareto criterion under four different types of social policy: good policy, good/bad policy (agnostic stance) and bad policy. There are four possible outcomes or results from any policy shown in Table 2-1.

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[8] True marginal cost equals the full marginal resource cost, otherwise known as marginal *social cost.*

[9] See Chapter 16, page 464.

| Cases | Policy outcomes under Pareto Criterion |
|---|---|
| **Case 1** | If there is a situation where some people gain and no one loses as a result of a policy then according to the Pareto norm it is a good policy and therefore ought to be implemented. |
| **Case 2** | If there is a situation where some people gain and some people lose whereby marginal benefit MB minus marginal cost MC (these are both all measured in money terms) is greater than or equal to zero (MB-MC $\geq$ 0) then in accordance with the Pareto norm it is unclear whether a policy should be undertaken or not. However with MB-MC $\geq$ 0 then in principle the gainers could fully compensate the losers in which case it would revert to a situation where there is a definite Pareto improvement. This is referred to as the PPI in which the Kaldor-Hicks compensation test is used to determine the appropriate compensation; that is to say if the policy is accompanied by a further policy designed to compensate any losers the two together will achieve a Pareto improvement. |
| **Case 3** | If there is a situation where some people gain and some people lose then where MB-MC <0 the Pareto norm suspends any judgement. In these circumstances there is no potential for Pareto improvement by gainers compensating losers but it is still difficult to establish whether a policy should be undertaken or not. The utility significance of the gains to the gainers may outweigh that of the losses to the losers when the marginal utility of money is different for different people.[10] |
| **Case 4** | If there is a social policy where some are worse off and nobody is better off in accordance with the Pareto norm this is a bad policy and in effect results in a Pareto decline. |
| For cases 2 and 3 where there is not a clear-cut *a priori* Pareto improvement an appraisal (e.g. Cost Benefit Analysis)[11] can be carried out to see if there is a PPI or not. In the outcomes 1 and 4 CBA may be used to substantiate the effectiveness of the policies, although in most instances 1 and 4 are hypothetical since most policies have some good and some bad implications. | |

**Source: Author's Own**

*Table 2-1: Policy outcomes under Pareto Criterion*

Under conditions that are not perfectly competitive or where certain externalities or imperfections are present, there is a strong case for the state to intervene and regulate within an economy because maximum welfare is not attained. The state intervenes when there are distortions in the market causing market "failure" or inefficiency, i.e. failing to achieve efficiency (Pareto optimality) in the allocation of society's resources. In practice markets rarely live up to these conditions, hence a variety of market failures are common. Market failures can be addressed by state intervention using a variety of policy instruments (e.g. fiscal instruments such as tax/subsidy, or legal regulatory instruments such as emission controls). Weimer and Vining (2005) note that the theory of market failures has been a key topic in the study of public policy for many years. The theory

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[10] This is in principle relevant to case 2 but if the gainers actually compensate the losers then with no one being worse off, consideration of the different marginal utilities of money become irrelevant.

[11] Discussed in more detail in Chapter 3.

suggests that the pursuit of private interests will lead to ineffective outcomes when considering the provision of public goods, natural monopoly, externalities and information asymmetry, and that the case for state intervention can be used to correct these problems. Kleiman and Teles (2008) also note that the theory of market failures is extensively used as a diagnostic tool for evaluating policy problems and as an analytical tool for making policy choices. Wu and Ramesh (2014) highlight the differences between market failure (imperfections) and government failures while also recognising the duality of both in avoiding such failures.

Examples of market failures (Pareto optimal conditions are not present) and policy responses are: EU Competition policy to deal with abuse of dominant position; taxes or subsidies used in order to promote various aspects of environmental policy such as renewable energy; and direct emission controls for cars.

The equity norm is not widely used in public transport policy except in relation to services for remote areas on the basis of accessibility and fairness rather than efficiency. Concessionary fares for older and disabled persons are another example. Provision of public transport in remote areas and concessionary fares may be considered to be inefficient allocation of resources, however can be considered to be equitable in terms of delivering services to rural communities and subsidising the older and disabled population who may not be able to afford such services.

Also implicit in much economic evaluation is the use of “equity” values for non-working travel time savings. For example, in the HM Treasury Green Book (2013a) it has been established practice to use a national average standard value of non-working travel time savings (averaged across all income groups and hence implicitly equity weighted) for all modes of transport for appraisal purposes. Standard values are used as they are considered to be independent of income.

The Pareto norm does not assist in achieving the equity norm since it assumes for a given income distribution no one is better or worse off. It does not make an assumption regarding how the income should be distributed. In order to achieve equitable distribution another mechanism would need to be implemented.

There are a number of distortions that may cause a market system to fail to achieve efficient allocation of resources in respect of safety in transport. These include monopoly, public externalities in the absence of certain types of property right, differing standards and information asymmetries or imperfections (these are discussed in detail in Section 2.5).

## 2.4 GOALS IN TRANSPORT SAFETY

### 2.4.1 Rational goals

Rosencrantz (2006) provides a succinct discussion on rationality in which he aims to provide new and alternative approaches based largely on ideas and suggestions originating from moral philosophy and philosophical decision theory and what this means in the context of transport policy decisions. He emphasises that: *"...rationality is the first virtue of decisions – whether made by individual agents making decisions for themselves or by officials making decisions for the public. A decision however thoroughly calculated and thought over must be rejected or revised if it is irrational"* (Rosencrantz, 2006, p2).

Rosencrantz (2006) is adopting a normative position here: that is, a position on how decisions *ought* to be made as opposed to how they are actually made in any particular context. Herein lies a link of rational policy choice to ethics and moral/political philosophy as the disciplines which discuss normative issues in depth; for Rosencrantz (2006) a person who makes a practically irrational decision is in some way irresponsible and morally blameworthy - hence, unethical. This is an area which has been extensively discussed by writers such as Rawls (1971), Harsanyi (1976) and O'Neill, (2004).

### 2.4.2 Aspirations, objectives and goals

Goals are the objectives that a decision-maker would like to realise and there may be a hierarchy of subsidiary goals leading to an ultimate objective. While it has been stated above that there is rationality of means and instruments we can also look to the rationality of the goals themselves, both the ultimate and the subsidiary goals. This becomes important in the context where transport safety is traded off against other government goals such as health or education.

Some solutions have been proposed for the analysis of conflicting or incoherent ultimate goals. When goals are inconsistent or incoherent a rational individual should revise their own goal system. In such an instance some goals may be partly achieved without abandoning or lowering the achievement level of other goals. The following authors' views provide some insight on how to address conflicting or incoherent goals.

Allais (1979) argues that multiple ultimate goals can remain rational providing that the ends are consistent and the differences can be accounted for by differences in individual preferences or tastes. He further suggests that rationality of ends should be consistent even though they may be arbitrary due to differences in individual tastes: *"It cannot be too strongly emphasised that there are no criteria for the rationality of ends as such other than the condition of consistency. Ends are completely arbitrary. To prefer highly dispersed random outcomes may seem irrational to the prudent, but for somebody with this penchant, there is nothing irrational about it. This area is like that of tastes: they are what they are, and differ from one person to the next". (Allais, 1953[1979[12]], p70).*

According to Allais (1979) goals are only rational if they are consistent, and irrational when they are contradictory.

Rosencrantz however suggests that there can be goals which are based on different policy priorities and therefore not irrational even though contradictory. He proposes to outline a general rationality criterion for a goal taken as an end in itself rather than in relation to other goals. He states that a goal should say or imply something about how the individual/agent who has the goal should act. Otherwise, he states, it would be appropriate to conclude that the goal would not be rational. Goals that fail to guide an individual's actions, that is to say are imprecise, vague and trivial, are not rational. Action guiding goals have been discussed by Edvardsson & Hansson (2005). More specifically they should satisfy the four rationality criteria of precision, evaluability, approachability and being motivating (motivity). These are similar to the SMART (*S*pecific, *M*easurable, *A*chievable, *R*ealistic, and *T*ime-bound) criteria used in public service project management.

Individual preferences exist which may have subjective elements and policy makers' preferences may be based on objective elements; however, these collectively aim to maximise overall utility.

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[12] This is the direct English translation, which appears for the first time, of 'Fondements d'une Théorie Positive des Choix Comportant un Risque et Critique des Postulats et Axiomes de L'Ecole Americaine' which was published in French as Memoir III annexed to Econometrie, Colloques Internationaux du Centre National de la Recherche Scientifique, Vol. XL, Paris, 1953, pp.257–332.

### 2.4.3 Assessing the rationality of goals - Vision Zero

When considering the approachability of goals it should be noted that goals can be rejected if deemed unrealistic or impossible to reach. For instance utopian goals are irrational (dysfunctional) since they cannot be achieved (Laudan, 1984). Rosencrantz et al. (2007) argue that this is often based on a black and white concept of goals as either achievable or non-achievable. This view they say is misconceived as they state that it ignores the fact that goals can be achieved at varying degrees (Cintora, 1999). Indeed, many important goals in social practice are difficult, or perhaps impossible, to achieve fully, though they can still encourage progress in the right direction. In this context Sweden's road safety policy "Vision Zero" can be considered to satisfy the criterion of approachability, despite being not fully realisable.

The rationality of a goal can be tested by taking the example of "Vision Zero". The 1996/1997 Bill states that: *"the long-term goal of traffic safety is that nobody shall be killed or seriously injured as a consequence of traffic accidents"* and that "*the design and function of the transport system shall be adapted accordingly*" (Government Bill, 1996/97:137). There are similar goals that have been introduced in countries such as Norway and Denmark and also at a European level. In September 2000, the Norwegian Parliament adopted a vision of zero killed and seriously injured (Steinset et al., 2002). The Danish government has formulated its vision in the slogan "*every accident is one too many*" (Færdselssikkerhedskommissionen, 2002). On an international level, the European Commission adopted a target to be realised by 2010, aiming at reducing the annual traffic fatalities in the European Union by at least 50 percent from the 2000 base year level (Peden et al., 2004). The long-term vision of a transport system in which no people at all are killed on the roads is however still restricted to a national level.

"Vision Zero" has been widely debated and criticised on a number of grounds (Nelson, 1996; Ekelund, 1999; Elvik, 1999a and 1999b; Lind and Schmidt, 1999). Criticisms include its being utopian or populist (zero risk of death or serious injury in a road accident), an improbable approach to trade-off (is road safety the only priority) and authoritarian (extreme precaution imposed rather than individual choice on risk provided no one else is harmed). Rosencrantz et al. (2007) argue that despite the above, Vision Zero is rational as it satisfies the criteria of precision, evaluability, approachability and motivity.

In order for Vision Zero to satisfy the first rationality criterion, it must be precise, clearly stated and free from vague and/or ambiguous terms, in order for the agent to know what to do. The three areas in Vision Zero that need precise definition are "road fatality", "serious injury" and "road traffic accident". In Sweden "road fatality" is defined "as person killed in a traffic crash or within 30 days after the crash (OECD/ITF, 2015, p434). For "serious injury", two definitions are used. *"...road traffic accidents with fatal and severe personal injury reported by the police are still used as official statistics. Another definition is used in the preventive road safety work. This definition is based on health loss following a traffic injury in which the previous health condition is not recovered within a reasonable amount of time. A person with any percentage of medical impairment, who has not recovered their previous physical health condition, is defined as seriously injured".* (OECD/ITF, 2015, p434). Hence, regarding clarity of definitions, Vision Zero is considered a specific goal targeting zero fatalities or serious injuries, although the definition of serious injuries is not precise as the time taken for the person to be well is not specified but referred to as a "reasonable amount of time". "Road traffic accident" is defined as an event that has occurred on a road, in which at least one moving vehicle has been involved and which has resulted in personal injury or material damage (SIKA and SCB, 2004)[13].

In terms of evaluability for Vision Zero, successful goal evaluation presumes that it is viable to assess actual goal achievement. As this goal can be measured as regards road traffic fatalities and serious injuries it is considered evaluable. Moreover the goal set interim targets for 2007 as it is long term.

Rosencrantz et al. (2007, p564) state that "*goals can be achievement-inducing not only by guiding action towards the desired end-state, but also by motivating the agent to act in ways that further the goal*". In terms of motivity, Vision Zero is action-inducing and it may be seen in the future through empirical evidence whether it fully satisfies this criterion.

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[13] The definition of "road traffic accidents" in Sweden does include bus boarding & alighting casualties at bus stops, which are included in the British data; however the Swedish data may not attribute them as bus users.

Overall the analysis provided by Rosencrantz et al. suggests that Vision Zero[14] is an action-guiding and, hence, a rational goal as it satisfies the criteria of precision, evaluability, largely satisfies approachability, and perhaps also motivity. In practical terms Vision Zero has led to a number of implementation measures, such as the construction of roundabouts and safer roadsides. Despite the steps that have been taken to reach Vision Zero, the goal is, presently, far from being realised. When Vision Zero was introduced, a target of a 50% of 541) reduction of fatalities between 1997 and 2007 was set. This goal was not achieved: the absolute number of fatalities in 2007 was 471. The initiative was extended to 2020 with a new target of no more than 220 fatalities or 47% reduction in fatalities from 2007. A recent progress report (Trafikverket, 2015) evaluates whether recent developments suggest that the 2020 targets are achievable and discusses progress on all road safety performance indicators. The main conclusion is that if current safety efforts continue then it would be reasonable to achieve the 2020 interim targets for fatalities and serious injuries, with the caveat that road safety for cyclists must increase. The conclusion is derived from comparing the annual fatality reduction in the years 2008–2013 (8%) with a required further reduction (5% annually).

Sweden has reduced road fatalities from 1997 (541) to 2013 (260) by 52% compared with the overall EU reduction of 57% (EU absolute numbers of fatalities were 60,267 and 25,938 respectively) during the same period (European Union, 2015). However as the Swedish case was from an already very low base in terms of fatalities per million population, it could be seen as a better performance.

### 2.4.4 Practical rationality

A distinction can be made between the rationality of goals and objectives as considered in the previous section and the rationality of the means and instruments to achieve these goals. Rationality of means or instrument, that is the practical rationality of an action, refers simply to the effectiveness of means in attaining the desired goal.

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[14] There has been some debate around Vision Zero by various stakeholders suggesting it is based on the rejection of economics and the substitution of ethics and values to a higher order of decision-making significance. The decision to use ethics as a decision-making guideline was arrived at after debate and discussion. Nevertheless, in this thesis Vision Zero has been presented as policy that is based on rational goals and this is further supported by Elvik (2008) who considers visionary targets as an element of the normative foundations of transport policy and in more recent work (2013) suggests that, "rationality is an ideal for transport safety policy …within normative welfare economics…" p. 62).

This work on CMS will primarily be concerned with the rationality of actions or decisions and hence *practical rationality*, including the means to achieve this through rational analysis methods. It will be presumed throughout the work that policy decisions *should* be practically rational or, at least, that practically rational decisions are ***better*** decisions. In effect, the position of this thesis regarding rationality closely follows a variety of previous work in this field: notably, work carried out by Spohn (2002), Mele & Rawling (2004), Rosencrantz (2006), Hansson (2006), Edvardsson (2006) and, more recently, Elvik (2013).

Elvik considers rationality an optimal basis for transport safety, albeit noting specific instances where there may be certain paradoxes[15] with respect to road safety policy and proposing reasonable solutions to overcome the contradictions. For example, strict adherence to the application of individual's Willingness-To-Pay (WTP) for improved road safety may be an inconsistent assessment methodology, as it is strongly influenced by variable factors such as personal income differences (earning ability may vary by an order of magnitude or more). This leads to differences between high income earners and low income earners in the marginal utility of money. Hokstad and Vatn (2008), citied in Elvik (2013) show that this problem with conventional WTP can be overcome by introducing the notion of "*relative willingness to pay*". When there are groups whose benefits from a measure vary extensively due to income differences, this variance can be overcome by adjusting for differences in the marginal utility of money by assigning "utility weights". The two groups are then more comparable regarding true costs and benefits and associated options that are presented. Elvik proposes a fixed value per life saved. This is normally recommended in official guidelines for CBA as is the case of Great Britain in the WebTAG appraisal guidance (DfT, 2014b).

## 2.5 THE CASE FOR INTERVENTION

The main arguments for state intervention to ensure transport safety can be considered in terms of externalities, monopolies, information asymmetries and harmonisation of standards. These are now discussed in a general sense followed by consideration of how this can be applied to transport safety and the impact of different organisational structures.

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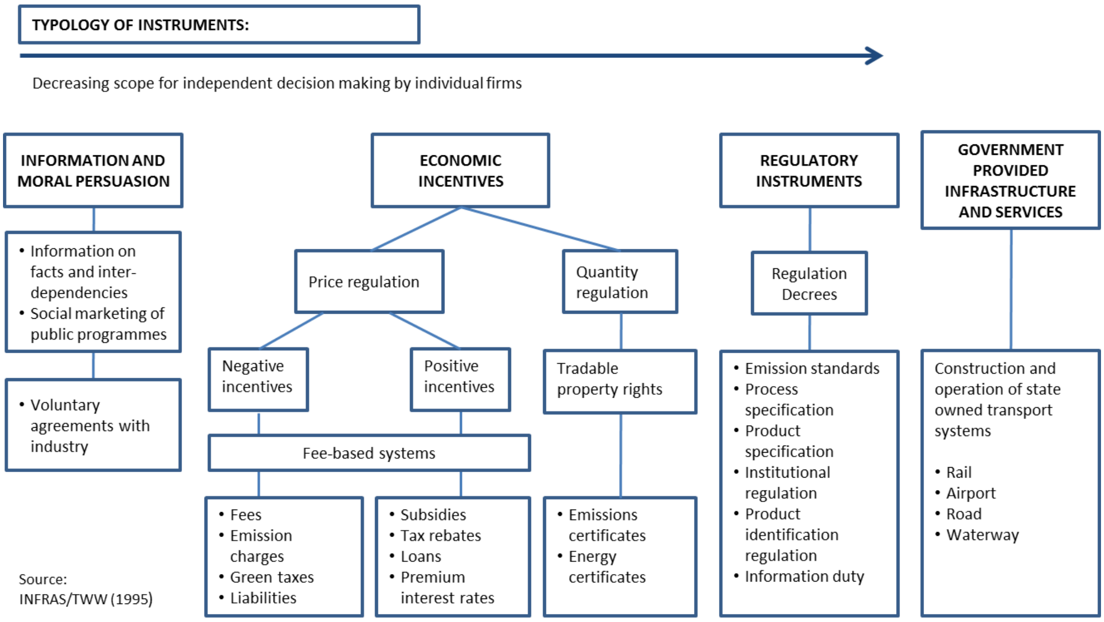
[15] Referring to situations in which conflicting choices can both be defended as rational.

### 2.5.1 General case for intervention

**Externality arguments**

Where there is market failure for goods that cannot be traded (typically due to the impossibility of "consumer exclusion" from enjoyment of public benefits) there is an incentive for regulatory bodies to intervene to bring about optimal allocation of resources through certain measures or policy regulations. Internalisation by the market of the effects is problematic. Figure 2-1 gives some idea of the range of such instruments.



Source: INFRAS/TWW (1995)

*Figure 2-1: Typology of policy instruments for internalising external effects*

From transport safety policy and CMS an important case of public non-excludable externality where regulatory intervention is required is in respect of third party safety. In certain cases, the externality represented by safety impacts on third parties can/may be internalised through third party insurance cover (which may be either voluntary or compulsory) but this is by no means always the case.[16]

**Monopolies: avoidance of abuse of dominant position**

There are two good examples of natural and non-natural monopolies within the transport sector. Railway infrastructures are classic examples of a natural monopoly in every country. Two examples of non-natural monopolies are: the local bus industry in bigger

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[16] In the case of aviation, while air operators are, in principle, insured for damages to third parties there is invariably a "combined single limit" which sets a ceiling on the total possible insurance payout to third parties. Once that limit is exceeded there is no insurance cover for any further damages.

cities, such in the UK prior to deregulation in 1986; and to a lesser extent, British Airways prior to 1986 when it faced duopolistic competition on a number of routes. Presently there is evidence of near-monopoly situations in many areas since deregulation. For example, certain rail routes in the UK are served by two operators but the majority are only served by one (e.g. First Great Western or Merseyrail) and this is similar for bus operators (e.g. First Cymru and Arriva Buses Wales).

The more general abuses of dominant position by monopolies are of limited relevance to transport safety.

**Information asymmetries/imperfections**

In transport safety this is potentially very relevant to the consumers who travel on the various modes of transport as there may be considerable imperfections in the information utilised by consumers regarding the relative safety of various modes. The need to address issues of information asymmetry/imperfections is therefore another valid reason for state involvement in the transport safety domain.

**The need for harmonisation of standards**

Rights of way are determined by the state in road transport. Similarly in aviation and shipping there are collision avoidance rules to provide safe passage for aircraft and vessels. It would be difficult to leave this to the private sector as different standards would inevitably emanate from different companies/firms or individuals. Common standards are essential in the transport sector to reduce the risk of death or serious injury. Although uncontrolled airspace suggests greater risk acceptable to private aircraft than controlled airspace, it does have a well-defined set of rules for rights of way, flight levels, etc. The development of the European Rail Traffic Management System (ERTMS) for example aims to make rail transport safer through the introduction of the European Train Control System (ETCS), which guarantees a common set of standards that enables trains to cross national borders (European Commission, 2015).

### 2.5.2 Application to transport safety

This section takes the general concepts introduced in the previous section and considers how these can be applied to the transport specific case. A general introduction is given and then this section follows the same basic structure as 2.5.1 i.e. externalities, monopolies, differing standards and information asymmetries.

Safety represents a good or benefit that can be consumed and traded off, as with other traditional goods and services; therefore, it can be considered as a characteristic of the transport good in Lancaster's classical sense of the term (Lancaster, 1991).

The treatment of transport safety as a commodity, or (following Lancaster) as a characteristic of the transport good, has been an underlying assumption in the literature of Moses & Savage (1990) and later King (1995). Both texts assert that together with price, speed, frequency and quality of service, safety can be considered to be an economic attribute. King (1995) asserts that the economic attribute 'safety' is dependent on consumers' willingness to pay for it and also that it can be traded off against other attributes. King also expresses that "*The equilibrium level of safety [is dependent on] willingness to pay ..., the type of market structure and the cost of provision. The precise relationship between these two demands is influenced by several factors ... under two broad headings: market and informational factors*" (p9-10).

In practice however, the treatment described above is open to some criticism, as consumers are not always rational and consistent in their choices, mainly because of asymmetries/imperfections of information and convenience factors[17]. More recently, transport studies from developing countries also recognise safety alongside other attributes such as quality, convenience and cost (Githui, 2010 and Vilakazi and Govender, 2014). Savage (2013b) outlines that safety, to a certain degree, is considered as a "product quality attribute" of transport and emphasises that while there are similarities with other transport quality attributes (time, congestion etc.), there are differences in terms of market failures. For example, congestion on a train may lead to inconveniences such as commuters having to stand, bus delays and traffic congestion, but this can be contrasted sharply with the much more important implications of safety failures (i.e. casualties and injuries).

### Public non-excludable externalities

The main thrust of the argument for regulatory intervention to promote safety must be on the grounds of public non-excludable externality and imperfections of information. As far as passengers are concerned, ***safety*** is one aspect of the good they buy from operators. There is an obligation in most cases on transport operators to provide their service with

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[17] For a full discussion of these issues see further Sjöberg (1987), Dixit & Stiglitz (1977), Dixit (1979), Viscusi (1992), Leland (1979), Shapiro (1982) and King (1995).

due regard to safety; but under conditions of competition there is also a market incentive to do so for passengers, since safety is a clear characteristic of the transport good. Safety should be provided to an "optimal" level[18] by competitive firms without any state intervention as previously noted.

In many cases this useful result does not arise in respect of risk of death or serious injury imposed on third parties by operators and infrastructure providers. Third parties are those without any direct market relationship with the operators or infrastructure providers either as passengers or as crew; and in many instances a public non-excludable externality is present regarding safety to third parties. In such cases the case for state intervention to provide optimal provision of safety to the third parties may be made. If the only externality-based case for intervention arises in respect of risks to third parties, it would follow that the case for state intervention is the strongest by far in relation to road transport. The reason for this is simply that in the case of aviation, maritime and rail[19] transport, risk of death or serious injury to third parties is generally low, whereas in road transport there is a much greater risk to third parties (DfT, 2014c and European Union, 2014). In aviation, most accidents occur in areas where there are no third parties present to be affected (such as at sea and in remote areas). In shipping, most accidents involve collisions with other ships, groundings or fire/explosions which rarely affect third parties. The exception is large oil spills, which have extensive impact on third parties. In rail transport, most accidents again are derailments or collisions with other trains which occur within railway land, are considered to be part of the same system and thus do not usually affect third parties. In recent years there have been far more casualties to road users in collision with trains in Britain. Road transport accidents, however, do affect third parties due to the multiple use character of road networks where motorised transport frequently comes into direct contact in accidents not only with other independent motorists but also with pedestrians and cyclists. To the extent that these impacts on the safety of third parties constitute public non-excludable externalities there is a case for state intervention to promote an optimal level of provision. The classic example of this (in recognition of the

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[18] Savage (2013, p2) argues that: "*…economists would have no problem in concluding that the "optimal" level of safety is most likely not perfect safety (presuming that it was even technically possible). This type of thinking clearly creates tension between economists and those who feel that it is somewhat "immoral" to decide not to spend money to avert some low probability risk…*"

[19] For rail the impact on third parties arises mainly at level crossings and with respect to trespassers. There are also some incidents arising from freight train derailments resulting in major fires, e.g. in Canada.

fact that this type of externality is most common by far in road transport) is the state-imposed legal requirement that all road users should hold third party insurance, which may be used to compensate third parties in the event of an accident which affects them.

### Monopoly arguments for intervention

As consumers can and do trade safety against other economic attributes in a consistent and rational manner, one possible abuse of a dominant position by any transport monopoly (especially those with inelastic demand) would be ignoring or paying little attention to consumers' wishes regarding safety; transport monopolies may take short cuts on safety because the consumer has no alternative for the service in question.

Notwithstanding the non-rational behaviour of some limited consumers who often make unsafe choices[20], there is a case for some type of regulatory intervention to control monopolies in order to mitigate the consequences of the abuse of a dominant position by such firms on the grounds of safety. Monopolists (sole providers of a service in the market) may not have the same incentive to provide for safety as competitive firms.

### Different standards emanating from different authorities

Common standards for transport safety are essential since varying standards have in some cases led to serious compromises on safety. It must be stressed that while national common standards are appropriate for some industries, they are not sufficient in transport since road, rail, air and sea transport (especially the latter two) are not confined within national boundaries. Transport routes cross national borders and therefore national standards *per se* are insufficient. This problem is particularly well illustrated by the much higher accident rate for Left Hand Drive (LHD) heavy goods vehicles (HGVs) on UK roads, caused by unfamiliarity with British road conditions of those who normally drive on the right, and/or visibility from that side of the vehicle. For example, in a study undertaken by the University of Loughborough on behalf of the Department of Transport, Danton et al. (2009) noted that 92% of all LHD HGVs accidents occur on motorways and A roads[21] with ‘‘vehicle blind spot' being the main contributory factor in 76% of the incidents. This is due to the drivers operating left hand drive vehicles while in the UK the standard is right hand drive vehicles. In comparison to Right Hand Drive (RHD) HGVs,

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[20] For example modes of transport such as rail and air are statistically safer than road, however consumers still choose to use travel by motorcycle (risk takers, i.e. young adult males) or car (for other reasons such as cost, convenience and/or personal space) even though this suggests inconsistent characteristics

[21] This is to be expected since most journeys for LHD HGVs are on motorways and A roads.

LHD HGV accidents were approximately 20% higher. Hence there can be a case for regulatory intervention at a supranational level to co-ordinate safety standards for any mode of transport which is international.

In practice, most countries, barring a few anomalies, comply with the international conventions and regulations on collision avoidance and rights of passage in the aviation and sea transport modes.

**Information asymmetries/imperfections**

Section 2.5.1 noted that consumers (passengers) may often be ill informed regarding modal safety and that this may give rise to sub-optimal modal choices. Better consumer information is needed which the market itself often fails to provide. This imbalance can be redressed by the improved provision of information by state organisations. A form of information asymmetry is adverse selection. Classically, this occurs when some players, often managers and other insiders, know more about the financial situation of firms than outside investors. In transport safety, adverse selection is broader. Rather than transport staff making better informed transport safety choices, the emphasis is on possible adverse selection by the travelling public as a whole because they are poorly informed of the real safety implications of their modal choices. The effective promotion of CMS may be a means to address this.

Examples of imperfect information in transport safety are sometimes clear cut. Taking the case of a used car, if the prospective purchaser is unaware of defects that may compromise safety the potential effects are obvious. The situation is less clear cut with other aspects of transport. In some cases, information may be available to the public if they are inclined to seek it out and assimilate it, but in most cases members of the public are not willing to do this. Therefore, as a result of withheld information, an unwillingness to seek information and the complexity of the information they do have, the public do not make modal choices with the full range of safety information available to them. This leads to a case of information asymmetry/imperfection.

One factor which has potentially helped this situation over the past decade, at least in terms of access, has been the rapid growth in the Internet. This has allowed the public to be better informed and may help to a certain degree to address the information asymmetry problem. The limitation of this advance is that while the information exists online and can be accessed by the public, it is not always in an approachable form. Furthermore, if the public do not consider there to be a specific safety risk at the outset, they are unlikely to use the means now at their disposal to access the statistics.

Arguably, while private operators have every incentive to provide such information at least for those modes which are safer, unfortunately for those modes which are less safe they have every incentive to *hide* the relevant information. It is thus important to note that published information usually serves the ends of those who publish it and this does not always coincide with the public's needs. For example, transport websites could publish information on risk factors for the various modes in the same way that they currently do for journey carbon emissions.

It must be emphasised in any case that for a market system to produce Pareto-optimal results it is indispensable that all consumers should be well-informed in matters relating to their choices; and in any case almost every type of intervention is, to some extent, "paternalistic."

### 2.5.3 Institutional structures

The ownership (public or private) of institutional structures is important as this impacts the nature and effectiveness of state intervention. If institutional structures are state owned then any regulatory intervention is facilitated by the state, whereas intervention in private ownership infrastructures is more difficult due to differing objectives and interests.

Transport sector ownership structures vary between and sometimes even within countries. Moreover, a key distinction needs to be made between infrastructures (roads, railway tracks, airports) and operations (airlines, train operators etc.). The former are almost entirely state owned throughout the EU, except airports[22]. In the case of railways for example, the network is almost always public sector controlled. Even in the UK, where the infrastructure was run by Railtrack, its successor Network Rail is classified as a government body under Treasury control since September 2014. In the case of operations there is considerable variability in the ownership pattern: for example, rail operations are privately owned in the UK (although with a degree of public subsidy in the case of many operators). While in other European states, freight operations are often partly or wholly

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[22] According to the ACI Europe Report on the Ownership of Europe's Airports (2010) the majority of European airports (78%) are publicly owned, with 13% owned by mixed public private shareholders and 9% fully privatised. In terms of passenger handling the publicly owned airports only handle 52% of passengers while the remaining 48% are handled by the mixed public-private ownership or fully privatised airports.

under private sector control, passenger operations are typically under varying degrees of public sector control (Hayashi and Morisugi, 2000).

## 2.6 OPTIMISING TRANSPORT SAFETY POLICY

### 2.6.1 Context

To provide context for the definition of optimal transport policies and within those, optimal transport safety policies, the literature on this topic is reviewed.

The elements of the normative foundations of transport safety policy (elements that define what the objective ought to be) are examined by Elvik (2008). He provides a comparative analysis of policy measures in Norway in terms of: visionary targets (e.g. Vision Zero – see Section 2.4.3 ); numerical targets and systems of management by objectives; notions of optimal safety and acceptable risk; and regulations, standards, incentives and mechanisms for resource allocation in the public sector for transport safety measures. Elvik concedes that defining an optimal level of safety has advantages in that it is rational, provided that the normative grounds of welfare economics are accepted. Although such a level has been estimated for road safety in Norway, he notes that wider support remains for Vision Zero by policy makers in Norway. The reason for this is that Vision Zero has democratic acceptance and is simple and transparent, while optimal transport safety policy notions are considered complex and have low democratic acceptance.

For transport policies in general, Timms et al. (2002) sought to define optimal levels of pre-defined transport measures using a method for devising transport strategies that made iterative use of transport models in nine European cities. A key element was the definition of objective functions which encapsulated policy-makers' objectives and allowed trade-offs between internal and external benefits/costs with respect to economic efficiency and sustainability. Their work noted that optimal strategies are comparatively insensitive to the costs of externalities. When costs of externalities are based upon accepted values, optimal strategies are similar to those with no value assigned to the externalities. This suggests that those strategies are most effective in achieving a balanced economic efficiency / sustainability objective and also perform best when this objective is extended to take into consideration the local environment and safety, using standard values for the costs of these. On the other hand, if greater emphasis was placed on local environment and safety through higher cost evaluation, optimal strategies would be likely to involve imposing higher charges for car use. This means that the most effective strategies to attain balanced economic efficiency/sustainability objectives perform equally well when these objectives are extended to safety and the local environment. If however greater prominence is attached to safety and the local environment, reflected through evaluating their costs at a much higher level, optimal strategies would then potentially lead to increased charging for less safe modes such as car travel.

Savage (2003, 2013b) discusses appropriate levels of safety and outlines optimal safety attained when an individual's willingness to pay (demand) is equal to the marginal cost of providing the safety (supply). The value individuals place on safety is referred to as Value of a Statistical Life (VSL), a metric much used in transport safety planning. Evans and Morrison (1997) calculated the optimal level of safety for a railway in the UK, from the information gained on the value that individuals place on safety; the marginal costs of accident prevention; and the connection between investment in the prevention of accidents and the actual number of accidents.

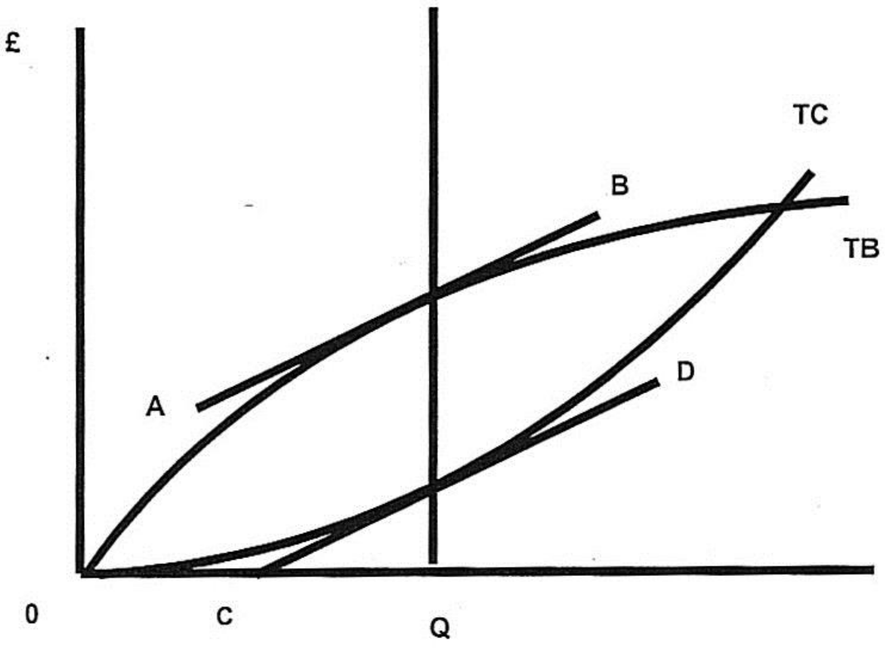
The debate on optimal safety here distinguishes between the cost of safety provision and the value of safety to individuals and society as a whole. This leads to friction between policy makers and safety advocates who believe in averting even the small probabilities of risk (Savage, 2013b). Evans (2013) highlights this issue concerning "*closely managed transport modes* [rail and aviation]..." and suggests that implementation of certain safety measures (train protection systems) can be very costly in relation to the value that is realised in terms of safety benefits. The next section examines overall optimal safety across all transport modes with respect to marginal costs and benefits.

### 2.6.2 Definition of an optimal safety policy

The case for state intervention under various headings and for various modes was reviewed in Section 2.5. Since this has been shown to be a multifaceted issue, a further question that can arise is the definition of an overall optimal policy mix in respect of transport safety across all modes.

Goss (1977) advocates: *'The subject* [optimal level of safety] *is important because, if it is not achieved, or it is achieved in one sphere of the safety regulations and arrangements made, and not in another, then it may well be that we would be devoting the wrong amount of resources to saving life and limb as well as mal-distribution of the total resources involved. This involves comparing the costs and the benefits and, since the benefits consist* *of deaths and injuries avoided, it is necessary to have some means of valuing life and limb.'* (p22).

If the costs and benefits of a continuous series of safety initiatives can be measured and monetised, Figure 2-2 illustrates how an optimal level of safety can be defined. This represents a different approach optimising the benefit cost ratio and hence a contrast to the more 'absolute' Vision Zero approach.

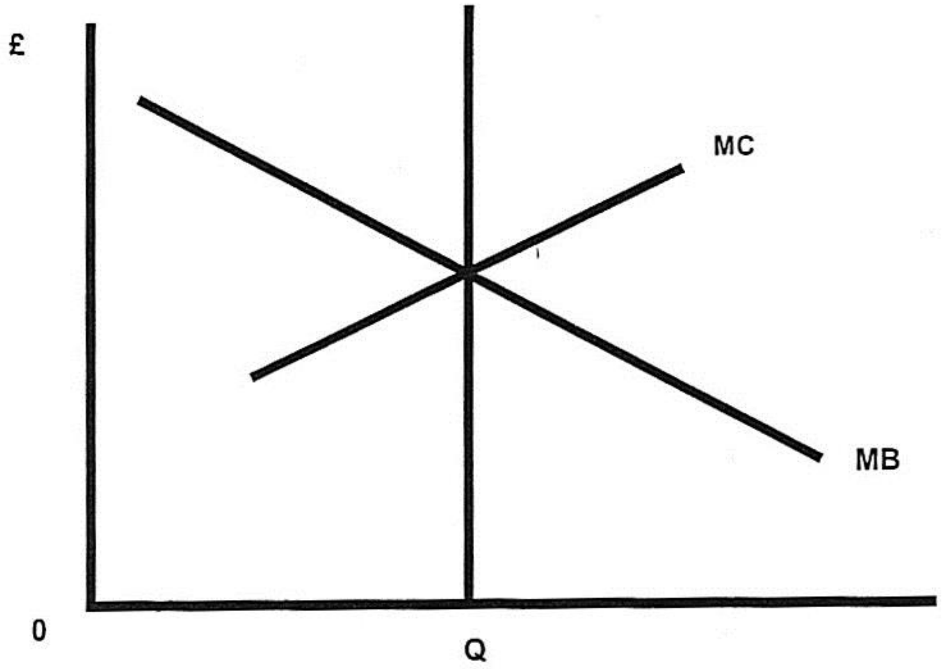


**Source: Goss (1977)**

*Figure 2-2: Optimal safety levels 1*

The vertical axis represents sums of money while the horizontal is the continuum of safety measures. The curve TC indicates the total costs. It rises gradually from the origin and accelerates with more safety measures since it is reasonable to assume that as one moves from simple safety measures to more complex ones they will become increasingly expensive. The curve TB represents total benefits and is concave from below. Basic safety measures will tend to result in large benefits while more complex or later measures will yield diminishing returns since previous measures will already have significantly contributed to the reduction of casualty rates.

The difference between the two curves TB and TC provides the net benefit derived from any given level of safety measure. The optimum net benefit is therefore where TB is furthest above TC, shown in Figure 2-2 by Q, whose location on the X axis will vary according to the assumptions by which the benefits are calculated. This may also be illustrated by obtaining relevant marginal curves as shown in Figure 2-3.



**Source: Goss (1977)**

*Figure 2-3: Optimal safety levels 2*

Here there is no change on the horizontal axis but the vertical axis measures the increments of the costs and benefits in moving from one option to another. Given the shapes of the two total curves areas in Figure 2-2, the marginal cost curve (from TC) must be rising and the marginal benefit curve (from TB) must be falling. The optimum level is where MC and MB cross and at 0Q (Goss, 1977).

The optimal level of safety investment is therefore where the difference between the marginal benefits - the value of marginal reduction in risk of death or serious injury - and the marginal costs - the increase in cost incurred as a result of a policy - is equal to zero. This can satisfy the Pareto norm. Where a change in policy has resulted in an improvement that leaves some gainers but no losers, the change is considered to be a Pareto improvement and ought to be undertaken. However, the $MB\text{-}MC \geq 0$ might still have some losers. If this is the case then compensation is necessary to convert a Potential Pareto Improvement (PPI) into an actual Pareto improvement.

## 2.7 SUMMARY

This chapter has developed the theoretical foundation within which CMS could be applied as an integral part of an overall optimal transport safety policy.

First of all the case for rationality in policy choice and in policy implementation is set out drawing on the work of Rosencrantz. Thereafter the notion of Pareto optimality is introduced as an appraisal approach and the exact meaning of optimality in relation to safety policy choices is discussed in depth. One key implication of adopting the Paretian approach for this thesis is that it allows one to adopt a vision of the efficiency of allocation of scarce resources across many transport modes and to compare the efficiency of allocating resources to safety policies as opposed to other areas of public policy. Within the Paretian framework the major sources of market failure which warrant the case for state intervention to promote a socially (Pareto-) optimal allocation are then considered in principle and as they apply to the case for transport safety promotion policies to be undertaken by the state. More detail on the practical tools for implementation of Pareto-optimal policies of state intervention, such as Cost-Benefit Analysis, is given in the next chapter.

The chapter has shown that rationality needs to be applied to both the setting of transport safety goals and the means used to achieve them. It has also highlighted that a rational approach requires a number of perspectives to be taken into account. Chief among these are psychological, cultural, economic and political power perspectives. It has also been noted that a rational approach needs to balance safety goals across modes so that investment is targeted where the benefits will be greatest.

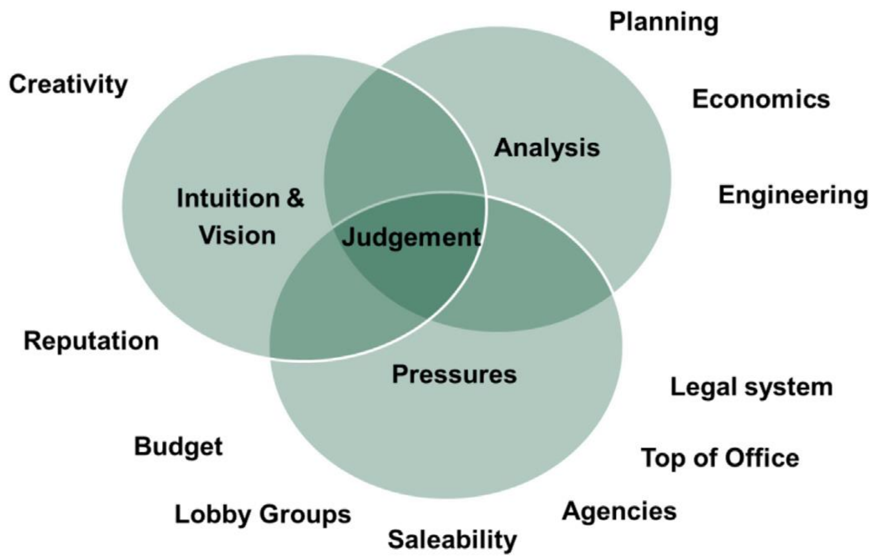
Methods for selecting the most appropriate policies are also considered in terms of norm and goals. This discussion considers both the ‘absolute’ options such as Vision Zero which sets almost unachievable targets as a means to push progress forward, and other approaches which trade monetised safety benefits against the costs of achieving them.

Arguments for state intervention are important because this is likely to be the basis for any interventions to implement CMS. Such interventions are normally justified on the basis of market failures and when Pareto optimality is not present. The next chapter will consider the appropriate methods of appraisal that are based on the efficiency norm and the associated tools to be used in the context of transport safety to assess CMS.

# 3 TRANSPORT APPRAISAL & TOOLS OF TRANSPORT SAFETY POLICY

To translate into practice the idea of a systematic cross modal dimension for a rationally founded safety policy requires effective analytical tools. These are now considered in this chapter to establish the best approach to be used for the appraisal of CMS in policy decision making.

Transport appraisal is the comparison of various costs and benefits that arise from policy or investment decisions which are presented in a comparable form. For Cost Benefit Analysis this involves monetary valuation of all costs and benefits while other techniques such as Multi Criteria Analysis allow for costs and benefits to be recorded in different units. Appraisal is extensively used in the transport sector as there are many effects of policies (time, safety, environment, etc.) and it is recognised that some type of common framework assists in the evaluation and understanding of the effects when there are budget limitations and several policy options being compared (Eliasson, 2014). Transport appraisal is dynamic with several feedback loops. Figure 3-1 provides an overview of how decisions and judgements can be distorted or misrepresented by vision, pressures and analysis (Mackie et al., 2014) in transport projects. It also shows the stakeholders involved.



**Source: Mackie et al., 2014**

*Figure 3-1: Decisions and judgements are affected by visions, pressures and analyses*

As decision makers' judgements are subject to a number of factors, including whose idea the project is, who wants it, who benefits, who pays, etc. it has been recommended that a common framework or formal guidance is required in transport appraisal. This is an alternative to decision makers deciding themselves, as they face large numbers of projects and it is unfeasible to fully process all the options within given time constraints. Mackie et al. (2014) summarises this well by noting that: "*Appraisal . . . makes it easier to structure information and remember and consider all or most aspects of a suggested project. It enables orders of magnitude to be created that are comparable both across projects and types of effects. A framework within which impacts are quantified on a consistent basis forces decision makers to face up to numbers, so decreasing optimism bias and our inherent reluctance to give up beliefs and ideas"* (p4).

## 3.1 TRANSPORT SAFETY APPRAISAL

This section reviews the appraisal techniques used in transport safety and outlines the most appropriate technique that will be used in this study. Jones-Lee (1994) discusses the need to design measures so that estimated safety effects can be appraised in an explicit and systematic manner in the public sector decision making process. He identifies six approaches, of which the first three ignore safety effects, rely on informal judgement and only use safety standards or targets. The remaining three, of greater relevance to this work, are:

- Cost-effectiveness analysis – an evaluation tool which compares mutually exclusive alternatives on the basis of the ratio of their costs to a given single effectiveness measure. This measure may be quantified, but importantly need not be monetised;
- Cost Benefit Analysis (CBA) – quantification in monetary terms of all relevant opportunity costs and expected benefits of policy measures. In the context of transport safety it encompasses explicit costing of risk and valuation of safety outputs; and
- Decision analysis – a sequential analysis method used when benefits accrue from contingencies which depend on the outcome of preceding contingencies, i.e. in sequence. The logical structure of the sequence is established using a decision tree and expected values are allocated to branches working back from outcomes to the

initial decision, in a process that eliminates branches yielding lower benefit values.

Of these, both the CBA and the decision analysis approach as developed by Keeney (1982) allow safety benefits to be traded off against other benefits and they explicitly take into account opportunity costs and potentially damaging consequences.

Evans (1994) also advocates the need for systematic tools to appraise transport safety using frameworks that can be applied to road and public transport. He classifies risk evaluation into three groups, namely CBA, industrial risk assessment (individual risk and societal risk) and the elimination of all avoidable accidents. Individual risk is defined *"…to be the probability of death to any specified individual in a year as result of some activity."* (p417). The probability range is split into three areas (high, middle and low). The middle range should be "*As Low As Reasonably Practicable*" (ALARP). The main focus is the area between high and middle range and assumed to be the risk of death of 1 in 1000 for those at work and 1 in 10,000 for third parties. The latter are assumed to have less risk as bystanders. Societal risk is concerned *"…with the distribution of the number of injuries or fatalities in any single accident … a particular concern with the risk of high-fatality accidents"* (p419).

Elimination of all avoidable accidents is another approach which avoids any monetisation or weighing up of benefits against opportunity costs (e.g. the Swedish approach of a centre barrier on single-carriageway roads to prevent overtaking). It is essentially a form of target setting.

In this work the elimination of all avoidable accidents is rejected as an approach on the grounds that such an attempt to achieve an absolute could and almost certainly would lead to misallocation of resources that could be better utilised elsewhere. As with Jones-Lee, Evans advocates a combination of CBA and risk assessment as a framework to appraise safety. Evans (1997) further expands his classification to include a fourth category, labelled "criteria based on accident frequencies" (previously referred to as societal risk) and the reduction of these (again a targets-based approach), although he concludes in favour of CBA combined with risk assessment. More recently Evans (2013) confirms that while target based approaches (all preventable accidents should be prevented) are used in closely managed transport modes such as rail and aviation, they make no allowance for the size and costs of the safety measure. Even if the risk is very small, the cost of mitigating the risk may be high. This leaves decision makers in a quandary, in that they do not want to accept preventable accidents but also want to have value for their investment of either public or private expenditure.

Generally, most of the available analytical techniques follow a similar process, at least in principle. Some of the key steps in the UK are outlined by the Department for Communities and Local Government (2009) as follows:

- Identify objectives;
- Identify options for achieving the objectives;
- Identify criteria to be used to compare the options;
- Analysis of options;
- Selection;
- Feedback.

This section summarised the appraisal tools used to assess CMS as a potential contributor to transport safety. Cost Benefit Analysis (CBA) is the primary method in this field, but before selecting this for this thesis, a range of alternatives are considered. These assessments are summarised below followed by a final section which selects the best technique to apply.

### 3.1.1 Cost Benefit Analysis

Broadly speaking CBA is used to facilitate efficient allocation of society's scarce resources to achieve the maximum benefits possible and thus to inform policymaker actions. It is based on welfare economics and requires all policy impacts to be expressed in monetary units (DaCoTA, 2012). Mackie et al. (2014) refers to it as *"...a framework within which all impacts of a scheme can be brought together and compared using the money metric*" (p.5).

There is an extensive body of literature on CBA as it has been developed over the last 50 years. There are several works explaining in detail the problems encountered in a cost-benefit analysis and how to solve these (Boardman et al., 2011; Pearce et al., 2006; Layard & Glaister, 1994; Mishan, 1988; Sen, 2000).

Although conceptually straightforward, the issues and the subjectivity in a CBA arise from the process of selecting and quantifying the benefits, selecting the discount rate and to a more limited extent assessing the costs. It is here that the views and objectives of the organisation preparing the CBA can significantly affect the outcome.

Over time CBA in various forms (sometimes as part of Multi-Criteria Analysis) has been incorporated in official guidance manuals that govern transport appraisal (e.g. WebTAG in the UK). The work carried out by Mackie and Worsley (2013) for the UK Department of Transport provides a summary of practices and compares CBA across seven countries. The outcome shows that there are strong similarities in practice among a number of the countries.

### 3.1.2 Cost Effectiveness Analysis

Cost Effectiveness Analysis (CEA) compares the costs of alternative ways of providing the same output (Communities and Local Government, 2009). CEA is therefore used under the following circumstances:

- When measurement of benefits in monetary terms is impossible;
- When the information required is difficult to determine or when any attempt to make a precise monetary measurement of benefits would be open to dispute;
- When dealing with intermediate outcomes whose specific benefits are not clear in isolation.

CEA is not used for consideration of subjective judgements or in the analysis of projects with multiple objectives. It generally omits impacts at the level of detail that would be included in a CBA analysis and a single measure of effectiveness is normally applied. For costs, non-budgetary costs are generally excluded.

As a result, a CEA is generally a simpler procedure, but less comprehensive than CBA. One description summarising this well by Boardman et al. (2011) is that with respect to technical efficiency CEA is able to rank alternative policies but it is not able to specify whether the project is worth undertaking or not (for example, a subsidy per trip for rural bus services). For this reason it is less well suited to the appraisal of CMS in this thesis.

### 3.1.3 Multi Criteria Analysis

Multi-criteria Analysis (MCA) provides a framework to compare unvalued costs and benefits using weighting and scoring. In some respects it is an alternative to CBA which avoids defining monetary values for the major costs and benefits, similar to CEA.

Nevertheless, MCA relies considerably on the judgement and experience of the people using it. An important function is to deal with the difficulties that human decision-makers have been shown to have in handling large amounts of complex information in a consistent way.

MCA helps decision-makers when their judgement is reliant on more than one criterion. Jensen (2012) describes MCA *"... [as] a set of alternatives, [defining] a set of criteria for decision making and ways of measuring them (measures are often not in the same units), and [deriving] weights for the criteria"* (p.51).

Bristow and Nellthorp (2000) refer to MCA frameworks that are objective led, with an equivalent set of indicators mirroring the success of the objectives and permitting weights to be allocated to the indicators. This results in a rankable value for each project.

MCA could be applied to the CMS case, but it is more subjective than CBA and hence less likely to convince planners and decision makers of the value of CMS.

### 3.1.4 Target based approaches

A target based approach sets a specific, usually quantifiable, target which policy is expected to attain in order to be judged effective and/or successful. The Swedish Vision Zero policy discussed in Chapter 2 is an example in the safety domain, with the target of eliminating all avoidable road fatalities (Tingvall, 1995).

Elvik (2003) discusses the role of target setting in seeking to reduce EU road casualties. The targets act as a tool for motivating and monitoring action by all relevant stakeholders to reduce death and injury in road traffic collisions. Sub targets such as specific types of collision or the involvement of specific road user groups can be also used but need to be set in accordance with the main target. Additionally, targets for behavioural performance indicators, like alcohol levels or seat belt use, are also valuable providing they can be monitored. Time scales are variable (5-20 years). A robust statistical methodology is necessary to set the reduction targets. Target setting in other transport modes is discussed in ETSC (2003b).

The problem with using the target approach is that it takes no account of the possible costs associated with meeting the desired standard. In some cases perhaps this cost may be deemed so negligible that the policy would self-evidently pass any more formal cost-benefit type of assessment; and in such cases the targets may be consistent with a CBA approach. Generally speaking, however, the targets approach is regarded as one-sided and partial: it looks only to potential benefits without any due consideration of costs of safety provision. However an interesting *a priori* reflection could be that if it were shown that the costs of CMS were in certain types of cases small or negligible a target type of approach could be adopted for CMS as a safety tool. Overall, the use of CBA is more convincing and will still demonstrate the value of an approach which has good outcomes and limited costs.

### 3.1.5 Goal achievement matrices/Decision analysis

#### Goal achievement matrices

Attempts to overcome some of the weaknesses of CBA have led to numerous extensions and modifications, such as the Planning Balance Sheet (PBS) or the Goal Achievement Matrix (GAM) (Hill, 1968). The latter defines and organises impacts according to a set of explicit goals that the proposed action is attempting to meet, and identifies consequences for different interest groups. It is also designed to accommodate non-monetary impacts, and uses a set of non-monetary value weights for computing a summary evaluation; it is thus similar to MCA.

Impacts such as social objectives that are not easily quantified in monetary terms can use GAM. Accident reduction measured by number of fatalities and reduction of air pollution measured by the amount of pollution are two examples of the application of GAM. GAM is a simple tool used where differing impacts can be considered through community consultation, and it considers equity effects that are difficult to monetise in CBA.

The disadvantage of GAM is that there is no common framework which can be used to estimate the level of achievement of all goals. The weights applied to goals are subjective and interdependencies of objectives are not reflected (NSW Government, 2013).

The GAM process is a useful tool for the consideration of issues whose benefits and costs are non-quantifiable in money values and are therefore unable to be included in a conventional cost benefit analysis. Booz Allen Hamilton (2003) for the Department of Transport, Ireland used the GAM technique to evaluate the qualitative goals of the identified railway projects for investment. The Planning Balance Sheet (Lichfield et al., 1975) stresses the importance of recording all impacts, whether monetary or not, and analysing the distribution of impacts among different community groups. Thus it adds the analysis as to whom cost and benefits accrue to the basic concept of CBA.

**Decision analysis**

This approach involves the following steps to a policy decision:

- Specify the logical structure of the decision problem in terms of sequences of decisions and realisation of contingencies. This tree links the initial decision (the trunk) to the possible outcomes (the branches).
- With the framework established the approach is to work backwards from the outcomes to the initial decision calculating expected values of net benefits across contingencies.
- Branches are then eliminated starting with the lowest expected values and working upwards.
- This leads eventually to the outcome of the best combination of net benefit and high probability.

### 3.1.6 Formal Safety Analysis (FSA)

In 2002, the IMO (International Maritime Organisation) approved guidelines for evaluating risk in the maritime field using Formal Safety Analysis (FSA). Montewka et al. (2014), citing the IMO guidelines (2002 and revised 2013), suggests FSA as *"a rational and systematic process for assessing the risks associated with shipping activity and for evaluating the costs and benefits of IMO's options for reducing these risks"* (p. 77). The underlying rationale of FSA is that it is a proactive tool (identifying hazards prior to a serious accident taking place) that assists in clear decision making. It enables a systematic and proactive view to be taken of transport safety allowing informed decisions to be made on the basis of objective analysis of risk.

FSA is essentially CBA applied to safety issues when the benefits are quantified in terms of reductions in risk. Safety in transport primarily addresses ways of reducing risk to humans, vehicles, freight and the environment. It therefore seems appropriate to apply FSA to transport safety appraisal since it encompasses both CBA and risk assessment. The FSA approach also permits continual assessment and improvement (review and revision). This is necessary to ensure optimal resource allocation when the associated risks are not static and changing technology and other factors lead to fluctuating risk levels. It consists of five steps:

1. Identification of hazards/accident scenarios with potential causes and outcomes;
2. Assessment of risks - evaluation of risk factors;
3. Risk control options - regulatory measures to control and reduce risks;
4. Cost benefit assessment - cost effectiveness of each risk control option; and
5. Recommendations for decision-making - information about hazards, associated risks and cost effectiveness of alternative risk control options.

The FSA approach is not new; it has been applied in the nuclear industry since the 1950s and is also applied in the maritime sector.

There are limitations to the FSA. Although it is proactive it is a complex and technical method that can be misused and therefore not necessarily provide the appropriate results for the system being analysed. Montewka (2014) notes that it could be more advantageous to have a more systematic risk perspective, integrating various features of the risk description and allowing the necessary recommendations to be addressed at the different stages of the risk analysis. For a critical review of FSA see Kontovas and Psaraftis (2009) and for a review of FSA see Psaraftis (2012).

The United Kingdom currently applies FSA in the shipping industry (e.g. cruise industry, Lois et al., 2004) and other transport modes are also increasingly using FSA. The rail sector for example has adopted measures similar to FSA in the *safety case* regime applied to certification of new train types.

### 3.1.7 Selection of technique

Sections 3.1.1 to 3.1.6 have described the CBA approach in the context of alternative techniques and shown why it is the preferred approach for this thesis. It meets the requirements for practical rationality, and although it has weaknesses these can be controlled. It has been shown that there are many opportunities for subjectivity within the CBA framework and that considerable care is needed to ensure that the result is fair and objective. To perform a CBA effectively requires not only an objective approach but also a good appreciation of the proposed development and its likely impact. CBA is applied in the UK through guidance provided by HM Treasury in the Green Book (2013a) and in the Netherlands by the Dutch General Guideline for Social Cost-Benefit Analysis (Romijn & Renes, 2014).

For a fuller discussion on transport project appraisal and techniques see Jensen (2012) and EIB (2013).

## 3.2 COST BENEFIT ANALYSIS (CBA)

### 3.2.1 Overview of approach

Cost Benefit Analysis (CBA) as outlined in Mishan's classic work on the subject (Mishan, 1988) has become an extensively used tool for the appraisal of optimal public policy choices based on the Pareto norm. Benefits as well as costs are monetised and the analysis goes beyond an individual consumer's or firm's private costs and benefits to embrace those of overall society. In effect, it is an attempt to resolve the measurement problem of Bentham's utilitarianism by attributing monetary values to all (marginal) benefits and (marginal) costs associated with a policy. It can be inferred that for any proposal with a positive marginal net benefit, the gainers in principle could compensate the losers by money transfers and still be better off (i.e. there is the potential to achieve a strictly defined Pareto improvement). This, in principle, involves the assessment of various safety projects in terms of their marginal net benefit: that is to say, marginal benefit (MB) minus marginal cost (MC); and where (MB ≥ MC) there is potential to make a Pareto improvement.[23] The (MB-MC) can be established for each project using CBA and other types of transport appraisal. When (MB-MC) has been established for a number of transport safety initiatives using CBA, the (MB-MC) calculation is used to **rank** the various possible policies or investments. The projects/policy initiatives with the highest (MB-MC) should be undertaken first. Where policy benefits and costs are spread over a number of years, the (MB-MC) becomes a net present value calculation, where the net benefits in future years are suitably discounted to equivalent present values. The NPV is calculated using the following formula:

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[23] Potential Pareto Improvement can be transformed into an actual improvement by appropriate re-distribution of resources.

$$\text{NPV} = \sum_{t=0}^{N} \frac{(\Delta Bt - \Delta Ct)}{(1 + r)^t}$$

$\Delta$Bt = change in benefits in period t

$\Delta$Ct = change in opportunity costs in period t

r = rate of interest used to discount returns (discount rate)

t = period of time in years

N = total number of years

It may be noted that the question of what discount rate to use in the calculation of NPV for public sector projects in general has been widely debated; but it is not necessary to go into the details of the debate for the purposes of this work. It is an issue which leads into the heart of the economic theory of capital and interest; and it is, in any case, an issue not just for transport policy appraisals but for all applications of CBA to public policy in a multi-period context.

### 3.2.2 Advantages and disadvantages

A CBA type of appraisal would lead to improved decisions overall and should be as wide ranging as possible to maximise its potential. Rather than not including poorly understood key impacts, it would be more appropriate to account clearly for uncertainty, thus imposing robustness between the different objectives being examined.

An OECD (2011) discussion paper considers the scope of CBA to have expanded gradually over time, and that it is capable of highlighting distributional and other indicators important for political objectives. It is considered compatible with changing strategic policy priorities.

Cost Benefit Analysis emerges as a structured, rational, transparent and relatively objective approach which can be used as a basis for assessing proposed transport safety measures. CBA looks at the costs involved in the means to attain goals while benefits are simply a measure of the degree to which goals are achieved. Therefore, CBA is the essence of a practically rational approach.

CBA can act as a remedy to single investments in transport which take a small amount from large groups (e.g. taxpayers) but benefit a small group (e.g. a segment of users), when considering several investment options within budgetary constraints.

CBA in transport can also effectively support the scarce allocation of resource within a programme where there are conflicting interests. Options and anticipated impacts have to be clearly described in the CBA framework, whereas decision-making is rarely expressed in this way (more often as visions or targets) and hence could result in conflict among the stakeholders (Figure 3-1).

According to Mackie et al. (2014), "*Cost-benefit analysis has become a widely used and well developed tool for appraisal of proposed transport projects. An important advantage of using CBA is that it is a way to overcome cognitive, structural and process-related limitations and biases in decision making"* (p10).

Methods of transport appraisal used in a number of countries were compared in a study carried out by Mackie and Worsley (2013). Their analysis showed that most countries use CBA within a comprehensive assessment framework that includes non-monetised benefits. There is an increasing focus on wider economic impacts and reliability valuation, although further development is required regarding time savings and reliability benefits.

The fact that CBA provides a monetised statement of the outcome means that the results can be used to support claims for the resources needed for the implementation of safety measures. So for example, the net benefits in terms of monetised lives saved can be used to justify the cost of a road improvement or a new rail system. As a result, CBA is considered to be the preferred option for transport safety policy appraisal for this thesis.

In spite of its rationality, CBA is not a panacea and one of the keys to its effective use is to be aware of its limitations and potential weaknesses. The limitations and questions for CBA are as follows:

- How acceptable is the underlying utilitarian moral norm? Are there other relevant moral norms for policy evaluation and do these preclude CBA or argue for it to be a part of a multi-criteria analysis?
- What levels of government intervention does it serve and what is its role in each?

- Subjectivity of benefit (and in some cases, cost) assessments cannot be avoided; it is inevitable where the future is uncertain.
- Perceptions of CBAs – the motivations of those doing it are often important in determining the outcome, i.e. they are rarely totally objective.
- Timescale issues – discounting of long term benefits adds more subjectivity.
- How suitable is appraisal of the introduction of CMS as suggested in this work?
- Technical issues surrounding the values and where they come from. How reliable are they and should private values or social adjusted values be considered?
- The difficulty of valuing intangible assets. CBA looks at both monetised and non-monetised impacts for this reason, but this leads to valuation issues for the money metric.
- The cost-benefit analysis does not tell us whether a scheme is widely accepted or bitterly controversial or whether there is investment available and so it is incomplete. It does not easily map onto the higher order strategic goals of the government.
- The key barrier to CBA is generally in the institutional and political environment, as appraisal is only effective where stakeholders (decision and societal) are open minded with respect to the social value for money and importance of any project.

### 3.2.3 Issues of standing

Given the points above, it is clear that CBA has many subjective elements in practice despite the rigour of the framework it provides. As a result, one of the first questions that should be asked of any CBA is who is doing it and why.

The result of this is to place limits on the acceptability of the method in the eyes of the public who become cynical of the stated billions that a myriad of proposed schemes are set to yield for the society. Some of the issues which relate to this are as follows:

- Jurisdictional membership: this relates not only to the benefits per se, but to whom the benefits accrue; i.e. how widely are we to cast the net when considering benefits; *whose* benefits are to count? If benefits relate only to a certain group of people, they are less likely to be accepted by others who may be omitted or even be worse off by the proposed change.

- Exclusion of socially unacceptable preferences. The classic case here is the Ralph Nader case, in which a US motor manufacturer used CBA to justify continuing to produce an unsafe car design because to change would have been more costly than to compensate the victims. Fully factoring in social costs is therefore an important part of a CBA.
- Inclusion of preferences of future generations. The change in the valuation of benefits over time is achieved using a selected discount rate as mentioned. The selection of this rate often has an important bearing on the result.

### 3.2.4 Political implications of CBA

Related to the issues of standing, considered above, are the political aspects of CBA. This returns to the issue of who is undertaking the work, why they are doing it and who is paying them. The potential for subjectivity allows for values to be selected which will make the outcome suit a particular purpose and hence, over time, the results become less believable. This has important impacts on levels of public discourse and, ultimately, on the process of democracy.

Since it has been suggested that CBA is the most appropriate method for assessing the possible role of CMS as an element of transport safety policy in this work, it is important to note the potential limitations and political implications of using such an analysis (Sections 3.2.3 and 3.2.4 ). Some of these limitations and issues are particularly pertinent to the application of CBA to transport safety, such as the exclusion of socially unacceptable preferences, jurisdictional membership and the consideration of full social costs. For example when assessing the extent of modal switch from one mode to another it is useful to determine who actually benefits from the transfer (a large group or a specific group).

## 3.3 EVALUATION OF CBA

### 3.3.1 Baselining – the counterfactual

One of the first problems when developing a CBA is to baseline the proposed development properly. In practice, this means developing a model of what there is now, and what would happen ‘anyway’ in the future, i.e. without the proposed development. The process of defining the counterfactual evolution of the situation is difficult, but it is complicated further when the interactions with the proposed change are taken into account. Taking as an example the construction of a local road traffic improvement measure, its performance in the future will depend on a range of time varying factors, but the construction of the improvement may itself impact traffic flows in ways beyond those it is designed to do. Similarly, if lower speed limits are introduced independently, the benefit of the new measure may be much more limited.

### 3.3.2 Valuation of benefits and costs

One of the main criticisms of CBA is that the determination of the benefits is a subjective process. The same may also be said of the costs, though these are often related to more tangible assets and activities and thus have a greater grounding in ‘objective fact’. Some of the problems faced when seeking to determine a statement of benefits which can be regarded as sufficiently objective are as follows:

- Forecasting – Benefits are often more difficult to forecast than costs. There may have been similar activities in the past that can be cited as points of reference, but there are usually sufficient differences to allow serious questions to be raised.
- Valuation – even if the occurrence of the benefits can be forecast with confidence, the next problem is to ensure that they can be valued effectively. This issue, as it relates to safety, is dealt with in Section 3.4.4 , but at this point it is important to note the subjectivity of this process and the sensitivity of the final outcome of a policy appraisal to how this is done. This subjectivity is epitomised in the ‘willingness to pay’ approach often used for the valuation of intangible and non-marketable benefits, whereby individual users give some indication of their willingness to pay for a proposed improvement (such as the preservation of a landscape or their safety) when using certain modes of transport. For example, there is a wide range of values which have been used for the so-called Value of Statistical Life (VSL) or Value of a Preventing a Fatality (VPF).
- Cost – Although less subjective than benefits assessment, the determination of costs is also open to question. In part, the selection of the approach to baselining will help to determine which costs are included and which excluded. This approach can be used to hide costs if a less than objective approach is being taken. Even when objectivity is sought, the costs may be based on forecasts or proposals

which prove to be optimistic (in effect an optimism bias)[24]. This is illustrated by the recurrent problem of cost overruns which seem to plague so many large capital intensive public sector projects (e.g. the West Coast Mainline railway infrastructure upgrade in UK). To address this optimism bias in projects it is recommended (HM Treasury, 2013b) that an adjustment or uplift should be made to reflect underestimation of scheme costs (Flyvbjerg and COWI, 2004). The DfT (2014d) provides specific guidance on the estimation and reporting of the costs of transport schemes and their importance, in that overly optimistic cost estimates can affect the viability and the value for money of a scheme. For this study optimism bias has not been considered since modal transfer does not envisage any large capital investments and the costs of transfer are known.

### 3.3.3 Timescales and discounting

An important issue that must be addressed in most CBAs is how the benefit and cost profiles develop over time. The results of a CBA are often presented through a Net Present Value (NPV) which combines the discounted profile of benefits minus opportunity costs for the whole period over which the costs and benefits are considered. The discount rate selected is therefore an important part of the analysis and is another way in which subjectivity can enter the process.

For some developments, the discount rate is related to the actual cost of borrowing the money needed to fund the project. For many others however, there is more flexibility. Proposed projects with a significant environmental benefit are a good example of the issues associated with the selection of discount rates. Although there are standard rates provided by governments at national and international level, often in the region of 4% (in real terms), these are often considered to be too high for projects with long term environmental benefits. The result of applying “too high” a rate is to emphasise the present at the expense of the future, which can prevent efforts for long term improvement from proceeding. There is an argument that in considering public sector projects the state should apply a zero discount rate, since the state is an entity which lives on and is expected to represent the interests of future as well as current generations. Benefits in 50 years’

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[24] HM Treasury (2003) with reference to the Review of Large Public Procurement in the UK notes that there is a demonstrated, systematic tendency for project appraisers to be overly optimistic and that to redress this tendency appraisers should make explicit, empirically based adjustments to the estimates of a project’s costs, benefits, and duration.

time may be difficult to predict precisely today but they will nonetheless be very real for future generations; and the state as an institution is supposed to represent those unborn future generations. HM Treasury (2013), in the Green Book, state that the Social Time Preference Rate (STPR)[25] should be used as the standard real discount rate. The current rate of STPR is calculated at 3.5%. Earlier rates used in transport project appraisal were 8% and then 6% respectively (Burgess and Zerbe, 2011). For long term projects over 31-60 years, they suggest lower rates (3%) be used. The reason for using lower rates in the long term arises from future uncertainty for long term forecasting (e.g. a 60 year time horizon for a project coming into use under current Green Book rules). Lower discount rates have been used and noted by Mackie and Worsley (2013) in their international comparisons, where the Netherlands use a 2.5% discount rate with a 3% risk premium, while Hepburn (2007) shows the social discount rate for the Czech Republic to be 1% compared with other OECD countries. Generally, European countries tend to utilise 3-4% discount rates and have fairly long project lives while the USA, Australia and New Zealand use rates of 7-8% with shorter project lives.

### 3.3.4 Sensitivity analysis

One way in which the subjectivities of CBA as to likely future benefits can be controlled in an environment of uncertainty is to undertake a sensitivity analysis. This provides for an assessment of the variability of the outcomes of the analysis when ranges of variability are assigned to some of the key variables. To undertake such an analysis helps to define the confidence that can be placed in the final outcome. In some cases, it is useful to identify the cross over point at which net expected benefit (benefits minus costs) ceases to be positive. If, for example, the benefits assessment is highly conservative at this point, it indicates that the case is robust enough to justify the proposed development.

## 3.4 APPLICATION OF CBA TOOLS

Previous chapters and sections have concentrated on and addressed how governments can intervene to promote an optimal level of safety using CBA as the effective and practical

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[25] HM Treasury (2013) in the Green Book states, “Social Time Preference is defined as the value society attaches to present, as opposed to future, consumption. The Social Time Preference Rate (STPR) is a rate used for discounting future benefits and costs, and is based on comparisons of utility across different points in time or different generations” (p.97).

tool of appraisal. However, appraising the extent to which governments should actually intervene to promote transport safety using CBA raises issues that require detailed and careful scrutiny. These issues are broadly:

(a) Safety output/benefit measurement;

(b) Risk; and

(c) Valuation of life.

The following sections consider each of these issues, which are fundamental to understanding CBA for transport safety measures.

### 3.4.1 Measurement of safety output

When examining transport safety in a cost-benefit framework it is of primary importance to establish attained safety levels by mode (these are the outputs which after all constitute the key benefits of safety policy) and the rates of change of these outputs in response to policy changes. A standard measure must be used for all transport modes to permit cross-modal and cross-country comparisons of the risk of fatality and/or serious injury.

A review of the literature on this subject quickly reveals that there are a number of different ways of measuring attained safety levels of transport modes: see Walmsley (1992), Collings (1994), Jørgensen (1996), ETSC (1999), Hakkert and Braimaister (2002), Evans (2003), and SafetyNet (2007). Much of this literature concentrates solely on presenting measures that indicate safety levels for a specific purpose/study with a limited discussion on the most appropriate measure for wider cross-modal comparisons.

While this might raise only limited problems when examining attained safety levels within a particular transport mode, the choice of the appropriate measure becomes crucial the moment we begin to look at the cross modal safety comparisons which are central to this work.

In general, an averaged measure of the risk of a fatality in the various modes can be obtained by calculating the ratio between an indicator of fatalities over a determined period and an indicator of total amount of travel on the specific mode. Similarly, the average risk of serious injury can be calculated as the ratio of the total number of injuries of a defined type over a period and the total amount of travel on the specific mode in that same period. For one period of time ($t$) this can be summarised by the following fraction:

$$\frac{\text{Total number of fatalities or injuries during time } t}{\text{Total amount of travel on mode during time } t}$$

The numerator of this fraction is relatively straightforward conceptually, although there may be some argument about the number of fatalities to attribute to a mode.[26] In general the rule should be to use "casualties", or, in other words, the accidents that relate to the specific transport mode, independent of inadmissible passenger or third party behaviour and of natural causes. For example there could be a debate as to whether air deaths due to terrorist activities or sabotage should be included as fatalities in aviation. They may not be directly attributable to aviation in one sense but then neither is the weather; yet a significant number of aviation accidents are directly attributable to bad weather[27] and these are counted in the fatality statistics. There is also the issue of whether occupants including crew, and also workers on associated infrastructure, especially road and rail maintenance, are included. It would appear that it is appropriate to include all fatalities on a mode in a year other than those which are due to deliberate misadventure (e.g. suicides from people jumping deliberately under trains should not count as railway fatalities).

A fundamental theoretical problem arises, however, with the definition of the denominator. The main question is how to measure the risk exposure on the total amount of travel completed. The literature, as mentioned above, indicates a range of measures for this denominator: total number of trips, total number of hours spent on a particular mode by passengers, total vehicle-km and total number of passenger-kilometres completed. It is the contention of this section that there is actually just one primary denominator and hence just one definition of the average risk of a fatality or serious injury that is appropriate, especially when cross-modal comparisons are made, namely the passenger or person-kilometres denominator and the resultant measure of safety output. The caveat to this is when journeys of different lengths can provide the same utility to the traveller. For example, an air journey may be longer in comparison to a shorter journey by another mode, but may be completed in the same time period. In this case, the number of journeys would be a valid comparison. In general however, the contention is that distance travelled

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[26] For instance, is a fatality to a person who was trespassing on the railway to be counted as a fatality in rail?

[27] A number of aviation accidents in the landing phase are attributable to attempted landings in the presence of cumulonimbus clouds and associated wind shear in the vicinity of airports.

is an important factor in the assessment, as underscored by its inclusion in most national transport safety statistics. Travellers are not indifferent to journey time and the extensive studies on travellers' valuation of time recognise this.

First of all it should be noted that to use a measure which has passenger journeys as denominator will fairly evidently be inappropriate. This is because, all else held the same, where journeys are shorter the risk of a fatality or injury will be lower (the exceptions are boarding and alighting and take offs/landings discussed later in this section). Hence, a journeys-based measure will make certain modes (with shorter journey times) appear to be intrinsically safer when, in fact, the apparently better safety record only reflects shorter journey times.

The main alternatives to the journeys-based measure are the passenger-hours and passenger-kilometre variants, both of which have, in the past, been used widely enough in the measurement of safety output. Both clearly avoid the distortion described above. The passenger-hours denominator provides a measure of safety output in terms of "exposure time" (time spent travelling), while the passenger-kilometres denominator provides a measure of safety in relation to distance travelled. When we are comparing safety among modes (or even different vehicles within a mode), and where the average speed of the modes/vehicles is similar, the comparative ranking in terms of safety will also be similar no matter whether passenger-hours or passenger-kilometres measure is used, and so no great conceptual problems arise. If, however, as in this thesis, a comparison is being made of safety outputs among modes which have very different average speeds (e.g. average speeds at sea are in the region of 20 knots, compared to 300 in aviation), the comparative ranking in terms of safety will be critically affected by the measure that is used. To be precise, faster modes of transport will, all else held the same, be ranked as comparatively safer under the passenger-kilometres as opposed to the passenger-hours measure.

Consequently it is crucial to decide on which is the more appropriate measure of safety output: that based on passenger-hours or that based on passenger-kilometres.

Using the principles of Lancaster's well-known theory of goods' characteristics it is possible to justify the preference for the measurement of the total amount travelled on the basis of passenger-kilometre. Lancaster (1991) pointed out that many goods which consumers demand and enjoy possess not just one, but a number of characteristics which make them attractive:[28] "*In general, a good will possess more than one characteristic, and many characteristics will be shared by more than one good*." Transposing this to transport, it can be said that when people use transport they consume a fairly basic good, namely travel, for which safety is one relevant characteristic for the consumer.

However, among the characteristics which define the travel good, time to destination also plays an important role in influencing consumers' modal choice in almost all instances: all else held the same, consumers prefer a faster mode of transport since it saves them time. Put in terms of Lancaster's theory, a faster journey time implies a more "valuable" good (higher marginal utility)[29] for which consumers are willing to pay higher prices: for example, over most of Europe people generally pay higher fares to travel on faster trains on the high-speed train networks such as the TGV in France and Eurostar Italia in Italy.

Subsequently, time en route is a key element but not, of course, the only element of the travel good. Hence, it follows that what is of interest to the passenger is not the amount of time spent on board per se[30] (this would point to the use of the passenger-hours denominator in our average risk fraction), but rather the distance travelled within a particular time. From this consideration it follows that the appropriate denominator for our risk assessment fraction is total passenger-kilometres over the period of averaging.

The risk assessment fraction can be further refined dependent on the availability of appropriate data according to population demographics by mode (old and young car drivers for example) or various other refinements (such as differentiation of aviation risks by time of year or by destination, both of which have a link to weather and hence to accident risk in aviation). Another refinement would look at subsidiary risk measures relating to specific components of a journey that should be taken into consideration for certain modes of transport, notably boarding and alighting on buses and take-off and landing in planes where there are significantly higher risk levels in comparison to the rest of the overall journey. These refinements are relevant; they imply, for example, that on an air journey which involves connecting flights as opposed to the same journey on a direct flight, the risk of death/serious injury will be greater. Nevertheless that does not

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[28] For example, particular cars may be at once a mode of transport for a person, and convenient.

[29] For example, when travelling from Reading to London why do people either travel by car or train rather than travel by bicycle? Transatlantic passenger liners disappeared upon the serious growth of scheduled transatlantic air services.

[30] See Lancaster (1991).

undermine the basic validity of measuring the overall risk from either type of flight in terms of passenger kilometres in the denominator.

Although this might seem a definitive statement on the appropriate statistical measure of safety output, in light of the above considerations, this is defensible. Furthermore, since some standpoint on this issue must be taken in order to make conclusive safety comparisons between modes whose average speeds are different, it is considered that passenger-kilometre is, among the possible alternatives, the unit of measurement for which there are the most plausible supporting arguments. Bergantino and Patel (2000) also supported per passenger km unit of measurement and calculated estimations of safety output to provide a statistical comparison of safety output levels attained in various modes for Great Britain and Italy, while ETSC (2003) provided modal comparisons of safety performance in the EU.

There is a corollary of this argument for use of the passenger-kilometre denominator when calculating attained safety output. Where within a particular mode there are large variations in average speed, and where both separate figures on fatalities and injuries for the different elements within a mode (e.g., separate figures for fatalities/injuries on high-speed trains and slower trains) and figures for total passenger- kilometres for each element are available, it would be possible - and in the light of the Lancaster arguments outlined above, highly appropriate - to present a separate safety output figure for the high-speed and low-speed elements.

### 3.4.2 Risk

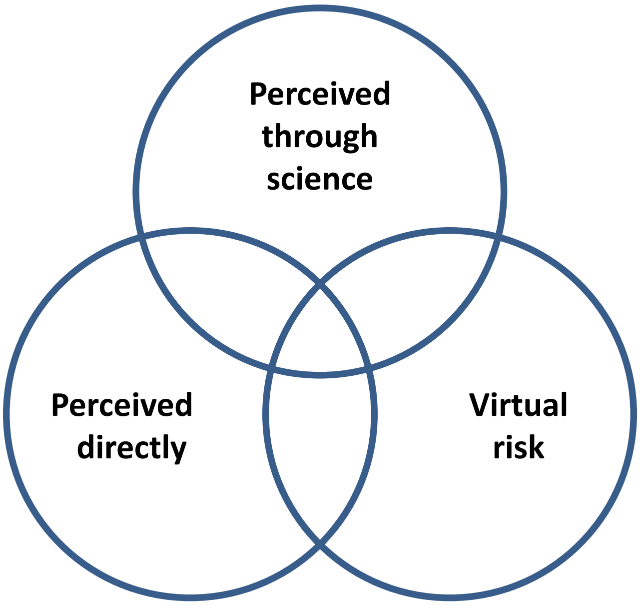
#### General

Prior to reviewing the risks relevant to this work a brief outline is provided of what risk is to give some context. Beck (2009) classifies risk under a number of categories including existent and non-existent and individual and social responsibility. For the former category he notes that risk is the anticipation of a future threat and therefore regards risk to be both existent (if the anticipated risk is realised) and non-existent (if the risk fails to materialise). He also considers risk from an individual and a social responsibility perspective. An individual accepts responsibility for their own decision and subsequent consequences of their decision; this is contrasted with the social responsibility of others, i.e. to what extent others are impacted by the risk decision of individuals and the degree to which they are involved or not in the decision process.

Adams (1999) in his work discusses the management of risk under conditions of uncertainty and refers to it as a “balancing act”. He identifies three types of risk, highlighted in Figure 3-2, which are not mutually exclusive. Risks perceived directly are considered as risks where some judgement is taken by the risk taker. For example a pedestrian crossing the road does not undertake a probabilistic risk assessment before doing so; they rely on some mixture of instinct, intuition and experience to cross safely.

Risk perceived through science is mainly referred to in the risk management literature. Here, risk is considered through a wide body of research, statistics, cause-and-effect and inferences. Probability of risk is examined under this category and it is also where most published work on transport safety appears.

Lastly, virtual risk contains uncertainty and unknowns. If there is no clear or convincing scientific evidence, judgements about these risks will be influenced by people’s predisposition to view the evidence in particular ways. The four common types of dispositions are the individualist (optimist, science provides the solutions), the egalitarian (pessimist, if something cannot be proved to be safe it is considered dangerous), the hierarchist (all risks need to be managed, science needs regulation) and the fatalist (no power and reliant on luck).



**Source: Adams (1999)**

*Figure 3-2: Risk typology*

Adams (2012) highlights the problem of uncertainty in transport risk using road safety as an example. He suggests that the problem lies in differing risk managers in the different circles in Figure 3-2. Institutional risk managers, such as legislators and regulators making and enforcing rules regarding transport safety, are in the ‘perceived through science’ circle, versus individual risk managers (directly perceiving risks) who are guided by judgement.

Risk arises in any situation where there is uncertainty of outcome, and probability is the mathematical way of measuring that risk (perceived through science) which also provides a means to assess different combinations of risks. It goes without saying that risk is pervasive in human affairs.

While risk is not necessarily a priority element or consideration for most policies, it is essential when examining transport safety policy. This is due to the fact that the principal benefits that emanate from a transport safety policy are definable in terms of risk reduction. For this work, taking the risk typology diagram of Adams, the focus is mainly in the examination of perceived risk through science (will be referred to as objective risk) and risk perceived directly (will be referred to as perceived or subjective risk).

The introduction of Automatic Train Protection in UK, for example, would essentially be geared to produce a reduced risk of death or serious injury to passengers or others; whereas an area being designated as a public park has no risk reduction benefits. Transport presents a serious risk of accidental death or injury on a daily basis irrespective of the measure that is used to gauge what the level of risk is on a specific mode.

Evans (1994) suggested that there are four different types of measure commonly used to determine the level of risk in any transport activity:

a) the number of accidental deaths (and/or serious injuries) per year associated with transport by comparison with other activities;
b) the number of accidental deaths (and/or serious injuries) per hour spent travelling by comparison with other activities;
c) the number of accidental deaths (and/or serious injuries) per passenger kilometre; and
d) the number of major accidents per year.

The debate on which measures ideally should be used was examined in greater depth in Section 3.4.1 .

### Objective risk

The objective assessment of risk refers to the actual estimation of risk in any activity or situation on the basis of objective data. Rundmo et al. (2013) define objective risk as *"the probability of an adverse event that is estimated by statistical methods and risk estimation techniques based on accidents and incidents (probability × consequence × exposure)"* (p1664). The risk may be estimated in two ways, which are quite similar:

(a) to appraise accident risks using past statistics on relevant accidents, or

(b) to appraise accident risk by constructing a model for the purpose of forecasting the likely risk profile (this may be based on statistical projections, technical assessments of the impact of a new development, or a combination of the two)

Both methods of estimating risk have limitations in accuracy. A major problem for method (a) to estimate risk is knowing how representative the statistical records are for the proposed assessment. This is because in using past data there is an inference that the past is a reliable guide to future events and therefore there is a logical problem of induction. If, for example, air accident risks were being determined then it would be evident from the data that the types of air accidents have changed significantly and using past data to predict future accidents may not always be very accurate or precise. This particular problem could be overcome by trying to use more extensive data sets wherever possible or by seeking to extrapolate from past data in a more sophisticated manner; for example, by the identification of systematic trends as opposed to straight extrapolation of averages. It is, in any case, a problem of all scientific method and not just confined to objective risk estimation in transport.

There are also problems associated with the size of some data sets. Some accident risks are very difficult to estimate since there may not be sufficient accident data available for a new vehicle, aircraft, vessel that has been introduced. For instance, the introduction of High Speed Craft in the maritime sector is relatively new and there is a distinct lack of accident data available for this type of vessel. A remedy for this would be to determine accident risks by the construction of a model, but this is also susceptible to flaws since it too involves predicting the future based on stated assumptions that could be inaccurate (as the assumptions will usually be based on some sort of inference from past experience). The Channel Tunnel offers a possible example of this. Even though one might have thought that there could have been considerable confidence in estimates, for example, of fire risks in railway tunnels based on vast past experience of over 100 years of rail tunnels, the Channel Tunnel would appear to be *sui generis* for a number of reasons and so estimates of fire risk appear to have been understated.

Prospect theory is a further dimension to take into account because this addresses subjective attitude to objective risk. It should be noted that perceived risk combines the perceived risk of an accident occurring and the perceived consequences. Prospect theory is a behavioural economic theory that describes the way people choose between probabilistic alternatives that involve risk, where probabilities of outcomes are known. The theory states that people make decisions based on the potential value of losses and gains rather than the final outcome, and that people evaluate these losses and gains using certain rules to form judgements and make decisions. The model is descriptive: it tries to model real-life choices rather than optimal decisions which are characteristic of normative models. Kahneman and Tversky (1979) created the theory and developed it (Tversky and Kahneman, 1992) as a more accurate description of decision making than the expected utility theory.

Kahneman and Tversky (1979) explained the major violations of expected utility theory as being choices between risky prospects with a small number of outcomes. They found empirically that people underweight outcomes that are merely probable in comparison with outcomes that are obtained with certainty; also that people generally discard components that are shared by all prospects under consideration. Under prospect theory, probabilities are also replaced by decision weights. The value function is defined by deviations from a reference point and is normally concave for gains (implying risk aversion), commonly convex for losses (risk seeking) and is generally steeper for losses than for gains (loss aversion).

### Perceived (subjective) risk

Perceived risk is the perceived probability of an accident occurring and the perceived consequences of such an event.

When accident risks have been determined through risk estimation objectively, those examining the issues will adopt their own subjective attitude to the risks as objectively measured. It is well established that individuals differ widely in their subjective attitudes to clearly defined risks (e.g. risk taking and risk averse people) and there would also appear to be some identifiable broad cultural differences in this matter. As a result, the level of risk associated within and across specific modes of transport is only a perceived risk; whether by individuals, governments or whole societies. This can lead to serious anomalies; for example, in the aftermath of various train or aviation disasters both modes of transport have been perceived to be extremely dangerous ways of travelling although that is not the case.

The aviation accident of a Concorde aircraft F-BTSC in Paris on Tuesday 25 July 2000 highlights the point clearly (BEA, 2000). The accident resulted in the death of all the crew and passengers on board the aircraft, totalling 109 fatalities. Shortly before take-off, the front right tyre of the left landing gear was damaged and pieces of the tyre were thrown against the aircraft structure. A major fire broke out under the left wing. Problems appeared shortly afterwards on engine No. 2 and for a brief period on engine No. 1. The aircraft was neither able to climb nor accelerate. The crew found that the landing gear would not retract. The aircraft maintained a speed of 200kt and a radio altitude of 200 feet for about one minute after which engine No. 1 stopped. The aircraft then crashed onto a hotel at La Patte d'Oie in Gonesse.

This aircraft type had been in operation for over 25 years and this had been the first fatal incident. Therefore, the subjective perception of high risk by governments and individuals seemed an excessive over-reaction at that time, in view of the fact that all Concorde aircraft were grounded for a period of one year and then subsequently taken out of service. This subjective perception may of course have been allied to a desire to remove from service an aircraft that was no longer cost effective. There is also a large disparity between the subjective perceptions of risk across different regions and between countries and also in attitudes to perceived risk, which is problematic when comparing the risk either within or across modes.

Problems associated with subjective perceptions of risk can be partly resolved by using and disseminating objective risk assessment analysis. This can assist in identifying and quantifying actual levels of risk inherent in specific modes of transport in an objective manner and may help to dispel misunderstanding in the subjective perception of risk, although it cannot eliminate the problem altogether.

The discussion on risk gives an indication of the problems that arise when seeking to quantify the risks associated with transport in terms of a probability of death or serious injury, and is a vital element in the rational appraisal of policy benefits within an overall cost-benefit analysis of safety policy.

### 3.4.3 Total journey risk

In most of the literature to date, safety outputs have been defined for a specific mode taken in isolation and in effect for what are presumed to be seamless journeys. Yet, in practice, many journeys involve the combination of a number of modes; or they may involve stopping and taking connections at some point in the journey even when the whole journey is carried out in the same mode. All of these factors can have a significant impact on the total risk exposure for the person making the journey. The analysis of total journey risk seeks to take this into account.

The concept is, perhaps, best grasped through some simple examples. A typical city commuter who takes the train to work daily will need to get to the local railway station from his/her residence/workplace in order to get the train. This will typically involve a walk, a cycle ride or a car trip to the station daily. Since the risks of death and serious injury vary significantly among modes this unfortunately means that it is not accurate or sufficient to take the commuter's risk as the relevant rail safety figure for the country/region (deaths/serious injuries per person kilometre on trains in the region). A composite figure combining the relevant rail risk with a figure for the pedestrian/cyclist/car risk for the part of the journey from home to station is required. This composite figure can be designated as the total journey risk.

The calculation of this composite follows easily from the considerations given above regarding the most appropriate way to measure safety output on any given mode: deaths/serious injuries per person kilometre. The distance travelled in each mode during a composite journey needs to be calculated and these distances need to be used as weights to get an overall weighted average composite risk for the journey. A similar point also applies when connections have to be made among separate services within the same mode. Making the connection may increase the journey risk by comparison with a direct journey involving no connections.

There is a much debated theory in the risk literature regarding risk compensation. Peltzman (1975) suggested that risk compensation offsets any safety measures introduced in the car industry (e.g. seat-belts or anti-lock braking). He noted that drivers increase their exposure to risk (for example by driving faster) as compensation for the increase in the safety of their vehicles. The essence of the risk compensation debate lies in assessing which risk changes will produce compensating behavioural change. Whether this effect occurs and the extent to which it does exist has been debated and contested in the literature. Risk compensation can be evaluated through individual behaviour or examining aggregate data to measure the impact of laws and regulations. While studies acknowledge that there may be some behavioural change/s, the effect on crashes and injuries is not clear. There is also inconclusive evidence at present on the extent of the overall risk compensation on safety measures (Hedlund, 2000). Risk compensation proponents (Adams, 1995) acknowledge this dilemma: *"... the multi-dimensionality of risk and all the problems of measuring it ... preclude the possibility of devising any conclusive statistical tests of the [risk compensation] hypothesis."* Hedlund (2000) provides a comprehensive review on the topic and some useful rules for thinking about how risk compensation and behavioural adaption may affect the outcome for safety policies. Noland (2013) highlights that many of the theoretical debates are not clearly resolved, although there is a consensus that behavioural adaptation occurs and theory can provide guidance on when this is likely to be a large effect. He proposes a theoretical framework that is intended to clearly provide an understanding of the motivations of travellers (i.e. their utility-maximizing behaviour) and how trade-offs are made between risk and mobility, as well as other attributes that influence transportation choices. The main conclusion from the study is that road safety studies and the guidance developed from these should be based on a theoretical foundation that considers the behavioural reaction to a policy change.

In view of the debate surrounding the literature on risk compensation, the uncertainty on the level of risk-compensating behavioural change, and the inconclusive explicit evidence on safety outcomes, this thesis will not take risk compensation into consideration any further except to acknowledge that both at an individual and at an aggregate level there may be behavioural changes after safety policy measures that could be considered to be risk compensating. In addition risk compensation applies mainly to changes in the risk profile within a mode, for example developments in vehicle safety. Since the CMS concept is based on exploiting the relative gradients in safety between modes, the impact of risk compensation on CMS is more limited than it would be on the specific mode affected through safety measures.

Overall, there is extensive literature on objective and perceived risk, both in general and specifically related to transport. For a fuller discussion see Adams (1995), Noland (1995), Sjøberg (1999), Kirwan (2006) and Rundamo (2013).

### 3.4.4 Valuation of safety (fatal and non-fatal)

The third of the complicated issues arising from safety assessments is the valuation of human life and limb; this seems to be the most contentious[31] aspect in economics and especially of most CBAs in transport. Safety improvements can only be achieved at a cost, and so the question arises what the appropriate monetary valuation to place on safety improvements enabling the direct comparison of costs and benefits and ensuring scare resources are allocated efficiently would be (Jones-Lee and Spackman, 2013). In economics, the measure for avoidance of fatality or injury is the risk-money trade-off for small changes in risk (probabilities) of death. These values are referred to as VSL or VPF[32]. There have been many critiques of this approach to valuation of safety benefits but in many of them there is a simple misunderstanding of the terminology (Viscusi, 2005). Often the critiques miss a very basic point: it is not the value of a human life per se that is being valued, rather an evaluation in monetary terms of the value of the small changes in the risk of death or serious injury due to some policy.

**Approaches and methods of valuation**

Jones-Lee (1989) considers the explicit valuation of safety under two broad objectives, namely national output maximisation and social welfare maximisation. Firstly, he

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[31] With the exception of direct financial reduction by insurance companies for the bus and car industries. For example, Pay As You Drive (PAYD) is a car insurance policy which better reflects crash risk, as the insurance premium is paid per mile/kilometre actually driven. The PAYD insurance premium can be further differentiated to reward safe driving behaviour with a lower premium due to advanced monitoring technologies. The PAYD underlying principle is that car drivers will be incentivised through variable cost of travelling to adapt their travel behaviour. Norwich Union Insurance, UK [now 'Aviva'] fully implemented their PAYD insurance after a pilot in 2003. The company provides direct incentives to the individual driver to improve safety. Travel behaviour is monitored using a GPS-based black box in the vehicle that registers how often, when and where the vehicle is driven. Different insurance rates apply for young drivers (23 and younger) and those between ages 24-65. For night time (23:00-5:59) driving, young drivers have to pay higher prices (e.g. the price per kilometre is £1 ($1.22). For older drivers, night and morning peak are expensive, although this is not as high as with young drivers and billing is on a monthly basis (Zantema et al., 2008).

[32] Value of Statistical Life (VSL) is more commonly used in the US although both terms are identical.

considers other approaches to the valuation of life. They were based on the life insurance method (the costs of death/injury correlated to the amount people insure life and limb), the court award method (based on damages awarded by the court representative of an individual's loss of future output or unclear societal cost of death/injury), implicit public sector valuation (based on previous public sector decisions on values of life and safety) and the valuation in terms of time (where the remaining life expectancy of an individual is determined through aggregate time value over remaining life expectancy). All these methods, while each having apparent merits, were considered to be lacking both in the context of national output maximisation and maximisation of social welfare objectives. The decision analysis approach developed by Keeney (1980) was also cited by Jones-Lee; this required the construction of a multi-attribute "organisational" utility function reflecting the value judgement of the decision maker/group regarding various trade-offs of choices and consequences (see Jones-Lee for a fuller discussion on the critique of these methods).

The aforementioned methods were largely superseded by output based (net/gross output also known as human capital methods) and willing to pay approaches. This last is based on revealed or stated preferences. The subjectivist willingness to pay approach has now replaced an earlier objectivist approach to the valuation of safety. Both methods are discussed in the following section.

### Willingness-to-Pay Approach

Although a variety of methods have been used to estimate the value of life and safety, it is intended that within the context of this thesis, the WTP approach will be considered as the most appropriate method of estimation. A large body of literature advocating the WTP approach has been developed over a number of years. See Drèze (1962), Schelling (1968), Mishan (1971), Bergstrom (1982), Dalvi (1988), Jones-Lee (1989) and Bahamonde-Birke et al. (2015). The main rationale for economists behind the WTP approach is that it is based within welfare economics (Paretian)[33] and its principles are:

*"(a) that social decisions should, so far as possible, reflect the interests, preferences and attitudes to risk of those who are likely to be affected by the decisions and,*

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[33] This is based squarely on utilitarian moral principles.

*(b) that in the case of safety, these interests, preferences and attitudes are most effectively summarised in terms of the amounts that individuals would be willing to pay (or would require compensation) for variations in safety…if a public sector project is undertaken"*[34] (Dalvi, 1988, p6).

Under the WTP approach it is important to note that changes in safety provided by public sector projects will usually result in very small changes in probability of death or serious injury for a specific individual during a defined period in the future. Although, in valuing life and safety it should be highlighted we are not dealing with either:

- how much money specific individuals will pay or are required to be compensated for avoidance of death/certain death, or
- the amount of money legally required to compensate;
- *but* rather the sums of money each person in a community should pay/would in principle accept to be compensated for the change in risk they face as a result of policy changes. The degree of risk and compensation may vary by country according to legal system, extent of liability, etc.; e.g. airline code sharing.

While this is in principle clear enough, some interesting difficulties arise when trying to apply WTP in practice. Early forays in this field tended to presume that there would be a single figure that could be applied to any individual for the valuation of a change in risk of death/serious injury due to a transport safety policy measure. Yet people differ in their attitudes to/preferences for risk: both as individuals and due apparently also to cultural factors. Then there is the crucial point that the amount which a person may be willing to pay to reduce risk, say on the railways by 0.001 per 1000M person kilometres per annum, will depend on how many kilometres that person travels by train in a year. In the extreme case somebody who never uses trains will not want to pay anything to improve rail safety (unless of course they are motivated by a sense of social solidarity)[35]. In practice there

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[34] Dalvi's mathematical expression for an individual's WTP to avoid death is:

$$\left[ \sum_{t=0}^{T} Bt/(1+r)^t \right] A$$

where: T = remaining life time, Bt = utility (or benefit) enjoyed by living (labour income, non-labour income, non-market activities and leisure, premium for pain, grief and suffering), r = individual rate of time preference and A= risk aversion factor.

[35] This, of course, touches on a very fundamental potential weakness of the whole utilitarian based approach to welfare economics: it simply cannot get to grips with people "caring" for each other or acting in a selfless manner to serve the community.

will be likely be no single figure for WTP but a whole range of figures for different individuals depending on their preferences and on how many kilometres per annum they travel on particular modes of transport. This latter difficulty could no doubt be overcome by taking the average annual distance travelled by a typical user of a mode in a country and relating this to the change in risk per 1000M person km, but that still involves some crude averaging out across people who may have very different total distances travelled per year. See Dalvi (1988) for further discussion in this area.

According to Ball (2000) the view is to use a broad number of outcomes from various techniques that have existed rather than a single methodology. The main reason for this is that valuation techniques entail considerable problems, such as those mentioned above, and also include methodological problems (induction) and the problems surrounding different subjective attitudes to objectively qualified risks. Therefore the values of changes in risk of death and serious injury are considered as a range rather than a single point value. Presently, the range lies between £1-10 million (with most between £2-4 million) per life saved in 1000M person km. The advantage of using a range is that it provides decision makers a degree of flexibility in arriving at safety decisions because of complex contextual factors, rather than by the application of any more “formulaic recipes”. In the UK, the contingent valuation using stated preference willingness to pay is mostly advocated because of its sound methodology, anchored in the principles of welfare economics; although there still remain some unresolved problems with contingent valuation, some of which have been reduced and which are addressed in the next section. The UK Department for Transport currently considers the VPF based largely on the WTP but also includes additional smaller elements of avoided output losses and medical and ambulance costs[36].

Bristow & Nellthrop (2000), Hayashi & Morisugi (2000), Miller (2000) and Mackie and Worsley (2013) have provided valuations of life figures for a number of different countries. The values are significantly spread but these could be attributed to the differences in safety standards in different countries and/or differences in subjective valuation or attitudes to the change in risk.

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[36] VPF defined and estimated as VPF= (WTP+NQ+MA) where WTP is the willingness to pay, NQ is the present value of the avoided loss of net output and MA is the avoided medical/ambulance costs per statistical fatality.

**Critique of Willingness-to-Pay Approach**

Early critique on the WTP approach is addressed by Broome (1978) and involves objections to the approach itself rather than a rejection, according to Jones-Lee (1989). Broome questions the limitations of the hypothetical compensation test using the WTP approach but this objection has largely been answered by Bergstrom (1982) and Dehz and Dreze (1982) using constrained maximisation of a social welfare function that yields similar results. He also raises the issues of how distributional weights (this is a general problem, not just in risk) and divergences are specified in subjective perceptions of risk, and of concerns regarding individuals' willingness to pay, not only for marginal changes in risk using the WTP approach, but also for more sizeable risks (non-marginal changes). For example, using WTP cost associated with the exposure of 1,000 people to an increased risk of death by 0.001 will be higher than the costs involved with exposing 1,000,000 to incremental individual risks of 0.000001 even though the expected loss of life is the same in both instances. In such a scenario, Broome suggests that a government may choose the least costly option and hence act "incoherently" whereas they should be indifferent between the options. He argues that the value for the statistical life should be independent of the population at risk (and thus the size of the variations in risk). In the end, an alternative is not offered by Broome and others but their work points to the need of some caution in the use of the approach.

More recently, Deloitte (2009) in their Review of Highways Agency Value of Life estimates for the purposes of Project Appraisal for the NAO highlight the main limitations as:

- how to prompt individual preferences;
- determining the value placed on small reductions in risk; and
- combining individuals' WTP.

WTP aims to value the rate at which people are willing to trade safety against other goods and hence to reflect the preferences and attitudes of people who are likely to be affected by accidents towards risk. Revealed preference or stated preference methods are used to determine these preferences empirically. Revealed preference consists of the identification of circumstances where choices involve different safety outcomes. For example, labour market studies show how people trade off income versus physical risk, i.e. wage premia for high risk jobs. Stated preference (using contingent valuation) involves asking a representative sample population about the amounts they would be willing to pay for improved safety.

Revealed preference relies on the isolation of risk-wage related differentials from other factors. A person may choose a job due to the proximity to their home rather than the quality of the risk/wage trade-off. This can result in variable ranges of values and inaccuracies.

Contingent valuation has problems associated with individuals' understanding and valuation of small risks reductions; several small risks of the same size need to be valued for WTP to be precise (i.e. a person facing a number of small risk of a similar size may pay reduced sums for each successive risk as the overall budget is restricted). WTP also does not necessarily equate to actual ability to pay, people can overstate amounts in hypothetical scenarios and the combination of individuals' WTP may not result in the social WTP as external social cost is not considered.

Elvik (2013) also addresses some of the issues pertaining to the willingness-to-pay approach, including choice between options with identical impacts on safety, and preference reversals associated with preference aggregation. These could both be overcome by providing a fixed value per life saved instead of a non-linear demand function. Elvik notes the failure of conventional WTP to reflect the intensity of preferences, and the failure to adjust for the marginal utility of money; this can be overcome by assigning utility weights to individuals' willingness to pay or income.

Divergence between compensation ex ante and compensation ex post, "*concerning whether ex post compensation should adjust for hedonic adaptation among injury victims"* (p69), could be resolved through a "capabilities approach" where the quality of life is assessed on the basis of an individual's ability to do something. Lastly, conflicts between individual and collective rationality can to a certain degree be overcome by the introduction of pricing (where the external effects can be internalised, taxation and fees can be used to mitigate the effect of the externality).

A recent article by Bahamonde-Birke et al. (2015) suggests that despite all of the acknowledged limitations WTP appears to be the most pertinent and accurate approach for valuation of safety and for non-market goods more widely.

The valuation of life and injury using the WTP approach is thus a central element in cost-benefit analysis despite certain problems which have been highlighted in the literature.

As shown, many of these can be overcome in a suitably refined analysis and variations thereof. Its validity will therefore be presumed in what follows and it is a natural progression from safety output measurement. The value of life and serious injury figures used later in this work are fixed values as provided by the DfT's Web TAG Databook (2014, Table A 4.1.1). Fixed values can help to overcome some of the issues relating to the WTP approach as noted by Elvik (2013) earlier in this section.

## 3.5 SUMMARY

The first part of this chapter described and discussed the CBA approach in the context of alternative techniques, evaluated the options and showed why CBA is the preferred appraisal approach for this thesis. It meets the requirements for practical rationality and although it has weaknesses, these can be controlled by careful application. It can therefore be applied with confidence to the treatment of CMS.

The chapter also investigated some of the theoretical issues in applying CBA in practice such as safety measurement, assessment of actual and perceived risks and the valuation of safety policy. The question of the best measure of the "output" of safety policy draws on the earlier analysis and work of Bergantino and Patel (2000) and has concluded that safety output should be measured in terms of fatalities (and serious injuries) per person-kilometre, or as in most cases, per 1000M person km.

In evaluating the reduction in risk of death or serious injury as a result of safety policies, it is argued that the "willingness to pay" method is the only appropriate and promising monetary measure of the "VSL/VPF" in accordance with the wide body of literature on the topic. Combining all the tools allows a measure of the monetary value of the benefits achieved through a reduction of fatalities from a cross-modal switch impacting the risk of death; and these (along with an analogous measure of the benefits in terms of reduced risk of serious injury) have been the primary measure of the benefits resulting from a policy of encouraging or requiring modal switch by passengers.

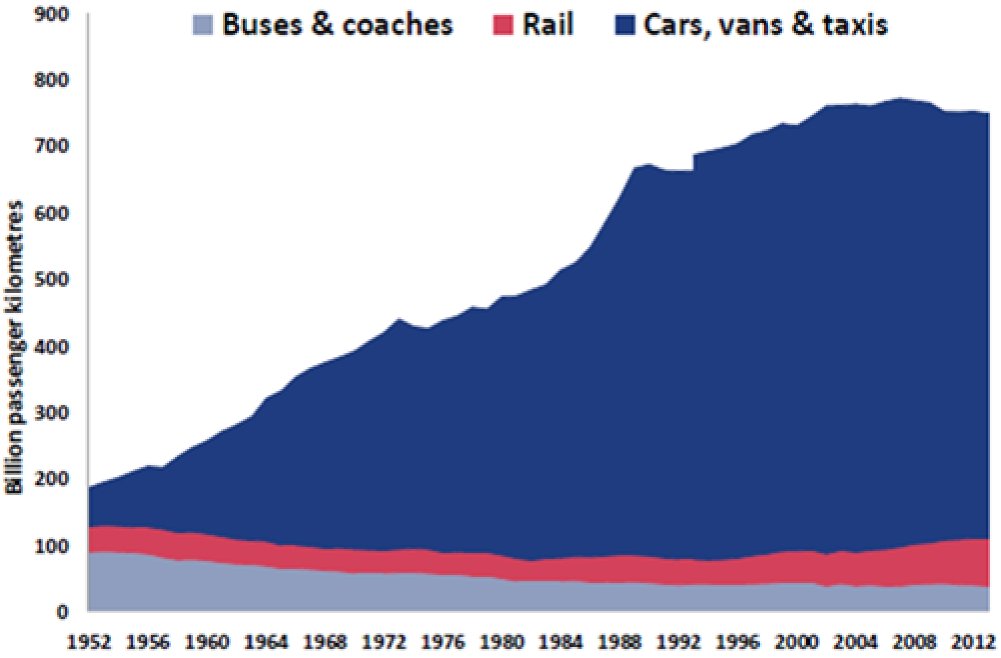
Later chapters, particularly Chapter 6 (Casualty Risk Assessments) and Chapter 9 (Net Benefit Calculations) provide a basis for the CMS benefit assessment because they calculate the risks which can be combined with the Value of Prevented Fatality/Injury (VPF/ VPI) valuation. This means that the differences between modes can be set out in monetised terms and, hence, the advantages of CMS can be set out in a form that policy makers will be able to use.

# 4 CROSS MODAL SWITCHING (CMS)

With the background of the definition of an optimal transport policy and the methods used that have been examined in the previous chapters (2 and 3), this chapter introduces the essential innovative conceptual framework of the work: the use of CMS as an instrument of transport safety policy. Firstly a brief historical overview of modal change over the second part of the 20th century is provided as context. A general overview of CMS is then given in the context of policy and modal behaviour with examples in the first part of the chapter, while the second part reviews the literature on CMS as it relates to various applications and specifically with respect to safety improvements.

## 4.1 HISTORICAL CONTEXT FOR MODAL CHANGE

To demonstrate the dynamics of transport mode use over a long time period, Figure 4-1 highlights some of the changes in the use of surface travel modes from 1952 to the present.



**Source: DfT (2014c)**

*Figure 4-1: Passenger kms by mode: Great Britain 1952-2013*

This shows that over this 61 year period there was in Great Britain a fourfold increase in total distance travelled in all modes (excluding air) and that almost all of this increase was based on the use of private road vehicles, mainly passenger cars but also taxis and vans. Although not visible in Figure 4-1, domestic air travel has increased by 50 times since 1952 (ONS, 2010). Accompanying this was a major switch away from bus, with this mode falling by about half over the period and a relatively static use of rail for much of the period, though with a significant increase in use from the mid-1990s onwards. This confirms that modal use is by no means constant over time. For travel outside Great Britain, in addition to the very large increase in air travel there has also been provision of services such as the high speed Eurostar train and Le Shuttle car travel to France which provides travellers with more capacity and frequency options that were not there prior to 1994 when the Channel Tunnel opened. Table 4-1 provides 2014 values which can be compared with 1993 when only ro-ro ferry/ train services were available with very limited uptake.

| Route | Rail Share (%) | Air Share (%) |
|---|---|---|
| Paris – London | 81 | 17 |
| Paris – Brussels | 95 | 5 |

**Source: Adapted from Marie, 2014**

*Table 4-1*: Rail-Air market shares on specific routes

Taking more recent trends, DfT (2014c,e) and DfT (2013a) provide an indication of average total distance travelled by people in England[37] in each of the main surface modes for the period 1995/1997-2013. This is presented in Figure 4-2. This confirms the trend that was visible in the later part of the time series shown in Figure 4-1, namely a gradual but steady reduction in the use of the car over the 1995 to 2013 period. This is about 12% for drivers over the period and passenger levels also reduce, but slightly more slowly at 10%, suggesting a very gradual increase in occupancy rates.

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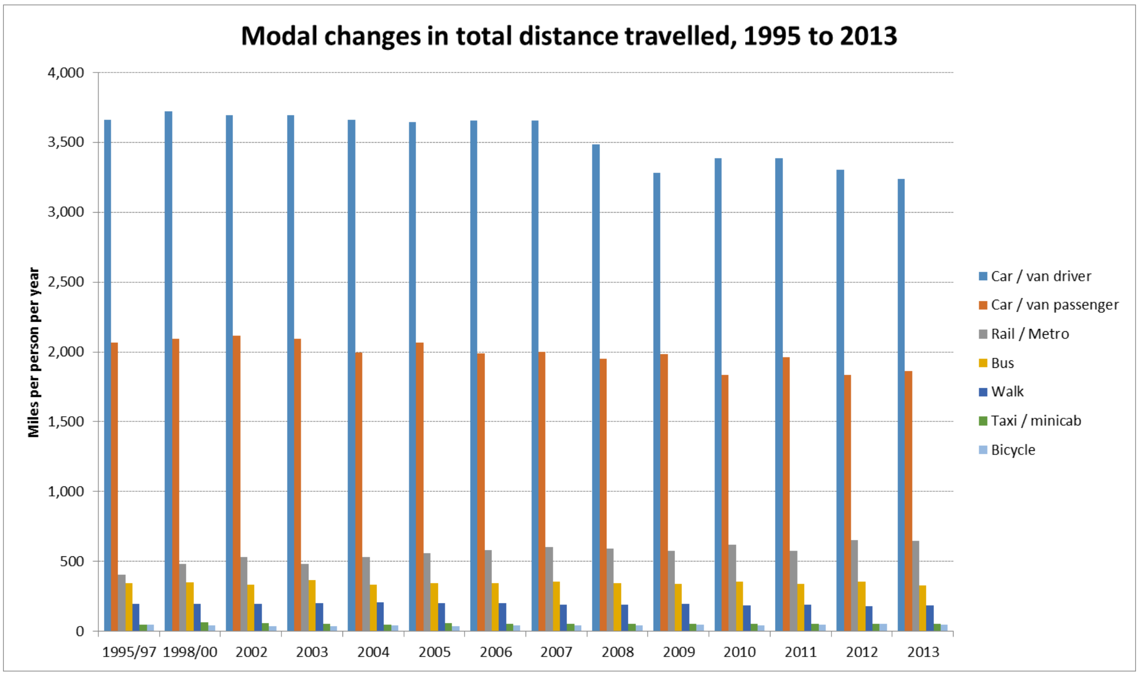
[37] Since 2012 DfT and NTS publish data only for England due to Scotland and Wales conducting own surveys.



**Source: Adapted from Table NTS0305 Average distance travelled by mode: England, 1995/97 to 2013 (DfT, 2014e)**

*Figure 4-2: Average distance travelled by mode: England, 1995/97 to 2013*

The growth in rail/metro use is also confirmed over this period, again as a steady rise. This is made up of surface rail growth of 66% while the London Underground's miles per person per year also grew by 24%. The largest fall, overall, was in non-local bus which was down by 49%, but London bus mileage increased by 68% and other local bus was almost steady. It should be noted that operator data suggests an absolute growth in scheduled express coach travel in Britain, although this may be offset by declines in other forms of coach travel. Cycling increased by 8% and walking reduced by 6%, DfT, 2014e (Table NTS0305).. Modal use, even on this shorter timescale, is therefore relatively fluid, supporting the prospects for encouraging further modal change in support of safety policy.

Long term aggregate modal changes are made up of a large number of individual mode changes and hence support the proposition that switching does occur in some instances in the short-term. They also give some indication of what modal changes have been possible and in response to what stimuli e.g. some of the 'switching' may be people changing journeys (e.g. new job etc.) and selecting different modes from their previous job, but some changes are likely to consist of people actually changing from one mode to another for reasons of cost, convenience or preference (USEmobility, 2013).

The modal changes observed have taken place for varying reasons. Broader travel patterns have altered due to changes in disposable income (substantial change of behaviour by young adults (17-20), especially males where driver licences have reduced from 51% in 1995/97 to 30% in 2013 (Berrington and Mikolai, 2014), more affordable pricing, greater accessibility on certain routes due to network or infrastructure expansion, increased capacity, environmental pressures and avoidance of traffic congestion. Increases in public transport infrastructure and networks have enabled more use of public transport rather than cars to access city centres. Examples include the large increase in bus capacity in London (DfT, 2015a) and the increases in train capacity initially by removing seating but also by lengthening train formations (Stagecoach, 2015). Taxation and user charging has also played a part. In particular the London congestion charge (to reduce congestion and emissions) encourages use of public transport and cycles in preference to private cars (TfL, 2013). It is also true to say that technology improvements play a part in promoting modal change, particularly the availability of reliable information about public transport both in real time and to allow for journey planning but also more recently apps such as Uber promoting increased use of public taxis. These examples illustrate therefore that modal switching does occur over time in response to a range of incentives including better provision of alternatives, financial instruments such as charging, taxation and incentives as well as convenience and avoidance of delays.

The significance of this for this thesis is that it confirms the willingness to consider substitution among modes by passengers; this is, after all, central to the practicability of a policy designed to promote overall safety by encouraging or requiring modal substitution.

## 4.2 CROSS MODAL SWITCHING - OPTIMAL SAFETY POLICY ACROSS ALL MODES

### 4.2.1 General

In principle, a degree of substitutability among transport modes has been assumed for passengers on a wide variety of routes, as statistical studies show that there is significant actual and potential capacity for substitution across modes. This opens up the possibility that one way of improving passenger safety on those routes where substitution is possible would be to encourage or even require modal shift to the extent that passenger safety is demonstrably different between modes. This point has been noted as a side effect in a number of previous studies (e.g. the effects of new railway lines or new systems of rail signalling which allow faster or more frequent rail journeys in transferring some passengers from road to rail, thereby reducing road accidents). Early work has focused, for example, on studies by Allsop and Turner (1986) on the inter-relationship between public transport fares, motorcycle use and accidents in London in the early 1980s, as well as the work of Hillman et al. (1990) and others on the decrease of cycling and walking and the increase in car use for the journey to school. Accident savings have been highlighted as a benefit of many new rail schemes, going back to the study of the Victoria Line in London by Foster and Beesley in the 1960s (1963) and Nash and Preston (1991) on how rail investment projects should be based on social cost benefit analysis including wider user and economic benefits. This thesis aims to show that CMS merits systematic consideration as a means of improving transport safety; and that it may be seen as a primary instrument of safety policy rather than as just a side effect of policies designed for other quite different purposes. In other words, CMS could be valuable in itself as a safety improvement tool. It will be argued therefore that it should be seen as an integral part of an overall optimal safety policy that considers all (practical) modes simultaneously. This is the innovative conceptual framework of the thesis, which will be evaluated using empirical data analysis in later chapters.

### 4.2.2 Intermodality and cross modal substitution

Two concepts relevant in this framework which are useful to introduce and whose differences need clarification are intermodal transport and CMS.

#### Intermodal transport

Intermodal transport has been considered in the context of both freight movement and passenger transport. The European Commission (1997) in a document on intermodality defined it as "*a characteristic of a transport system*" (referring to the use of two or more modes in an integrated manner) and considered "*a quality indicator of the integration between different modes*" (quantifying the intensity of the integration and complementarity). Last and Manz (2003) also adopt this definition of using two or more modes during a single journey for passenger intermodality. The European Forum on Intermodal Passenger Transport (Link, 2011, p6) defines intermodality *"…as a characteristic of a transport system that allows at least two different modes to be used in an integrated manner in a door-to-door transport chain.*" This contrasts with their multimodal definition which is the "*use of different modes of transport at different opportunities (trips/trip chains);* [and] *policy principle not to stick to one single mode. The development of a seamless web of integrated transport chains, linking road, rail and waterways*" (p7). More recently, the concept of co-modality is considered to be the *"efficient use of different modes on their own and in combination. Policy principle of the Delphi*

*(DG MOVE) includes the following areas…:*

*1. Optimise each mode (clean & efficient)*

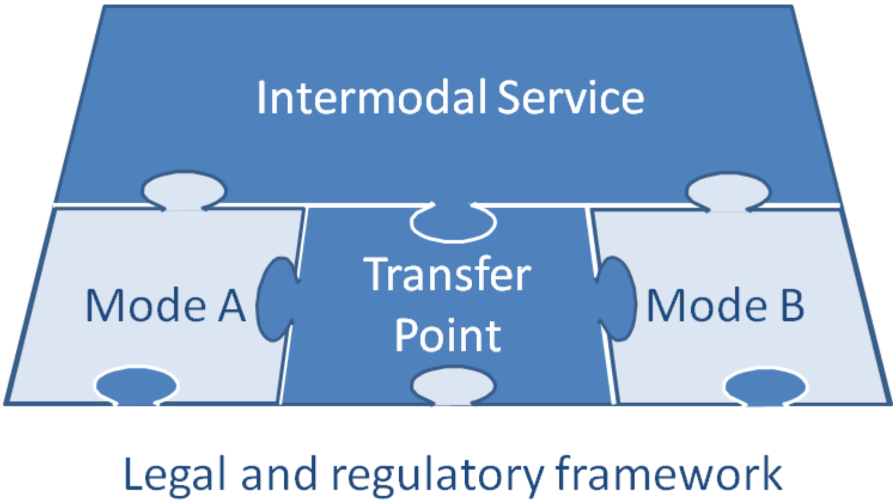
*2. Integrate modes for seamless transport (intermodality)*

*3. Modal shift (long-distance, urban areas, congested corridors)*" (p8).

Within the framework of this thesis the term "intermodality" (meaning mode complementarity) will primarily be used while acknowledging that, in the literature, there is not a rigid distinction between "multimodal" and "intermodality" (Bak et al., 2012).

The intermodal transport system is shown in Figure 4-3 and would include:

- an independent mode A;
- an independent but complementary mode B;
- a transfer point connecting the modes A and B;
- a set of value-adding services, e.g. joint ticketing;
- a legal and regulatory framework valid for all of them.



**Source: Last and Manz (2003)**

*Figure 4-3: Intermodal interdependencies*

The transport suppliers' perspectives on intermodal transport systems are mainly focused on the integration of competing modes. They regard intermodal transport systems as beneficial if there are compelling operational and or strategic economic advantages. Intermodal co-operations lead to the strengthening of this individual economic potential. In Germany, for example, Lufthansa German Airlines, Deutsche Bahn German Railways and Fraport, the owner of Frankfurt/Main Airport, signed a memorandum of understanding to co-operate on intermodal services. The motivation for this was that Lufthansa wanted to remove unprofitable short haul flights into the hubs, Deutsche Bahn expected access to new customer segments and Fraport wanted to strengthen Frankfurt Airport's domestic and European position. An important determinant, however, of intermodal transport is the ease of interchange. Users are limited due to constraints, habits and disabilities (for example the needs and requirements of a business traveller vary from those of a leisure traveller). For that reason, users' needs, limitations, preferences and competence all require careful consideration when supplying intermodal services. For an extensive discussion on intermodal transport systems and intermodality see Manz and Last (2003), Goetz and Vowles (2000), Alt, Forster and King (1995), Oberstar (2003), Bak et al. (2012) and Laparidou and Alander (2014)[38].

Historically, CMS and intermodal interdependencies have not been considered when assessing safety matters. This could be primarily due to the fact that the various modes of transport have not developed simultaneously. The different modes of transport also have quite different infrastructures and operational requirements and therefore intermodal comparisons have not been feasible or straightforward. This is highlighted in the case study presented in the article by O'Sullivan and Patel (2004) on fragmentation in transport operations. The study outlines the problems of interconnections and inter-ticketing for a specific rail/ship route (Fishguard-Rosselare) and the lack of system integration in general.

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[38] There have been a number of projects and activities funded by the EU in the last 12 years including CIVITAS Intermodality in urban areas (2002-2009), Towards European Passenger Intermodality (2004), MODAIR Measure and development of intermodality at airports (2005-2006), Air and Rail Competition and Complementarity (2006), eMOTION Europe-wide multimodal on-trip information (2006-2008), KITE Knowledge Base on Intermodal Passenger Travel (2007-2008), WISETRIP – Wide scale network for multi-modal journey planning (2008-2011).

### Cross modal substitution

Cross-modal substitution is when passengers decide to swap one mode of transport for another to make the same journey. An example of this is passengers who normally travel from London to Paris by air deciding to use rail as their main mode of transport. It is thus quite a distinct concept from intermodality. However it may be noted that in many cases where substitution among modes is being considered in practical terms by a consumer of transport, often what is being compared is not a straight choice such as rail versus air but rather a choice of a number of composite intermodal journey options. For example, travelling from Tilehurst (just outside Reading in the UK) to Paris could plausibly involve any of the following travel options:

- Car door to door plus train (Eurotunnel);
- Car plus ship (ferry);
- Train for the whole journey (plus perhaps a short walk or taxi ride at each end);
- Coach to airports plus flight or even coach as the main mode;
- Train to airports plus flight.

In effect, on a closer examination almost every option for the desired journey is intermodal in character to a greater or lesser extent.

### 4.2.3 Pareto and optimising cross-modality

Having considered optimal safety policy in earlier chapters it would be useful to examine if optimal safety policy can be determined across four modes of transport and thus used to support analysis of cross modality.

Optimal policy is reached when investment has been pushed to the point where (MB-MC) or more precisely NPV = 0. Beyond this point it is not worthwhile making any further investment to improve safety since the costs exceed the benefits (both tangible and intangible). As noted previously, CBA/MCA can also be used as a tool for ranking projects in order of desirability. This ranking, in particular, can be used in an interesting manner to rank the desirability of various approaches to or instruments of an overall transport safety policy.

Traditionally, transport policy in general, and especially transport safety policy, has been developed separately for each mode with safety projects being ranked for a specific mode such as rail or sea. It is also evident that limited attention has been paid to other transport modes when setting safety policy within a specific mode. That is to say, no account has been taken of what policies exist in other transport modes and what impact (for example conflicting policies) they may have on the transport mode being considered.

In instances where no substitution (modal switching) is possible among the various modes of transport that have been outlined, there are only two possibilities that can be envisaged for an overall approach to transport safety. Firstly, it would be possible to promote MB-MC=0 in each mode if that condition had not been met in some specific modes but had been attained in others. When assessing various safety projects in terms of their marginal net benefit (MB-MC) and where (MB≥ MC) there is a potential to make a Pareto improvement. It is also possible that marginal benefit may not exceed marginal cost if substantial levels of expenditure are required to make sufficient transfers between modes to have a significant effect on overall safety levels. In this case, or if only limited safety benefits/gains are possible, the review will consider if it is worthwhile to encourage modal shift. The MB-MC, or NPV for multi-period projects, can be established for each project using CBA or MCA. When this has been carried out for a number of transport safety initiatives the projects can be ranked for each mode; optimal policy is reached when investment has been pushed to the point where MB-MC=0, beyond which there are no possible safety improvements. It would be important to consider the physical volumes of modal shift in terms using average or country-specific risk rates.

Transport safety policy on a cross-modal basis, i.e. considering all the modes together when the possibility of substitution (modal switching) for passengers is recognised, presents a more complex set of considerations regarding optimal policy. If there is the possibility of substitution (modal switching) across the modes of transport and the level of safety differs between modes, there is also the possibility of promoting greater safety by promoting safer modes at the expense of others. Passengers can be encouraged, through payment, persuasion or prohibition, to switch modes irrespective of their perceptions of risk if the objective is to decide safety policy on a rational basis. Such encouragement of cross-modal switching or transfer has been employed to date across various modes of transport for factors other than safety, notably for environmental policy reasons (see 4.3 for examples). Paying or encouraging people to switch to modes where the safety benefit is the greatest (i.e. modes with the highest safety in terms of fatality/injury per person km) could, per se, lead to improved safety. The modal switching here would be promoted without the need to provide any extra resources to the mode which passengers are being encouraged to use, provided that sufficient spare capacity exists in the receiving mode. If, for example, users of road transport were being urged to switch to rail transport for purposes of increasing overall travel safety, then no extra resources (or at least no extra specifically safety-related resources) would be required in rail transport for the modal switch to improve safety[39]. There could, of course, be financial incentives from the government to encourage the switch; and if the numbers involved are large the train operators might have to increase capacity and thus costs; but unlike almost any other type of transport safety initiative there would be no costs associated with the safety gain per se. Whereas increasing car safety by installation of airbags implies an additional cost in the production process of cars, encouraging people to switch from road to rail has no directly attributable "production" cost.

### 4.2.4 Importance of passenger perceptions

A counter argument to the proposal presented above could be that passengers who desire safety will inevitably have considered the greater ***perceived*** safety in certain modes when making their modal choice, along with other factors such as price, speed, convenience and quality (further discussion on user perceptions is provided later in this thesis where travel user surveys have been carried out). It is known that safety differs according to mode and it can be argued that individuals have balanced their perceived safety differential among modes against any inconveniences arising. In this instance there cannot be any net gain from government intervention to encourage modal switch on safety grounds. Passengers who fly with full service carriers, such as British Airways, do so to some degree because they appreciate the good safety record of the airline and perhaps perceive it to be superior to that of other airlines. The inconvenience they encounter, however, is usually in the form of the cost of travel, although even this is changing as these full service airlines are now competing with Low Cost Carriers (LCCs) and are therefore reducing their prices considerably.

For the above counter-argument to be valid and to invalidate the case for use of modal switch as a tool of overall transport safety policy certain conditions need to hold true:

a) that all users are sufficiently well informed about comparative safety levels; and

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[39] Here the modal shift is assuming zero infrastructure investments in rail transport.

b) that the only people whose safety is affected are those making the modal choice.

In practice, the situation referred to in point (a) rarely occurs due to asymmetric information regarding safety on the various modes of transport; perceptions and reality can be dramatically out of line as regards risk of death or serious injury in the various modes. The statement in (b) is clearly not the case, as has been already established in Chapter 2 when developing the general arguments for state intervention to promote transport safety. The impacts (externalities) are often on third parties and it is in respect of these impacts that state intervention may become necessary since those affected have not exercised any choice.

It has been argued that where the user can have some influence directly on the level of safety through their own behaviour (e.g. people driving their own cars) that figures for average deaths and serious injuries per person km are not particularly pertinent; the driver, in effect, feels that they can outperform the figures and that the safety figures do not apply to their case. While the driving safety record of different population groups varies, as reflected in insurance premiums, safety on the roads is also very much dependant on external factors beyond the driver’s control, not least the behaviour of other drivers and the weather.

Consequently, we cannot discard the case for modal switch considerations in safety policy on the supposed ground that these will have already been taken into account in choices. Rather, modal switching should be seen as a new instrument for giving effect to a transport safety policy which, in turn, is based on the classic considerations of public non-excludable externality, abuse of dominant position, asymmetries of information and harmonisation of standards. CMS specifically is most relevant as a policy tool for interventions to deal with public non-excludable externalities and imperfections of information; but against this possible limitation of relevance it should be noted that encouragement of modal switching will typically be a very low-cost policy instrument for the promotion of safety. The exact extent of this is something this work aims to explore; but *a priori* it is plausible to assume that a safety policy which involves some marginal shifting between modes without any need for construction of new infrastructure will effectively be low-cost.

### 4.2.5 CMS and transport policy

If there is a possibility of CMS which is accepted, then transport safety policies for individual modes cannot be developed rationally in isolation from one another. Rather, it would be appropriate for transport safety promotion policy to be set together for all modes in an integrated manner. Although the DETR (1998) and subsequent DETR (2000) transport policy in the UK addresses the integration of transport policy in general, it still examines transport safety only on a mode-specific basis. It outlines what is envisaged with respect to safety in road, rail, air and sea taken individually but does not mention any integration of transport safety policy or modal switching. If all the modes were to be considered together, both safety projects that concentrate on improving safety within a specific mode in the traditional way (for example ATP) *and* projects that would seek to improve safety by encouraging or requiring a modal switch for some groups of passengers would be included. More recently, Preston (2012) addresses the general issues concerning transport integration policies in the UK and in Europe and concludes that the implementation has been difficult and obstructed by competition among different modes of transport.

It is accepted that that government funding for safety policies is limited due to budgetary constraints; therefore simultaneous consideration of safety policies across all modes (rather than a fragmented approach for each mode independently) can be useful to establish the projects that show notable benefit cost ratios (BCRs) overall.

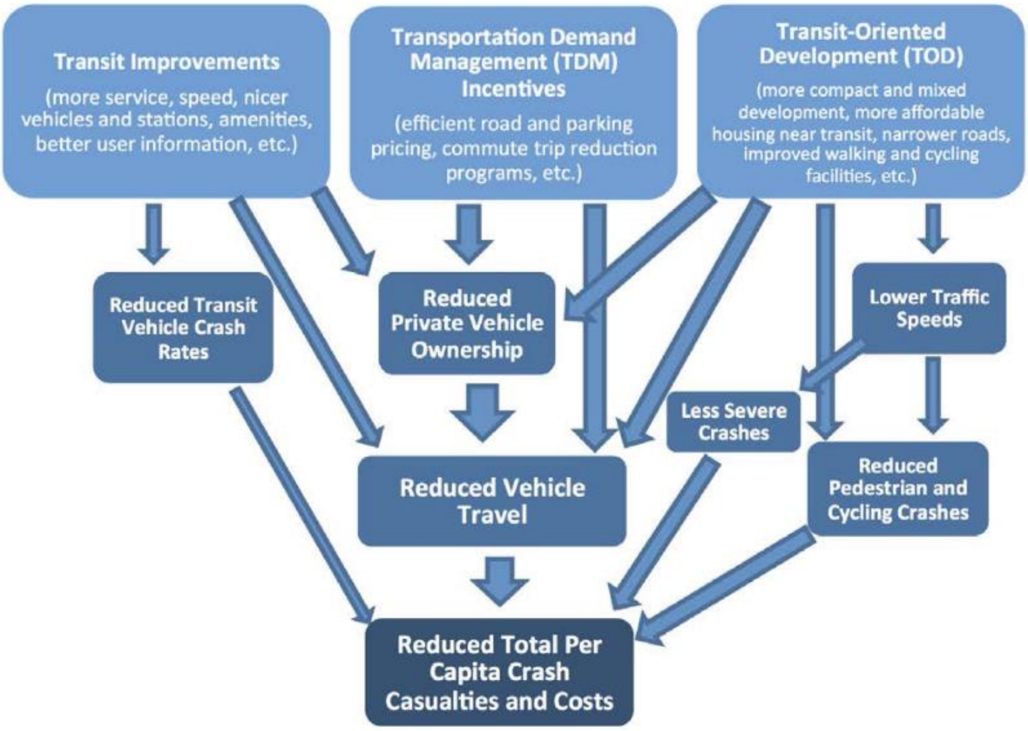
Regarding the modal switch, the benefits that can accrue to passengers from switching to an alternative mode of transport do not imply any extra resources being devoted to the safer mode. Any resources deployed would be purely to encourage users of one mode of transport to switch to another safer mode. This can be achieved in a number of different ways, for example through subsidised rail fares and through HGV driving restrictions in some European countries (France, Germany, Luxembourg and Italy). In the latter, there are two categories: the first comprises restrictions with a (series of) fixed calendar dates where the restriction on HGVs is in place. Information on this type of restriction is commonly well communicated in advance of the actual date of restriction; for example, general night bans and weekend driving bans, and holiday period or public holiday related driving restrictions. The second category is non-fixed calendar date restrictions, whereby although the specifics of these restrictions are well communicated, the calendar date normally is only known shortly before the actual occurrence. These restrictions relate to, for instance, the current weather situation or the traffic density on a certain day (van den Engel 2010). This approach to considering optimal safety policy today is appropriate and in tune with calls for integrated transport solutions.

For the North American situation, Litman (2014) highlights public perceptions that public transport is more dangerous than other modes and a resulting reluctance to use it and support its expansion. He confirms that these views are at odds with the risk statistics for public transport and result from the nature of the travel experience, media coverage of specific incidents, emphasis on danger rather than safety in messages transmitted. These views combine with an undue underestimation of car travel risks.

Litman’s (2014) conclusions are based on a comparative review of the statistics for different transport modes. This also acknowledges the impacts of higher risk feeder modes such as walking and cycling but suggests that these high risks are offset by reduced risks to third parties and the health benefits to those undertaking them. Litman also notes from a 2012 review of 101 US cities that there is a link between greater public transport use and overall transport safety, though the strength of this relationship is higher in pro-public transport cities such as Seattle and Denver compared with Dallas and Houston. The explanation given for this link is the wider implications for urban design, so increased public transport use tends to be linked to better and safer overall urban design.

In policy terms he stresses the importance of better communication of safety benefits of public transport travel. Linked to this he recommends to encourage traffic safety experts to recognise public transport safety impacts and consider pro-public transport policies as potential traffic safety strategies. The logic of the links between increased public transport use and overall safety improvements is summarised by Litman (2014).

He acknowledges that there can be multiple impacts emanating from a specific policy or planning decision (Figure 4-4). Improvement in commuter public transport can benefit those who shift mode directly and indirectly reduce risk through reduced vehicle ownership by some households, which in turn reduces their non-commuter vehicle travel. Various proactive public transport policies, including service improvements, transportation demand management (TDM) incentives, and support for transit oriented development can have cumulative effects when implemented simultaneously, as their impacts are greater than if applied independently.



**Source: Litman (2014)**

*Figure 4-4: Transit improvement and incentives' traffic safety impacts*

Litman (2016) presents similar findings to Litman (2014) but in a more policy oriented document produced by the American Public Transport Association. The logic expressed in this paper aligns well with the overall approach of the present thesis. In summary the key points made are as follows:

- *"Transit supportive policies can provide substantial traffic safety benefits, which result in saving lives and reducing injuries.*
- *Modest increases in public transit mode share can provide disproportionally larger traffic safety benefits.*
- *Safety strategies intended to reduce higher-risk driving become more effective if implemented in conjunction with public transportation improvements.*
- *Public transportation investment is among the most cost effective ways to enhance traffic safety for a community."*

This review re-asserts the link between public transport use and overall safety levels. The implications of the Litman papers (2014, 2016) are that CMS can have an impact directly, but that there are also wider impacts on overall safety from improvements in public transport provision and use. Some of these are indirect impacts resulting from a greater overall interest in the safety of the travelling public, and others affected by transport risk.

## 4.3 APPLICATIONS OF CMS

This section reviews the literature on applications of CMS to improve safety, approaches and methods used to encourage modal switching and develop use of active transport modes, experience of CMS in Asia and India and EU transport projects which include CMS. The objective is to understand how modal transfer has been achieved and to consider the most effective methods applied to achieve CMS for safety as well as other applications. A particular consideration is how much modal transfer is possible from one mode to another, i.e. the net shift rather than suppressed or new demand, because this has important implications for CMS in this work with respect to quantifying the actual benefits of the modal transfer.

### 4.3.1 CMS on the basis of safety

To date, the literature reporting studies carried out on CMS purely for safety has been limited. ATSB (2002) provide modal safety comparisons and outline the results from Australian and other studies. They note that comparisons have been limited by availability and reliability of data on risk exposure and that single safety risk measures can produce inconsistent results across different modes. Overall, they conclude that high capacity public transport modes are the safest forms of transport per person-km, particularly air; with rail and bus the safest land modes and motorcycling the least safe.

Other work by Baanders et al. (2011) reviews efforts to promote substitution from car to public transport 20 years previously in the Netherlands and considers whether the arguments are still applicable. They argue that a measure affecting one mode neither causes a significant shift to or from the other (i.e. car and public transport are not “communicating vessels”) nor has an impact on how these modes evolve in the future. They conclude that the arguments for modal switching are still valid but that there is only real competition between car and public transport in certain parts of the network at certain times of day around major cities in the Netherlands. Their findings suggest that in the future this situation will not change (excepting drastic shocks in fuel supplies) but there remains a challenge for policy makers to counter increases in car dependency.

Evans and Addison (2009) provide more detailed investigation into CMS as a basis for safety improvements in their investigative work on how road and rail safety interact in Great Britain. The paper concentrates on two areas: namely, analysis of whole journey risks (with rail as main mode) including access modes used to and from the rail system, and the impact of safety risk of intermodal transfers between road and rail. They estimated, based on DfT statistics, that walking constitutes the highest proportion of risk for a door to door journey[40] at 65%, followed by 21% for rail and 14% for all other access modes (i.e. percentage components of total door-to-door risk). They investigated the possibility of increasing rail fares to fund safety measures by combining the results of the modal split with corresponding casualty rates and considered two illustrative combinations:

> *(1)"a safety measure or set of safety measures, reducing all surface rail risk, including non-passengers, by 10%, funded by a 0.5% increase in fares; and*
>
> *(2) a safety measure reducing risk only to rail passengers by 10%, funded by a 5% increase in fares"(p53).*

The safety measure noted in (1) above was considered to be representative of a number of general safety measures or groups of safety measures on railways. They noted that any set of safety measures capable of preventing 10% of all casualties would be fairly substantial, however smaller sets of safety measures with the same benefit/cost ratio would give proportionally similar outcomes (e.g. a safety measure preventing 1% of casualties for a 0.05% increase in fares). The direct impact of the measures noted in (1) above would prevent 3.3 fatalities (or 4.6 fatalities plus weighted injuries) per billion passenger-journeys (equivalent to a 10% fall in overall rail casualty rates per year). These reductions are attributable to passengers and to non-passengers including rail staff and third parties (e.g. users of level crossings). The increase in rail fare would however result in a modal shift from rail to car. As expected there would be less rail journeys, less access to rail journeys and increased car journeys with a counterbalancing increase in casualties because of the higher risks associated with this mode. Ancillary effects would be small due to limited modal shift. The cost per equivalent fatality was estimated at £1.3 million,

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[40] Casualties per billion passenger-journeys with surface rail as main mode including access: Great Britain, 2003.

similar to the official DfT 2003 valuation. The requirements for rail safety were contrasted with a lack of similar requirements for road.

The safety measure noted in (2) above is representative of a “high-cost system” safety measure (e.g. in this case use of additional ATP). The results showed that the increase in fares (5%) would yield £130 million and support a capital sum for investment of up to £2 billion (cost of ATP examined), taking account of the modal shift of passengers from rail to car due to the fare increase. Evans and Addison note that passenger casualties would not be reduced by more than 10% even though the measure would be effective, because it would only address yield reductions for certain types of train accidents. Other elements of the existing accident statistics such as falls and other accidents could not be prevented with the ATP measure.

It was estimated that the direct impact of the measures in (2) would result in the reduction of rail passenger fatalities by 1.3 (or 2.2 plus weighted injuries) per billion passenger-journeys: roughly 10% of the current numbers per year. The ancillary effects of the modal shift from rail to car would be greater than the measures noted in (1) above since the presumed fare increase is 10 times more. The reduction in rail journeys and access to rail journeys are compensated by the increase in casualties due to replacement car journeys. A net increase of 1 equivalent fatality per billion passenger journeys is estimated, showing limited rail safety benefit. The impact of the modal shift (rail to car) is also surprisingly restricted, since the whole-journey risk does not increase by a factor of 10 but rather 2+: as a reduction in rail travel also reduces access and on-rail risks. There are also some rail users who do not shift to car since there are households without cars or users without driving licences (estimated at 39%) and these therefore do not add to the high risk through modal transfer. The value of measure (2) above is not considered to be worthwhile due to the cost of £130 million safety measure versus the prevented 2 on-rail equivalent fatalities and serious injuries annually.

Several studies have shown that risks to pedestrians and cyclists are non–linear; the more pedestrians and cyclists there are, the lower the risk posed to each group. If a very large transfer from motor vehicles to walking/cycling were to take place, the total number of accidents could actually be reduced. The ‘safety in numbers’ effect of pedestrians and cyclists combines with lower motor vehicle numbers and thus results in lower overall numbers of accidents. Elvik (2009) was the first to estimate the road safety effects of shifts from car to bicycle and walking using Accident Prediction Models (APMs) in which a non-linear relationship between casualties and volumes is assumed. He also quantifies the level of transfer from motor vehicles to walking or cycling needed to pass the point at which the combined benefits of “safety in numbers” and a reduced number of motor vehicles lead to fewer accidents. No distinction is made between different modes of motorised transport (car, bus, tram etc.) although they have very different average injury rates.

The findings in the study show that in the current transport system users of active modes of transport are exposed to a higher risk of injury accidents than motorists, especially car drivers. Non-linearity of risk faced by pedestrians and cyclists is suggested in several studies. In theory the total number of accidents could decrease if a significant share of motorised trips is transferred to walking/cycling. The effects on accidents of modal transfer are dependent on the degree of non-linearity of risk, i.e. the more linear the risks faced by pedestrians or cyclists, the likelier that increased use of active modes of transport will be linked with an increased number of accidents. Elvik’s estimates are only exploratory and do not take into consideration those reported in the official accident statistics or of accidents involving pedestrians and cyclists.

Schepers and Henin (2013) examine the effect of modal shift from short car trips to cycling in Dutch municipalities. They use crash and mobility data to develop APMs that take into consideration the non-linearity of risk. Their findings noted that there is little effect on the number of road deaths from a shift from car to bicycle, although the number of serious injuries would be expected to increase mainly due to an increase in single-bicycle crashes. Their study highlighted the large differences between age groups in the effect of a modal shift. Fatalities over the age of 65 were expected to increase while in the 18-24 age group the numbers were expected to decrease. The greatest road safety gain is for the 18-24 age group of young drivers per exchanged car kilometre.

### 4.3.2 Approaches and methods of CMS

Andrejszki et al. (2014) identified the modal shift of passengers by analysing their preferences using stated preference methods and online questionnaires. They developed utility functions to identify the future impact of modes on regional development. Modal choice was based on five key factors: travel cost, travel time, comfort, safety and environmental efficiency. Some research was carried out on soft measures (DfT, 2009) that influenced growth and modal transfer to bus from car in England. The results suggested that soft measures (safety, security, quality of in-vehicle experience, ease of use, etc.) have a positive impact on demand and come into play after hard factors such as frequency and reliability reach certain thresholds. They can also be independent, such as where there are low-floor buses on existing service frequencies. Important soft issues emerging from the research were safety and security. Zimmer and Schmied (2008) reviewed methodologies that can be used to determine the impact on traffic of a modal shift from road to rail and ship for passenger and freight transport, based on data from 2000-2003 in Europe. The approaches considered for determining the modal shift potential used capacity calculations, transport demand modelling or analyses of surveys. They estimated a theoretical shift towards rail transport from 9.5% to 17.3% which they suggest is viable if combined with policies and measures to address travel costs, time and railway networks.

Lalive et al. (2013) explored how modal shift in Germany can be enhanced through policy incentives, particularly subsidisation, to permit increases in frequency. They consider whether government support to the railways would reduce road traffic externalities, in view of a railway reform that enabled newly created regional agencies to procure regional passenger lines competitively. They analysed services on 551 regional passenger lines before the reform and then again a decade later, together with information on severe road traffic accidents, concentrations of local air pollutants, and infant mortality. Their results indicate that a large increase in service frequency on competitively procured lines observed over the 10 year period after the railway reform provided notable benefits in terms of reduced road traffic externalities. Road accidents were shown to reduce by 4.7% and nitric oxide emissions by 3.8% for every 10% increase in regional passenger railway services. Their findings also showed that an increase in service frequency by 10% reduces car and motorcycle use for commuting to work by 2.7% and by 2.8% for leisure trips. Overall the results showed that people did substitute from cars to trains because the passenger service frequency increased.

### 4.3.3 Modal shift to active modes of transport for health and environmental benefits

Rabl and de Nazelle (2012) highlight the health and environmental benefits of shifting from car to more active transport modes (bicycling and walking). The estimated level of health impacts for a shift from car to cycling took account of the health benefits to those who switch, health benefits for the general population due to reduced pollution, changes in exposure to ambient air pollution and changed risk of accidents. Walking effects were found to be similar, although fatality rates per km were higher for bicycles. Accident risk is dependent on local context with variations in rates between rural and urban areas. The study found that fatal accident risk increases were offset by the overall health benefits. Differences between different countries and cities with large bicycle culture (Netherlands and Denmark) and limited bicycle culture (Italy, France and Belgium) were also noted. Dekoster and Schollaert (1999) cite similar fatality rates for cars and bicycling in the Netherlands, although this is unlikely elsewhere. The main benefit of switching, by far, was health and, to a lesser degree, environment (reduction in noise and pollution) and congestion.

Schepers et al. (2014) outline a conceptual road safety framework model consisting of interacting factors for risk exposure such as modal split due to travel behaviour and risk of accidents. Their model is then linked to research on cycle safety, to land use and infrastructure and to policy consequences. They examine the level of risk of injury and cite work carried out by Schepers and Heinen (2013), indicating that a shift from car to cycling means that individuals are less hazardous to other road users due to lower levels of kinetic energy in the event of an accident. The impact of public "bikesharing" (shared use of a bicycle fleet) in North America is examined by Martin and Shaheen (2014) within Washington D.C. and Minneapolis. Using surveys the study found that bikesharing, overall, led to a reduction in driving and use of taxis in highly densely populated areas. Shifts in public transport modes, such as rail and bus, were mixed. Those moving towards public transport modes lived in the urban periphery and shifts away from public transit to bike share cycles were notably in core urban areas with high population densities. Evidence suggested that bikesharing was a first and last mile option where the public transport network was less intensive (i.e. facilitating access to and from the public transport system). Bikesharing was considered to be complementary to public transport in small or medium size cities while a substitute in larger and more populated cities.

### 4.3.4 CMS in Asia and India

CMS experience from Asia and India has also been examined in the work of Nurdden et al. (2007), Satiennam et al. (2015) and Bajracharya (2008). The effect of transport policies on modal shift from car to public transport was evaluated by Nurrdden et al. (2007) using a survey and a binary logit model for three modes (car, bus and rail). Modal choice factors included gender, age, car ownership, travel time and income. The work concluded that appropriate incentives were required for commuters to switch to public transport (bus and rail) such as reduced travel time, fare subsidies and a short distance from home to public transport stations. In Thailand, the modal shift from car and motorcycle users to Bus Rapid Transit (BRT) for Khon Kaen City (Satiennam et al., 2015) was examined. The findings were similar to those in Malaysia in that travel time and cost were significant factors in determining modal choice. The study concluded that the modal shift from cars and motorcycles to BRT could be further enhanced through priority lanes for buses, improved access, door to door services and increased service frequency. The reason for encouraging the modal shift was environmental, namely to reduce $CO_2$ emissions. The impact of modal shift on the ecological footprint was highlighted in the work of Bajracharya (2008) using the case study of a proposed BRT in the city of Ahmedabad, India. A survey was conducted and discrete choice modelling used to estimate the shift at 34% of two-wheeled vehicle users moving to BRT. Bajracharya suggested that the ecological footprint would be reduced by the introduction of a BRT that would represent a sustainable transport system. The reduction in environmental impact could be supported through further policy measures.

### 4.3.5 EU transport projects

Some earlier EU projects have been undertaken in relation to the EU's Common Transport Policy which emphasised modal substitution, albeit not specifically as a result of safety promotion. Examples of EU funded projects addressing aspects of modal switching are the AIUTO project (MIP Europe, 1999) on models and methodologies for the assessment of innovative urban transport systems and policy options, the CONCERT-P project (Barcelona Tecnologia, 1999) co-operation for the evaluation of city road pricing tools and TRANSPRICE (euroTRANS, 1999) trans-modal integrated urban transport pricing for optimum modal split.

AIUTO aimed to develop a framework of models and methods for the simulation and evaluation of Transport Demand Management (TDM) measures. The TDM policies examined the fact that modal switching is not effective unless it is supported by incentives to switch, especially in the case of the modal switch from private cars towards public transport modes; although this was not examined with respect to safety. The CONCERT-

P project evaluated the use of road pricing measures to change modal split in urban areas, in order to address problems of air pollution, congestion and noise in European cities. TRANSPRICE aimed to demonstrate and assess pricing strategies co-ordinated across modes, identifying effects on modal split and public acceptance. Demonstrations and modelling work in five cities showed that road-use pricing is an effective way of changing modal split from private car to public transport and Park & Ride, giving city centre traffic reductions of 5 - 25% (for charge levels of 1 - 3 EUR). This demonstrates the possibility of promoting modal switching, albeit not in these cases for a safety application. Arguably, most people are sensitive to cost rather than safety issues but it is clear that public sector pricing could be influenced to reflect safety policy through appropriate manipulation of charging structures similar to that for congestion.

### 4.3.6 Overview of findings from the literature

Table 4-2 summarises the findings from the literature to provide an overview from the context-specific examples (Sections 4.3.1 to 4.3.5 ).

| Author/s | CMS Context | Findings |
|---|---|---|
| Baanders et al. (2011) | Modal transfer on the basis of safety | • Review over 20 years showed that significant modal switching in the Netherlands from car to public transport is only competitive on certain parts of the network at specific times (i.e. limited to certain situations).<br>• Substitution of trips from car to public transport resulting from policy measures will differ strongly according to trip purpose, origin, destination and distance, since the availability and relative quality of public transport varies between market segments. |
| Evans and Addison (2009) | Impact of safety risk of intermodal transfers between road and rail | • Assessed a safety measure preventing 1% of casualties funded by a 0.05% increase in fares that would result in 10% fall in overall rail casualty rates per year.<br>• Corresponding modal shift from rail to car would lead to a counterbalancing increase in casualties because of the higher car travel risks.<br>• A “high-cost system” safety measure assessed (e.g. use of additional ATP) reducing risk to rail passengers only by 10%, funded by a 5% increase in fares, was not considered to be worthwhile due to the cost of £130 million safety measure versus the prevented 2 on-rail equivalent fatalities and serious injuries per annum.<br>• The impact of the modal shift (rail to car) is also surprisingly limited since the whole journey risk does not increase by a factor of 10 but 2 as reduction in rail travel also reduces access and on rail risks.<br>• Additionally some rail users do not shift to car as there are households without cars or users without driving licences (estimated at 39%) and these do not add to the |

| Author/s | CMS Context | Findings |
|---|---|---|
| | | high risk through modal transfer. |
| Elvik (2009)<br>Schepers and Henin (2013) | Modal transfer of active modes of transport and their safety impacts | • APMs used to suggest that in theory a large modal shift from car to cycling results in reduced total number of accidents.<br>• Reason for counter-intuitive outcome thought to be reduced car numbers and 'safety in numbers' for additional cyclists.<br>• The more pedestrians and cyclists there are, the lower the risk posed to each group (non-linear risk); conversely higher risk if less pedestrians and cyclists (linear risk).<br>• The effect of modal shift from short car trips to cycling is examined in the Netherlands considering non-linearity of risk using crash and mobility data to develop APMs.<br>• The findings show that there is little effect on the number of road deaths from a shift from car to bicycle, but an increase in the number of serious injuries mainly due to an increase in single-bicycle crashes.<br>• Noted large differences between age groups in the effect of a modal shift. Fatalities over the age of 65 were expected to increase while in the 18-24 age group the numbers were expected to decrease.<br>• The greatest road safety gain is for the 18-24 age group of young drivers per exchanged car kilometre. |
| Andrejszki et al. (2014)<br>Zimmer and Schmied (2008)<br>Lalive et al. (2013) | Modal transfer approaches and methods | • Modal shift of passengers determined by analysing stated preferences in online questionnaires.<br>• Modal shift potential towards rail determined using capacity calculations, demand modelling and analyses of surveys.<br>• Estimated shift towards rail transport from 9.5% to 17.3% considered viable if combined with policies and measures to address travel costs, time taken and changes to the railway network.<br>• Road accidents in Germany are shown to reduce by 4.7% and nitric oxide emissions by 3.8% for every 10% increase in regional passenger railway services.<br>• Findings also show that a 10% increase in rail service frequency reduces car and motorcycle use for commuting by 2.7% and for leisure travel by 2.8%. |
| Rabl and de Nazelle (2012)<br>Dekoster and Schollaert (1999)<br>Martin and Shaheen, (2014) | Modal transfer on the basis of health and environmental benefits | • Modal transfer from car to more active transport modes (bicycling and walking) investigated.<br>• Small increases in fatal accident risk (in monetary terms) offset by the wider overall health benefits.<br>• Differences observed in the effects between countries/cities with different bicycle cultures.<br>• Incentives such as "bikesharing" a first and last mile option where public transport network less intensive.<br>• "Bikesharing" considered complementary to public transport in small or medium size cities but a substitute in larger and more populated cities. |
| Nurdden et al. (2007), Satiennam et al. | Modal transfer for environmental reasons and | • Modal shift in Malaysia from car to public transport (bus and rail) required incentives such as fare subsidies or reduced travel time. |

| Author/s | CMS Context | Findings |
|---|---|---|
| (2015) and Bajracharya (2008) | sustainable transport from Asia and India experiences | • Modal shift from car and motorcycle users to BRT in Thailand concluded that cost and travel time were key factors for modal choice.<br>• In India discrete choice modelling estimated that a 34% shift from two-wheeled vehicle users to BRT for a specific city could be possible. |
| European Union projects (1999) | Modal transfer on the basis of pricing | • Projects considered pricing mechanisms as a basis for promoting use of different modes and hence provide useful background for the approaches considered later in this thesis. |

**Source: Author's own**

*Table 4-2: Overview of findings from CMS literature*

## 4.4 SUMMARY

This chapter has highlighted that safety policy in transport has hitherto been considered on a mode specific basis without considering policies set in other modes and that this could result in the development of sub-optimal safety policies. The reasons for this are a mixture of limited government funding, the fact that many aspects of transport safety are necessarily mode specific and because although substitution factors have been considered to some extent for other applications, this has been very limited as regards safety policies.

The main conceptual innovative framework in this work is advocating the move away from single mode policies towards developing an optimal safety policy that spans all transport modes simultaneously including (but not just confined to) by means of CMS of passengers from modes that yield limited safety benefits to those modes that yield the highest safety benefits.

# 5 ANALYSIS METHODOLOGY

## 5.1 INTRODUCTION

This chapter sets out the objective and overall rationale for the analysis conducted in the thesis, describes the approach and details the methods used to test its hypothesis. Figure 5-1 outlines the logical flow of the approach from the primary and secondary data sources through the analysis process to the expected outcomes.

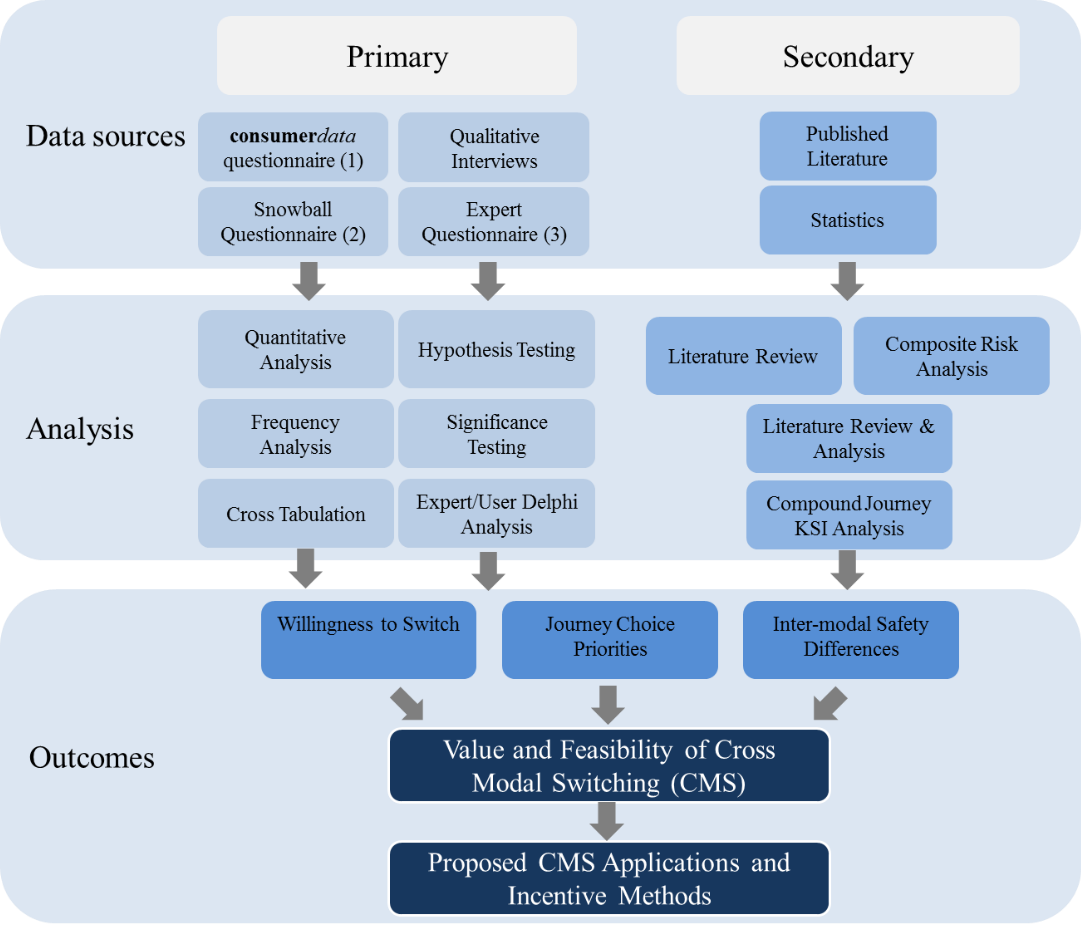

*Figure 5-1: Overview of data sources, analysis method and outcomes*

Overall the thesis examines the extent to which effective promotion of CMS can enhance safety on urban and long-distance passenger transport, considering the total passenger journey.

## 5.2 RATIONALE AND APPROACH TAKEN

### 5.2.1 Rationale

As established in Chapter 2, the rationale for the thesis is underpinned by two viewpoints. The first is that transport safety policy gains from a rational approach, taking a long term perspective rather than short term responses to specific incidents. Secondly, that transport safety policies have previously been developed largely with reference to single modes in a tightly compartmentalised manner. Although some work has been undertaken at the multimodal level which recognises that safety should be considered as part of the overall evaluation of multimodal projects, much of this seems to be at a cursory level. European Commission (2013) passenger transport thematic research summary looks at safety considerations but focused mainly on road safety. Most studies on multimodal transport focus on time savings, health benefits and environmental benefits with limited emphasis on safety aspects.

By treating modes independently and not taking full account of the options within a specific journey, policy has hitherto disregarded a potentially important contribution to overall passenger safety, a contribution which, for many journeys, could be achieved at relatively low cost.

### 5.2.2 Overview of approach

Based on the premises set out above, the thesis sets out to consider whether CMS is worth promoting (safety differences between modes) and if so, whether such promotion is likely to be effective (in practical terms). The overall approach showing links to where each factor is addressed in the thesis is set out in Figure 5-2.

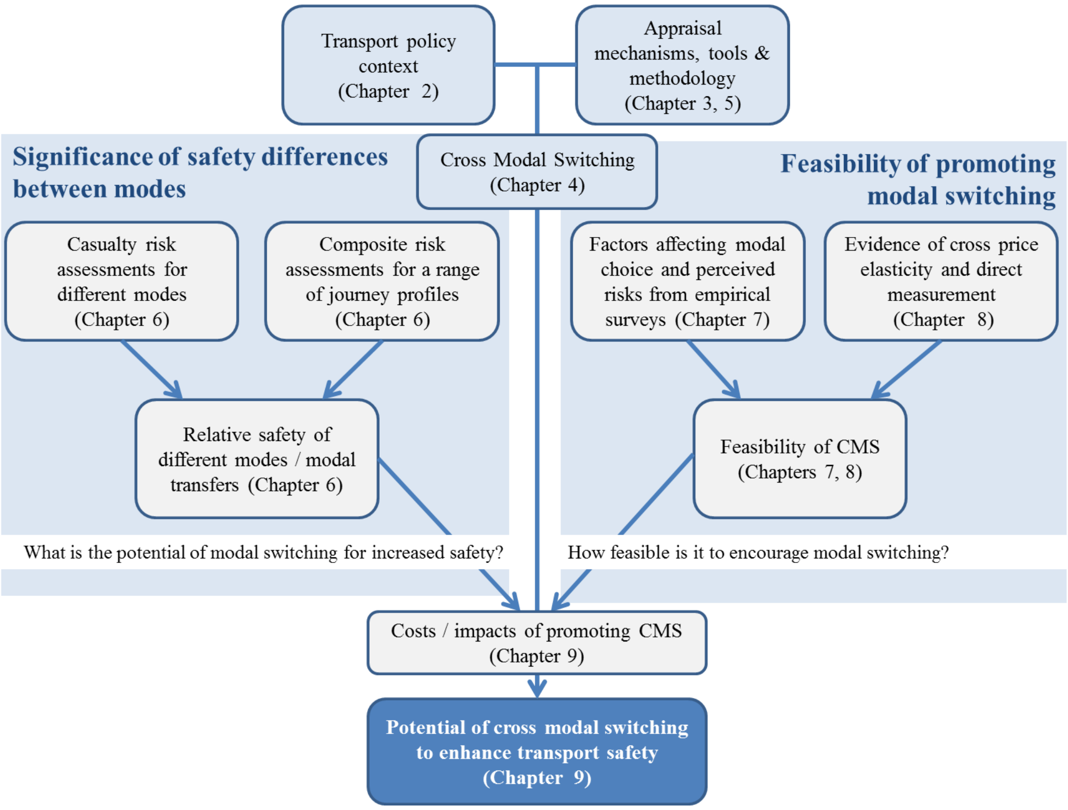

*Figure 5-2: Overview of approach*

Firstly, the two initial areas are considered:

**Transport safety policy:** Prior to the consideration of the two elements above, the overall approaches to transport safety are examined as context. The logic is that a rational response to transport safety, of the type typified by CMS, is a more effective one than being driven by major events, even if these events are prominent to the general public.

**Appraisal mechanisms for CMS:** A second preparatory section is needed to examine and select the most appropriate appraisal tools with which to consider the success or failure of CMS approaches.

The subsequent tasks/objectives are then outlined in Table 5-1.

| Topic | Question | Tasks/Objectives |
|---|---|---|
| **CMS basis** | The key question needed to justify the use of CMS is whether some modes are significantly safer than others when used for equivalent journey types.<br>This requires an analysis of the basic accident statistics, with consideration of full ‘end to end’ journeys including all necessary transfers. | Steps involved in this include:<br>• Analysis of statistics from national surveys<br>o Review of accident and KSI statistics for all major transport modes<br>o Identification of safest modes<br>• Review of end to end journey statistics for a wide range of typical journeys<br>• Identification of transfer hazards<br>Risk differences on different odal combinations for the same journey types suggest value of switching |
| **CMS practicality** | The second key question is whether it is practical to expect some people to switch modes in response to incentives.<br>CMS can only be realised if people are willing to switch modes and can be incentivised to do so. | Topics which need to be considered to establish this are:<br>• Preferences and willingness to switch (considered via questionnaires)<br>• Safety perceptions (also considered via questionnaires)<br>• CPEs<br>• Incentives necessary for these modal switches<br>Result – what incentives are needed to enable switching? |
| **CMS value** | What would be the outcome of such switches in terms of overall safety improvements? | • Appraisal tool outcomes as per Chapter 4<br>• Use of CBA as an appraisal tool to determine if CMS is worth promoting<br>• Statistical review of CBA outcomes |
| **Practical recommendations** | What are the practical learnings from the earlier analysis that could be used to improve CMS implementation | • Identify which mode to mode switches would be recommended.<br>• Consider how changes could be incentivised.<br>• Determine what rate of benefit (safety improvements) could be expected. |

*Table 5-1: Objectives and tasks to appraise the value of CMS*

Starting with the potential value of CMS, the thesis firstly seeks to develop this insight at a theoretical level, setting it within the literature on transport safety. It investigates the safety gains on specific journey types which can be achieved by modal switching or by changing the modal mix. This process has been undertaken for a wide range of possible journey types and for different modal combinations within each of these types. By comparing the risk of death/serious injury per passenger km in different modal combinations, the work establishes the extent to which levels of safety differ between modes. This includes analysis of the sequence of different travel modes normally necessary to complete an end to end journey. If significant differences in safety between substitutable modes can be established, then overall transport safety can be improved by encouraging travellers to switch to safer modes for at least part of their journey.

To support the overall appraisal, the initial comparisons of risk are then monetised to provide a basis for CBA, the selected policy appraisal tool. At this stage, the benefits are defined to allow the CBA to be undertaken once the practicality and cost of the promotional methods are known.

The next stage in the assessment is to consider practical aspects necessary to make CMS potential achievable. These include the levels of substitutability between modes and the CPE of demand. These are addressed through two questionnaire surveys providing data from users in a range of mode/journey type combinations, together with one expert survey linked to follow-up qualitative interviews with experts and users. The results of this data-gathering are combined with reviews of the literature to test the validity of the approach.

If a valid basis for CMS, and an optimal way to apply it, can be established, the final stage is to consider the implications for overall transport safety policy. The work has significant implications for a wide range of transport types: from road and rail travel through to the more recent efforts to promote urban cycling as a way to reduce emissions and congestion.

The specific components of the thesis method are now considered in more detail section by section.

## 5.3 RISK EVALUATION FOR COMPOSITE JOURNEYS

The thesis evaluates a number of practical cases where *a priori* there may be good grounds for advocating modal switch as an approach to transport safety policy. These cases are analysed within a framework of consumer choice theory and the theory of goods characteristics. The journey categories selected are shown in Table 5-2, with a number of specific examples examined in each case.

| Journey Category | Definition of categories |
|---|---|
| **International**<br>(e.g. London to Paris) | The International category aims to capture a range of European inter-city journeys, including not only major centres, such as London and Paris, but also smaller centres such as Bristol and Birmingham. Routes from the United Kingdom (large cities) to European destinations (cities) are covered. The distances range from 450 km to |
| **International dual-mode long distance**<br>(i.e. including two long journey legs in different modes e.g. Newbury to Seville via London Stansted airport) | This group of journeys considers travel within Europe by air but which involve complex travel to the airport including a number of modes. This is a useful approach to aviation risks because, although the aviation risk rate per unit distance is very low, travel to the airport involves many feeder routes which may render the overall journey risks comparable with other modes. The distances range from 392 km to 1,849 km. |
| **Domestic long distance** (e.g. London to Edinburgh) | This category considers a mixture of both leisure and business journeys for longer-distance travel, mainly between large cities, in the UK. A mixture of routes is included to illustrate different combinations of major trunk routes (such as London to Edinburgh) with very good connections in all modes, as well as 'cross-country' routes (such as Aberdeen to Bournemouth). This group of journeys also consider using domestic air travel as a modal option. The distance range is from 403 km to 725 km. |
| **Inter-Urban**<br>(e.g. Reading to York) | This category considers a mixture of both leisure and business journeys between large and medium sized cities in the UK. The distance range is from 55 km to 394 km. |
| **Inter-Urban Commute** (e.g. Milton Keynes to London) | This category covers commuting routes between 20-130 km using car and various public transport modes, to reflect inter-urban commuting in the South East of England. |
| **Urban Commute**<br>(e.g. Kingston to City of London) | This category covers a regular urban commuting route (suburb to city centre) under 20 km and allows for cycling to be a main mode for the selected trip.<br>The example chosen is Kingston upon Thames in South West London to a central London location. With increased pressure on parking, traffic congestion and, in London, the Congestion Charge, rail travel is now running at close to capacity on these routes. As a result, four of the five routes are based on a rail commute and are differentiated by the feeder modes. The fifth example, and one that is increasingly used in this area, is the bicycle commute. |

**Source: Author's own**

*Table 5-2: Journey category definitions*

In each case, composite risk assessments have been calculated for a range of modal options for each journey. For each option the composite risk was calculated as a distance-weighted average of the risks for each modal segment. These calculations are derived from distance based average risk measures, but some risks are associated with each trip made rather than distance as such (e.g. take-off in the case of air travel and boarding and alighting on buses and rail). These risks not related to distance are examined to see if they need to be included in the composite risk calculations and how this could be achieved.

The risk assessments for each mode are drawn from national statistics on death and serious injuries from transport accidents. Sources from a range of transport modes are needed, so the analysis has standardised these to the greatest extent possible. This is particularly important given the range of assumptions which had to be controlled to ensure the analysis was meaningful. In particular, the definition of serious injuries recorded varies substantially according to the purpose and mode for which they are recorded.

## 5.4 CROSS MODAL SWITCHING: PRACTICAL APPLICABILITY

Having established the theoretical basis and analytical tools and undertaken the analysis of potential CMS safety improvements for a range of journey types, the later stages of the work explore the detail and practical scope for CMS.

The work includes an examination of the limited cross modal and multi modal safety literature to see if there is any empirical evidence already existing on modal substitution and safety. An initial approach based on CPE of demand measurement associated with modal choices was used, in order to try to establish the degree of substitutability.

Some of the key issues addressed are listed below:

(a) CMS presupposes that over a particular route there is a degree of substitutability among modes for the consumers. The review stage makes particular reference to the extensive values contained in Dargay's ITC (2010) study on CPEs of demand between modes. This is the most recent study on long distance travel providing CPEs based on a consistent research method for various modes.

(b) Original empirical data have been gathered using two questionnaires distributed online and extended associations covering some relevant travel routes where there is a fairly clear *prima facie* scope for modal choice. The results assess individuals' awareness of alternative modal possibilities and their willingness to consider modal switch.

(c) Where there is an indicated willingness to substitute, a case can be made for using modal switch as a policy tool. This possibility is addressed by a detailed examination of the elements relevant to modal choice by the marginal consumer: that is to say, a consumer who is just at the point of indifference between which modes to use for a journey. Drawing on Lancaster's theory of goods characteristics, the work enumerates the various characteristics of the transport good and seeks to evaluate them as a step towards defining an optimal modal switch policy. As in the previous point, some of the questionnaire elements also help to explore consumers' willingness to change modes.

Through the theory of characteristics of the transport good combined with some of the questionnaire responses it has also been possible to a make a comparison of consumers' implicit perceived risk assessments for transport modes (transport good characteristics) with what may be called the "objective" risk figure from historical data on risk and safety in the various modes. From this, practical conclusions regarding the extent to which CMS may actually be used as an effective tool of transport safety policy can be drawn.

One of the key issues determining modal choice is the price of the journey. Drawing on evidence for the CPE of demand between modes, it is possible to estimate the changes in fares that might be required to cause a substantial shift between modes.

This thesis has a taken a direct approach to the assessment of substitutability among modes and its relation to transport safety by developing questionnaires distributed to different sets of users and experts. The questionnaire asked people directly about their actual travel decisions for a certain journey, and also explored the degree to which they have considered alternatives and why (including asking them directly if safety was a consideration in their modal choice).

The questionnaires were intended to draw meaningful conclusions about substitutability in general among modes and to establish its relationship to safety.

Information gathered from these questionnaires included the following:

- Purpose and frequency of journey (context for analysis);
- Ultimate origins and destinations;
- Feeder modes used (enabling estimation of risk for end to end journey safety);
- Alternatives considered (indication of perceptions and flexibility as well as basis for substitutability);
- Monetary costs of journey (including feeder elements) and whether for single or return;
- Ranking of modal choice factors (gives relative importance) including safety if it

is ranked as a consideration by people; and

- The degree to which safety (and other aspects of the transport good) are dominated by the principal mode on a journey or the degree to which safety in the feeder modes is seriously considered.

Overall, the data from these questionnaires allow a much more robust assessment of passenger perceptions and a measure of substitutability.

## 5.5 DETAILS OF SOURCES

The data for this thesis have been derived from a mixture of primary and secondary data sources. The literature review has been carried out using secondary data already published. Composite risk assessment calculations for varying journey types have been compiled using a variety of secondary data sources. These include Transport Statistics Great Britain (for KSI risk rates), WebTAG Databook, Department of Transport for Value of Statistical Life (VSL) and Value of Serious Injury (VSI) and data provided directly by Transport for London for London Underground accident risk rates.

The two quantitative data surveys carried out used the **consumer***data* database for long distance travel (online electronic survey) and the databases of a network of extended contacts/associations (“snowball” electronic questionnaire distribution) for long distance travel survey over a number of European journeys.

The qualitative research was conducted using primary data sources. The expert questionnaire was carried out using the extensive University of Westminster data listing of air transport experts. A very small subset of these had direct or indirect experience with safety issues. The qualitative interviews were conducted directly with a sample from the expert’s questionnaire and a sample from the quantitative personal user questionnaires.

## 5.6 DESCRIPTION OF MODELS AND METHODS USED TO COLLECT DATA AND RATIONALE

### 5.6.1 Composite risk assessments

Composite risk assessments (total journey risks) were calculated to make an initial assessment of the practical scope of the cross-modal switch policy by examining a number of practical cases where *a priori* there may be good grounds for advocating modal switch as an approach to transport safety policy.

The assumptions and generic variables such as risk rates for the journey calculations were compiled in an excel spreadsheet and provided in control tabs. The risk rates for the killed and seriously injured were separated according to the mode of transport. Mostly, the risk figures for each mode are per billion (1000M) person km from DfT (2014c) and are average risk rates. The risks rates for London Underground were provided by Transport for London directly and the road type risk rates per person have been calculated using Vehicle Occupancy Rate from DfT (2013a), Risk rate from DfT (2014a, Table RAS30017), Road Traffic Statistics (2013d, Table TRA0204). It should be noted that averages over the 10 years for the risks for different road types have been provided by the DfT. Provision was made in the control sheets for a sensitivity analysis in which the risk rates can be readily adjusted to explore the effects of different rates.

In most of the literature to date, safety outputs have been defined for a specific mode taken in isolation and, in effect, derived for what are presumed to be seamless journeys. Yet, in practice, many journeys involve the combination of a number of modes; or they may involve stopping and taking connections at some point in the journey even when the whole journey is carried out in the same mode. Both of these can have a significant impact on the total risk exposure for the person making the journey. The analysis of total journey risk takes this into account.

The calculation of the composite risk follows directly from the considerations given above regarding the most appropriate way to measure safety output on any given mode, which is considered to be deaths/serious injuries per passenger kilometre. The distance travelled is calculated for each mode during a composite journey and used to weight the risk for each mode to provide an overall weighted average composite risk for the total journey. Thus, if a commuter travels 1 kilometre on foot and 29 kilometres by rail daily then if x is the pedestrian fatality risk per kilometre and y the rail risk of fatality per kilometre the composite risk will be calculated as:

$$(x + 29y)/30$$

Where the units are: $(km*(deaths / km) + km*(deaths / km))/km$

Which contracts in effect to: $((deaths + deaths)) / km$

and so to: deaths per km.

This example relates only to fatalities (K), but risks of SI (Seriously Injured) and other levels of risk severity were also considered applying the same principles.

### 5.6.2 Attitudinal and revealed preference quantitative/qualitative questionnaires

Two main questionnaires were developed to cover representative categories of travel, namely: holiday, business, visits to friends and relatives and ‘other’ category. An online questionnaire based on the **consumer***data*[41] traveller database was used to address primarily leisure travellers from UK to varying destinations, while a second snowball questionnaire was circulated to travellers in various European countries who travelled primarily for business.

The electronic **consumer***data* questionnaire was conducted first in March 2013 followed by the snowball questionnaire survey in May to July 2014. Improvements and modifications were made to the snowball questionnaire using feedback from the **consumer***data* responses, but the key questions were designed to remain compatible across both so that the results analysis could be applied across both samples in selected cases.

The **consumer***data* questionnaire was posted as an online survey and completed by 203 respondents. There was a good uptake of most questions and most respondents completed the whole questionnaire. As expected, there was a strong bias towards leisure travellers in the survey. This, and the fact that the survey was UK-based, meant that a large number of respondents used air travel as the primary mode of transport, augmented by various access modes at the origin and destination of the journey.

The questionnaire was designed to measure trip characteristics, safety perceptions and modal switching issues. Questions about accident safety were included among related issues such as personal security to help limit direct bias. Revealed preference questions were used to collate information on individuals’ actual choices while attitudinal preference questions presented a series of journey scenarios for respondents to select,

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[41] **consumer***data* is part of the privately owned Cadogan Information Group. Outside the UK and Europe they have a global reach extending to over 30 countries. They administer, collect and analyse self-completed customer surveys, comment cards and online questionnaires, and process a large number of surveys annually.

rank and rate. The questions presented varying complexities for the respondent ranging from simple alternative choice questions to more complex questions requiring order of preference.

Revealed and stated preference questions have advantages and disadvantages (Ahern and Tapley 2008). Revealed preferences show current situations better and choices made by respondents are recognised outcomes. In particular they permit one to examine real choices made by travellers and to describe how people really travel. Stated preference questions provided an understanding of how decision making varies when different characteristic profiles and levels are considered and when the suggested outcomes are probable outcomes. Stated preference studies allow us to examine how choices might change if there were changes in the available alternatives usually presented in hypothetical scenarios. Combining both types of questions allows for balanced responses. Cherchi and Ortuzar (2006) argue that a combination of revealed and stated preference studies allow the benefits of both to be maximised, while overcoming some of the limitations of each method.

A small pilot was carried out to identify any difficulties in answering some of the questions. The draft questionnaire was distributed to a sample of 10 regular transport users known to the author and also some researchers of **consumer***data* who regularly designed and conducted large questionnaire surveys. The main revisions were to the wording and phrasing of some questions including a number of safety questions. The responses to the final questionnaire provided online were coded, analysed qualitatively and quantitatively and the results given in Chapters 7 and 8.

The snowball questionnaire was developed to question individuals travelling for business/work. Modifications were made based on lessons from the **consumer***data* questionnaire, but questions remained compatible to allow for larger overall sample sizes with inputs from a wider range of user types. The second questionnaire asked respondents for demographic data, which was not possible in the **consumer***data* questionnaire. The number of questions asked was also slightly reduced.

This sample for the snowball questionnaire consisted of 111 respondents. The survey was distributed using a network of contacts located in various parts of Europe who were undertaking business related distance journeys in Europe in excess of 200km. A snowball/extended associations sampling method was used. This is a special non-probability method that uses extended associations through previous acquaintances. A group or an individual receives information from different places through a mutual intermediary.

Snowball sampling is so called because as more relationships are built through mutual association, more connections can be made through those new relationships and information can be collected, much like a snowball. Snowball sampling is a useful tool for increasing the number of participants and is therefore used when a restricted number of respondents or test subjects are available. So that more respondents can be acquired, snowball sampling depends on referrals and recommendations. Initial efforts to increase the sample size are augmented in later rounds by this process. Every study has issues of bias, and aggregating the amount of participants in this manner is no exception because of a tendency for acquaintances to have similar preferences in a way that may not be representative. Nevertheless, the results reveal a range of views, and attitudes revealed by the qualitative responses given at the end of the questionnaire provide some confirmation that the sample bias from the selection process is limited.

### 5.6.3 Transport expert Delphi style questionnaire and qualitative interviews

To widen the inputs further and take advantage of the knowledge of a panel of experts, a third questionnaire was developed for use with this expert panel. This contained more general questions which allowed the experts to expand on some of the wider safety related issues and to rank some of the key related variables.

Although not directly compatible with the other two questionnaires, this one was designed to complement the responses gained in the other two questionnaires (electronic online and snowball survey). For this qualitative questionnaire a Delphi style approach was deemed suitable. Experts were asked to complete the questionnaire and this was followed up by qualitative interviews with a sample of the expert group. Prior to the interviews being undertaken the experts were provided with the results of the questionnaire survey, which they could comment on and validate during the interviews.

The Delphi method uses structured surveys to make use of the experience and knowledge of the participants, who are mainly experts. It provides both qualitative and quantitative information which supplements the results of the two principal questionnaire surveys. Opinions from the experts are sought to add context to and aid interpretation of the earlier results, and to assist with the explanation of outcomes. Generally Delphi's are constructed to help identify and prioritise policy goals.

Cuhls (1998) states that Delphi is an "*…expert survey in two or more 'rounds' in which, in the second and later rounds of the survey the results of the previous round are given as feedback.*"

This is the approach that was adopted in this case where the expert interviews followed from the expert questionnaire. A characteristic of this was that, as the results of the expert questionnaire were circulated prior to the interviews, in the second round the experts answered to an extent under the influence of their colleagues' opinions. This is a specific characteristic of Delphi as compared to standard opinion surveys. Respondents learn from the views of others, without being overly influenced.

The Delphi method is a *"relatively strongly structured group communication process, in subjects, on which naturally unsure and incomplete knowledge is available, are judged upon by experts"*, according to Häder and Häder (1995, p12).

Delphi studies tackle issues formulated in statements about which uncertain and incomplete knowledge exists, as is the case here. Delphi involves making judgments in the face of uncertainty and the people involved are only asked to give estimates on quantitative questions.

To add explanation and further depth to the responses from the expert and user questionnaires, additional qualitative interviews were undertaken with a sample of five respondents from each questionnaire type. These responses were analysed and are reported in Chapter 7.

## 5.7 SAMPLING

The population about which inferences are being made by these samples is clearly very large since it is, in effect, the travelling public across Europe. Accordingly the sample size is unlikely to approach the size necessary for formally significant testing. Nevertheless, by capturing primarily leisure travel in the first case and a wider selection focused more on business travel in the second, the surveys covered a wide range of travel types. Although the focus was on longer distance journeys, the use of feeder modes was also included and this addressed these shorter legs (with the exception of regular commuting travel). The **consumer***data* questionnaire was conducted in March 2013, the snowball questionnaire May to July 2014, Delphi style expert questionnaire June 2014, the expert interviews October/December 2014 and the user interviews March/April 2015.

The responses for the two main questionnaires and qualitative interviews were as shown in Table 5-3.

| **Type of questionnaire/qualitative interview** | **Responses** |
|---|---|
| **consumer***data* Online Questionnaire Survey | 203 |
| Snowball extended associations questionnaire | 111 |
| Expert Delphi Style Questionnaire | 20 |
| Qualitative Expert/User Interviews | 10 |

*Table 5-3: Summary of Questionnaire response rates*

## 5.8 CONFIDENTIALITY ISSUES

Confidentiality and anonymity was assured to all participants of the surveys. This has been preserved in the information presented in the thesis.

## 5.9 LIMITATIONS OF METHODOLOGY

### 5.9.1 Fares data limitations

Originally, three approaches were considered to be suitable to establish the level of substitutability between the different modes by direct calculation of CPEs of demand in transport.

These were calculation through multiple regression analysis using fare and data on load factors, direct elasticities using data from the empirical user surveys and published data.

Initially, fares were collated for 16 months duration in order to calculate actual CPE for specific journeys over a given time frame. The original intention was to collect data on quantities demanded at the various prices using data on load factors, with a view eventually to calculating elasticities of demand from the data on quantity and price. However this multiple regression analysis was not possible because the necessary data were not available for commercial confidentiality reasons.

### 5.9.2 Questionnaire survey and net benefit calculation limitations

It should be noted that there were some known limitations of the questionnaire process. These points, which are noted below, should be taken into account when considering the results:

- There was a lack of random sampling as the questionnaires were conducted using online and electronic surveys. This could lead to bias in the samples recorded and this must be acknowledged during the analysis of the results.
- Online and electronic surveys rather than direct face to face interviews limited the degree of qualitative explanation available from the respondents, though in the 'Snowball' survey respondents were asked for open qualitative explanations of their choices which did provide some useful insights.
- The c**onsumer***data* survey was mainly based on leisure travellers by air from the UK to other countries; this meant that the main mode alternatives for many of these travellers were very limited. This could have affected the sample of respondents citing alternatives and hence introduced a bias in the sample obtained.
- It was not possible to obtain any socio-demographic data from the **consumer***data* survey sample. This restricted more detailed analysis such as age specific risks.
- Data for the net benefit calculations were obtained from different sources as rail passenger volume data on specific routes was not available from ATOC. The results from the calculations hence were quite sensitive to the precise methodological assumptions made in respect of the consumer surplus.

## 5.10 STATISTICAL TOOLS USED

The main statistical package used was IBM SPSS Statistics 20. Pearson's chi-square was used for significance testing.

# 6 CASUALTY RISK ASSESSMENTS

This chapter considers the potential value of the CMS policy by analysing practical cases where *a priori* there may be good grounds for advocating modal switch as an approach to transport safety policy. These cases are analysed within a framework of consumer choice theory and the theory of goods characteristics. The information sources and the approach to the journey risk calculations are considered first. This is followed by a specific section on the additional risks which can occur on transfers between modes, i.e. during boarding and alighting. Based on these considerations the analysis is applied to different modal combinations within a range of journey types to identify the risk contrasts between modal combinations in each case.

## 6.1 INFORMATION SOURCES AND DEFINITIONS

### 6.1.1 General Data

The scope for promoting transport safety overall by switching passengers between modes can be assessed using risk figures for deaths, serious injuries and overall injuries. There is now a rich level of resources in this respect both for the UK and for Europe as a whole. The Department for Transport (DfT) in the UK collects and publishes an extensive set of data on all aspects of utilisation of the various transport modes including safety information, while sources in Europe include the Union Internationale des Chemins de fer (UIC) for rail, and Eurostat, the EU statistical agency, which also has a section dedicated to transport.

UK data for the cross modal comparisons were obtained from the DfT (2014c), which lists passenger casualty rates per billion passenger kilometre by mode. This includes figures for killed, seriously injured and for overall injury in each mode. The ways these figures are compiled differs between transport modes and, in some cases, the definitions are not the same. It has therefore been important to take account of these differences in the experimental design and when interpreting the results of analysis.

Road accidents generally occur in an 'uncontrolled' environment for example, and often involve multiple parties. As a result, the police or other emergency services are the main source of the information. On the railways on the other hand, accidents occur in an institutional environment and so, in the UK, the statistics are collated and provided through the Rail Safety and Standards Board (RSSB)/Office of Rail Regulation (ORR).

Different definitions are applied as a result and these have been considered and provided in Appendix A.

### 6.1.2 International statistics

Although in general UK transport risk statistics are applied, risk rates are also required for international journeys in some of the examples analysed. The approach to these is as follows:

**Rail**

To provide risk rates comparable to the UK equivalents, the document "Railway Safety Performance in the European Union" (ERA, 2014) has been used. This involved converting the current 'per million train km' data to 'per 1000 passenger km' data firstly using a 1000 conversion factor to get to billions and then dividing by the train passenger load for France and Spain (161 and 105 persons per train respectively; information available from the same source). For the Eurostar the Killed (K) rate was set to 0 because no passenger fatalities have occurred on that line since its inception. For the journey into Italy, the train is a TGV for the whole route and so the French values were used.

The European rail Seriously Injured (SI) figures in the report were derived by using the ratio of the K value to the KSI total which is given for the EU as a whole. The EU average for KSI = 0.28 per million train km (= 2.61 per billion passenger km) and the EU average for K = 0.13 per billion passenger km. The split of the total is thus 4.98% killed to 95.02% seriously injured (Table 6-11). The K and SI outcomes for France and Spain are split using this ratio, thus giving an estimate of the SI figure in each case. The UK SI values were applied to the Eurostar (Table 6-8).

**Road**

French road fatality risks were applied to non-motorway routes in Europe since almost all non-UK travel was in France. Only a single fatality risk value was available for all roads in France, but it is too high to be representative on motorways (based on comparisons with the UK). It was therefore applied to the non-motorway roads by taking an average of the UK and French rates for non-motorway roads in cases where the journey was conducted in both countries. For seriously injured, the UK figures were used. This means that national risk figures are applied to the international journeys as far as possible given the data available (Bouaoun, 2015).

**Aviation**

Aviation statistics are already international and hence regular statistics could be applied to each flight route considered.

### 6.1.3 Modal safety differences

Differences in the accident statistics exist, as highlighted in previous sections, yet these are sufficiently small enough that meaningful comparison of attained safety levels between modes over time may still be carried out. Comparing modes it is clear that there are large differences in the level of safety. The overall average killed rate per billion passenger km for the period 2004-2013 for rail was 0.0136; for bus and coach it was 0.3; for private cars it was 1.9; for walking (including collisions) 29; for pedal cycles 27 and for motorbikes 89 (DfT, 2014c, Tables RAS53001 - TSGB0107). A transfer of passengers between modes can thus significantly impact the level of safety for passengers, e.g. a person using train has significantly less risk of casualty (being killed or seriously injured) than a person using car. Nevertheless, there is a lack of consistency in the definitions of severity of casualty. The value of such transfers will, of course, depend on the overall combination of modes that make up the total journey. For example, if the train station is a much longer walk away than a bus stop then the safety impact of the longer walk may outweigh the impacts of the main modal transfer. Given the substantial differences in safety levels among modes that are practically substitutable there is, in principle, a fertile field for investigation of the potential for improving transport safety by switching passengers among modes.

## 6.2 RISKS UNRELATED TO DISTANCE

This section examines issues associated with the distance based measures of risk used for the thesis. A particular area of investigation is the treatment of risks which are not distance related and may occur between modes, such as boarding and alighting for buses and trains, and take-off and landing risks in aviation.

The potential significance of risks arising from transfers between the modes, how risks within modes which are not proportional to distance travelled should be handled and to what extent these transfer risks are already implicit in the risk assessments need to be examined. Figure 6-1 illustrates these issues using examples from the aviation domain.

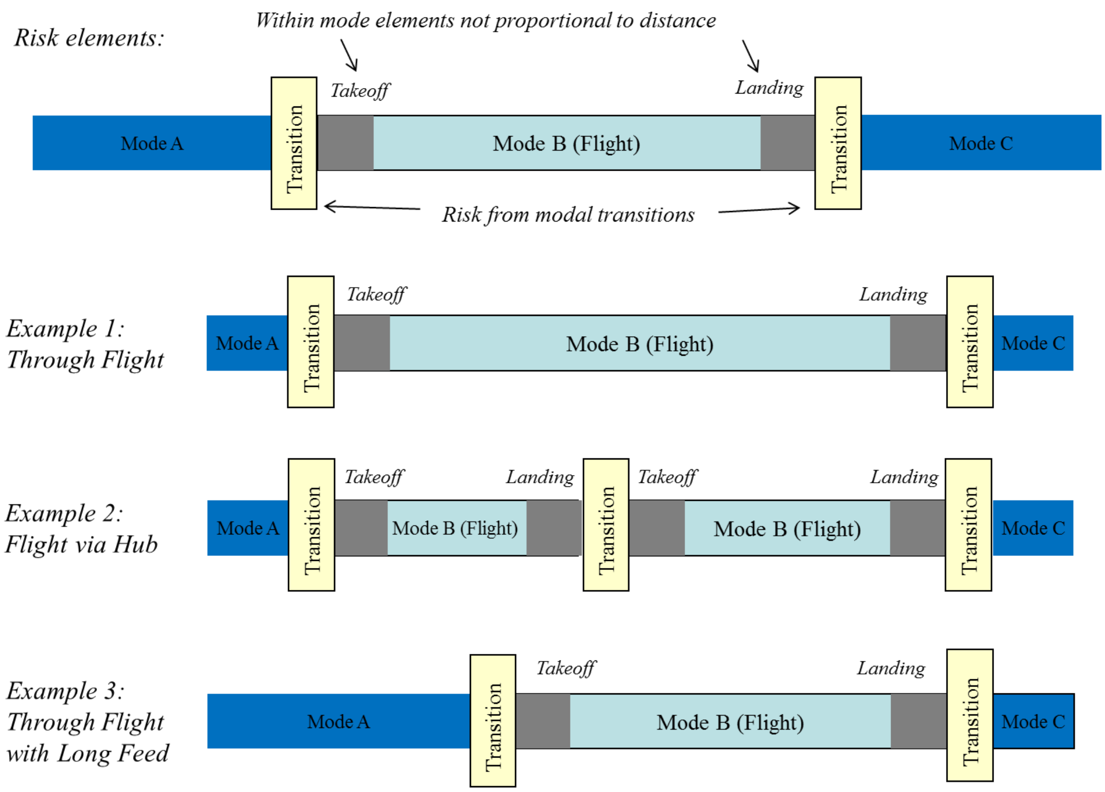
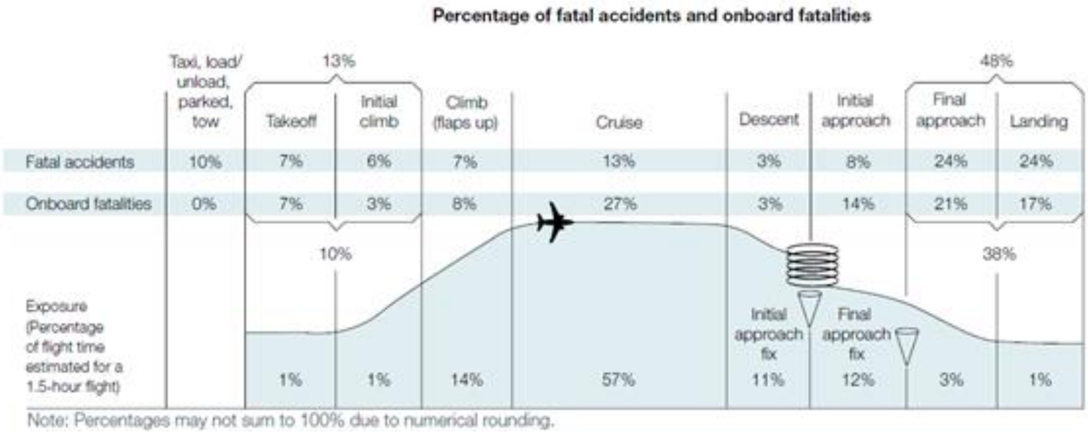


*Figure 6-1: Illustrations of transitions and risks for modal combinations*

These issues will be analysed for aviation, bus and rail travel in turn.

### 6.2.1 Aviation

It is well known that within a flight the greatest risk of accidents is associated with the initial climb/take-off and landing phases of flight as shown in Figure *6-2*.

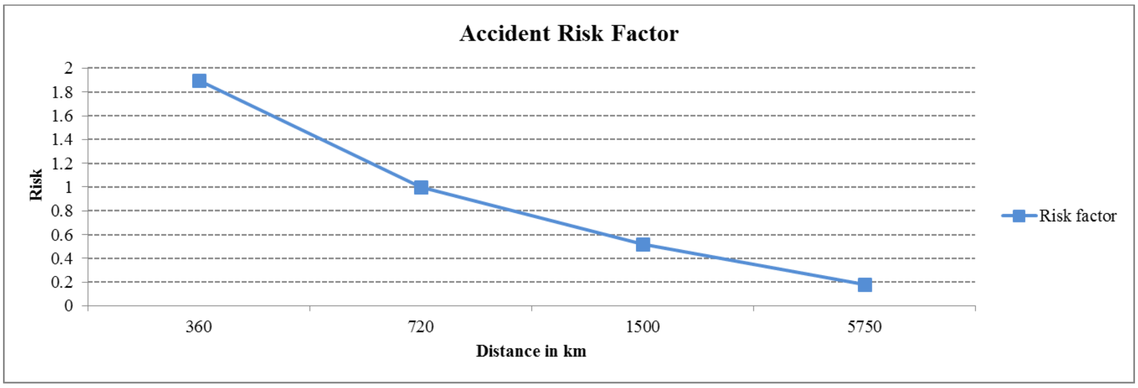


***Source: Boeing (2015)***

*Figure 6-2: Percentage of fatal accidents and on-board fatalities*

It follows that passenger risk will be higher on a journey between two points which involves an intermediate landing and taking a connecting flight than on a direct flight between the same two points. For the latter journey a composite risk calculation would be appropriate although to date passenger safety figures for aviation are not readily available in a format that breaks down passenger risk by phase of flight. Some caution needs to be applied in using the statistics, especially when interpreting results.

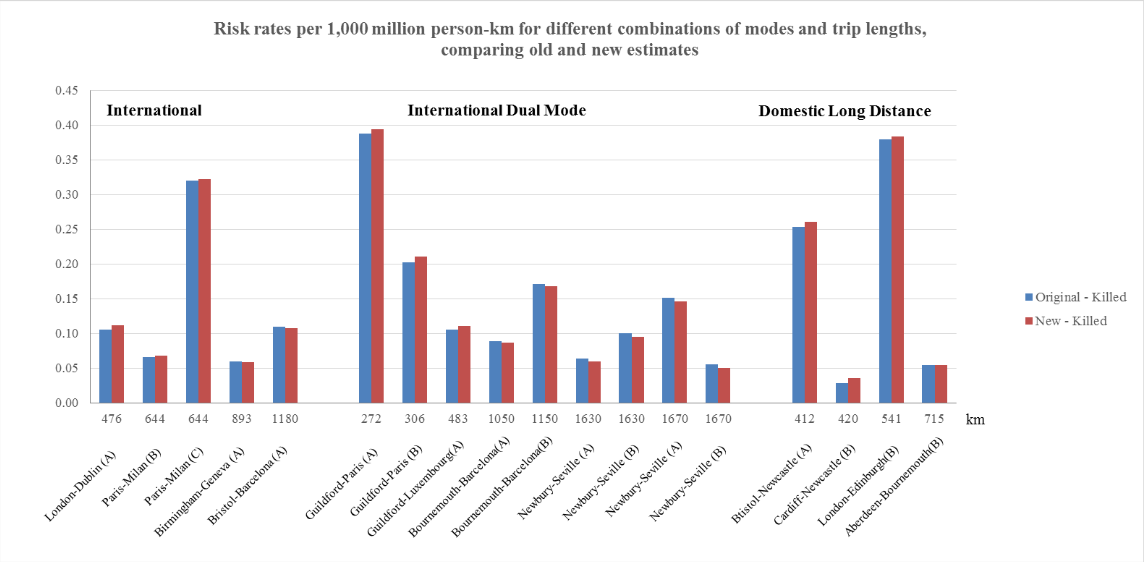
ETSC (2003c, Table 4, p24) provides relative fatality risks per flight, flight duration and distance which allows for non-cruise time and cruise time for certain flight durations and distances and a resulting accident risk index per flight, hour and distance. Figure 6-3 shows that shorter distances have higher risk rates per unit distance than longer distance journeys due to a larger proportion of the journey in the take-off and climb phases and final approach and landing phases as highlighted in Figure 6-2. The values in Figure 6-3 were calculated based on flight durations of 1 hour, 1.6 hours, 2.5 hours and 7 hours respectively, with 1.6 hours being the 'standard' European flight duration and thus having a risk weighting of 1. At averaged flying speeds these durations correspond to 320, 720, 1,500 and 5,750 km respectively as shown in Figure 6-3.



**Source ETSC (2003c)**

*Figure 6-3: Accident risk factor as a function of distance*

Using this approach, a risk factor which takes into consideration the higher risk phases of flight (i.e. take-off, climb, approach and landing) can be used to provide an adjusted air risk rate. For the air components of the journeys used in Section 6.5 adjusted air risk rates for fatalities were calculated for sensitivity to see if there were notable differences compared to the average risk rate for air used in DfT statistics.



**Source: Author's Own using figures from ETSC, 2003c**

*Figure 6-4: Comparison of adjusted air risk rates with original average air risk rates*

The differences in the air risks rates for the journeys considered with an air component are marginal even when applying a higher factor for journeys with shorter distances, as shown in Figure *6-4*. Given that the differences were not material for the purposes of this thesis, the air risk factor was not applied to the average air risk rates used in Section 6.5

### 6.2.2 Bus

Travel by bus is a relatively safe mode, but, as with aviation, there are specific risks for many users encountered when boarding and alighting from the bus. A recent study in Sweden, Berntman et al. (2010), found that:

> *"Using public transport nevertheless means choosing a safe transport mode. However, if the whole travel chain is considered, accidents to and from terminals or stops must be incorporated...., the comparison reveals a less positive safety perspective...... However, as Vaa [1993] stated, the door-to-door or travel chain perspective reveals quite alarming risk estimates. Comparing the risk of travelling door-to-door solely by bus to walking the same distance door-to-door points at a risk ratio of over 100:1"*

The key results from the Berntman et al. (2010) study suggest that out of 1,261 injuries, 38% were pedestrians moving to and from stops or terminals.

So the number of injuries is as high for the pedestrian phases before and after the bus journey as for the bus journey itself. The authors also highlight the fact that the age profile for bus users is high which tends to exacerbate the risk from boarding and alighting problems. There is also a strong seasonal influence as might be expected in Sweden.

Against this background, the UK statistics also provide information on the relative role of problems of boarding and alighting. A comparison of STATS19 and HES (Hospital Episode Statistics) statistics yields specific information on the percentage of bus related injuries due to boarding and alighting as shown in Table 6-1. The proportion of casualties injured when boarding or alighting is lower in STATS19 compared to HES data. Perhaps such accidents are less likely to be reported to the police than other types of accidents in which bus occupants are injured.

HES data provides a means of monitoring the number of road traffic accident casualties admitted overnight to hospital. This provides an alternative, but not equivalent, measure to the number of seriously injured casualties reported to the police and compiled by the Department for Transport under STATS19 (DfT, 2006).

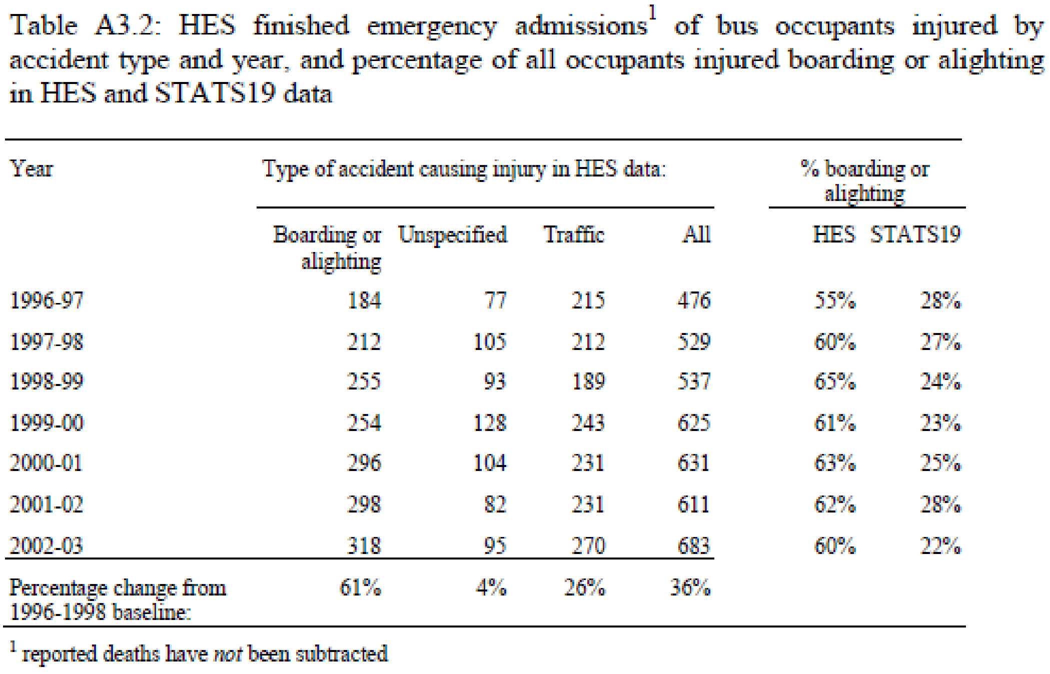


Table A3.2: HES finished emergency admissions[1] of bus occupants injured by accident type and year, and percentage of all occupants injured boarding or alighting in HES and STATS19 data

| Year | Type of accident causing injury in HES data: | | | | % boarding or alighting | |
|---|---|---|---|---|---|---|
| | Boarding or alighting | Unspecified | Traffic | All | HES | STATS19 |
| 1996-97 | 184 | 77 | 215 | 476 | 55% | 28% |
| 1997-98 | 212 | 105 | 212 | 529 | 60% | 27% |
| 1998-99 | 255 | 93 | 189 | 537 | 65% | 24% |
| 1999-00 | 254 | 128 | 243 | 625 | 61% | 23% |
| 2000-01 | 296 | 104 | 231 | 631 | 63% | 25% |
| 2001-02 | 298 | 82 | 231 | 611 | 62% | 28% |
| 2002-03 | 318 | 95 | 270 | 683 | 60% | 22% |
| Percentage change from 1996-1998 baseline: | 61% | 4% | 26% | 36% | | |

[1] reported deaths have *not* been subtracted

**Source: DfT (2006, p32)**

*Table 6-1: HES finished emergency admissions of bus occupants injured by accident type*

DfT (2013b, Table RAS30010) shows that the risk statistics used include boarding and alighting accidents for buses and coaches and hence are implicit in the risk rates used in this thesis. Yet, there is a problem in that the use of the per-km basis as the unit of measurement means that the risk figures do not differentiate between journeys with transfers and those without. This is also the case for journeys involving rail transfers. The implications of this are further discussed in Section 6.2.4 .

### 6.2.3 Rail

The issue of boarding and alighting injuries with trains is one which is closely related to the design of the trains and the platforms, and, to some extent, the ways these are operated. Clearly all stations have additional hazards, such as stairs, which are a problem when people are hurrying to catch trains departing at fixed times. Nevertheless, the main issues arise from the design of the trains, in particular the older manually operated train doors versus more modern, automatically controlled doors. Separation of platforms from trains is also an important issue here.

Many of these problems have been addressed in recent years, yet are of importance because UK risk figures can include a long historical record. Therefore the risk rates reflect some problems that have now been resolved. Boarding and alighting remains important, but some of the worst aspects have now been improved.

Some key aspects of boarding and alighting affecting UK trains are now discussed in turn.

**Train characteristics**

A particular historical example affecting UK rail journeys was the removal from service of the older 'slam door trains' with manually operated doors, particularly on London commuter routes with very high traffic volumes. While permitting shorter in station dwell times, these carriages required a level of user common sense and so posed a wide range of hazards to some passengers; for example, falling out when opening prior to arrival, hitting people on platforms when opening prematurely and attempting to board when the train is already moving. They also allowed for en-route hazards, such as passenger operated windows large enough for people to lean out of and hence fall.

Statistical records going back more than 10 years will include some statistics related to the operation of these types of trains and so may over-represent the risks posed by current rolling stock. For example, the HSE (2003) Annual Report on Railway Safety stated that:

> *"52% of train collisions involved the striking of open doors on slam-door trains... As more new sliding door trains are brought into service during 2003/04 in the South East, it is likely that the number of train collisions involving doors will continue to fall."*

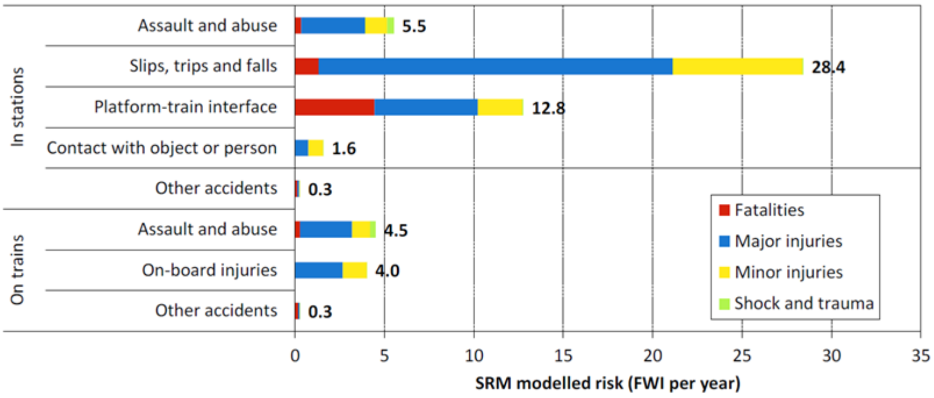
Similarly, a Health and Safety Commission document (1998) says that:

> *"There are also a number of fatalities, usually between two and four a year, and a larger number of injuries, resulting from falls from the slam doors of Mark 1 rolling stock, which do not have central locking. In addition, many people are injured every year as a result of being struck by open doors on Mark 1 trains" (p23).*

This report noted that the number of fatalities as a result of falling from slam door stock has dramatically reduced from the late 1990s to virtually zero today. This is probably attributable to the Mark 1 stock renewal programme in the last decade.

**Station characteristics**

Annual estimates of risks from station related incidents on the UK network are given from the Safety Risk Model[42]. These cover non movement incidents, i.e. those events not involving a moving train. Figure 6-5 highlights risk to passenger and public on trains and in stations by type of accident (derived from Safety Risk Model). Platform-train interface (PTI) includes injuries during boarding and alighting and also falls from the platform edge. This category contributes to a relatively high level of fatality risk but it should be noted that boarding and alighting seldom cause fatal injury.



Source: SRMv8.1

**Source: RSSB Annual Safety Performance Report 2014/15 (Chart 33)**

*Figure 6-5: Risk to passengers/public on train and in stations by accident type*

Similar to the bus/coach statistics, DfT (2014c, Table TSGB0806) on Railway movement accidents: passenger casualties and casualty rates: GB annual from 2001/02 to 2013/4 includes "*passenger casualties owing to train accidents and movement accidents*

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[42] The Safety Risk Model (SRM) is a quantitative representation of the potential accidents resulting from the operation and maintenance of the UK rail network. It comprises a total of 121 individual models, each representing a type of hazardous event. A hazardous event is defined as an event or an incident that has the potential to result in injuries or fatalities (RSSB, 2015).

*involving people on board trains or in the act of boarding or alighting from them…*" The overall rail risk rates suggest that the statistics allow for the risk of boarding and alighting to and from trains, although as noted in earlier in Section 6.2.2 there is an issue of the lack of differentiation between journeys with and without transfers. Additionally, in the case for rail, in station risks such as slips, trips and falls and some PTIs are not considered in the casualty statistics. The implications are examined in Section 6.2.4 .

### 6.2.4 Implications

This section presents a discussion of some of the main issues which affect the specific and non-distance related risk profiles for aviation, bus and rail travel. These are important considerations because, in some cases, they cover elements of risk which may not be included in the analysis in its current form. A review of the basis for the statistics in the three transport modes considered established that for bus and rail travel, boarding and alighting figures are already implicit in the overall totals[43]. As noted in the earlier sections there is an issue of how risk should be addressed when considering journeys with transfers. To date there are no established transfer risk rates that are readily available which could be applied to reflect this additional risk at the transfer stage/s. A possible solution may be to apply an additional constant risk factor to the different transfer stages. To illustrate this, a risk factor was applied to a journey from Cardiff to London using different modal variations. Table 6-2 shows the composite risk rates for a journey from Cardiff to London, not considering the transfer stages in Case A and C.

| Journey | Modes Used | Original Composite Risk (K) | Original Composite Risk (SI) |
|---|---|---|---|
| Cardiff - London Case A | W-LB-R-M-W | 0.29 | 3.77 |
| Cardiff - London Case B | C | 1.75 | 24.29 |
| Cardiff - London Case C | W-LB-CO-M-W | 0.54 | 10.72 |

*Table 6-2: Original journey composite risk rates for Cardiff to London not including transfer risks*

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[43] Railway movement accidents: passenger casualties and casualty rates: GB annual from 2001/02 to 2013/14; Rail Safety and Standards Board (RSSB), Updated: December 2014

Table *6-3* shows an illustrative example of applying a risk factor per transfer stage (0.1), which results in an aggregate risk factor of 0.4 for Case A and C since they have the same number of transfers (4). As transfer risk for K and SI is not proportional (i.e. no significant numbers will be killed as a result of transfers) an allocation of 5% for K and 95% for SI has been assumed and allocated. The incremental risk is shown in the table, which is the result of applying the risk factor for K and SI followed by the new composite risk rates, and calculating the resulting percentage change from the originals rates in Table *6-2*. From the illustration one can see that there are changes in composite risk rates that include the transfer stages versus the original rates, but these are not notable.

As expected, shorter journeys are penalised when compared to longer journeys: in Case A, the composite risk increases by 7% and 10% for K and SI respectively compared to 4% only for both K and SI in Case C. The higher allocation for SI rather than K also leads to a consistent result as it reflects a higher increase of SI than K. Case B shows no change to the original values as only one mode of transport was used and no transfer risk factor applied.

| **Journey** | **Modes Used** | **Amount of Transfers** | **Risk factor per transfer** | **Aggregate transfer risk** | **Incremental Risk** | | **New Composite Risk** | | **Percentage Change** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **K*** | **SI*** | **K** | **SI** | **K** | **SI** |
| Cardiff - London Case A | W-LB-R-M-W | 4 | 0.1 | 0.4 | 0.02 | 0.38 | **0.31** | **4.15** | 7% | 10% |
| Cardiff - London Case B | C | 0 | 0.1 | 0 | 0 | 0 | **1.75** | **24.29** | 0% | 0% |
| Cardiff - London Case C | W-LB-CO-M-W | 4 | 0.1 | 0.4 | 0.02 | 0.38 | **0.56** | **11.10** | 4% | 4% |

* Proportional allocation of total incremental Risk for K and SI.

| **Killed** | **Seriously injured** |
|---|---|
| **5%** | **95%** |

*Table 6-3: New journey composite risk rates for Cardiff to London including transfer risk factor*

For this study, as only average published risk factors have been applied, it follows that the journey analyses and net benefit assessments do not take account of all of transfer risk. Further research would be necessary to quantify the specific transfer related risk per mode of transport. Overall using the illustrative calculation it has been shown that allowing for the additional risk factor for transfers does not change the total composite risks substantially.

For aviation there is no indication that the figures include boarding and alighting effects. Boarding and alighting occurs in a much more controlled environment however, and so the likelihood of such injuries occurring is much smaller and can therefore be discounted as an additional source of K and SI impacts. The journey distance issue remains important to address for aviation assessments overall as noted in Section 6.2.1 , but in this case it has been demonstrated that applying a risk factor to allow for increased risk probabilities in the high risk phases of a flight yields only marginal differences, and hence requires no specific treatment for comparative purposes.

## 6.3 JOURNEY RISK CALCULATIONS

### 6.3.1 Total journey risk calculation

Total journey risk has already been defined in the literature review as the total risk incurred by a person throughout the whole journey from door to door.

The calculation of risk is based on a weighted average and will include such factors as for example the pedestrian risk in walking to a railway station or bus stop, or a car or coach-ride to an airport etc. The total journey risk is most appropriately calculated as a weighted average of the risks of the various modes involved in a journey where the weights are the distances travelled on each mode during the journey. The formula used is therefore a summation from 1 to n (the total number of modes within the journey) of the product of the distance travelled (*D*) and the risk (*R*) for each mode (*i*) divided by the total distance travelled. Generalising, this gives the following expression where the results are in deaths and/or injuries per 1,000M person km travelled:

$$\frac{\sum_{i=1}^{n}(Di.Ri)}{\sum_{i=1}^{n}Di}$$

This is, essentially, a weighted average of the distances for each mode multiplied by the risks for that mode. Dividing by the total distance converts the outcome into the risk rate overall for that journey.

For this analysis, total journey risk has been evaluated for different modal combinations used to travel equivalent journeys for six different journey types. The aim is thus to identify whether there are sufficient modal differences in each category to make CMS worthwhile. In some cases more than one journey is considered in each category. The journey types considered are categorised as shown in Table 6-4.

| Journey Category | Definition of categories |
|---|---|
| **International** (e.g. London to Paris) | The International category aims to capture a range of European inter-city journeys including both major centres, such as London and Paris, and smaller ones such as Bristol and Birmingham. Routes from the United Kingdom (large cities) to European destinations (cities) are covered. The distance ranges from 450km to 1,700km. |
| **International dual mode long distance** (i.e. including two long journey legs in different modes e.g. Newbury to Seville via London Stansted airport) | This group of journeys considers travel within Europe by air but which involve complex travel to the airport including a number of modes. This is a useful approach to aviation risks because, although the aviation risk rate per unit distance is very low, travel to the airport involves many feeder routes which may render the overall journey risks comparable with other modes. The distance ranges from 392km to 1,849km. |
| **Domestic long distance** (e.g. London to Edinburgh) | This category considers a mixture of both leisure and business journeys for longer distance travel mainly between large cities in the UK. A mixture of routes is included, in order to illustrate different combinations of major trunk routes (such as London to Edinburgh, with very good connections in all modes) and 'cross country' routes (such as Aberdeen to Bournemouth). This group of journeys also considers using domestic air travel as a modal option. The distance range is from 403km to 725km. |
| **Inter-Urban** (e.g. Reading to York) | This category considers a mixture of both leisure and business journeys between large and medium sized cities in the UK. The distance range is from 55km to 394km. |
| **Inter-Urban Commute** (e.g. Milton Keynes to London) | This category aims to cover commuting routes between 20km and130km using car and various public transport modes to reflect inter-urban commuting in the South East of England. |
| **Urban Commute** (e.g. Kingston to City of London) | This category aims to cover a regular urban commuting route (suburb to city centre) under 20km and allows for cycling to be a main mode for the selected trip. |

*Table 6-4: Journey category definitions*

To illustrate total journey risk calculations, an example of an Inter-Urban has been considered. This shows the differing impact on the total journey risk measure of the different modal combinations for the journey. For longer journeys the total risk calculation can be expected to be less affected by short walking/pedestrian elements or short bus rides.

The illustrative example is Reading to York. It assumes that this journey is from a suburban house in Reading (UK) to a central hotel in York (UK). Let us suppose that the house in Reading is 3km from Reading railway station. The distance by train from Reading to York is approximately 278 kilometres and there is a further 2 km to the hotel in York. The total journey is thus 283 kilometres. Two options for making this journey are examined:

**Option A**

Option A is based mainly on a train journey, starting with walking and bus travel and ending with a taxi ride as follows:

| | |
|---|---|
| Walk from house to bus-stop: | 1 km |
| Bus to Reading station: | 2 km |
| Train to York: | 278 km |
| Taxi to hotel in York: | 2 km |

For this option, the total journey risk is calculated as follows. The risk figures are taken from the DfT (2014c, Table TSGB0107) and are shown in this thesis in Table 6-7 and Table 6-8. To avoid the potentially distortive effect of major accidents on any one year's figures, a ten year average figure for 2004-2013 is taken from the table which provides these figures along with the annual figures. The selected 10 year horizon was used to avoid including long term trends that would make outcomes less relevant to the current situation. This means that the result is more relevant for CMS purposes while still taking account of transport technology changes. It is, however, accepted that if a longer horizon was used then the outcomes would be different.

The composite journey risk for Option A for "killed" is therefore:

> (1*29 + 2*0.3 + 278*0.01 + 2*1.9) / 283 = **0.13** per 1000M person km over this particular route.

The composite journey risk for Option A for "seriously injured" is therefore:

> (1*313 + 2*8.7 + 278*0.9 + 2*16.10) / 283 – (killed) = **2.03** per 1000M person km over this particular route.[44]

**Option B**

Option B is to undertake the whole journey door to door by car with 377km distance. In this case, the journey is split according to different risks on different road types (motorways, rural roads, other roads and urban roads). As well as differences in risks

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[44] Person km is used instead of passenger km to take account of car drivers, those walking and cyclists.

when switching between modes, there are also notable variations in risks when switching between certain road types for a specific journey. For example, motorway risk is significantly lower compared to using urban roads with a more diverse range of road users. Furthermore, although different road types partially capture the differences in risk for different journeys, there is still a simplification involved in the risk rates. Other factors such as the time of day (day or night times have not been considered), the type of user (young or aged persons) and even transitions between road types (roundabouts, traffic lights and other junctions) will also play a role. The distances on each different road type were estimated using Google Maps for this Reading-York car journey. The composite journey risk for Option B for "killed" is therefore:

> (337*0.97 + 15*6.65 + 15*2.19 + 10*8.33) / 377 = **1.44** per 1000M person-km over this particular route, where the weights reflect the distance travelled on each of the four road types.

The composite journey risk for Option B for "seriously injured" is therefore:

> (337*7.24 + 15*48.56 + 15*45.96 + 10*183.69) / 377 – (killed) = **13.67** per 1000M person-km over this particular route.

The sharp divergence between the risk figures between options A and B is to be expected. What is more interesting to note is how the total composite journey risk in option A comes out at 0.13 per 1,000M person km whereas an estimate which assessed the risk purely as train risk (since this accounts for the bulk of the journey distance) would yield a figure of just 0.01 deaths per 1,000M person km. This underlines the value of including total journey risk as a composite figure because even the addition of small transfers by other modes can change the overall risk profile substantially. The seriously injured figure is also lower by walking, local bus, train and taxi than by car. This is because, although car journey injuries via motorway are dominant and also much lower than injuries via other road types at 7.24, this is still higher than the equivalent for mainline rail which is 0.90. The killed and injured rates for mainline rail have fallen significantly since the major accidents of 1999, and the early 2000s have fallen outside the timeline for the calculation, which now starts with 2004.

### 6.3.2 Monetising total journey risk

To assess the safety value of a modal shift in a way that can be traded off against the costs needed to effect this safety improvement, it is necessary to monetise the change in total risk for a given route as a result of changing modes. The change in total journey risk between Option A and B for the Inter-Urban example above (Reading-York) is:

- **Killed:** The difference in composite risk (Option B – Option A, i.e. car – rail) is 1.44 - 0.13 = **1.31** (per 1000M person km). This means **1.3 fewer** deaths per 1000M person kilometres and is hence a safety gain.
- **Seriously Injured:** The difference in composite risk (Option B – Option A, i.e. car – rail) is 13.67 – 2.03 = **11.64** (per 1000M person km). This means nearly **12 fewer** injuries per 1000M person km.

The changes in composite risk for both killed and seriously injured can then be monetised using the appropriate values of statistical life and injury, which are € 2,338,398 and €262,770 respectively using DfT valuations (at 13 November 2014 exchange rate). Multiplying these values by the change in composite risk while remembering that a reduction in risk of death represents a positive benefit gives a positive benefit of €3,061,626 for killed per 1000M person km and €3,057,115 for seriously injured per 1000M person km for this route.

Taking the killed and seriously injured values together gives an overall benefit of € 6,118,742 per 1000M person km. The positive figure indicates that it ***is*** beneficial overall to have a modal shift from Option B (travelling the whole route by car) to Option A (walking, local bus, rail, taxi) in terms of the combined killed and seriously injured element. Since this gain is still expressed in terms of per 1000M person km, the extent of this positive outcome would also depend on the number of passengers switching (and hence the total distances travelled), and also on the costs required to achieve these transfers.

To determine the monetised benefit for the actual journey it is necessary to multiply by the journey distance (which was divided out for the weighted average) and divide by 1,000,000,000 to give the risk for the actual number of km travelled.

## 6.4 DATA AND ASSUMPTIONS USED FOR THE SPECIFIC JOURNEYS

A composite risk spreadsheet in excel was developed to implement the methodology set out in this chapter. The spreadsheet consists of two primary tabs (control and main) which perform the calculations (Table 6-7, Table 6-8 and Table 6-12) and three additional tabs which present the outputs in the required formats (these are incorporated in Section 6.5).

The aims of the journey calculations performed by the spreadsheet are as follows:

- To demonstrate the extent to which overall journey risks can vary according to the different modal combinations used;
- To assess six journey types which are designed to cover the main types of journey made;
- To break each journey into its component parts, assess actual risk for each part based on distance travelled and combine results to give an overall risk profile.

**Structure**

The spreadsheet is set out as follows:

- **Control** – The overall control tab defines the K and SI risks per mode and references these to the original sources. This allows for updating because all other sheets refer back to control for these values. Monetisation values for K (VSL) and SI (VSI) are also included and referenced to the source.
- **Main** – provides the overall risk calculation for each of journey type and within these considers the various modal options. The journey types are:
    - International – 5 routes with 2 or 3 modal combinations
    - International dual mode long distance (travel via hub to remote airport) – 4 routes each with 2 modal combinations
    - Domestic long distance – 4 routes with 2 or 3 modal combinations
    - Inter-Urban – 6 routes each with 2 or 3 modal combinations
    - Inter-Urban commute – 5 routes each with between 3 and 5 modal combinations
    - Urban commute – 1 route with 5 modal combinations

For each of the routes within each journey type, one of the modal combinations is specified as the base case. This is in recognition that this is the ‘standard’ or expected default mode for this journey as far as it is possible to define this.

A total composite risk of K and SI is calculated for each modal combination within each journey type. The change in risk for each of the modal combinations in relation to the base case is then calculated. Differences between all the modal combinations are assessed.

The differences for K and SI are then monetised using the values set out in the control tab to express the benefits or disadvantages of the modal shift for each in terms of €/1000M passenger km. The K and SI benefits are then added to provide the overall monetised risk in €/1000M passenger km, and finally this is converted to the overall monetised risk differences between modal combinations.

The headers in the main sheet of Table 6-12 are described in Table 6-5:

| Heading | Description |
|---|---|
| Journey type | Modal combination |
| Actual journey | Indicated using a code which sets out the sequence of modes used for that journey. The legend is provided in Table 6-9. |
| Modes | A series of columns, one for each mode, which contain the total number of km travelled in that mode for that modal combination. |
| Total distance | Sum of the distance in each mode, giving the total journey distance in km. |
| Total composite risks | Two columns, one for K and one for SI, which in each case are the sum of the distance for each mode multiplied by the risk for each mode in K or SI per 1000M person km. |
| Comparisons | For specified pairs of journeys, the difference in K and SI risk between the two modal combinations for the same journey. Units are risk of K or SI per 1000M person km. |
| Valuations for the benefit of the modal switch | This takes the values from the Comparisons, and multiplies each by the VSL for K and monetised value of SI respectively. The units are thus € per 1000M person km. |
| Combined total | This is the combined valuation of the K and SI differences between the modal combinations (the sum of the two valuations in the row above). |
| Combined difference | This is the Combined Total multiplied by the actual distance travelled and then divided by 1,000,000,000. This gives the actual difference between the modal combinations for the journey in €. This is the final monetised benefit in € of the given modal switch per traveller for the specified journey. |

*Table 6-5: Main sheet header descriptions*

The remaining tabs are designed to show the output from the ‘main’ tab in graphical format. Accordingly, they take values from the ‘main’ tab, organise them in a suitable format and present them as a graph. In some cases, unit conversions are applied so that the outputs are as required. These presentation tabs are shown in Table 6-6:

| Heading | Description |
|---|---|
| Results Risk K & SI | This tab presents the results of risk of K and SI. Individual charts are presented for each journey type. Within these, the K and SI risk values are given for each of the modal combinations for each of the routes. |
| Results - € combined | This tab provides the monetised risk differences between routes in €M per 1000M person km and for the actual journey distance for the route under consideration. |
| Results - € K & SI | This tab displays charts of the monetised value of the modal switch for K and SI for each modal combination referenced against the base case. |

| Heading | Description |
|---|---|
| Ranking | This provides a ranking of the modal combinations in terms of the safety related benefit of the switch per traveller. |

*Table 6-6: Presentation tab descriptions*

It should be noted that only the headers ‘journey type’, ‘actual journey’, ‘modes’, ‘total distance’ and ‘total composite risks for K and SI’ are shown in Table 6-12. The results from all other headers above are shown in Section 6.5 .

## Risk (Killed)

| Short code | Mode | Standard risk: per 1000m person km (2004-2013) | Vehicle occupancy rate | Sensitivity Multiplier | Standard risk: per 1000m person km (2004-2013) | Source |
|---|---|---|---|---|---|---|
| **W** | **Walking** | 29.00 | | 1 | **29.00** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| **B** | **Bicycle** | 27.00 | | 1 | **27.00** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| **TX** | **Taxi** | 1.90 | | 1 | **1.90** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| **LB** | **Local Bus** | 0.30 | | 1 | **0.30** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| **CO** | **Coach** | 0.30 | | 1 | **0.30** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| **T** | **Tram** | 0.41 | | 1 | **0.41** | Transport for London – Data forwarded by Colin Shepard on number of killed and injured and person km (1000M) 2003-2014 Travel in London Report Figure 3.12 and Figure 5.2 |
| **M** | **Metro** | 0.41 | | 1 | **0.41** | Transport for London – Data forwarded by Colin Shepard on number of killed and injured and person km(1000M) 2 003-2014 Travel in London Report Figure 3.12 and Figure 5.2 |
| **R** | **Mainline Rail (UK)** | 0.01 | | 1 | **0.01** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| | **Mainline Rail (F)** | 0.03 | | 1 | **0.03** | RAILWAY SAFETY PERFORMANCE IN THE EUROPEAN UNION (2014 - ERA) |
| | **Mainline Rail (ES)** | 0.09 | | 1 | **0.09** | RAILWAY SAFETY PERFORMANCE IN THE EUROPEAN UNION (2014 - ERA) |
| | **Mainline Rail (Eurostar)** | 0.00 | | 1 | **0.00** | Used same figure as for UK - DfT (2014c, Tables RAS53001 - TSGB0107) |
| **A** | **Air** | 0.01 | | 1 | **0.01** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| **S** | **Sea** | 0.40 | | 1 | **0.40** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| **Cars by Road Type** | | | | | | |
| **MR** | **Motorways (Car)** | 0.97 | 1.57 | 1 | **0.97** | Vehicle Occupancy Rate from DfT (2013a), Risk rate from Road Casualties (DfT, 2014a, Table RAS30017), DfT (2013d) Road Traffic Statistics (Table TRA0204) |
| **RR** | **Rural Roads (Car)** | 6.65 | 1.57 | 1 | **6.65** | Vehicle Occupancy Rate from DfT (2013a), Risk rate from Road Casualties (DfT, 2014a, Table RAS30017), DfT (2013d) Road Traffic Statistics (Table TRA0204) |
| **OR** | **All Minor Roads (Car)** | 2.19 | 1.57 | 1 | **2.19** | Vehicle Occupancy Rate from DfT (2013a), Risk rate from Road Casualties (DfT, 2014a, Table RAS30017), DfT (2013d) Road Traffic Statistics (Table TRA0204) |
| **UR** | **Urban Roads (Car)** | 8.33 | 1.57 | 1 | **8.33** | Vehicle Occupancy Rate from DfT (2013a), Risk rate from Road Casualties (DfT, 2014a, Table RAS30017), DfT (2013d) Road Traffic Statistics (Table TRA0204) |
| **FR** | **All Roads (France)** | 3.60 | 1.57 | 1 | **3.60** | 2007-2008 figures |

*Table 6-7: Risk rates by mode (Killed)*

## Risk (Seriously Injured)

| Short code | Mode | Standard risk: per 1000m person km (2004-2013) | Vehicle occupancy rate | Sensitivity Multiplier | Standard risk: per 1000m person km (2004-2013) | Source |
|---|---|---|---|---|---|---|
| W | Walking | 313.00 | | 1 | **313.00** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| B | Bicycle | 568.00 | | 1 | **568.00** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| TX | Taxi | 16.10 | | 1 | **16.10** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| LB | Local Bus | 8.70 | | 1 | **8.70** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| CO | Coach | 8.70 | | 1 | **8.70** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| T | Tram | 15.68 | | 1 | **15.68** | Transport for London – Data forwarded by Colin Shepard on number of killed and injured and person km(1000M) 2003-2014 Travel in London Report Figure 3.12 and Figure 5.2 |
| M | Metro | 15.68 | | 1 | **15.68** | Transport for London – Data forwarded by Colin Shepard on number of killed and injured and person km (1000M) 2003-2014 Travel in London Report Figure 3.12 and Figure 5.2 |
| R | Mainline Rail (UK) | 0.90 | | 1 | **0.90** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| | Mainline Rail (F) | 0.57 | | 1 | **0.57** | RAILWAY SAFETY PERFORMANCE IN THE EUROPEAN UNION (2014 - ERA) |
| | Mainline Rail (ES) | 1.73 | | 1 | **1.73** | RAILWAY SAFETY PERFORMANCE IN THE EUROPEAN UNION (2014 - ERA) |
| | Mainline Rail (Eurostar) | 0.90 | | **1** | **0.90** | Used same figure as for UK - DfT (2014c, Tables RAS53001 - TSGB0107) |
| A | Air | 0.00 | | 1 | **0.00** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| S | Sea ("Water") | 53.60 | | 1 | **53.60** | DfT (2014c, Tables RAS53001 - TSGB0107) |
| **Cars by Road Type** | | | | | | |
| MR | Motorways | 7.24 | 1.57 | 1 | **7.24** | Vehicle Occupancy Rate from DfT (2013a), Risk rate from Road Casualties (DfT, 2014a, Table RAS30017), DfT (2013d) Road Traffic Statistics (Table TRA0204) |
| RR | Rural | 48.56 | 1.57 | 1 | **48.56** | Vehicle Occupancy Rate from DfT (2013a), Risk rate from Road Casualties (DfT, 2014a, Table RAS30017), DfT (2013d) Road Traffic Statistics (Table TRA0204) |
| OR | All Minor Roads | 45.96 | 1.57 | 1 | **45.96** | Vehicle Occupancy Rate from DfT (2013a), Risk rate from Road Casualties (DfT, 2014a, Table RAS30017), DfT (2013d) Road Traffic Statistics (Table TRA0204) |
| UR | Urban Roads | 183.69 | 1.57 | 1 | **183.69** | Vehicle Occupancy Rate from DfT (2013a), Risk rate from Road Casualties (DfT, 2014a, Table RAS30017), DfT (2013d) Road Traffic Statistics (Table TRA0204) |

*Table 6-8: Risk rates by mode (Seriously Injured)*

| Legend | |
|---|---|
| W = Walking | T = Tram |
| B= Bicycle | CO = Coach |
| LB= Local Bus | A =Air |
| R = Mainline Rail | TX= Taxi |
| C = Car | M=Metro |

*Table 6-9: Legend for Tables 6.6, 6.7 and 6.12*

| Monetisation | Euro | Source |
|---|---|---|
| **VSL for Killed** | 2,338,398 | Web TAG Databook November 2014 (Table A 4.1.1 ) Average Value of prevention per casualty |
| **VSI for Serious Injury** | 262,770 | Web TAG Databook November 2014 (Table A 4.1.1 ) Average Value of prevention per casualty |

*Table 6-10: Values for VSL and VSI*

| Working for European rail safety assessments | France | Spain | |
|---|---|---|---|
| Train km (B km) | 0.512 | 0.189 | |
| Passenger km (B km) | 85.2 | 20.8 | |
| **Passengers per train** | **166.4** | **110.1** | |
| European KSI figures (Figure 2) | | | |
| **K and SI (per M train km)** | **0.1** | **0.2** | |
| **Per B passenger km** | **0.60** | **1.82** | **Ratio** |
| **K only per B passenger km** | **0.03** | **0.09** | **0.0498** |
| **SI only per B passenger km** | **0.57** | **1.73** | **0.9502** |

**Ratio based on fatality risk (0.13 per billion passenger km) / overall railway SI (2.61 per billion passenger km) and K (0.0498 per billion passenger km)**

*Table 6-11: Risk of rail Killed and Seriously Injured derived for France and Spain*

|  |  |  | km | km | km | km | km | km | km | km | km | km | km | km | km | km | KILLED | Seriously Injured |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Bicycle | Local Bus | Tram | Coach | Motorways | Rural Roads | Other Roads | Urban Roads | Taxi | Metro | Rail | Sea | Air | Total distance |  |  | km |
| 1) (Risk of death per 1000M km for this combination of modes)<br>2) (Risk of serious injury per 1000M km for this combination of modes) NB KSI used, so prev. column subtracted to give only injuries)<br>**International** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| London-Paris Case A | W-M-R-M | 1 |  |  |  |  |  |  |  |  |  | 5 | 495 |  |  | 501 | 0.06 | 1.61 | B-A |
| London-Paris Case B | C-S-C |  |  |  |  |  | 352 |  | 18 | 50 |  |  |  | 33 |  | 453 | 1.56 | 30.08 |  |
| Paris- Milan Case A | W-M-R-TX | 1 |  |  |  |  |  |  |  |  | 4 | 1 | 641 |  |  | 647 | 0.09 | 1.09 | A-B |
| Paris-Milan Case B | W-M-A-LB | 1 |  | 6 |  |  |  |  |  |  |  | 16 |  |  | 644 | 667 | 0.07 | 0.86 | C-B |
| Paris-Milan Case C | C-A-C |  |  |  |  |  |  |  |  | 35.4 |  |  |  |  | 644 | 679 | 0.32 | 9.25 | A-C |
| Bristol-Barcelona Case A | C-A-TX |  |  |  |  |  |  | 8 |  | 4.4 | 16.5 |  |  |  | 1180 | 1209 | 0.11 | 1.10 | B-A |
| Bristol-Barcelona Case B | LB-R-TX |  |  | 6 |  |  |  |  |  |  | 10 |  | 1683 |  |  | 1699 | 0.04 | 0.65 |  |
| London – Dublin Case A | TX-A-TX |  |  |  |  |  |  |  |  |  | 25.3 |  |  |  | 476 | 501 | 0.11 | 0.71 | B-A |
| London – Dublin Case B | C-S-C |  |  |  |  |  | 458 |  |  | 20 |  |  |  | 107 |  | 585 | 1.12 | 20.64 | B-C |
| London – Dublin Case C | LB-R-S-TX |  |  | 3 |  |  |  |  |  |  | 4 |  | 364 | 107 |  | 478 | 0.12 | 12.76 | C-A |
| Birmingham-Geneva Case A | C-A-TX |  |  |  |  |  | 8 |  | 2 | 4 |  |  |  |  | 893 | 907 | 0.06 | 0.92 | B-A |
| Birmingham-Geneva Case B | W-R-M-R-TX | 1 |  |  |  |  |  |  |  |  | 7.6 | 1 | 1017 |  |  | 1027 | 0.07 | 0.93 |  |
| **International Dual Mode Long Distance** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Newbury – Seville via Stansted Case A | C-A-TX |  |  |  |  |  | 156 | 3.5 |  | 8 | 11 |  |  |  | 1670 | 1849 | 0.15 | 1.45 | A-B |
| Newbury – Seville via Stansted Case B | W-R-M-R-A-TX | 2 |  |  |  |  |  |  |  |  | 11 | 7 | 128 |  | 1670 | 1818 | 0.06 | 0.51 |  |
| Newbury – Seville via Heathrow Case A | W-R-CO-A-TX | 2 |  |  |  | 45 |  |  |  |  | 11 |  | 25 |  | 1630 | 1713 | 0.06 | 0.65 | B-A |
| Newbury – Seville via Heathrow Case B | C-A-TX |  |  |  |  |  | 68 |  |  | 8.2 | 11 |  |  |  | 1630 | 1717 | 0.10 | 1.17 |  |
| Bournemouth via Southampton– Barcelona via Girona Case A | C-A-CO |  |  |  |  | 91 | 52.6 |  |  | 2 |  |  |  |  | 1050 | 1196 | 0.09 | 1.20 | B-A |

|  |  |  | km | km | km | km | km | km | km | km | km | km | km | km | km | km | KILLED | Seriously Injured |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Bicycle | Local Bus | Tram | Coach | Motorways | Rural Roads | Other Roads | Urban Roads | Taxi | Metro | Rail | Sea | Air | Total distance |  |  | km |
| Bournemouth via Heathrow – Barcelona Case B | C-A-C |  |  |  |  |  | 152 |  | 10.4 | 6 |  |  |  |  | 1150 | 1318 | 0.17 | 1.87 |  |
| Guildford -Luxembourg Case A | W-R-M-A-TX | 1 |  |  |  |  |  |  |  |  | 10.3 | 9 | 44 |  | 483 | 547 | 0.11 | 1.10 | B-A |
| Guildford -Luxembourg Case B | W-R-M-R-M-R-TX | 1 |  |  |  |  |  |  |  |  | 10.3 | 4.3 | 907 |  |  | 923 | 0.07 | 1.09 |  |
| Guildford – Paris via Stansted & Paris Beauvais Case A | C-A-CO-M |  |  |  |  | 92 | 128.5 |  |  | 4.5 |  | 2 |  |  | 272 | 499 | 0.39 | 4.80 | A-B |
| Guildford – Paris via Gatwick Case B | C-A-R |  |  |  |  |  | 51 |  |  | 3 |  | 2 | 30 |  | 306 | 392 | 0.20 | 2.27 |  |
| **Domestic Long Distance** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| London – Edinburgh Case A | W-T-M-R | 1 |  |  |  |  |  |  |  |  | 2 | 4 | 532 |  |  | 539 | 0.08 | 1.57 | A-B |
| London – Edinburgh Case B | C-A-TX |  |  |  |  |  | 20 |  |  | 20 | 19 |  |  |  | 541 | 600 | 0.38 | 6.50 |  |
| Bristol – Newcastle Case A | C-A-TX |  |  |  |  |  |  | 5 |  | 7 | 7 |  |  |  | 412 | 431 | 0.25 | 3.56 | B-A |
| Bristol – Newcastle Case B | W-R-LB | 3 |  | 3 |  |  |  |  |  |  |  |  | 397 |  |  | 403 | 0.23 | 3.05 | C-B |
| Bristol – Newcastle Case C | C |  |  |  |  |  | 472 |  |  | 12 |  |  |  |  |  | 484 | 1.15 | 10.47 | C-A |
| Aberdeen -Bournemouth Case A | B-R-TX |  | 5 |  |  |  |  |  |  |  | 3 |  | 714 |  |  | 722 | 0.21 | 4.68 | A-B |
| Aberdeen -Bournemouth Case B | C-A-TX |  |  |  |  |  |  |  |  | 2 | 8 |  |  |  | 715 | 725 | 0.05 | 0.63 |  |
| Cardiff - Newcastle Case A | W-LB-R-M-W | 2 |  | 2 |  |  |  |  |  |  |  | 1 | 402 |  |  | 407 | 0.16 | 2.35 | A-B |
| Cardiff – Newcastle Case B | TX-A-TX |  |  |  |  |  |  |  |  |  | 4 |  |  |  | 420 | 424 | 0.03 | 0.13 | C-B |
| Cardiff - Newcastle Case C | C |  |  |  |  |  | 490 |  | 3 | 22 |  |  |  |  |  | 515 | 1.29 | 13.71 | C-A |
| **Inter Urban** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Reading – York Case A | W-LB-R-TX | 1 |  | 2 |  |  |  |  |  |  | 2 |  | 278 |  |  | 283 | 0.13 | 2.03 | B-A |
| Reading – York Case B | C |  |  |  |  |  | 337 | 15 | 15 | 10 |  |  |  |  |  | 377 | 1.44 | 13.67 |  |
| Reading – Swindon Case A | W-LB-R-TX | 1 |  | 2 |  |  |  |  |  |  | 4 |  | 58 |  |  | 65 | 0.58 | 6.29 | A-B |

|  |  |  | km | km | km | km | km | km | km | km | km | km | km | km | km | km | KILLED | Seriously Injured |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Bicycle | Local Bus | Tram | Coach | Motorways | Rural Roads | Other Roads | Urban Roads | Taxi | Metro | Rail | Sea | Air | Total distance |  |  | km |
| Reading – Swindon Case B | W-LB-CO-TX | 1 |  | 2 |  | 65 |  |  |  |  | 4 |  |  |  |  | 72 | 0.79 | 12.55 | C-B |
| Reading – Swindon Case C | C |  |  |  |  |  | 65 |  | 5 | 5 |  |  |  |  |  | 75 | 1.54 | 20.05 | C-A |
| Cardiff - London Case A | W-LB-R-M-W | 2 |  | 1.5 |  |  |  |  |  |  |  | 3 | 209 |  |  | 216 | 0.29 | 3.77 | B-A |
| Cardiff - London Case B | C |  |  |  |  |  | 214 |  | 4 | 25 |  |  |  |  |  | 243 | 1.75 | 24.29 | B-C |
| Cardiff - London Case C | W-LB-CO-M-W | 2 |  | 2 |  | 237 |  |  |  |  |  | 2 |  |  |  | 243 | 0.54 | 10.72 | A-C |
| Manchester - Liverpool Case A | W-T-R-W | 2 |  |  | 3 |  |  |  |  |  |  |  | 50 |  |  | 55 | 1.09 | 11.97 | A-B |
| Manchester - Liverpool Case B | C-R-TX |  |  |  |  |  |  |  |  | 4 | 1 |  | 50 |  |  | 55 | 0.65 | 13.82 | C-B |
| Manchester - Liverpool Case C | C |  |  |  |  |  | 46.7 |  |  | 9.3 |  |  |  |  |  | 56 | 2.19 | 34.35 | A-C |
| Liverpool – Ipswich Case A | W-R-TX | 3 |  |  |  |  |  |  |  |  | 3 |  | 316 |  |  | 322 | 0.30 | 3.65 | B-A |
| Liverpool – Ipswich Case B | C |  |  |  |  |  | 373 |  | 7 | 14 |  |  |  |  |  | 394 | 1.25 | 12.95 |  |
| Cardiff-Leeds Case A | C |  |  |  |  |  | 307 |  | 20 | 38 |  |  |  |  |  | 365 | 1.80 | 25.93 | A-B |
| Cardiff – Leeds Case B | W-R-W | 6 |  |  |  |  |  |  |  |  |  |  | 281 |  |  | 287 | 0.62 | 6.81 |  |
| **Inter-Urban Commute** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Kingston – Guildford Case A | B-R-B |  | 6.8 |  |  |  |  |  |  |  |  |  | 26 |  |  | 33 | 5.61 | 112.86 | E-A |
| Kingston – Guildford Case B | W-R-W | 5.5 |  |  |  |  |  |  |  |  |  |  | 26 |  |  | 32 | 5.07 | 50.32 | E-B |
| Kingston – Guildford Case C | W-R-LB | 2.4 |  | 3.8 |  |  |  |  |  |  |  |  | 26 |  |  | 32 | 2.21 | 22.87 | E-C |
| Kingston – Guildford Case D | C |  |  |  |  |  |  |  |  | 36.2 |  |  |  |  |  | 36 | 8.33 | 175.36 | E-D |
| Kingston – Guildford Case E | B |  | 37.3 |  |  |  |  |  |  |  |  |  |  |  |  | 37 | 27.00 | 541.00 |  |
| Milton Keynes-London Case A | B-R-B |  | 6 |  |  |  |  |  |  |  |  |  | 72 |  |  | 78 | 2.09 | 42.43 | A-B |
| Milton Keynes-London Case B | LB-CO-LB |  |  | 15 |  | 84 |  |  |  |  |  |  |  |  |  | 99 | 0.30 | 8.40 | C-B |

|  |  |  | km | km | km | km | km | km | km | km | km | km | km | km | km | km | KILLED | Seriously Injured |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Bicycle | Local Bus | Tram | Coach | Motorways | Rural Roads | Other Roads | Urban Roads | Taxi | Metro | Rail | Sea | Air | Total distance |  |  | km |
| Milton Keynes-London Case C | C |  |  |  |  |  | 74 |  |  | 12.7 |  |  |  |  |  | 87 | 2.05 | 31.04 | A-C |
| Brockenhurst – Guildford Case A | W-LB-R-LB | 1 |  | 5 |  |  |  |  |  |  |  |  | 84 |  |  | 90 | 0.35 | 4.45 | B-A |
| Brockenhurst – Guildford Case B | C-R-TX |  |  |  |  |  |  |  |  | 16 | 4 |  | 84 |  |  | 104 | 1.37 | 28.24 | B-C |
| Brockenhurst – Guildford Case C | C |  |  |  |  |  | 83 | 13 |  | 5 |  |  |  |  |  | 101 | 2.07 | 19.23 | C-A |
| New Malden -Swindon Case A | C-R-M-R-W | 2 |  |  |  |  |  |  |  | 5 | 4 |  | 127 |  |  | 138 | 0.79 | 11.70 | B-A |
| New Malden -Swindon Case B | W-R-M-R-LB | 1.6 |  | 1 |  |  |  |  |  |  |  |  | 127 |  |  | 130 | 0.37 | 4.44 | B-C |
| New Malden -Swindon Case C | C |  |  |  |  |  | 112 | 12 |  | 8 |  |  |  |  |  | 132 | 1.93 | 19.76 | C-A |
| Basingstoke-Guildford Case A | C-R-LB |  |  | 3 |  |  |  |  |  | 8 |  |  | 36 |  |  | 47 | 1.45 | 31.06 | B-A |
| Basingstoke-Guildford Case B | B-R-W | 3 | 8 |  |  |  |  |  |  |  |  |  | 36 |  |  | 47 | 6.46 | 110.89 | B-C |
| Basingstoke-Guildford Case C | C |  |  |  |  |  | 38 |  |  | 12 |  |  |  |  |  | 50 | 2.74 | 46.85 | C-A |
| **Urban Commute** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Kingston – Central London Case A | W-R-W | 4.8 |  |  |  |  |  |  |  |  |  |  | 16 |  |  | 21 | 6.70 | 66.22 | E-A |
| Kingston – Central London Case B | W-R-M | 1.6 |  |  |  |  |  |  |  |  |  | 3.2 | 16 |  |  | 21 | 2.30 | 24.88 | E-B |
| Kingston – Central London Case C | W-R-LB | 1.6 |  | 3.2 |  |  |  |  |  |  |  |  | 16 |  |  | 21 | 2.29 | 23.82 | E-C |
| Kingston – Central London Case D | C-R-M |  |  |  |  |  |  |  |  | 1.6 |  | 3.2 | 16 |  |  | 21 | 0.71 | 16.52 | E-D |
| Kingston – Central London Case E | B |  | 18.6 |  |  |  |  |  |  |  |  |  |  |  |  | 19 | 27.00 | 541.00 |  |

*Table 6-12: Journey composite risk*

## 6.5 ANALYSIS OF SPECIFIC JOURNEYS

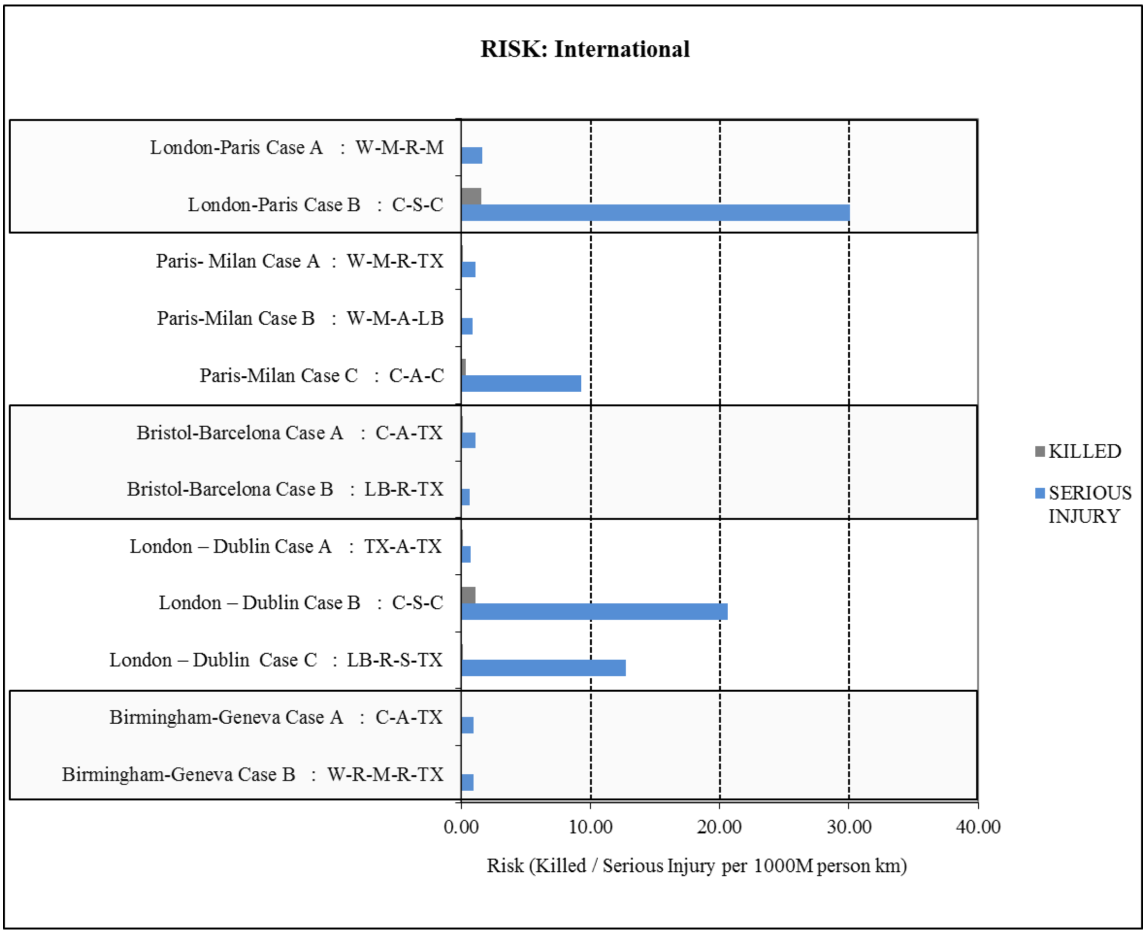
This section presents the results of the journey analyses introduced in Section 6.3 . This is performed for six groups of journeys defined in in Table 6-4 which aim to represent a wide range of frequently undertaken journey types at national and international level taking full account of multiple mode use in cases where single mode end to end travel is not possible. Modal comparisons within these groups identify the impacts that CMS can have for similar journey types, and this can help ensure that any subsequent policy recommendations can be targeted effectively. The basis for the trips selected was to explore whether modal change can make a substantial difference to overall safety on one or more of a wide range of travel routes. Trips were selected to show total journey risk for different travel type combinations on identical door to door examples within each journey category, and allow for different but realistic modal combinations to understand how the risks compared on specific journeys. Trips were also selected to reflect a range of users, from commuters through to leisure travellers (implied in choice of O and D pairs). Lastly, the selection was made to show changes including the risks of “low risk modes” when combined with “higher risk modes” for the total journey.

In each case, the assessment is supported by two graphics and a table which show the outcomes of the assessment from different perspectives:

- A graphic showing K and SI risk per 1000M person km for each of the journeys assessed.
- A table showing the differences between monetised risk rates for similar journeys using different modes as a basis for the assessment of CMS. In these tables, the initial column uses the journey letters to show the different modal combinations. The second column then provides detail of the comparison by listing the two journeys being compared using the nomenclature given in the key to list the modes used.
- A graphic showing the differences between modes in terms of monetised risk of both K and SI, highlighting the fact that the differences for killed and serious injuries can operate in different directions to one another, even within the same comparison.

### 6.5.1 International

The International category aims to capture a range of European inter-city journeys including both major centres, such as London and Paris, and smaller centres such as Bristol and Birmingham. Travel between the UK and Ireland is included, as this requires sea or air transport. It should be noted that the risk rates applied to these European journeys are as set out in Section 6.1.2 . Figure 6-6 sets out the journeys and their associated risk levels.



**Key:**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| W | Walking | TX | Taxi | CO | Coach | M | Metro | A | Air |
| B | Bicycle | LB Bus | Local | T | Tram | R | Mainline Rail | S | Sea |

*Figure 6-6: International risk*

The London to Paris journey compares rail and metro with a car equivalent, though with the car using the ferry crossing between Dover and Calais. The risk of K and injury are both higher with the car journey, with death being 26 times as high (1.56 compared to

0.06) while injury rates are 19 times as high (30.08 compared to 1.61). This is an interesting comparison because the reasons for the modal choices are likely to be different. Here a typical car journey would be for a holiday, perhaps for a group of people or a family with luggage, while the rail journey could be taken for a variety of reasons and perhaps more likely by individuals.

The Paris to Milan journey highlights the near zero risk rating applied to air travel such that in both cases, the real comparison is effectively between the 'feeder' journeys, i.e. walk/metro/local bus in one case and car in the other. Between these two, the K rate is substantially higher in the case of the car journey. The air and rail journey rates for both SI and K are similarly low.

The Bristol to Barcelona example illustrates the impact of very similar figures for rail and air, with the difference between the journeys based on the feeder modes. In this case, the rail journey would not be considered by most people, for practical reasons of cost and journey time. Some fluctuations have existed because of specific accidents in the past, e.g. in Spain, cited earlier in this chapter where a single multi-fatality accident had a significant effect on the fatality rate[45]. The use of time averaged figures helps to offset this.

The London to Dublin journey again emphasises the risks of car travel, though it also shows the effect of using ships for approximately 20% of the journey distance. The effect is to increase the risk for the rail/ship journey to a slightly higher level than the taxi/air/taxi journey in terms of K and to nearly 18 times higher for SI. The car/ship journey remains the most risky.

The comparison of rail and air for journeys between Birmingham and Geneva highlights the impacts of feeder modes when low risk main leg modes are used. The impact of the walking and taxi legs is to raise the rail based journey to a higher level of risk than the air based alternative, though not by much. Notably, the injury risks for these two examples are unusually similar. Table 6-13 and Figure 6-7 provide monetised risk comparisons for international journeys. Negative results mean that the second case has a higher monetised risk than the first from which it is subtracted, e.g. the Paris to Milan case where

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[45] For the European journeys the 2012 risks rates for rail have been used from the European Railway Agency's (ERA) Railway Safety Performance in the EU 2014 report.

walk/metro/rail/taxi carried a lower overall monetised risk than the car/air/car equivalent for the same journey and hence produced a negative outcome.

| Journey Comparison | | Combined KSI difference in monetised risk (€ per 1000M person km) | Difference in monetised KSI for actual journey (€) |
|---|---|---|---|
| B-A | London-Paris Case B (C-S-C) minus<br>London-Paris Case A (W-M-R-M) | 10,977,673 | 5.50 |
| A-B | Paris- Milan Case A (W-M-R-TX) minus<br>Paris-Milan Case B (W-M-A-LB) | 108,706 | 0.07 |
| C-B | Paris-Milan Case C (C-A-C) minus<br>Paris-Milan Case B (W-M-A-LB) | 2,801,086 | 1.87 |
| A-C | Paris- Milan Case A(W-M-R-TX) minus<br>Paris-Milan Case C (C-A-C) | -2,692,380 | -1.83 |
| B-A | Bristol-Barcelona Case B (LB-R-TX) minus<br>Bristol-Barcelona Case A (C-A-TX) | -278,572 | -0.34 |
| B-A | London – Dublin Case B (C-S-C) minus<br>London – Dublin Case A (TX-A-TX) | 7,604,825 | 3.81 |
| B-C | London – Dublin Case B (C-S-C) minus<br>London – Dublin Case C (LB-R-S-TX) | 4,411,075 | 2.58 |
| C-A | London – Dublin Case C (LB-R-S-TX) minus<br>London – Dublin Case A (TX-A-TX) | 3,193,750 | 1.53 |
| B-A | Birmingham-Geneva Case B (W-R-M-R-TX) minus<br>Birmingham-Geneva Case A (C-A-TX) | 32,538 | 0.03 |

*Table 6-13: Monetised risk differences for international journeys*

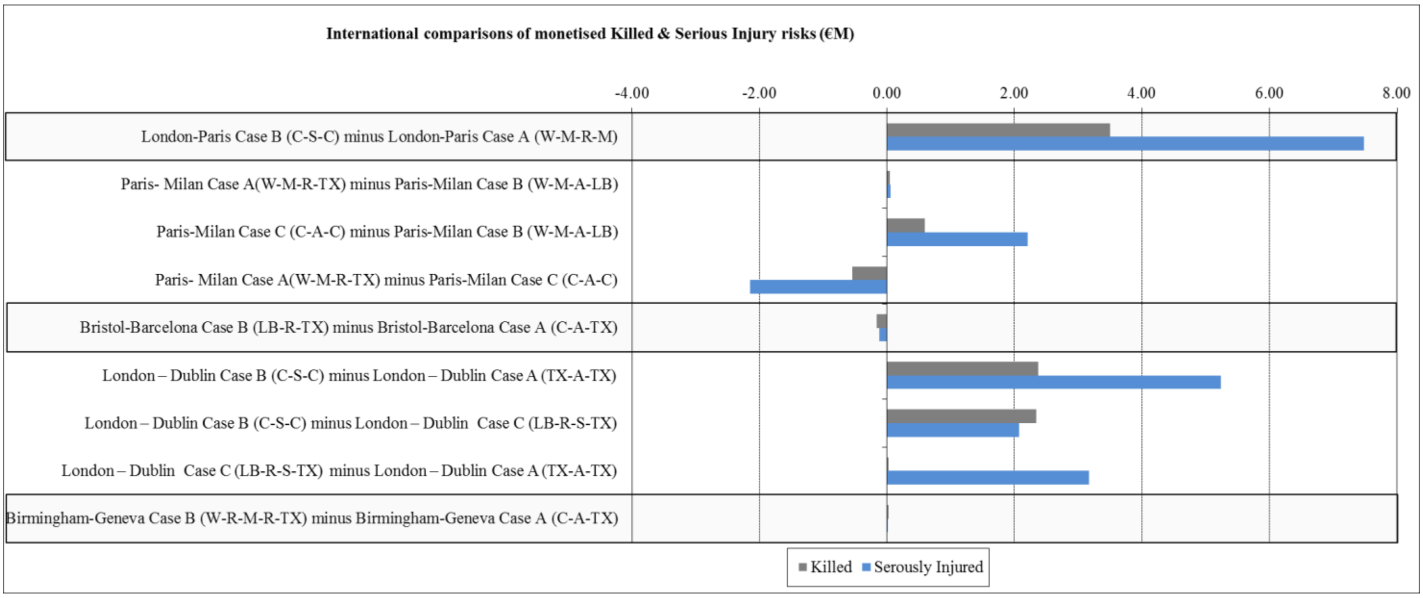
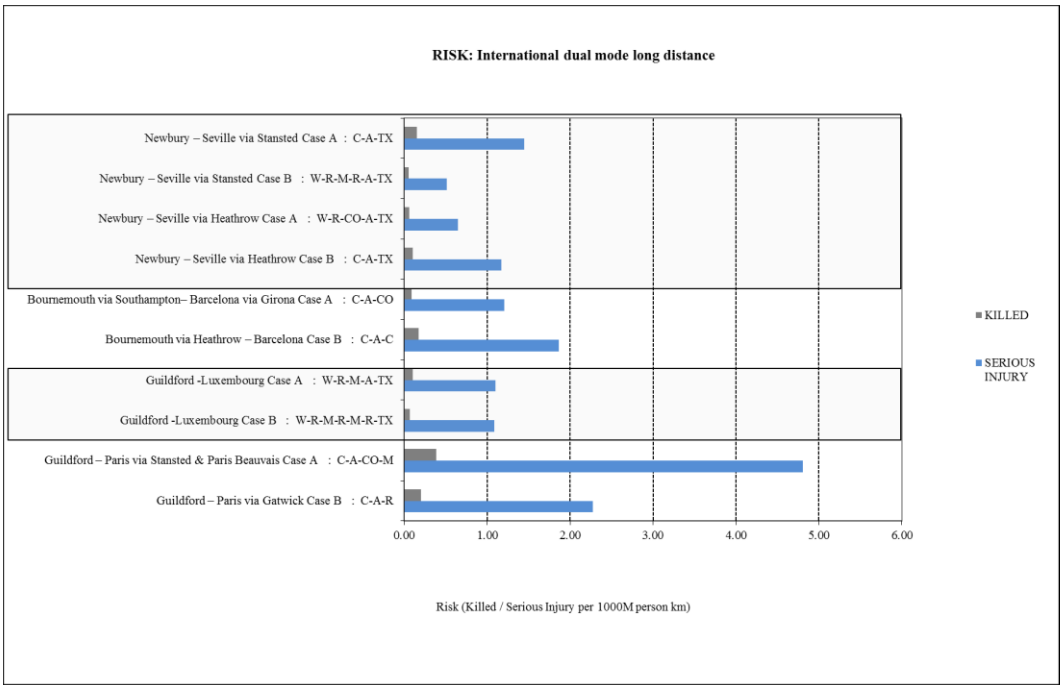


*Figure 6-7: International comparisons of monetised KSI (€M)*

Here, the greatest differences are for the London to Paris and London to Dublin cases. In each of these examples, the safety gain of up to €5.50 and €3.81 respectively per passenger per journey is derived from a switch from a car based journey to one centred on rail or air. The differences in all other cases are much smaller.

### 6.5.2 International dual mode long distance

This group of journeys considers travel within Europe by air but which involve complex travel to the airport including a number of modes (Figure 6-8). This is a useful approach to aviation risks because, although the aviation risk rate per unit distance is very low, travel to the airport involves many feeder routes which may render the overall journey risks comparable with other modes. For the Guildford to Luxembourg case, a rail version of the journey using the Eurostar and TGV via Paris has also been included for comparison.



**Key:**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| W | Walking | TX | Taxi | CO | Coach | M | Metro | A | Air |
| B | Bicycle | LB Bus | Local | T | Tram | R Rail | Mainline | S | Sea |

*Figure 6-8: International dual mode long distance risk*

Guildford to Paris via Stansted and Paris Beauvais which includes car, coach and metro as feeder modes is most notable. The risk rates for killed and seriously injured are double that of the equivalent journey via Gatwick with car as the feeder and rail as the second supporting mode. This is because of the very long car and coach components in the former and the very low rail risks in the latter case. The Guildford to Luxembourg examples are notably lower because of the different feeder modes and the similarity of the risk rates between air and Long Distance Rail (LDR).

The majority of these journeys involve substantial air components with very low risk rates, meaning that these journeys carry only the risks associated with their feeder legs. As a result, the Newbury to Seville examples are separated by the extent and nature of the journeys to Heathrow or Stansted, since the same taxi ride is included at the Seville end in each case. In this case, however, the long distance of the main leg means that all of the combinations have a low overall risk rate for K but higher SI risks for the Heathrow or Stansted options by car.

The Bournemouth to Barcelona examples again are differentiated by the extent of the car component of the journey and remain relatively low-risk overall, again because of the influence of the longer overall distance. Table 6-14 and Figure 6-9 provide monetised risk comparisons for dual mode long distance.

| Journey Comparison | | Combined KSI Difference in monetised risk (€ per 1000M person km) | Difference in monetised KSI for actual journey (€) |
|---|---|---|---|
| A-B | Newbury – Seville via Stansted Case A (C-A-TX) minus Newbury – Seville via Stansted Case B (W-R-M-R-A-TX) | 469,181 | 0.87 |
| B-A | Newbury – Seville via Heathrow Case B (C-A-TX) minus Newbury – Seville via Heathrow Case A (W-R-CO-A-TX) | 221,533 | 0.38 |
| B-A | Bournemouth via Heathrow – Barcelona Case B (C-A-C) minus Southampton – Girona via Bournemouth Case A (C-A-CO) | 366,918 | 0.44 |
| B-A | Guildford -Luxembourg Case B (W-R-M-R-M-R-TX) minus Guildford -Luxembourg Case A (W-R-M-A-TX) | -93,665 | -0.05 |
| A-B | Guildford – Paris via Stanstead & Paris Beauvais Case A (C-A-CO-M) minus Guildford – Paris via Gatwick Case B (C-A-R) | 1,098,364 | 0.55 |

*Table 6-14: Monetised risk differences for international dual mode long distance*

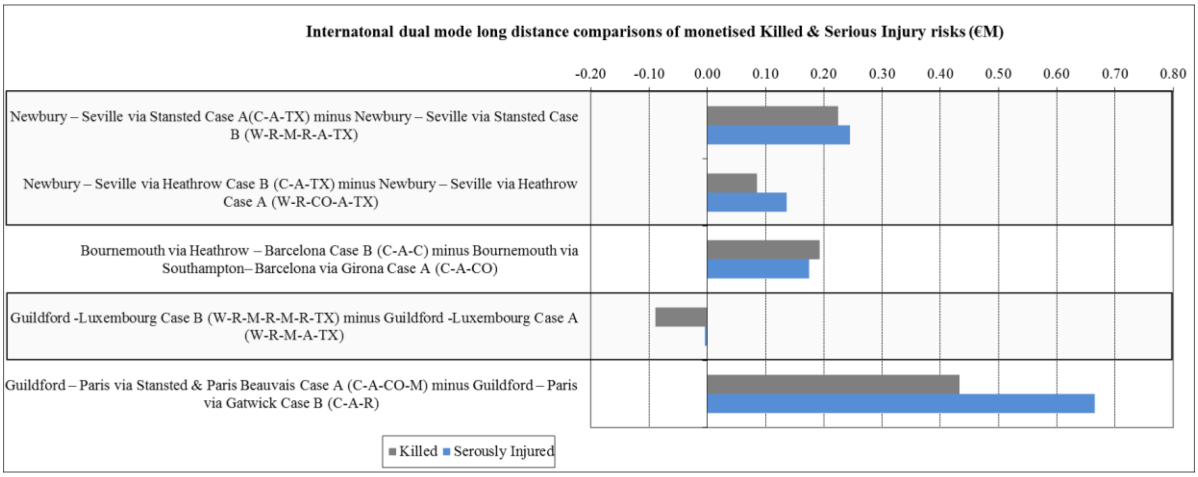
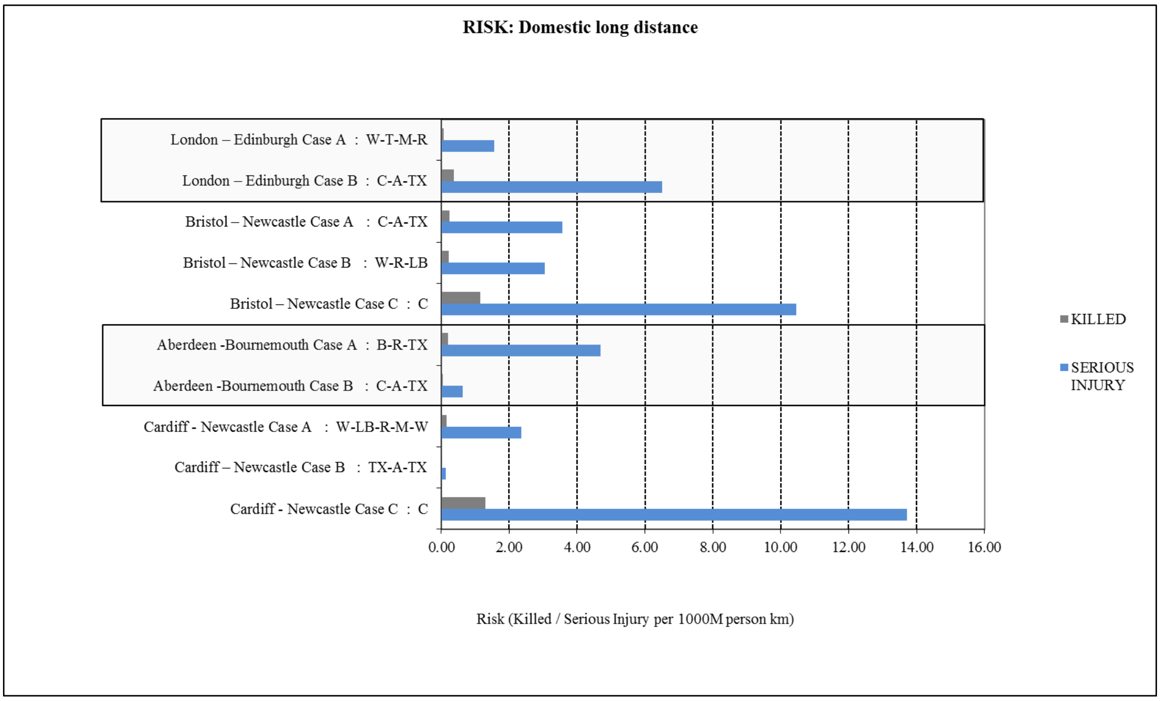


*Figure 6-9: International dual mode long distance comparisons of monetised KSI (€M)*

These examples have notably small overall safety gains per journey from the switch. This is because, despite the impact of the feeder modes, the dominant force remains the long distances using low risk forms of transport, i.e. air and rail.

### 6.5.3 Domestic long distance

This case considers longer distance travel between major towns/cities in the UK (Figure 6-10). A mixture of routes is included to illustrate different combinations of major trunk routes with very good connections in all modes, such as London to Edinburgh, and 'cross country' routes such as Aberdeen to Bournemouth.



| Key: | W | Walking | TX | Taxi | CO | Coach | M | Metro | A | Air |
|---|---|---|---|---|---|---|---|---|---|---|
| | B | Bicycle | LB Bus | Local | T | Tram | R | Mainline Rail | S | Sea |

*Figure 6-10: Domestic long distance risk*

The London to Edinburgh route in this comparison shows the effects of the very low risk of air travel, but that this is largely offset for both K and SI by the longer car and taxi feeds needed for the air travel. This is a general characteristic of air travel because, despite the growth in regional airports, access to rail stations remains far better and hence longer taxi or car journeys tend to be included in the air travel mix.

For Bristol to Newcastle, the feeder for air travel remains longer than rail and this offsets the slightly lower air risk rates to give a very similar outcome for both of these combinations. The comparison with the car journey highlights the high K rates as the risk is almost five times as great in this mode.

The Aberdeen to Bournemouth case shows the effects of rail risk weighted over long distances. The overall journey risk is heavily influenced by the 5 km initial bicycle ride included prior to the rail journey. Short car and taxi feeds have only a very limited influence over the very long distance of the main journey leg by air.

On Cardiff to Newcastle the notable modal combination is by taxi and air, which because of the short (4 km) taxi journeys and the almost zero rated risk for air travel, is almost a risk free journey. Comparison of the other two journeys (car vs. rail) shows the same pattern of higher K and SI risk for car. It should be noted that the taxi risk, in the absence of specific DfT figures for this mode, has been averaged across all four different car travel risk levels based on the four different road types. This approach was taken after discussion with the DfT statisticians.

Table 6-15 and Figure 6-11 provide monetised risk comparisons for domestic long distance journeys.

| | Journey Comparison | Combined KSI difference in monetised risk (€ per 1000M person km) | Difference in monetised KSI for actual journey (€) |
|---|---|---|---|
| A-B | London – Edinburgh Case A (W-T-M-R) minus<br>London – Edinburgh Case B (C-A-TX) | -2,001,857 | -1.08 |
| B-A | Bristol – Newcastle Case B (W-R-LB) minus<br>Bristol – Newcastle Case A (C-A-TX) | -183,667 | -0.08 |
| C-B | Bristol – Newcastle Case C (C) minus<br>Bristol – Newcastle Case B (W-R-LB) | 4,104,896 | 1.65 |
| C-A | Bristol – Newcastle Case C (C) minus<br>Bristol – Newcastle Case A (C-A-TX) | 3,921,229 | 1.90 |
| A-B | Aberdeen -Bournemouth Case A (B-R-TX) minus<br>Aberdeen -Bournemouth Case B (C-A-TX) | 1,424,993 | 1.03 |
| A-B | Cardiff - Newcastle Case A (W-LB-R-M-W) minus<br>Cardiff – Newcastle Case B (TX-A-TX) | 889,310 | 0.36 |
| C-B | Cardiff - Newcastle Case C (C) minus<br>Cardiff – Newcastle Case B (TX-A-TX) | -612,412 | -0.26 |
| C-A | Cardiff - Newcastle Case C (C) minus<br>Cardiff - Newcastle Case A (W-LB-R-M-W) | 5,638,778 | 2.90 |

*Table 6-15: Monetised risk differences for domestic long distance*

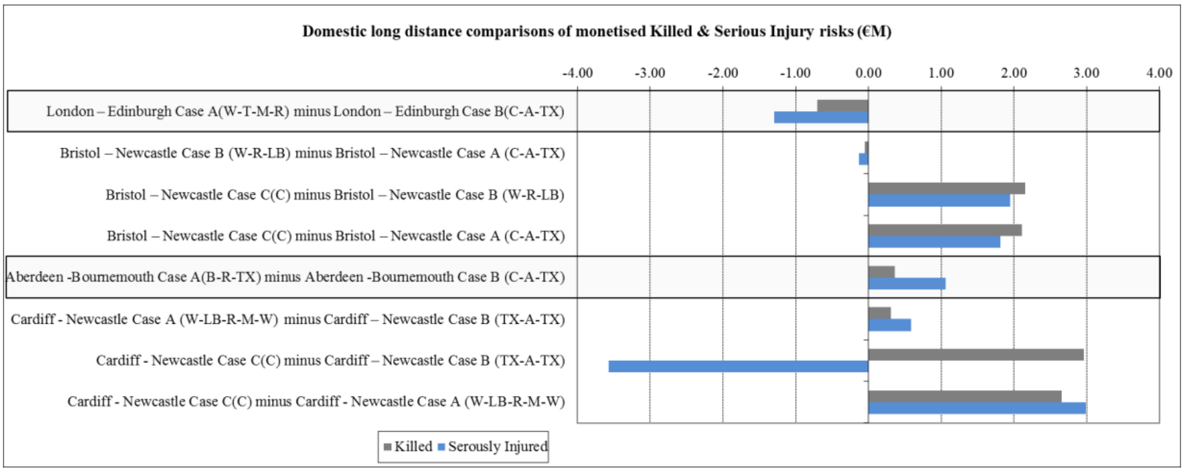
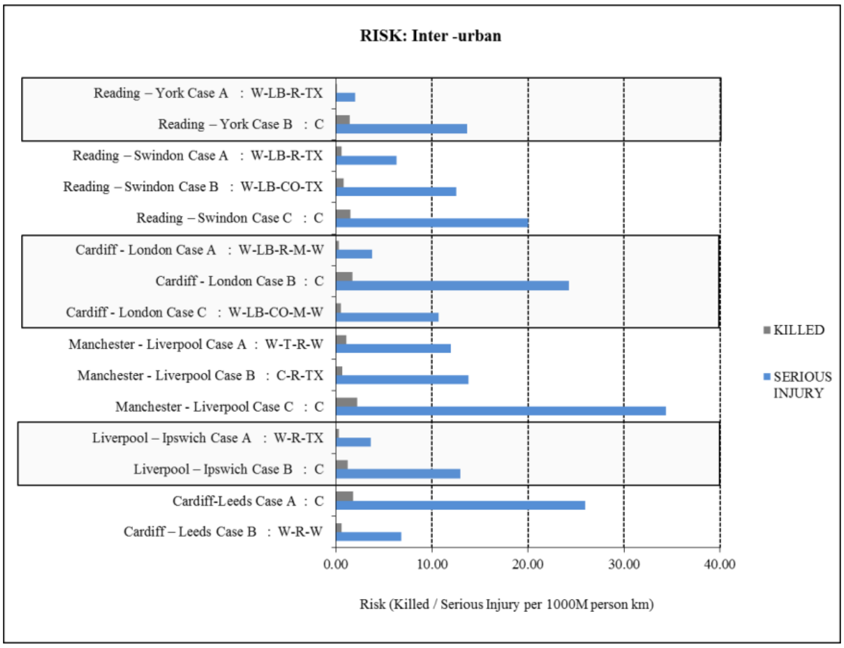


*Figure 6-11: Domestic long distance comparisons of monetised KSI (€M)*

These show relatively small safety gains between journey combinations which would only be partly offset by the number making the journey since these numbers are likely to be relatively limited.

### 6.5.4 Inter-urban

This inter-urban category considers a mixture of both leisure and business journeys between large and medium sized cities in the UK. A range of distances is included from Manchester – Liverpool to Liverpool – Ipswich (Figure 6-12).



**Key:**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| W | Walking | TX | Taxi | CO | Coach | M | Metro | A | Air |
| B | Bicycle | LB Bus | Local | T | Tram | R Rail | Mainline | S | Sea |

*Figure 6-12: Inter-urban risks*

The Reading to York journey by car shows a higher risk of K and also a higher risk of SI compared to the mainly rail alternative. The risk of K on the rail journey is very small because the distance is dominated by rail and the more dangerous feeder modes, mainly walking, are only over short distances.

The Reading to Swindon rail vs. coach vs. car trade-offs shows better safety by rail for both K and SI compared to bus/coach, which has a risk rate of 0.3 deaths per 1000M person km compared to the mainline rail risk of 0.01. The car journey gives a higher risk of K and SI than both of the other options.

Comparing the walk/local bus/rail/taxi journey from Reading to York with the journey from Reading to Swindon illustrates the impacts of the ‘feeder’ modes in relation to different overall distances. Risks are higher to Swindon because the walk, local bus and taxi elements are larger in proportion to the 65 km journey to Swindon than the 283 km journey to York. The Taxi element is 4 km for the Swindon journey as opposed to York where it is 2 km and thus is again much bigger relatively. This stresses the relative importance of feeder journeys as part of the overall journey risk profile for non-car trips. This is an important issue to explore in the development of CMS policy.

For Cardiff to London, the risk by rail is lower than the coach trip in terms of mortality risk and, particularly, injury risk. The car journey carries a much higher risk than either form of public transport for K and also for SI.

In the case of Manchester to Liverpool, the tram and rail combination shows a K rate just over half that for the car alone. This is mainly because the 2 km walk (a high risk mode) is higher as a proportion of the overall distance of about 55 km. The car/rail/taxi journey is the lowest combination for death risk, yet the highest for injury at 13.82; this is probably attributable to 4 km car use on urban roads, which have high rates for SI.

On Liverpool to Ipswich a similar comparison is made as was carried out for Bristol to Newcastle, although the final link for the rail journey uses taxi rather than local bus. Slight differences resulting from the overall distances and the change from the taxi to local bus feeders were evident but the outcome is similar and again much lower than the car only journey which, in this case, has 5 to 7 times the risk level.

The Cardiff to Leeds journey by car has the highest overall risk of this journey group. This is compared with a standard walk/rail/walk mode whose risk rate, though higher than most of the other rail travel combinations, is still three times smaller than that of the car only case. As the longest car only journey, this also has the highest injury risk of the overall group.

Table 6-16 and Figure 6-13 provide monetised risk comparisons for the inter-urban cases discussed above. The monetisation is based on the summation of the value of life and serious injury rates applied to the risk/distance components of each journey. The results are then differenced.

| | Journey Comparison | Combined KSI difference in monetised risk (€ per 1000M person km) | Difference in monetised KSI for actual journey (€) |
|---|---|---|---|
| B-A | Reading – York Case B (C) minus<br>Reading – York Case A (W-LB-R-TX) | 6,118,742 | 1.73 |
| A-B | Reading – Swindon Case A (W-LB-R-TX) minus<br>Reading – Swindon Case B (W-LB-CO-TX) | -2,119,119 | -0.14 |
| C-B | Reading – Swindon Case C (C) minus<br>Reading – Swindon Case B (W-LB-CO-TX) | 3,736,587 | 0.27 |
| C-A | Reading – Swindon Case C (C) minus<br>Reading – Swindon Case A (W-LB-R-TX) | 5,855,706 | 0.44 |
| B-A | Cardiff - London Case B (C) minus<br>Cardiff - London Case A (W-LB-R-M-W) | 8,802,527 | 1.90 |
| B-C | Cardiff – London Case B (C) minus<br>Cardiff - London Case C (W-LB-CO-M-W) | 6,396,479 | 1.55 |
| A-C | Cardiff - London Case A (W-LB-R-M-W) minus<br>Cardiff - London Case C (W-LB-CO-M-W) | -2,406,048 | -0.58 |
| A-B | Manchester – Liverpool Case A (W-T-R-W) minus<br>Manchester - Liverpool Case B (C-R-TX) | 533,566 | 0.03 |
| C-B | Manchester - Liverpool Case C (C) minus<br>Manchester - Liverpool Case B (C-R-TX) | 8,999,333 | 0.49 |
| A-C | Manchester - Liverpool Case A (W-T-R-W) minus<br>Manchester - Liverpool Case C (C) | -8,465,767 | -0.47 |
| B-A | Liverpool – Ipswich Case B (C) minus<br>Liverpool – Ipswich Case A (W-R-TX) | 4,672,384 | 1.50 |
| A-B | Cardiff-Leeds Case A (C) minus<br>Cardiff – Leeds Case B (W-R-W) | 7,796,265 | 2.85 |

*Table 6-16: Monetised risk differences for inter-urban*

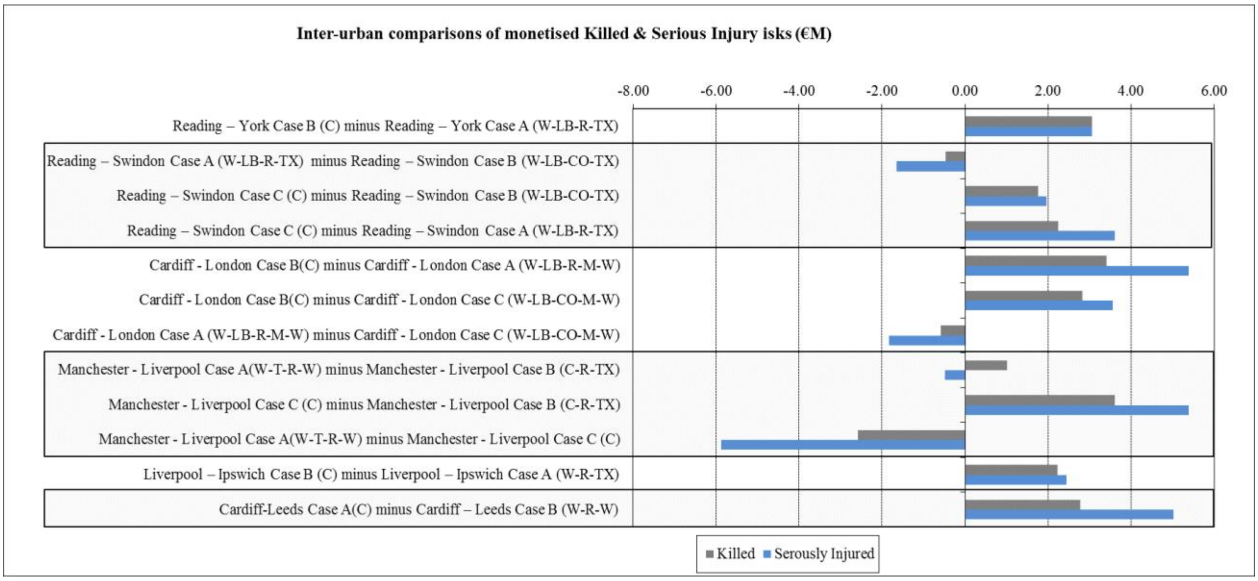
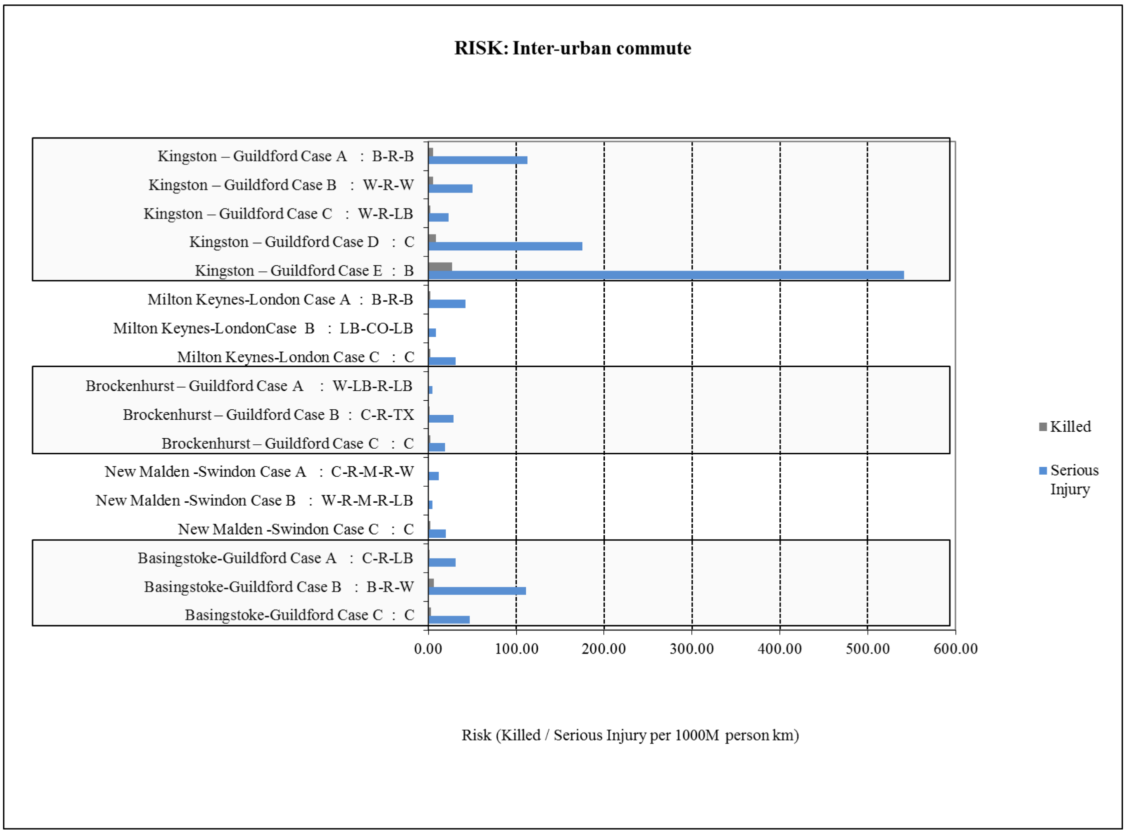


*Figure 6-13: Inter-urban risk comparisons of monetised KSI (€M)*

These examples highlight the significant differences in K and SI risk profiles for the journeys under different modal combinations but also the relatively small per journey gains in monetary terms.

### 6.5.5 Inter-urban commute

This group of journeys is based mainly on cross country travel between towns in the UK. This includes some examples of frequent longer distance commutes (e.g. Milton Keynes to London or New Malden to Swindon) as well as shorter outward commutes such as Kingston to Guildford and longer distance commutes between smaller centres (e.g. Basingstoke to Guildford and Brockenhurst to Guildford). On the whole, these would normally be undertaken by car unless a rapid rail service is available, as in the case of Milton Keynes to London (Figure 6-14).



**Key:**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| W | Walking | TX | Taxi | CO | Coach | M | Metro | A | Air |
| B | Bicycle | LB | Local Bus | T | Tram | R | Mainline Rail | S | Sea |

*Figure 6-14: Inter-urban commute risk*

The Kingston to Guildford journey provides an interesting comparison with the Kingston to Central London commute. In this case, the bicycle journey is also included and once again represents by far the highest risk for both K and SI. In fact, although the risks remain undeniably high and the journey is relatively unusual because of the distance, the risks would appear to be much lower than for the urban commute because of the much lower traffic hazards.

Of the remaining approaches to this journey, the others with moderately high risk are the walk/rail/walk or bike/rail/bike, where the risks mainly arise from the pedestrian/bike element, and the car journey where the risk of death is comparatively high overall and is applied to the whole journey distance.

The journey from Milton Keynes to London is included for comparison. Although the distance is greater, the safer road type means that the car journey is much safer, though in practice, this would depend on the extent to which the journey passes into London. The use of a bicycle at either end of the rail commute is enough to raise the risks substantially compared with the combination of local bus and coach although, in practice, the network of segregated cycle routes at the Milton Keynes end would help to offset this.

None of the remaining journeys involve bicycles and are therefore comparatively safe in comparison with the Kingston to Guildford journey. The Brockenhurst to Guildford journey is a typical long distance rural commute and here the trade-off between cars with high K risk vs. rail with high SI rates holds true. The overall rates are low because, particularly for the cars, motorways are considered relatively safe.

The New Malden to Swindon example again follows this pattern. It is interesting that travel via London (Journey A) carries a higher risk than the same journey via Reading with no metro leg. The car journey has the highest risk of the three, though this would likely be the preferred option for cost and convenience reasons.

Basingstoke to Guildford shows car and rail as broadly similar, but again the introduction of a bicycle feed to the rail leg raises both the risk of K and of SI to levels well over double the other modal combination with safer feeders, and to a level greater than the car only approach.

Table 6-17 and Figure 6-15 provide monetised risk comparisons for urban to urban journeys.

| | **Journey Comparison** | **Combined KSI Difference in monetised risk (€ per 1000M person km)** | **Difference in monetised KSI for actual journey (€)** |
|---|---|---|---|
| E-A | Kingston – Guildford Case E(B) minus<br>Kingston – Guildford Case A (B-R-B) | 162,524,442 | 5.33 |
| E-B | Kingston – Guildford Case E(B) minus<br>Kingston – Guildford Case B (W-R-W) | 180,206,518 | 5.68 |
| E-C | Kingston – Guildford Case E(B) minus<br>Kingston – Guildford Case C (W-R-LB) | 194,121,860 | 6.25 |
| E-D | Kingston – Guildford Case E(B) minus<br>Kingston – Guildford Case D (C) | 139,729,052 | 5.06 |
| A-B | Milton Keynes-London Case A (B-R-B) minus<br>Milton Keynes-London Case B (LB-CO-LB) | 13,127,533 | 1.02 |
| C-B | Milton Keynes-London Case C (C) minus<br>Milton Keynes-London Case B (LB-CO-LB) | 10,040,667 | 0.99 |
| A-C | Milton Keynes-London Case A (B-R-B) minus<br>Milton Keynes-London Case C (C) | 3,086,866 | 0.27 |
| B-A | Brockenhurst – Guildford Case B(C-R-TX) minus<br>Brockenhurst – Guildford Case A (W-LB-R-LB) | 8,624,021 | 0.78 |
| B-C | Brockenhurst – Guildford Case B(C-R-TX) minus<br>Brockenhurst – Guildford Case C (C) | 730,812 | 0.08 |
| C-A | Brockenhurst – Guildford C (C) minus<br>Brockenhurst – Guildford Case A (W-LB-R-LB) | 7,893,208 | 0.80 |
| B-A | New Malden -Swindon Case B (W-R-M-R-LB) minus<br>New Malden -Swindon Case A (C-R-M-R-W) | -2,880,130 | -0.40 |

| Journey Comparison | | Combined KSI Difference in monetised risk (€ per 1000M person km) | Difference in monetised KSI for actual journey (€) |
|---|---|---|---|
| B-C | New Malden -Swindon Case B (W-R-M-R-LB) minus New Malden -Swindon Case C (C) | -7,672,822 | -0.99 |
| C-A | New Malden -Swindon Case C (C) minus New Malden -Swindon Case A (C-R-M-R-W) | 4,792,692 | 0.63 |
| B-A | Basingstoke-Guildford Case B (B-R-W) minus Basingstoke-Guildford Case A (C-R-LB) | 32,689,938 | 1.54 |
| B-C | Basingstoke-Guildford Case B (B-R-W) minus Basingstoke-Guildford Case C (C) | 25,524,048 | 1.20 |
| C-A | Basingstoke-Guildford Case C (C) minus Basingstoke-Guildford Case A (C-R-LB) | 7,165,891 | 0.36 |

*Table 6-17: Monetised risk differences for inter-urban commute*

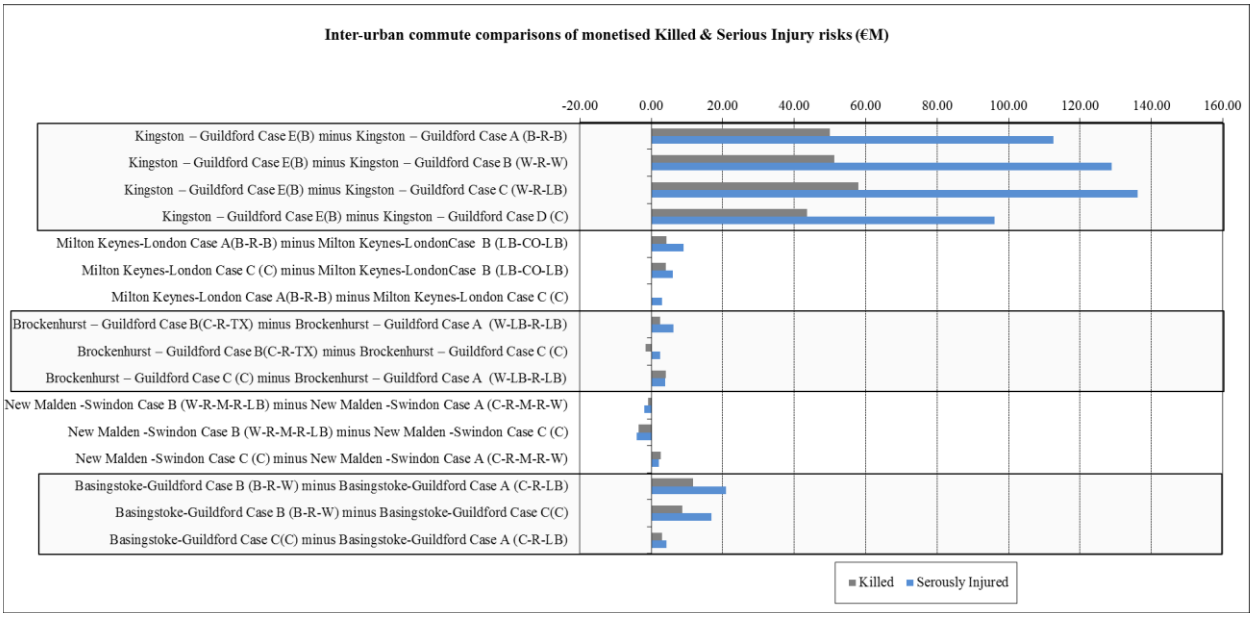
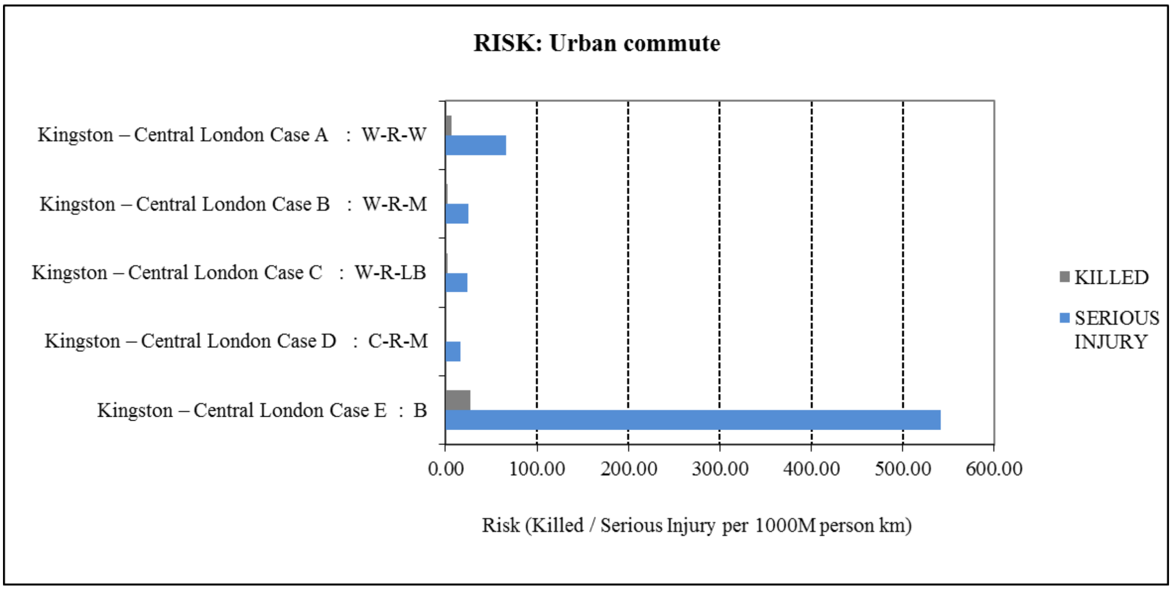


*Figure 6-15: Inter-urban commute comparisons of monetised KSI (€M)*

The range of benefits achieved per journey is not a surprise given the range of possibilities considered in this category. This is mainly because, as with the urban commute, the comparison for Kingston-Guildford journey used bicycle and hence the alternatives are much safer. The other notable case is the Basingstoke to Guildford case where the use of cycling as a feeder mode increases the overall risk considerably.

### 6.5.6 Urban commute

This journey type covers one of the most commonly undertaken journeys, the daily or at least regular commute from a suburb into the centre of a city. The example chosen is Kingston upon Thames in South West London to a central London location, in this case the Barbican area of the City (Figure 6-16). With increased pressure on parking, traffic congestion and the Congestion Charge in central London, rail travel is now running at close to capacity on these routes. As a result, four of the five routes are based on a rail commute and are differentiated by the feeder modes. The fifth example, and one that is used in this area, is the bicycle commute. Although bicycle is commonly used as a feeder, whether at one end of the journey or both, it is also increasingly common for commuters to cycle the whole distance in response to the extensive government promotion of cycling as a healthy solution to the congestion problem (DfT, 2015)[46]. This may be intermittent and more regular in the summer.



**Key:**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| W | Walking | TX | Taxi | CO | Coach | M | Metro | A | Air |
| B | Bicycle | LB Bus | Local | T | Tram | R Rail | Mainline | S | Sea |

*Figure 6-16: Urban commute risk*

These examples compare five different approaches to a daily commute from a London suburb to the centre of London. Most of the examples centre on the use of rail travel because it is the quickest and cost effective mode, particularly for well served centres such as Kingston, which has a choice of routes, including a 17 minute service to central London from the south of the town (from Surbiton) and a good frequency of service from the town centre itself. The example used here assumes a 1.6 km distance to the local station with 3.2 km journey within Central London which is typical.

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[46] This example is supported by the Cycle Superhighways which are part of a plan by TfL and the London Mayor to encourage more people to commute by bike. The provision of twelve cycle-only lanes, clearly marked blue, aims to increase cycling in London by 400 percent by 2025 compared to 2000 levels. AECOM is working on the planned route between Kingston Vale in the south west and Westminster.

Comparison of journeys A to E shows the high risk levels associated with pedestrian travel. The walk/rail/walk example (journey A), in particular, shows a high K and SI risk. The use of the metro or local bus for the travel within Central London provides a significant improvement in terms of both K and SI risk.

The impact of making the same journey by bicycle shows one of the most dramatic changes in risk profile of all the comparisons provided. The risk of K for this journey by bicycle is 27, with 541 for SI. This compares with the next most risky mode of walk/rail/walk which gives 6.70 and 66.22. Car, rail and metro on the other hand gives 0.71 and 16.52 which is 38 times less than cycling for K and eight times less for SI.

This example is very topical because of the current highly successful attempts to promote cycling, particularly in London. In this case, the argument is that although cycling KSI rates are very high relative to other modes, the absolute risks are not sufficient to offset the longer term health benefits from cycling as well as broader benefits such as reduced congestion and pollution. In this context, the safety assessments are a valuable input to a broader debate.

Table 6-18 and Figure 6-17 provide monetised risk comparisons for urban commute journeys.

| Journey Comparison | | Combined KSI difference in monetised risk (€ per 1000M person km) | Difference in monetised KSI for actual journey (€) |
|---|---|---|---|
| E-A | Kingston – Central London Case E(B) minus<br>Kingston – Central London Case A (W-R-W) | 172,221,073 | 3.58 |
| E-B | Kingston – Central London Case E (B) minus<br>Kingston – Central London Case B (W-R-M) | 193,370,578 | 4.02 |
| E-C | Kingston – Central London Case E (B) minus<br>Kingston – Central London Case C (W-R-LB) | 193,687,468 | 4.03 |
| E-D | Kingston – Central London Case E (B) minus<br>Kingston – Central London Case D (C-R-M) | 199,283,951 | 4.15 |

*Table 6-18: Monetised risk differences for urban commute*

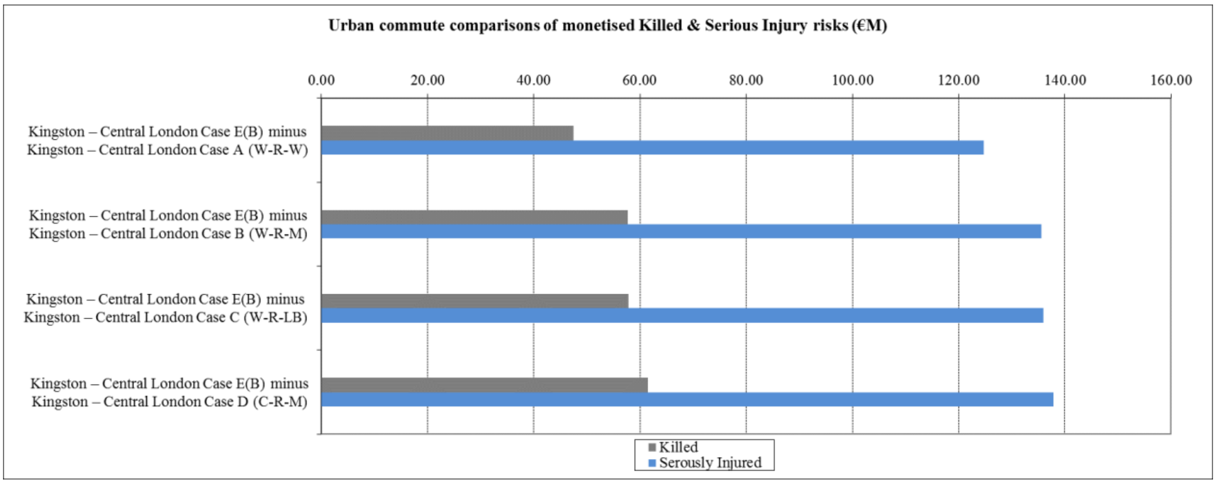

*Figure 6-17: Urban commute comparisons of monetised KSI (€M)*

The very large safety gains in this category per unit distance stem from the selection of the cycling mode as the base against which the other options are compared. Given the shorter distances involved; however, the benefits per journey are not so large, at €3.58 to €4.15 per journey. What is notable in practice is that the modal switches in London are presently very much in the opposite direction as solutions to carbon emissions; air quality reductions and congestion are all prioritised. For example, the HEAT Framework (WHO, 2011) aimed at developing guidance and practical tools for economic assessments of the health effects from (a) cycling and (b) walking.

### 6.5.7 Overall comparison

Table 6-19 ranks all the journey types considered above with a composite risk of death of 1 death per 1000M person km or more. Nevertheless if journeys of varying distances serve the same purpose (e.g. visiting a friend) then it should be noted that risk per distance is not the only metric that is of concern to some travellers but the risk per journey.

| Journey type | Journey | Modes used | Total Composite Risk (Risk of K per 1000M km for this combination of modes) |
|---|---|---|---|
| Urban commute | Kingston – Central London Case E | B | 27.00 |
| Inter-urban commute | Kingston – Guildford Case E | B | 27.00 |
| Inter-urban commute | Kingston – Guildford Case D | C | 8.33 |
| Urban commute | Kingston – Central London Case A | W-R-W | 6.70 |
| Inter-urban commute | Basingstoke-Guildford Case B | B-R-W | 6.46 |
| Inter-urban commute | Kingston – Guildford Case A | B-R-B | 5.61 |
| Inter-urban commute | Kingston – Guildford Case B | W-R-W | 5.07 |
| Inter-urban commute | Basingstoke-Guildford Case C | C | 2.74 |

| Journey type | Journey | Modes used | Total Composite Risk (Risk of K per 1000M km for this combination of modes) |
|---|---|---|---|
| Urban commute | Kingston – Central London Case B | W-R-M | 2.30 |
| Urban commute | Kingston – Central London Case C | W-R-LB | 2.29 |
| Inter-urban commute | Kingston – Guildford Case C | W-R-LB | 2.21 |
| Inter-urban | Manchester - Liverpool Case C | C | 2.19 |
| Inter-urban commute | Milton Keynes-London Case A | B-R-B | 2.09 |
| Inter-urban commute | Brockenhurst – Guildford Case C | C | 2.07 |
| Inter-urban commute | Milton Keynes-London Case C | C | 2.05 |
| Inter-urban commute | New Malden -Swindon Case C | C | 1.93 |
| Inter-urban | Cardiff-Leeds Case A | C | 1.80 |
| Inter-urban | Cardiff - London Case B | C | 1.75 |
| International | London-Paris Case B | C-S-C | 1.56 |
| Inter-urban | Reading – Swindon Case C | C | 1.54 |
| Inter-urban commute | Basingstoke-Guildford Case A | C-R-LB | 1.45 |
| Inter-urban | Reading – York Case B | C | 1.44 |
| Inter-urban commute | Brockenhurst – Guildford Case B | C-R-TX | 1.37 |
| Domestic Long Distance | Cardiff - Newcastle Case C | C | 1.29 |
| Inter-urban | Liverpool – Ipswich Case B | C | 1.25 |
| Domestic Long Distance | Bristol – Newcastle Case C | C | 1.15 |
| International | London – Dublin Case B | C-S-C | 1.12 |
| Inter-urban | Manchester - Liverpool Case A | W-T-R-W | 1.09 |

*Table 6-19: Ranked journey risks*

The specific key modal points which emerge from this analysis are as follows:

- Urban journeys dominate the risk profile, partly because their shorter distances make more risky forms of travel such as walking and cycling practical. Rail is also a common component of urban journeys, but here again the regularity with which cycling and walking are used as feeders increases the risks overall.
- The relatively high risk of car journeys which form the bulk of the non-urban journeys is noted.
- What is interesting at present, given the substantial margin by which the risk of urban cycling exceeds that of any other modal form of transport, is that switching to cycling is by far the greatest modal switching effort evident at present in the UK and particularly in London. The cycling safety issue is often questioned by those who promote the mode, including questions over the years used as benchmarks and the undeniable reduction in risks compared to earlier decades, but based on the figures used here, the relative risks are evident.

- The impact of feeder modes on otherwise very safe long distance transport modes, notably air and rail, is considerable.

## 6.6 SUMMARY

The casualty risk assessments show that feeder journeys often form a major component of the risk and must therefore be a target for CMS. Risks for the safer forms of transport such as aviation and rail are dominated by a very small number of specific incidents. In these cases, public policy needs to take account of the specific issues involved as well as the summary view provided by the statistics. Considering the transfer risks for aviation, rail and bus does not significantly alter the overall risk calculation, although these need to be acknowledged and further research is required to derive specific modal transfer risks.

The active transport modes, particularly cycling but also walking, are substantially more dangerous than other modes. While noting that there are other evident benefits (health and environmental) that result from these modes, these clearly are not safety benefits.

Overall, in terms of the modal comparisons, there is sufficient contrast between the options for journeys to warrant further investigation while accepting the limitation that a common accident risk for everyone does overlook the fact that there are higher risks for specific groups of the population (e.g. young motorists and older pedestrians). The risk gains are relatively small per person or per journey, but where measures could be put in place to support switching, the numbers involved could make this worthwhile.

# 7 TRAVEL PREFERENCES & MODAL SUBSTITUTABILITY

## 7.1 BACKGROUND

A prerequisite for CMS is a willingness on the part of the travelling public to switch modes in response to various stimuli. To test this, primary research was undertaken in the form of a series of questionnaires to help understand the views of individuals on transport safety, their willingness to switch modes and the reasons that would cause them to do this. Two primary qualitative and quantitative travel surveys (self-completing questionnaires) were designed to better understand individual travel perceptions of safety/risk and other factors affecting travel behaviour including main modes used, access/egress modes used and willingness to use alternative modes at certain percentage changes in price. The surveys were undertaken to predominantly capture different user groups (leisure and those travelling for work/business) and different geographies (from UK and other European countries). The approach is summarised in Figure 7-1.

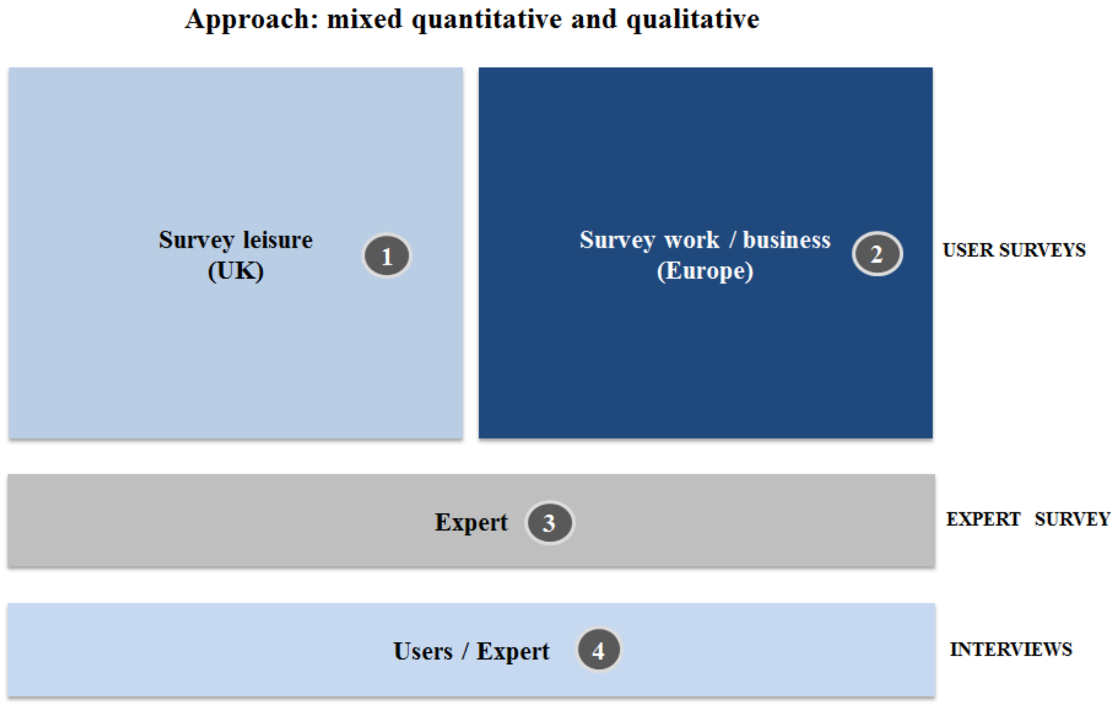

*Figure 7-1: Approach mixed quantitative and qualitative*

The travelling public as a population is a very challenging target to sample adequately. Accordingly, the following questionnaires were developed and implemented during the course of the work:

- **consumer***data* survey – a web-based questionnaire circulated by a market research organisation to one of their databases of leisure travellers. The responses to this survey captured leisure travellers' journeys and perceptions.
- Snowball survey – a survey was designed with a questionnaire similar to the **consumer***data* survey but targeted more towards work/business travellers to understand the user group. This is referred to as a 'snowball' survey because it was initially sent to personal/professional contacts who were then asked to identify further targets to help obtain a greater sample size. This type of survey was undertaken to capture a wider geographical user group which otherwise would have been challenging to target.
- Expert survey – an electronic survey distributed to transport safety experts using a University of Westminster database.
- Qualitative interviews – Delphi style interviews were undertaken with a small number of respondents from the user and expert surveys.

The types of questions used in the survey can be categorised three ways: revealed preference, ranking and attitudinal. In general, across both user questionnaire surveys the respondents were asked to report journey details including origin/destination, trip purpose, frequency and modes used (public such as air, local and LDR, underground, bus/coach, taxi, ferry/ship) plus private travel modes (car, bicycle, walking). Questions on factors affecting modal choice and alternative mode preferences were presented in the surveys. A specific question addressed the percentage reduction in price required for modal transfer. The questionnaires included risk perception (both accident risk and personal security) related to each of the aforementioned travel modes and how these varied from other factors, the impact of adverse weather and an option for respondents to provide any other specific comments. Some demographic questions were also asked in the survey mainly focused on those users who travelled for work/business purposes. The categories of questions in both questionnaires are provided in Table 7-1 in more detail.

| Type of question | Role of responses | consumer*data* Survey Questionnaire | Snowball Survey Questionnaire |
|---|---|---|---|
| **Journey characteristics**<br>• O&D<br>• Purpose<br>• Frequency<br>• Modes used | Context for the actual journeys made as well as purpose and regularity | QA – How often flown each year (1-4 times or 4-12 times) | |
| | | Q1a / Q1b – Journey start and ultimate destination | Q1 – Journey profile in stages and modes used at each stage |
| | | Q2 – Main purpose of the journey | Q2 – Purpose of the journey |
| | | Q3a – Transport modes used for the last overseas journey made | |
| | | Q3b – Description of actual journey (stages and modes used) | |
| | | Q4 – How often journey made between the same two points in last 12 months | Q3 – Frequency with which this journey made in last 12 months |
| | | Q12 & 13 – Preferred main mode and most frequently used main mode | Q10 – Mode used more often for this journey |
| **Potential for modal transfer** | Do people realistically consider alternative modes when planning travel? | Q6 – Are alternative modes considered? | Q5 – Are alternative modes considered? |
| | | Q7 – Alternative modes considered and reasons | Q6 – Alternative modes considered and reasons |
| **Pricing and impact on modal transfers** | To what extent is price a controlling influence? CPE calculation | Q8 – Cost/Price of each segment | Q7 – Cost/Price of each segment |
| | | Q9 –Price changes needed for alternatives to be taken up | Q8 –Price changes needed for alternatives to be taken up |
| **Safety and accident risk perceptions** | Direct statements about the role of accident safety in the decision making process and context from other factors | Q5 – Ranking of top 5 important issues influencing how to make the journey (1=Most and 5=Least) | Q4 – Ranking of top 5 important issues influencing how to make the journey (1=Most and 5=Least) |
| | | Q10 – If safety important whole or main part of the journey considered? | |
| | | Q11 – Factors which may cause a reconsideration of travelling (delays, bad weather, security measures, long queues) | Q9 – Factors which may cause a reconsideration of travelling (delays, bad weather, security measures, long queues) |
| | | Q14a– Personal security as a deciding factor (which mode?) | Q11a – Personal security as a deciding factor (which mode?) |
| | | Q14b – Risk of accident as a deciding factor (which mode?) | Q11b – Risk of accident as a deciding factor (which mode?) |

| **Type of question** | **Role of responses** | **consumer*data* Survey Questionnaire** | **Snowball Survey Questionnaire** |
|---|---|---|---|
| | | Q15 – Impact of adverse weather (air, rail, car) | Q12 – Impact of adverse weather (air, metro/local rail, LDR, car, bus/coach, taxi, ship/ferry) |
| | | Q16 – Most important selection factors (Ranked Most important, Second Most important and Least important) | Q13 – Most important – personal security or accident risk? |
| | | Q17 – Risk factors most likely to affect modal choice | |
| | | Q18 & 19 – Modes used for journey considered safest: used and overall safest. Maximum of 2 modes selected in each case | Q14 – From modes used which modes considered the safest (Rank 1-3 with 1 Safest and 3 Least safe) |
| | | Q14, 18 and 19 – Comparative assessment | |
| **Other** | Profiles and specific comments from respondents | Q20 – Additional comments from respondents | Q15 –Profile of respondent: Occupation, Age, Gender, Country of residence<br>Q16 - Additional comments from respondents |

*Table 7-1: Overview of* **consumer***data and snowball survey questions*

The questions in the expert questionnaire were for long distance journeys (greater than 200 km) and broadly categorised into the following topics: impact of major accidents; modal choice; travel behaviour; and (optionally) organisation profile of the expert. The experts were asked their opinions under each of the topics and also what they thought public perceptions in relation to modal choice and travel behaviour are. Table 7-2 provides the questions in more detail.

| Question Category | Role of responses | Expert Questionnaire |
|---|---|---|
| **Impacts of major accidents** | Are there any changes in public behaviour in the aftermath of high profile accidents? | Q1 – Impact of high profile accidents on public travel behaviour (Scale from Strongly Agree to Strongly Disagree or No Change options)<br>Q2 – Is the behaviour change in transport modes and/or operator?<br>Q3/4 – Duration of change in modal shift/operator (Scale from few weeks to permanent) |
| **Modal choice and accident risk perceptions** | Do people realistically consider alternative modes when planning travel?<br>Direct statements about the role of accident safety in the decision making process and context from other factors | Q5/6 – Does the public take into consideration accident safety issues when selecting transport modes / carriers? (Scale from Very strong evidence to No evidence)<br>Q7 – Modes most affected by accident safety considerations<br>Q8 – Evidence that safety has a higher priority than other factors? (Scale from Very strong evidence to No evidence)<br>Q9 – Influence of government in modal change? (Scale from Strong influence to No influence)<br>Q10 – Impact of age and gender in transport safety planning |
| **Travel behaviour** | Public travel behaviour and their view on safety | Q11 – What are the top 3 factors public considers when considering mode to use? (Rank 1-3 with 1 being the highest)<br>Q12 – How often do people consider alternative modes?<br>Q13 – Which modes the public perceives to be the safest (Rank from 1-8 with 1 being the safest)<br>Q14 – Influence of safety as a factor in long run for developed/developing countries |
| **Organisational Profile** | Optional | Name, organisation, position, main modes used in work, country/countries of work |
| **Other** | | Q15 – Specific comments from respondents |

*Table 7-2: Overview of expert survey questions*

The characteristic of the samples were examined using mainly descriptive statistics such as frequencies, significance testing through Pearson's chi-square, and determining CPEs. Data were prepared for SPSS using Excel in which free text responses were classified into manageable categories and unusable responses treated to ensure coherent output.

## 7.2 CONSUMER DATA SURVEY

This section considers survey findings from the web based questionnaire (described in Appendix B.1.1, Figures B.1-B.7). This was developed in conjunction with **consumer***data*, a travel survey organisation, sent to their database of 260,000 mainly leisure travellers and was completed in March/April 2013 *(n=203)*. Initially an attempt was made to conduct real time, in-person questionnaires at airports and on board trains using random sampling. The permission of airport authorities and train operating companies was sought for this but was not forthcoming despite several attempts due to security and confidentiality concerns. The web based survey through **consumer***data* was considered the next best option. The advantage of this approach was that it invited responses from a large database of travellers, from a wide range of UK locations. This organisation has considerable experience in travel surveys over a number of decades and provided advice on the types of questions that could reasonably be asked in such surveys.

There were some overall limitations to the **consumer***data* survey which need to be noted. From the outset it was understood that the survey would address predominantly leisure travellers from the UK and would therefore have a large bias towards air travel because of limited alternatives. It was decided to proceed with this nevertheless because of the advantages and to use a separate survey (snowball questionnaire) to ask very similar questions to a more business/work traveller oriented sample with greater coverage of continental Europe, thus providing a more complete picture overall. Although the sample obtained generally used air travel for the main stage of the journey and there were limited long distance alternatives, it did yield a wide range of access mode travel and alternatives were normally given for these journey stages along with reasons for the choice. **consumer***data* were requested to seek socio-demographic information as part of the survey but were unwilling to do so because of confidentiality concerns. This limits the degree which results can be contextualised.

Prior to the survey an announcement was made in an issue of CD-Traveller that a web based survey would be available to complete. The announcement summarised the survey's aims and the type of journey being examined. It was then sent to participants with confidentiality assurances to increase respondent interest. There was a follow up a few weeks later followed by a final reminder another few weeks afterwards. As the survey was web-based it was presented as a University of Westminster questionnaire with the appropriate design and logo. To further increase respondent interest an incentive in the form of two airline tickets for randomly selected respondents was offered and subsequently provided. Non-responders to the initial survey were contacted two times to encourage them to participate.

### 7.2.1 Journey characteristics

Respondents were asked for the location of the origin and final destination for their journey using free text entries. For presentation purposes a regional classification was applied to the responses to limit the range of outcomes for display. The regional classification used was based on the CAA Passenger Survey, as nearly all of the respondents used air travel on one segment of the journey. It conceals some of the detail of journeys but this is for presentational overview and to allow a high level classification of user locations. It also allows for illustrative comparisons with the CAA statistics.

From the 203 respondents the origin locations were relatively well distributed with just under 30% in the South East and 16.3% in the North West, and Scotland, the third largest start location, having about 13%. The vast majority of the journeys were outbound from the UK with only one journey being a ‘return’ from Gran Canaria. There were eight non responses to this specific question, representing 4% of the total. The regional breakdown of journey origin is illustrated along with the CAA (2012) breakdown by region of airport origin in Table 7-3. While it is recognised that the CAA data is not directly comparable with the survey journey origin data, the broad pattern of regional coverage is similar.

For example the CAA data indicates that 51.3% of UK leisure traffic emanates from the South East (which includes the major airports of London Heathrow, Gatwick, Stansted and Luton). There is also a large amount of leisure traffic from the North West through Manchester airport. Similarly, the combined traffic through East and West Midlands represented significant leisure traffic.

| **Overall Journey Start*** | **Frequency consumerdata survey** | **% consumerdata survey** | **% CAA survey** |
|---|---|---|---|
| South East | 59 | 29.1 | 51.3 |
| South West | 13 | 6.4 | 6.5 |
| West Midlands | 17 | 8.4 | 5.5 |
| East Midlands | 8 | 3.9 | 4.6 |
| East of England | 3 | 1.5 | 9.1 |
| North East | 5 | 2.5 | 0.4 |
| Yorkshire & Humber | 8 | 3.9 | 3.1 |
| North West | 33 | 16.3 | 7.0 |
| Wales | 11 | 5.4 | 2.3 |
| Scotland | 27 | 13.3 | 10.1 |
| Ireland | 2 | 1 | 0.1 |
| UK | 8 | 3.9 | - |
| Gran Canarias | 1 | 0.5 | - |
| No Answer | 8 | 3.9 | - |
| **Total** | **203** | **100** | **100** |

***Based on CAA Passenger Survey Classification Coding 2012**

*Table 7-3: Regional breakdown of journey origins*

For the destinations (Table *7-4*), almost 60% were in Southern Europe and most of these were in the Canary Islands. Of the remainder, the three next most frequent destinations were Western Europe, Asia and North America, each with about 7% of the total. For the destinations there were only three non-responses, representing 1.5% of the total.

| Overall journey destination | Frequency | % |
|---|---|---|
| Western Europe | 14 | 6.9 |
| Eastern Europe | 7 | 3.4 |
| Southern Europe | 115 | 56.7 |
| Africa | 12 | 5.9 |
| Middle East | 5 | 2.5 |
| Asia | 15 | 7.4 |
| Australasia | 2 | 1 |
| North America | 16 | 7.9 |
| South America | 2 | 1 |
| Central Americas and Caribbean | 12 | 5.9 |
| No Answer | 3 | 1.5 |
| **Total** | **203** | **100** |

*Table 7-4: Regional breakdown of journey destinations*

As expected, the main purpose of journeys was for holidays with over 83% in this category. Of the remainder, just under 6% were business trips and just over 5% Visiting Friends and Relatives (VFR). The results are provided in Figure 7-2 and compared with CAA statistics in Table 7-5.

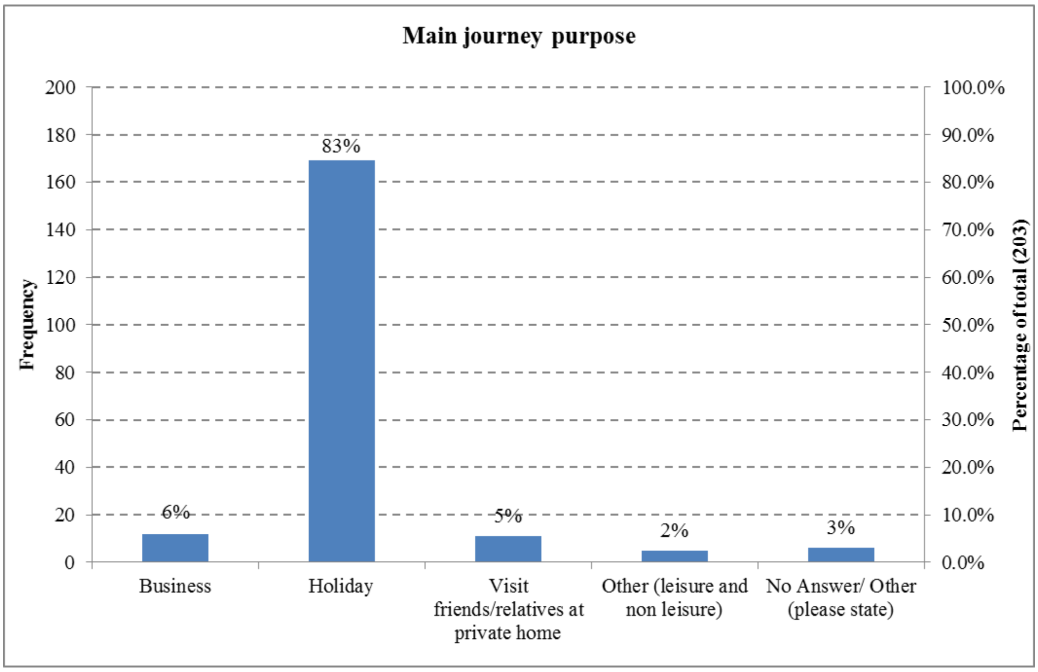

*Figure 7-2: Main journey purpose*

Comparing the journey purpose of the electronic survey conducted with CAA (2012) results, overall, the large proportion of journey purpose is for leisure travel. Some airports (London Heathrow and London City) have a larger proportion of journeys made for business purposes, whereas the more regional airports (East Midlands and Bristol) have more leisure travellers (see Table 7-5 below). In the **consumer***data* survey conducted there is a skew towards leisure passengers, since the databases used have predominantly leisure travellers.

| CAA Passenger Survey 2012 Journey Purpose | | |
|---|---|---|
| **Airport** | **Business Passengers %** | **Leisure Passengers %** |
| Birmingham | 18.0 | 82.0 |
| Bristol | 13.6 | 86.4 |
| Cardiff | 14.0 | 86.0 |
| East Midlands | 9.4 | 90.6 |
| Exeter | 18.0 | 82.0 |
| London Gatwick | 15.3 | 84.7 |
| London Heathrow | 29.8 | 70.2 |
| London City | 54.0 | 46.0 |
| Luton | 15.5 | 84.5 |
| Manchester | 18.6 | 81.4 |
| Stansted | 14.6 | 85.4 |
| **Survey (for comparison)** | **6** | **94** |

**Source: Compiled from CAA (2012) Survey Data**

*Table 7-5: Comparison of journey purpose with the CAA 2012 statistics*

In addition to source and destination, the survey also requested information about the modes of transport used for the journey, with respondents again being allowed to provide free text (Figure 7-3).

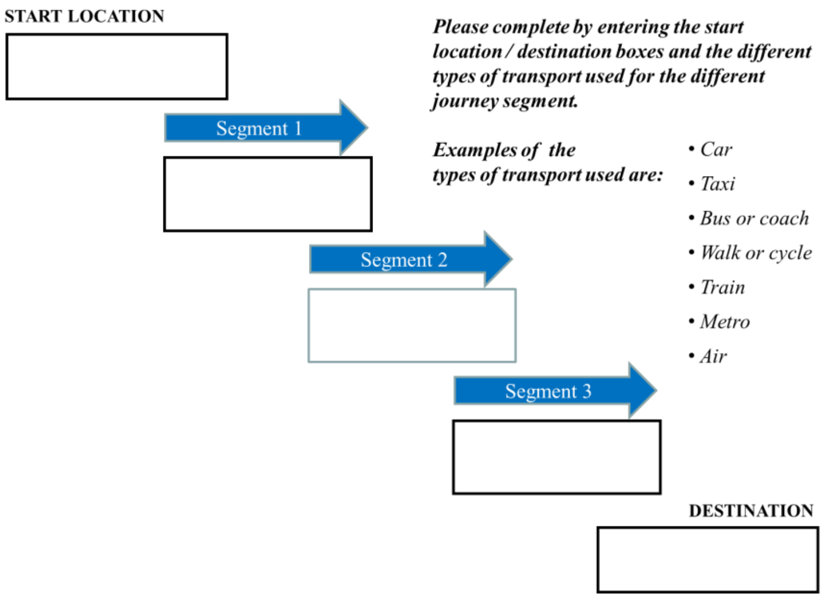

*Figure 7-3: Input request on journey modes used*

The origin/destination inputs were cross tabulated against the initial journey description to validate and this allowed the information to be completed properly where there were inconsistencies in the original entries. The respondents were allowed to provide only three modes, though in a number of cases they continued to provide additional modes instead of a destination. This was a limitation of the questionnaire design which did not allow space to fill more entries for more than three journey segments. Again, cross tabulating with previous origin/destination responses was helpful. Responses were highly consistent with only a few discrepancies, with a cross tabulation in SPSS conducted to validate. These discrepancies only reflected more detail being given in one response compared to the other. Depending on the journey profile, air travel was present in almost 100% of cases, confirming the information provided for the previous journey. The most frequently used access modes were car/taxi and rail/metro respectively.

The majority of respondents' journeys had air travel as the main mode with a variety of access modes to and from the airport. Accordingly, air is described as the 'main mode' and is mainly represented in the second stage of journeys where 87% are air. In 17% of cases there are two initial access modes and air travel is then in the third stage. 4% of respondents indicated air for both stage 2 and 3, suggesting interconnecting flights. For rail/metro there is a single instance of multiple access where a respondent has used rail/metro for the access stage and main stage of the journey.

Cross tabulating using SPSS showed a range of successive access modes. Bus/coach users in stage 2 of the journey primarily used it as a means of travelling from rail/metro or car/taxi to an airport. The most common combination overall was car/taxi to the airport in stage 1, followed by air travel in stage 2 and car/taxi in stage 3 from the airport to the final destination. The use of bus/coach in the third stage is thought to be airport to hotel transfers given that the majority of travellers were holidaymakers. The small number of entries in stage 4 should be treated with caution since, as noted above, space was not available for respondents who completed journeys with two access modes at either end of the journey (Figure 7-4).

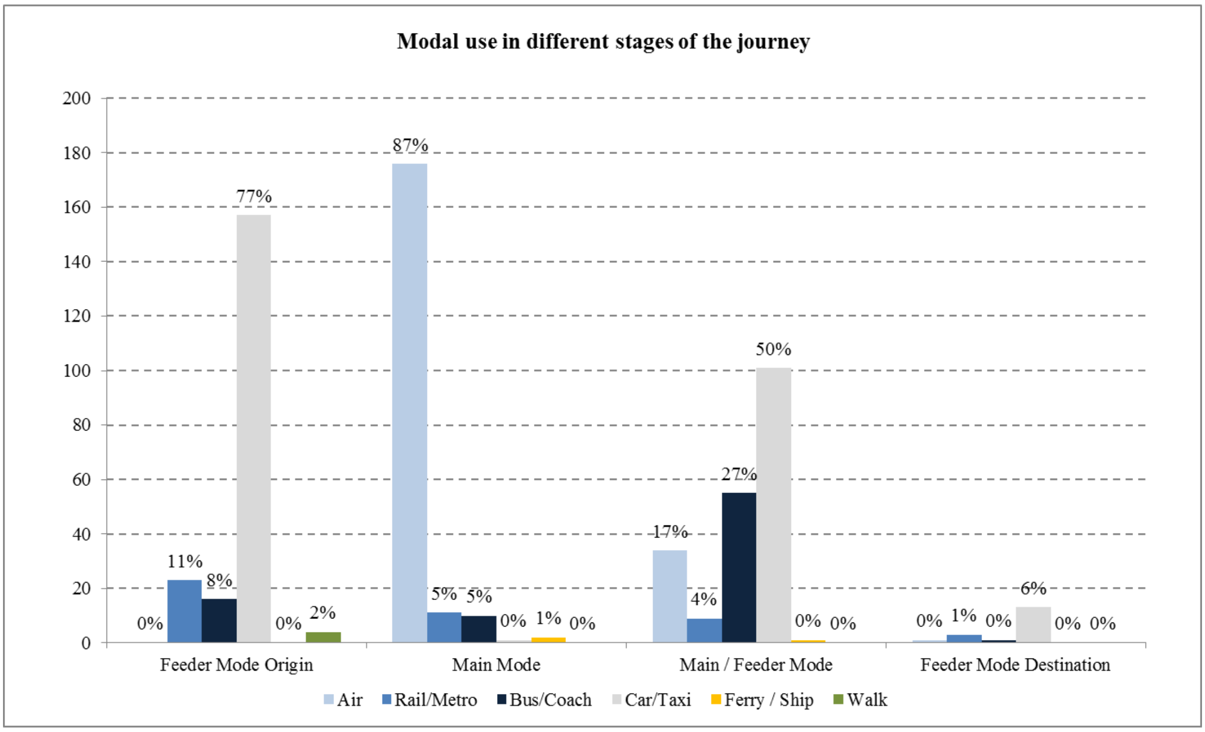

*Figure 7-4: Summary of modes used by respondents at different stages of the journey*

### Frequency of making journey

This information was not included in the analysis because the responses were ‘no answer’ in more than 99% of cases. This reflects the fact that for holiday travellers a return to the same destination within a 12 month period is unlikely.

### Frequency of flying

Respondents were asked about their frequency of flying (Figure 7-5). This question acknowledged the fact that most of those replying had recently completed a journey centred on a flight. The options provided were as follows:

- First flight
- 1-4 times a year
- 4-12 times a year
- Over 12 times a year

In most cases this was a holiday flight. Responses to this question were over 80% in the 1 to 4 times per year category which may reflect the typical profile of holiday travellers. No respondents replied with 4 to 12 or more than 12 flights per year. The remaining 18% did not answer the question.

The frequency of flight responses for a low annual flight number in the **consumer***data* survey are similar for instance when broadly compared to NTS (DfT, 2013a), as expected. The NTS data includes persons that did not fly at all during the year and all age groups are randomly selected. There is intercept bias in the **consumer***data* survey as it does not consider persons who did not fly at all, and, among those who do fly, is likely to intercept the more frequent flyers. Hence taking only the sub-section of those that travelled by air in the NTS survey (DfT, 2012a), 88% of the respondents said they had made at least one to three international flights in the last 12 months.

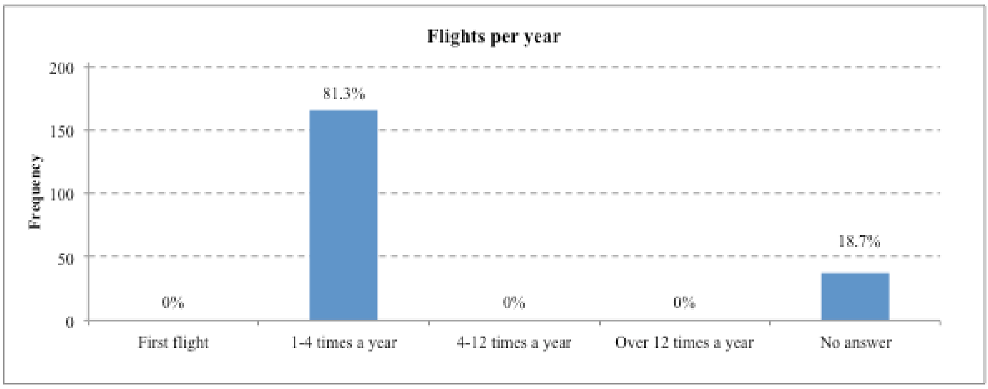

*Figure 7-5: Number of flights per year for consumer preference survey respondents*

**Transport modes used for the last overseas journey you made**

Respondents were also asked about the last overseas journey they had made and the options provided were the standard transport modes. In this case, selection buttons were used, so a yes indicates that the button was clicked for a specific mode while a no answer effectively means ‘no’.

The aim of asking about the most recent journey was to provide some context to the actual journey. The responses are presented in Figure 7-6, and the normalised percentage share of total possible observations per mode excluding air in Figure 7-7. The percentages were calculated based on the total observations for each mode, excluding air, divided by the theoretical maximum of all possible observations (i.e. 4 x 203 respondents equalling 812). Almost all of the respondents, over 99%, said that their previous journey had involved air travel. There was no restriction on the number of boxes the respondent could tick. Car/taxi was the second most frequent at 77% and rail/metro third at just under 20%. Cycling had a 0% response while walking, for which it is difficult to define a minimum qualifying distance, was included by 11%.

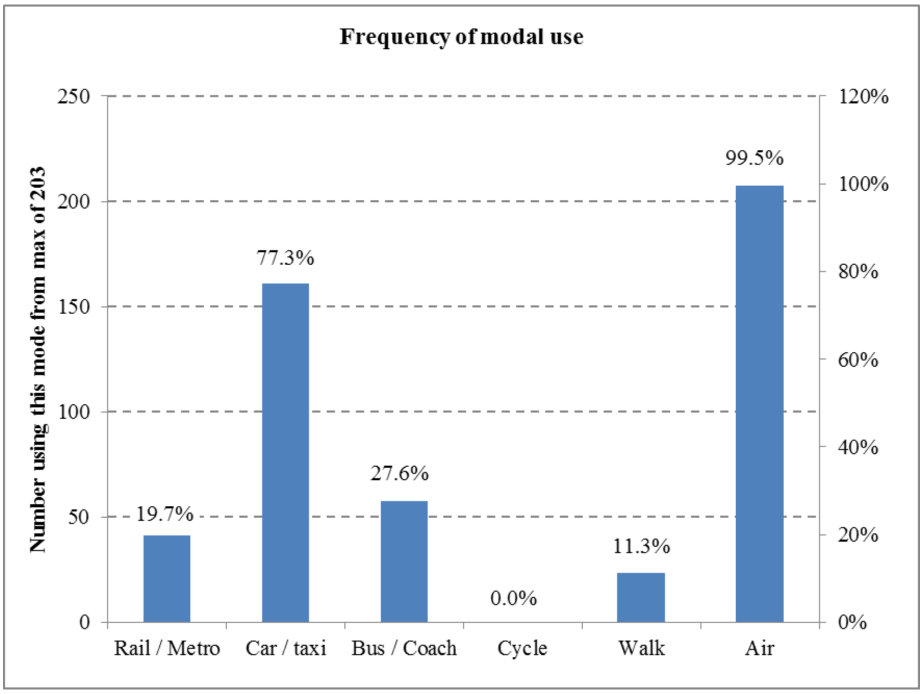

*Figure 7-6: Frequency of use for transport modes*

Comparing the survey data with the CAA (2012) data on modes of transport used in their survey, it is clear that access modes used to reach regional airports (Birmingham, East Midlands, Bristol, Exeter) tended to be more private transport modes (car/taxi), at between 80-90%, while at the larger airports in the South East there was almost a 50% use of public modes of transport due to greater accessibility and availability.[47]

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[47] CAA Passenger Survey 2012, Tables 7.1 and 7.2. The results are based on a departure survey of passengers.

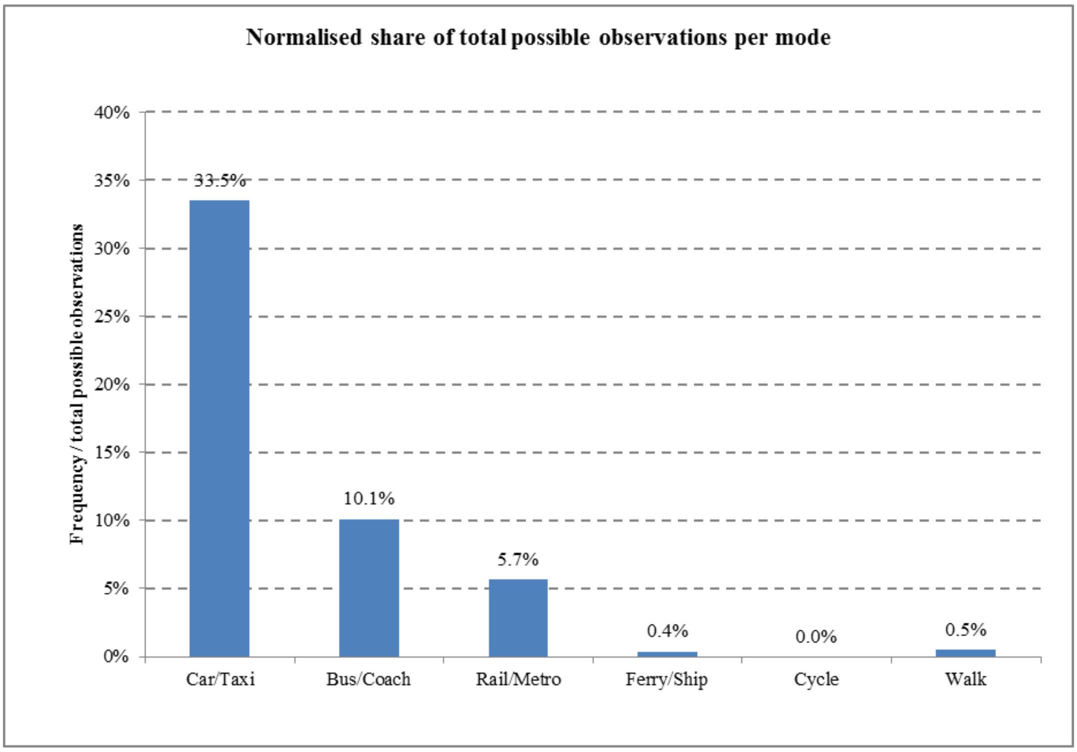

*Figure 7-7: Normalised share of total possible observations per mode*

**Preferred main mode and most frequently used main mode**

This question asked for the main part of your journey which type of transport was preferred and secondly which was the most frequently used mode (Figure 7-8).

This question covered the main mode of the journey. It was originally included for a wider survey of a range of route types but here the response confirms the relatively uniform travel itineraries of the respondents, which concentrated on medium to long distance holiday travel.

Following on from the previous question, this one asked in a more general sense what the preferred mode for the main journey mode was, i.e. not specifically to the journey being undertaken. In this case the results are very similar, though car/taxi is slightly more prominent here. This again fits with holiday travel which tends to be dominated by air travel, but with car/taxi as the prominent access mode.

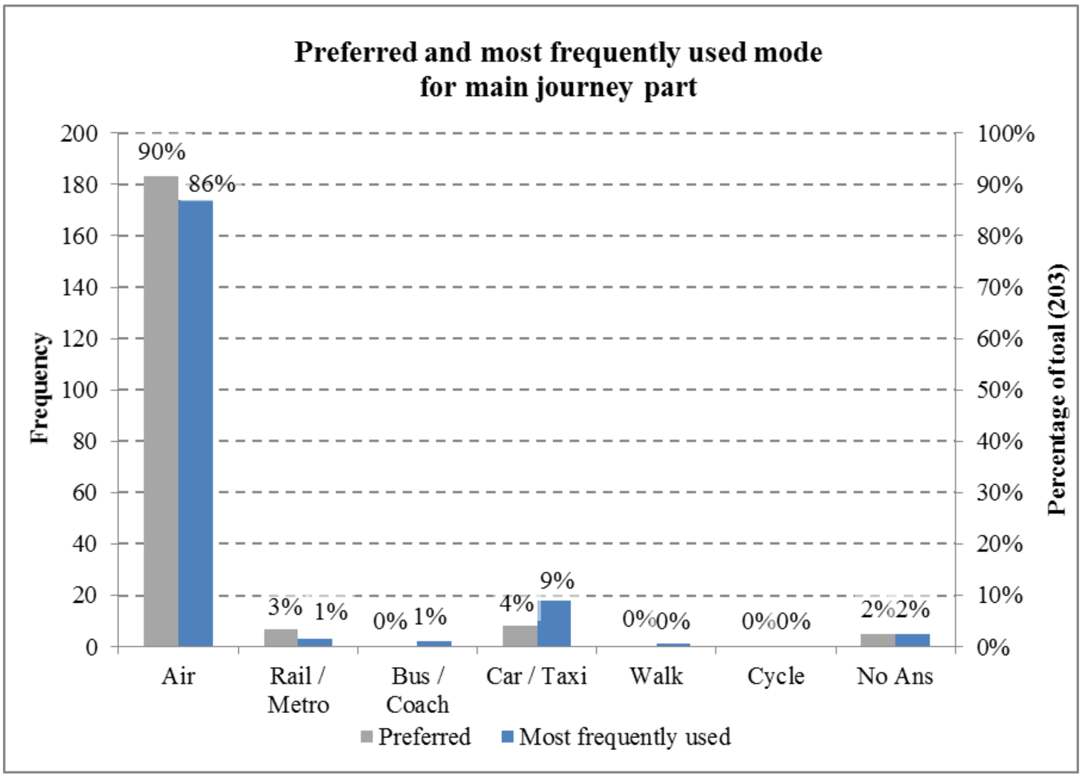

*Figure 7-8: Preferred and most frequently used mode for main part of journey*

### 7.2.2 Potential for modal switching

Having explored the specific journey characteristics, the next step was to explore the potential for alternative modes to be considered. The alternative modes that are considered and the possible motivations for switching are addressed in subsequent questions.

The initial question was simply to ask what alternative modes had been considered for any of the journey legs and, hence, to start exploring the basis for CMS. The fact that 63% of respondents did not look at an alternative mode suggests that alternatives are not often considered. This outcome does, however, need to be interpreted with some care. This is because many of the destinations are Southern European holiday destinations (e.g. Canary Islands) and in other cases Asia, North America or other long distance destinations. As a result there is rarely a viable alternative to air travel as the main mode for the journey, either on schedule or cost grounds (Figure 7-9).

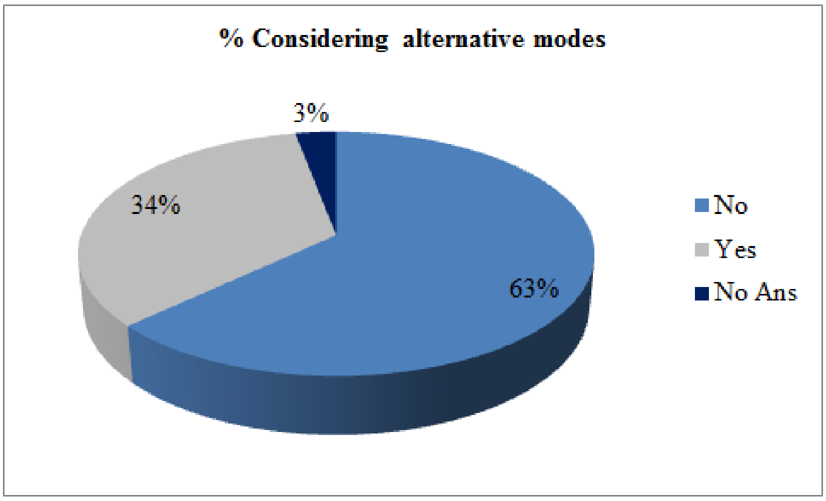

*Figure 7-9: Percentage of respondents considering alternative modes*

**Alternative modes considered and reasons**

Respondents were then asked if they would have considered an alternative means of transport for any part of their journey and if so, what the mode would have been and the reasons behind the selection. The following format was used:

| Current Mode | Possible alternative mode | Price | Convenience | Safety | Availability | Other |
|---|---|---|---|---|---|---|
| | | | | | | |

Referring to those who did consider an alternative mode together with those considering alternatives for the more minor ‘access’ modes, this question seeks to identify which modes could be substituted and the reasons that could drive such a substitution. For up to four cases the question provided free text for current and possible alternative modes and then allowed for ticks to describe the reasons. Free text responses were later classified into the main modal groups used in the analysis.

It is important to note that the ‘no’ answer rates for modes 1 and 2 were 52.7% and 82.3% respectively and the response rate for mode 3 was so low that the analysis was not included for this case. This reflects the fact that only 34% of the total respondents said they would consider an alternative mode.

For the mode 1 response, air travel represented only 11.8% of cases, which again reflects the lack of alternatives for the long distance holiday travel that is mainly the subject of the responses. Of the remainder the most prominent modes considered were car/taxi at 25.6% followed by rail and bus at the much lower levels of 5.4% and 3.9% respectively.

Rail was considered as an alternative in 16.7% of cases with car/taxi at 13.8%. The main reasons for changing were convenience at 27.1% and price at 23.2%. Safety was only given as the reason in 2.5% of cases.

The numbers entering a second mode alternative were much more limited and these were quite evenly distributed. Here, car/taxi travel was the most commonly specified mode for substitution but only at 7.4% while air travel was second at 4.9%. Of the alternatives, car/taxi was the greatest at 6.9%. Once again, convenience at 11.8% and cost at 7.9% were the top reasons with safety only reaching 1.5% on this occasion.

Figure 7-10 summarises the results for the mode alternatives, giving the current mode on the x axis with the possible alternatives given in each case shown by the coloured bars.

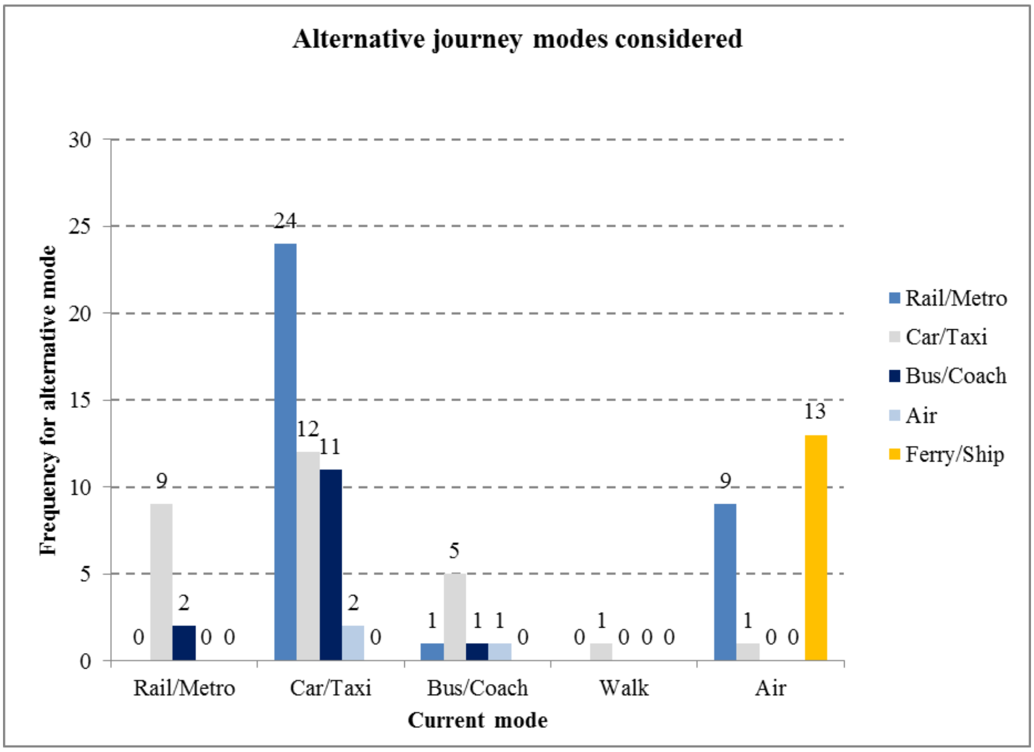

*Figure 7-10: Alternative modes considered*

**Substitution for Air**

For users who currently use air, two main alternative modes were proposed, rail and ship/ferry (Figure *7-11*). Of the 24 respondents who would be willing to switch from air as the current form of transport, 54% would switch to ship/ferry, 38% to rail and 4% to car/taxi. Given that most respondents were UK based, it is assumed that these responses refer mainly to cross channel ferries; for example, for a European touring holiday by car as opposed to going directly by air travel. The respondents' answers were compared to the origins and destinations they had indicated. This showed that the comparisons given were not related to the origin/destination described elsewhere in their response, for which the users could not have used any primary mode other than air. It has, therefore, been assumed that in Figure *7-11* the alternatives are what the users, in general, would prefer and not for the actual journey they have undertaken.

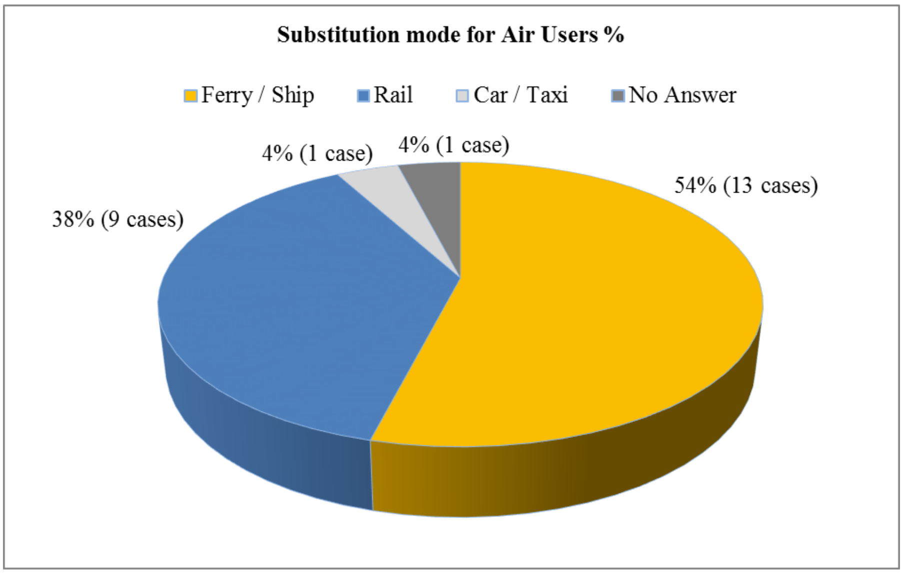

*Figure 7-11: Substitution for air users*

### Reasons for responses

The reasons given for choosing an alternative at each of the four levels plus other category are as shown in Figure 7-12 and this is mainly driven by convenience.

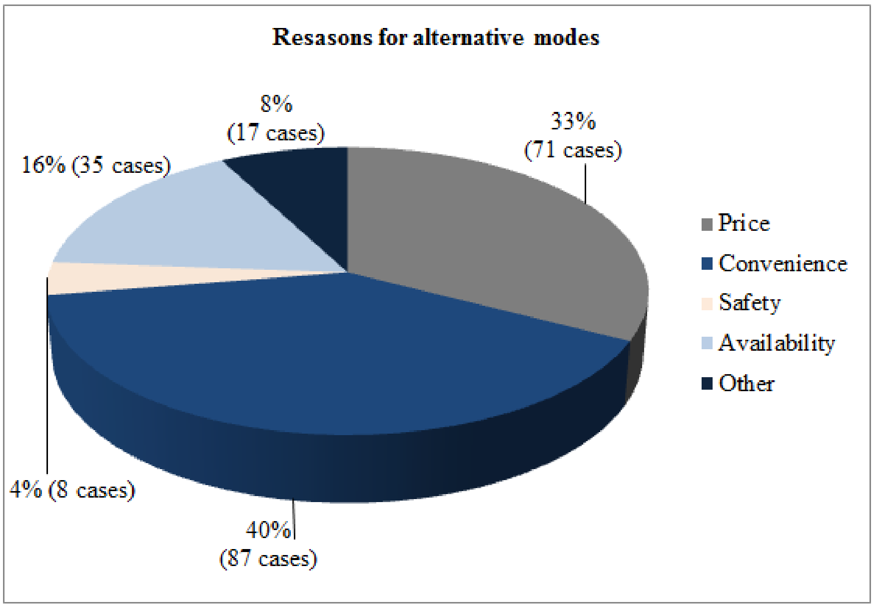

*Figure 7-12: Reasons given for potentially selecting alternative modes*

### 7.2.3 Safety and accident risk perceptions

Having explored the wider modal shift drivers, this section considers the safety related factors which could drive modal shifts.

Respondents were initially asked to rank the top 5 issues they considered most important when deciding how to make the specific journey under consideration, including all stages from start to finish, in order of importance.

The first question in this group aimed to determine overall priorities when selecting transport modes. It was posed by asking respondents to identify the top 5 issues for them when selecting journey modes. As a result, care is needed when interpreting the results because the 'least' important is in fact the 5th most important out of the 9 options given.

Figure 7-13 shows the breakdown of the factors specified as most important. Here price has the highest frequency with 31% of responses giving this as the top priority. Time taken and schedule were almost equal second, with 13.8% and 13.3% respectively. Accident safety was specified as a top issue by only 4.4% of cases, just over half of the 8.4% specifying personal safety as the top priority. Personal safety rather than accident being considered as a priority for respondents may be attributable to perception of risks in recent years due to the combination of extensive media coverage of threats to personal security from acts of terrorism and crimes such as muggings when travelling. Personal safety and security messages can often highlight risks without putting them into perspective, and the nature especially of public transport, which requires passengers to share sometimes crowded and uncomfortable spaces with strangers.

Accident safety priorities were 2.0% as second priority, 2.0% for third priority and 4.4% and 4.9% for fourth and fifth priority. The other options were relatively evenly distributed with no major peaks at the second to fifth levels, although the 'no answer' frequency did increase towards the 30% mark as people exhausted their priorities in some cases before they got to five options.

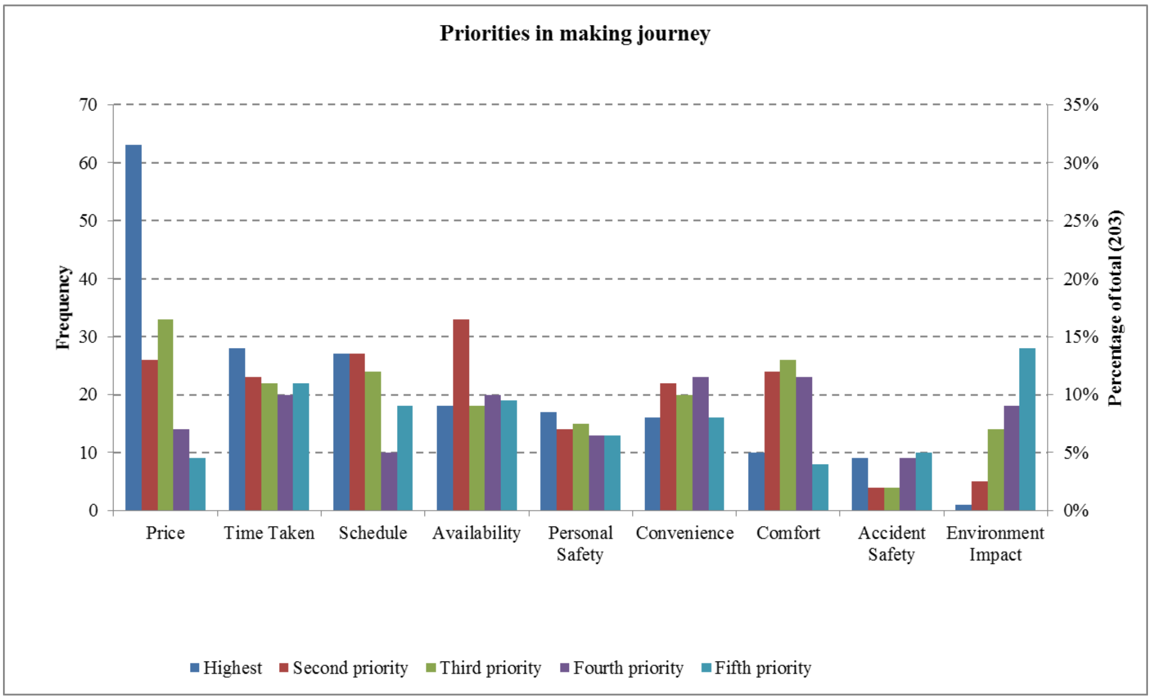

*Figure 7-13: Priorities in making the journey*

It is also possible to express these outcomes as single values by calculating weighted overall values (Figure 7-14). By applying a weight of 5 to the frequency of highest ranking for a stated priority, 4 to the second highest and so on through to 1 for the fifth, priority-weighted totals are given. The outcomes are shown in the following graph. The main bars show the overall totals resulting, while the data labels show for each priority the results expressed as a percentage of the maximum total possible, i.e., 203 (the sample size) * 5 (the maximum weight). The percentages are thus individual percentages of the total of 203 and hence do not add to 100.

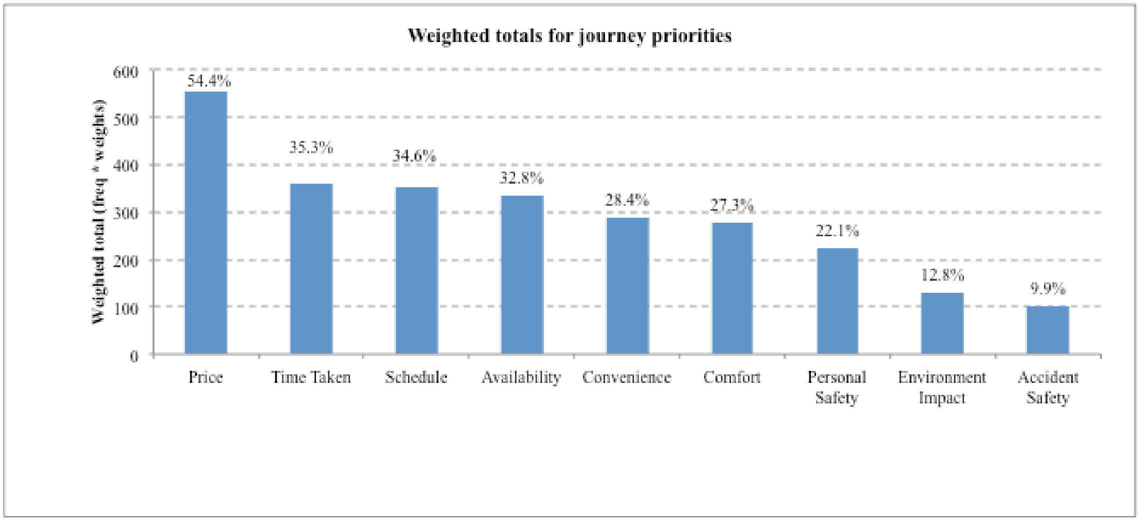

*Figure 7-14: Weighted totals for journey priorities*

### Importance of safety for door to door or main part of the journey

This question asked whether, if safety was an important issue for the journey, the respondent considered the whole journey door to door or just the main part. The question sought to understand whether travellers considered safety as an 'end to end' issue for the whole journey or simply considered the main mode, in this case largely air. Of the 69% who replied, 48% did consider the whole door to door journey safety.

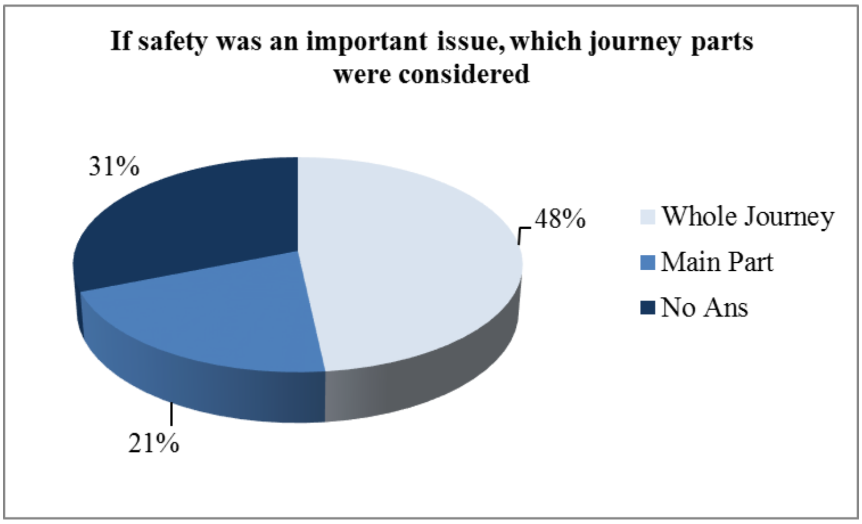

*Figure 7-15: Safety consideration for whole or only main part of journey*

### Causes of modal changes

This question asked if any of the following issues ever caused the respondent to re-consider which travel method they planned for a subsequent journey, compared to one where they experienced the problem:

- Severe delays (technical problems, shortage of staff)
- Bad weather (e.g. fog, heavy rain, snow)
- Security measures (inconvenience and comfort issues)
- Long queues at check in for rail or airports

This question was asked in a general sense to understand if any additional factors had driven consideration of modal change in the past, though no actual change in selection was required to answer yes. The questions were tick boxes so a yes is a positive response while a no answer is a no/not relevant. In summary the results are shown in Figure 7-16.

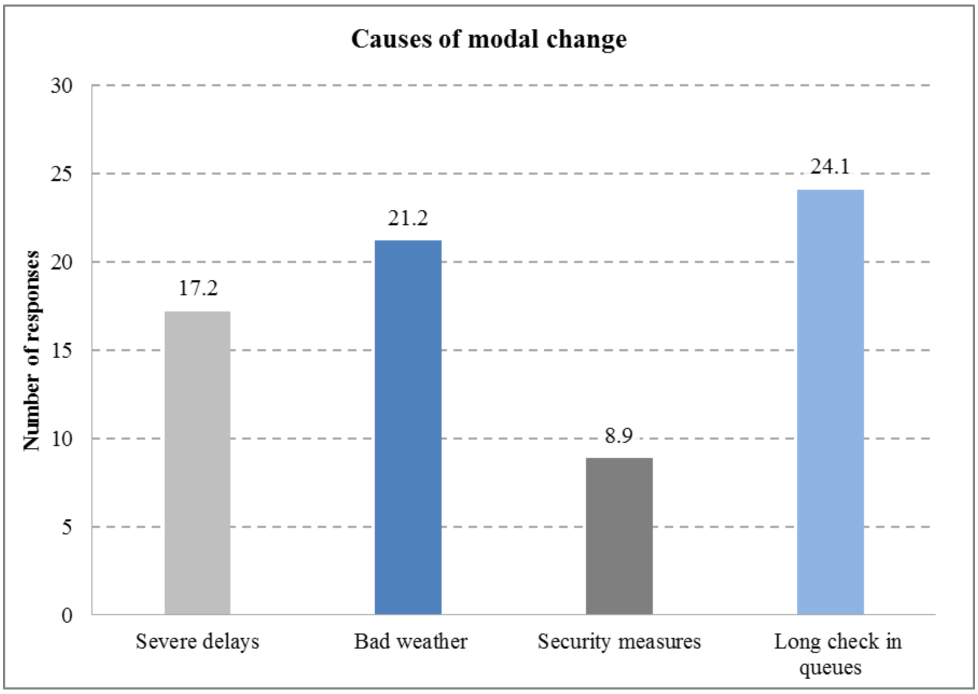

*Figure 7-16: Percentages considering suggested reasons for alternative modes for consumer survey*

This suggests that delays certainly motivate re-evaluation of transport modes, even if ultimately other reasons determine the final choice.

**Personal security as a deciding factor**

The question asked was whether personal security risk has ever been a deciding factor in choice of transport type for a journey. Respondents were asked to say yes or no for each of the standard mode combinations (Figure 7-17).

This question was asked partly to disguise the question about accident safety so that the answers to that question were more neutral. Personal security was an issue for 25.1% of air passengers, 14.3% of rail/metro travellers, 30% of bus/coach travellers, 18.2% of car/taxi users, 25.1% of those walking and 26.6% of those cycling.

The high level of concern for air travel was presumably centred on terrorism while concerns on other public transport were more likely to be motivated by more conventional forms of violence (e.g., muggings). Car/taxi travel raised the lowest levels of concern, though this may mask a significant difference between private cars and taxis for this issue.

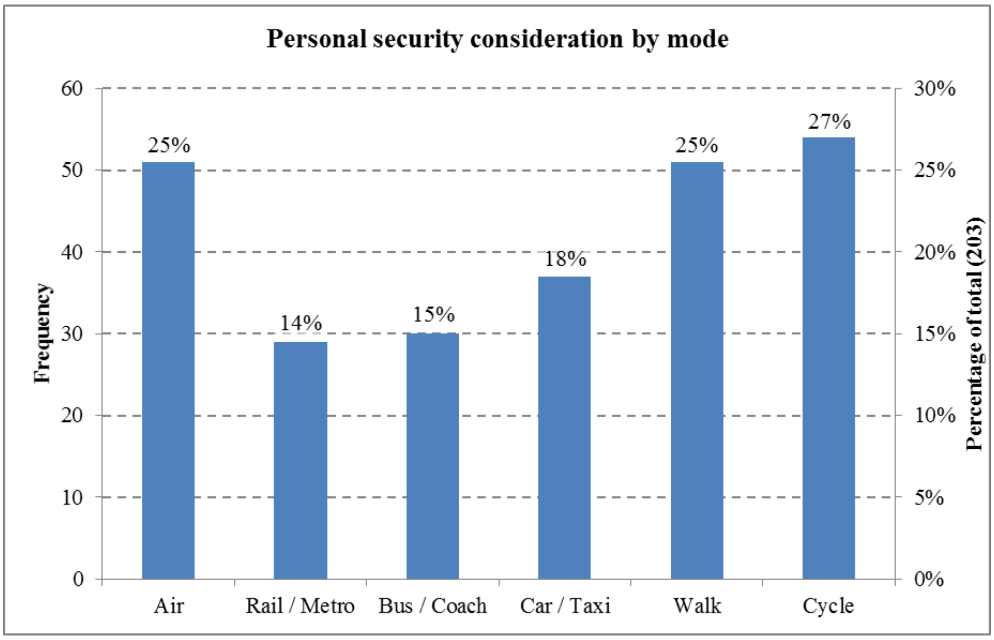

*Figure 7-17: Personal security as a consideration by mode*

**Risk of accident as a deciding factor**

The question examined whether accident risk has ever been a deciding factor in the choice of transport type for a journey (Figure 7-18).

This question is a key issue when considering the prospects for CMS for safety reasons, as it directly asks what the prospects are of making a modal change based on accident safety concerns. The outcomes in this case were 10.8% for air, 4.9% for rail, 10.8% for bus/coach, 12.3% for car/taxi, 9.9% for walking and, perhaps not surprisingly, 25.1% for cycling. These relatively low levels of concern also mirror the British Social Attitudes Survey (2013) expected levels of perceived risk with cycling and car use being highest and air and especially rail being lowest. Since 2005/06, only one passenger has been killed in a train accident DfT (2013e) while 59% of people responding to a British Social Attitudes Survey (DfT, 2013f) agreed or strongly agreed that it was too dangerous for them to cycle on the roads. The relatively low importance of accident risk as a deciding factor when travelling could mean that individuals are not concerned about safety per se since they rely on operators and providers to ensure safety standards are met and enforced. On the other hand individuals who are in control of a mode of transport (e.g. car) have the perception that they themselves are the safest, as noted in the additional comments from respondents for this survey (Appendix B-2).

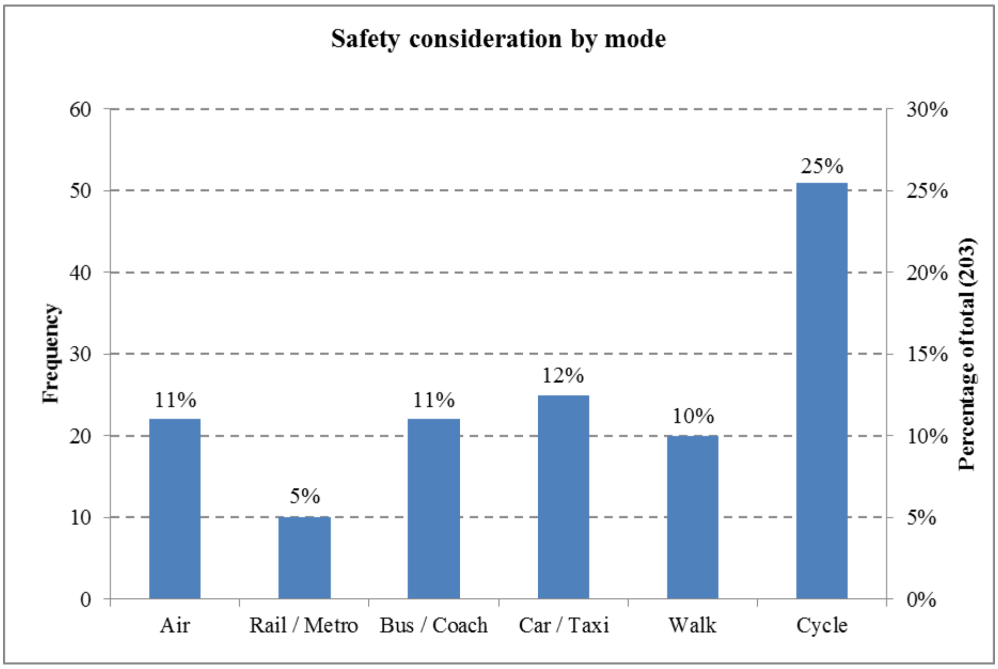

*Figure 7-18: Accident risk as a deciding factor by mode*

**Impact of adverse weather**

This question asked whether, if adverse weather conditions were likely to cause delays or to increase accident risk safety, the respondent would still be prepared to make the journey. For each option of air, rail and car respondents were asked to state yes, maybe or no (Figure 7-19).

For air travel the prospect of bad weather would cause 7.9% to consider not making the journey. For rail this is 11.3% and for car 28.1%. The extent of the bad weather would, of course, be a factor here since in some cases air and rail services could be curtailed in such conditions. It is also notable that the 'maybes' were 46.3%, 44.3% and 44.3% respectively which confirms that if conditions are bad enough, most respondents would consider alternative plans. The percentage values are individual percentages of the total of 203 respondents in each case and thus do not total to 100% overall.

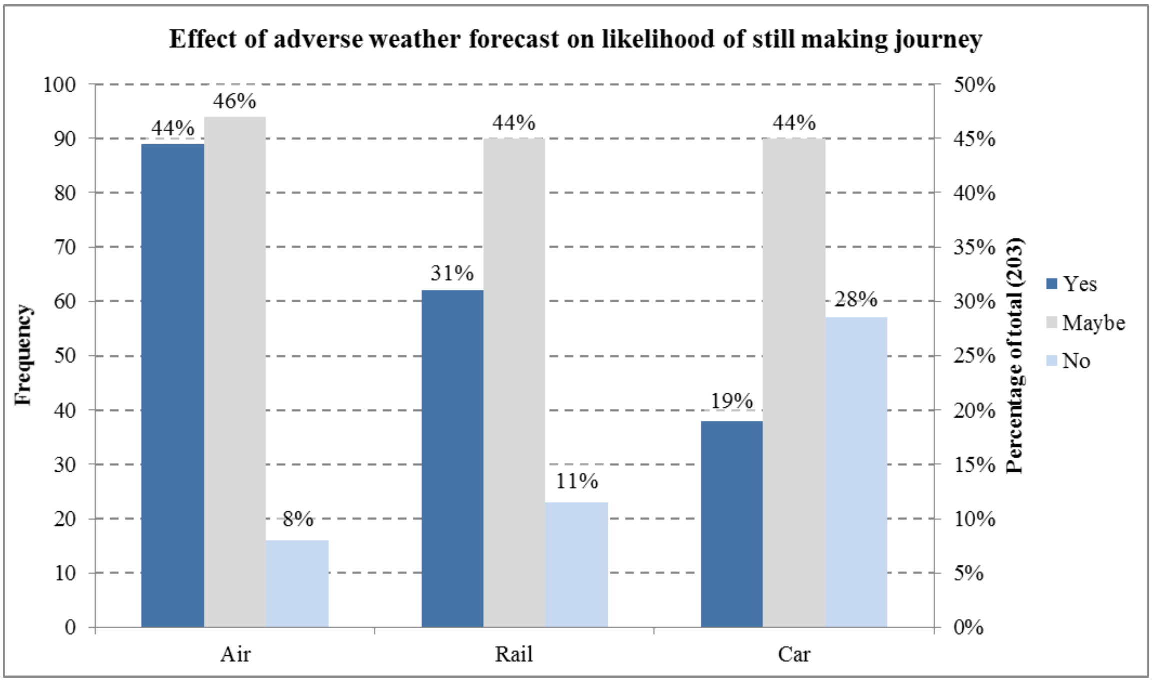

*Figure 7-19: Effects of adverse weather on likelihood of still making the journey*

### Most important selection factors

The respondents were asked the three most important factors which affected their choice of transport service in order of priority, with 1 being the most important and 3 the least important. The options provided were:

- Comfort of the journey
- Time or duration of the journey
- Cost of the journey
- Safety factors
- Catering facilities
- Other (please specify)

This question returned to the theme of the key factors behind the choice of journey mode. As in earlier questions, it should be noted that the 'least' important factor is, in fact, the third most important out of six. This question was answered by almost all respondents with very few 'no answers' (Figure 7-20).

The most prominent top priority factors were time/duration (39.9%), cost (36.5%) and comfort (17.7%). Safety was only given as top priority in five cases, i.e. 2.5% of total cases. Safety was second priority in 13 cases (6.4%) and third in 23 cases (11.3%). The last result shows that safety is an important 'background' concern once cost and convenience have been addressed, though even here it is well behind catering facilities, which was third priority in 70 cases (34.5%).

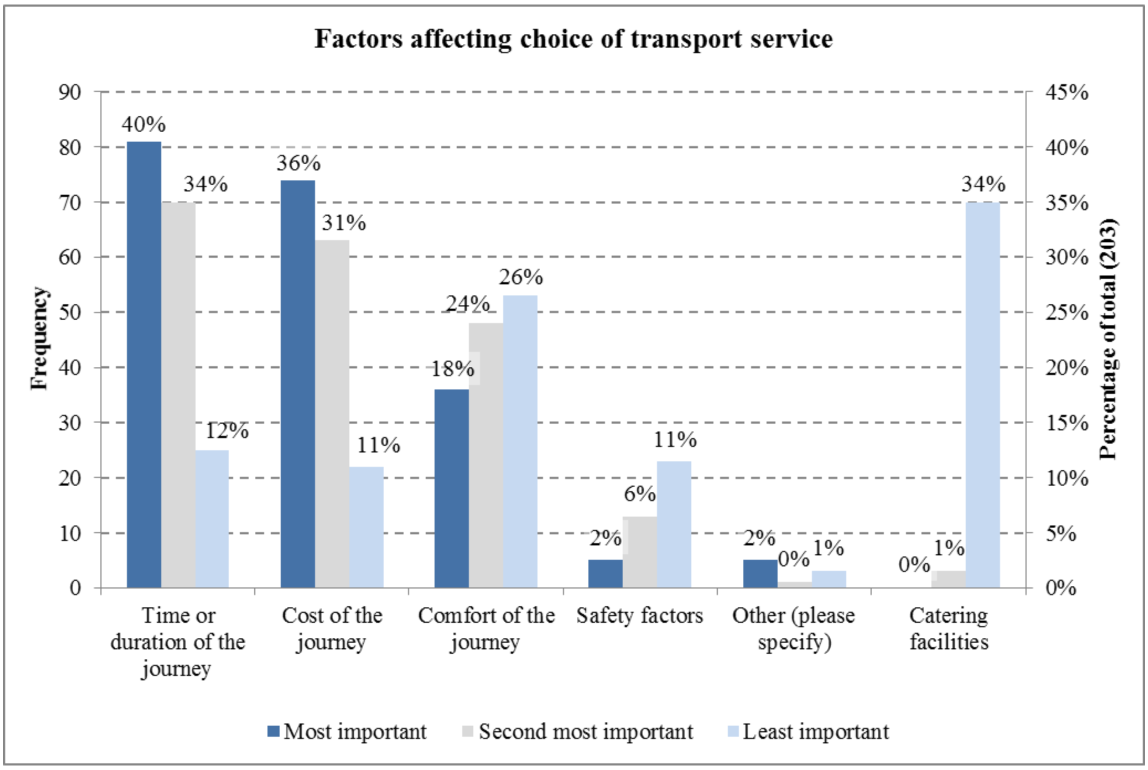

*Figure 7-20: Factors affecting choice of transport service*

**Risk factors most likely to affect modal choice**

Survey respondents were asked which risk type they personally consider more likely to affect their decision to travel by a particular type of transport.

- Personal safety (terrorist)
- Personal safety (mugging)
- Risk of a transport accident (safety)
- Other (please specify)

This question is an interesting counterpoint to the risk questions which asked separately about the impact of personal safety and accident safety on journey mode selection. In that case, personal security was highlighted as the more important concern (Figure 7-21). Here though, personal safety concerns are split into terrorist risks and mugging risks. As a result, accident risk is considered to be the second highest: at 35% of total risk just behind terrorist risk at 38.4%. Given the dominance of air travel with its protected environment this is perhaps an expected result. Nevertheless, mugging risks are also considered to be relatively high at just under 20%. These dominated the response with others at 2.5%.

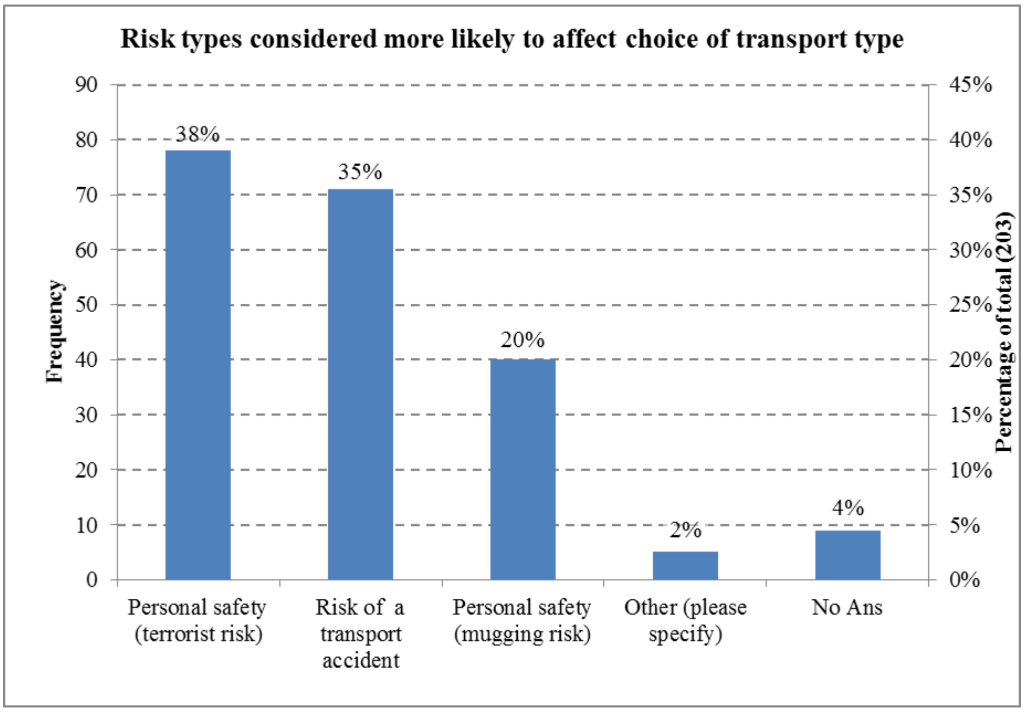

*Figure 7-21: Risk types most likely to affect selection of transport mode*

**Modes used for journey considered safest (used and overall)**

For the standard transport mode types, the following two questions were asked:

- Considering the types of transport you have used for this journey which do you think were the safest (less risk of accident)? (Maximum of 2)
- Which type of transport do you think in general the safest (less risk of accident) to travel? (Maximum of 2)

The earlier questions asked about the relative importance of accident safety concerns and found that these were comparatively low. Given these low levels, however, this question asked about the relative safety credentials of the different modes as applied to the journey in hand (Figure 7-22).

Air with 87.2% is considered to be the safest mode by quite a margin. The next highest was car/taxi with 31% while - surprisingly given earlier answers - rail/metro was third with 30.5%. Bus/coach travel was only seen as safest by 7.9%, worse than walking at 8.4% while cycling was at only 1.5%.

The second question followed from the safest mode used, but here the question is posed for the more general case, which would affect future decisions. Once again, air comes top with 86.7% considering this the safest mode, very similar to the 87.2% achieved in the question on the safest mode used.

Of the remainder, the split here between car/taxi and rail/metro is much different. Car/taxi is considered safest of the remainder by 36% while rail/metro only by 12.8%. Walking is similar at 9.9% but bus/coach is only 3.9%, only just ahead of cycling which is a fraction higher at 2%.

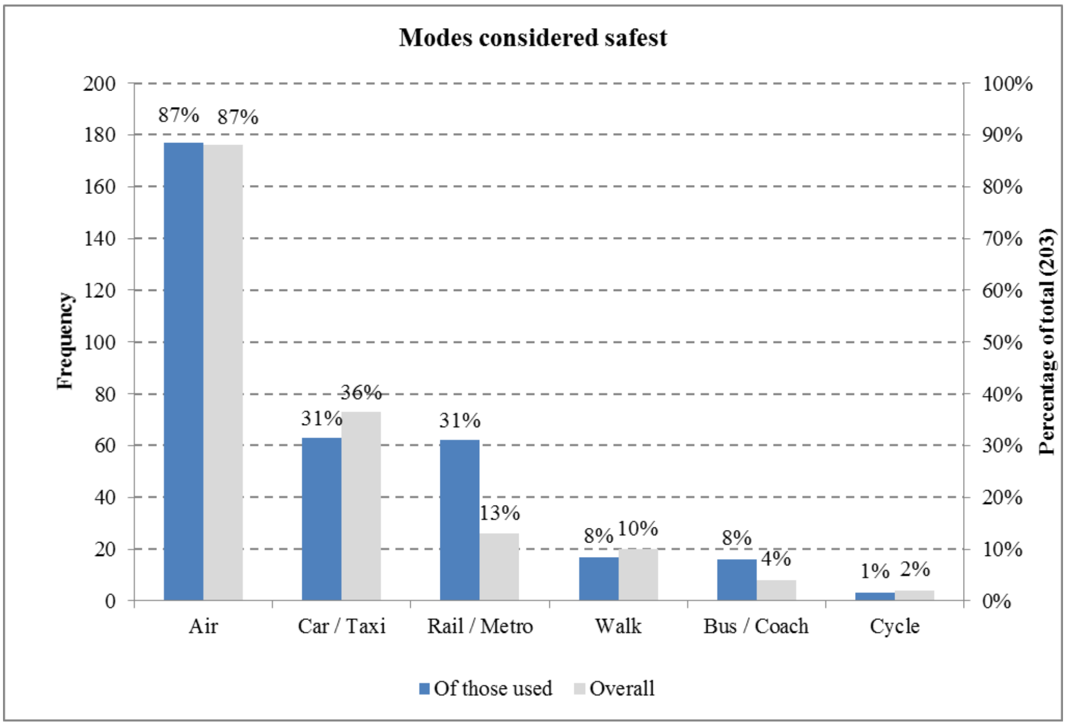

*Figure 7-22: Modes considered to be the safest*

**Comparative assessment**

The following questions in the survey approached the safety aspect from slightly different perspectives and, hence, it is useful to consider the outcomes together.

- Q14 asked whether (a) personal security or (b) accident risk had ever been a deciding factor in the choice of mode for a journey (yes or no for each mode);
- Q18 asked which modes the respondent considered the safest for the specific journey under consideration (maximum of two);
- Q19 asked overall which modes the respondent considered the safest (maximum of two).

The outcomes of these questions are plotted in Figure 7-23 and Figure 7-24, firstly with the outcomes presented by mode and secondly with the outcomes presented by question.

In general, it would be expected that the responses to the first of these, which asked if security was an issue, would be the inverse of the other two which asked which the safest modes are. This was not always the case, however, as discussed.

For the first question it was possible for a respondent to reply yes or no to all of the cases. With the latter two, on the other hand, only a maximum of two safest modes could be identified.

Figure 7-23 and Figure 7-24 show that air travel stands out as the perceived safest mode in the latter two questions, i.e. both for the journey being considered and for the general case. At 87% in both latter questions, it is substantially ahead of the second choice (rail) at 36% for the specific journey, and rail plus car/taxi as equal second for the general case.

Contrasting the outcome of the personal security/accident risk question for air with the responses to the other two is interesting. While air was the second lowest in accident risk at 11%/22 responses, it was substantially higher in personal security at 25%/51 responses. Since personal security in air travel, in the sense of direct attacks on a person, is extremely well controlled, it is highly likely that these concerns relate to the perceived terrorism threat. The opposite would be the case for cycling (27% for Q14a) and walking (25% for Q14a) where direct attacks on the person such as mugging would be a much greater perceived risk. The other interesting response for personal security was for car/taxi (18%), but this is likely to relate to the taxi part of the category. One respondent did point out that taxi risk varies considerably between countries, so that while UK taxis may be perceived as relatively safe, taxis in some other countries may be perceived as more risky, whether justifiably or not. In general, responses on the specific journey are biased according to the modes actually used for the journey. As mentioned, cycling was rarely used and walking was also rarely identified. The high (31%) rating for taxi therefore could be partly related to the high frequency with which this mode is actually being used.

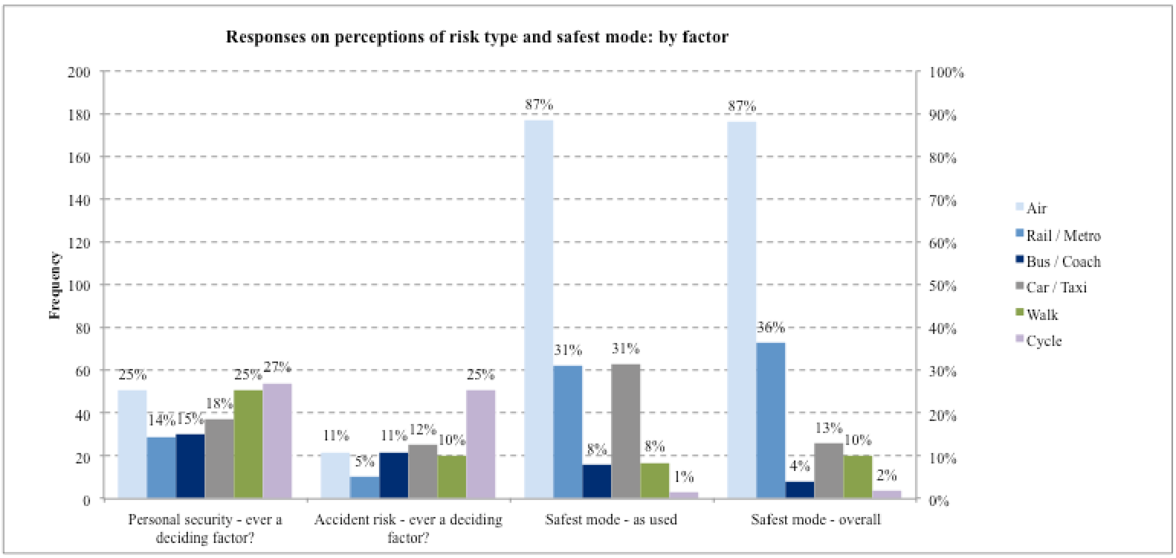

*Figure 7-23: Comparison of safety influences on modal choice – by factor*

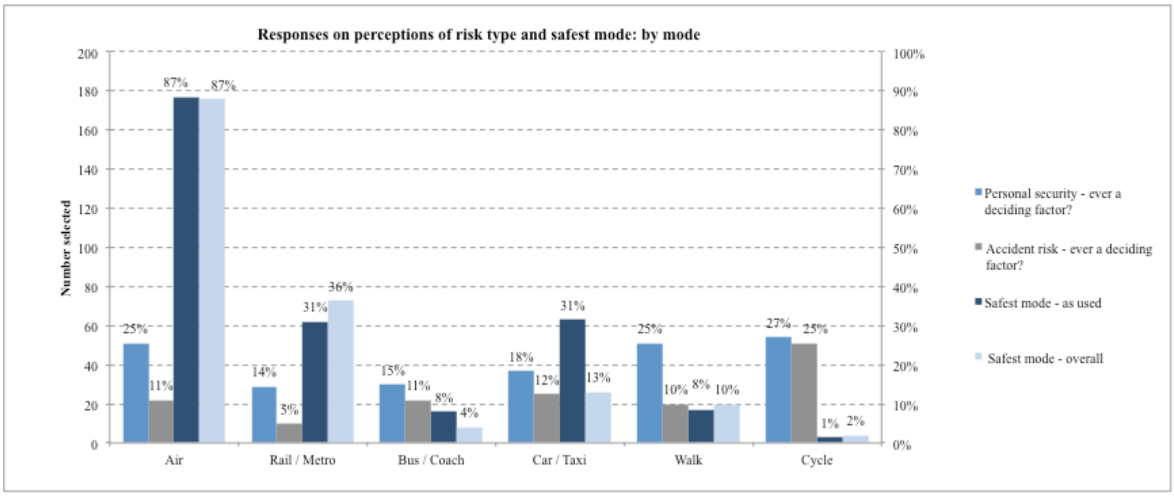

*Figure 7-24: Comparison of safety influences on modal choice – by mode*

Of the remaining modes, cycling was the least selected. In the specific journey case it received only 1% (3 responses) for the specific case, where in any case it is unlikely to have been a practical feeder mode, but only 2% (4 responses) in the general case. This corresponds well with the fact that it was the most selected in the personal/accident question with 27% (54 responses) stating personal safety as a concern for cycling and 25% (51 responses) stating accident safety as a concern; in both cases the largest response for a single mode.

In summary therefore, air travel is perceived to be the safest mode by the survey respondents, both for the specific journey they made and also for the general case. While only 11% of travellers had concerns about accidents, 25% had concerns about their security when travelling by air. By contrast, cycling is the reverse, being selected as safest by only 1% to 2% and raising the greatest number of safety and even security concerns.

Specific comments made by respondents are given in Appendix B-2.

## 7.3 SNOWBALL SURVEY

This section considers the survey findings from the snowball survey which was completed between May and August 2014 *(n=111)*. This additional survey was conducted to capture business/work travellers not covered by the **consumer***data* survey as noted above and hence to provide a more complete overall picture.

Although ideally a real time questionnaire survey would be more appropriate, the snowball survey provided access to business/work travellers in the UK and Europe which otherwise would not have been possible. The selection bias and lack of random sampling for this type of survey is acknowledged. A very similar questionnaire format and question structure to **consumer***data* was used to allow the results of the two surveys to be considered together as far as possible.

The snowball survey is described in Appendix B.1.2. Prior to the snowball survey a short email was sent to targets summarising the aims of the survey, the type of journey being explored (long distance in excess of 200 km in Europe) and confidentiality assurances to increase respondent interest in the survey. In this case it was possible to request demographic information and in addition a more comprehensive written commentary was provided by many respondents that provided insightful information to back up the choices specified.

### 7.3.1 Journey characteristics

**Frequency of making journey**

Respondents were asked to give the town or location starting area, including any interchanges at stations, airports, etc. and how they got from the arrival station to their final destination. Type of transport modes were: rail, car, taxi, bus/coach, walk/cycle, train, metro, air.

They were firstly asked for the location of the start and the final destination for the journey and the modes used at each stage of travel. This allowed for free text entries. As with the consumer data traveller survey it was necessary to apply a classification to the responses in order to limit the range of responses for analysis. A country classification was used which can be seen in Figure 7-25. This also shows the start locations by percentages. The overall absolute number of respondents was 111.

Start locations (origin) were distributed with just under 40% in France, 16% in the UK, and the third largest start location of about 14% in Luxembourg. The majority of journeys were therefore outbound from France. Overall, there was a 100% response from respondents to this question.

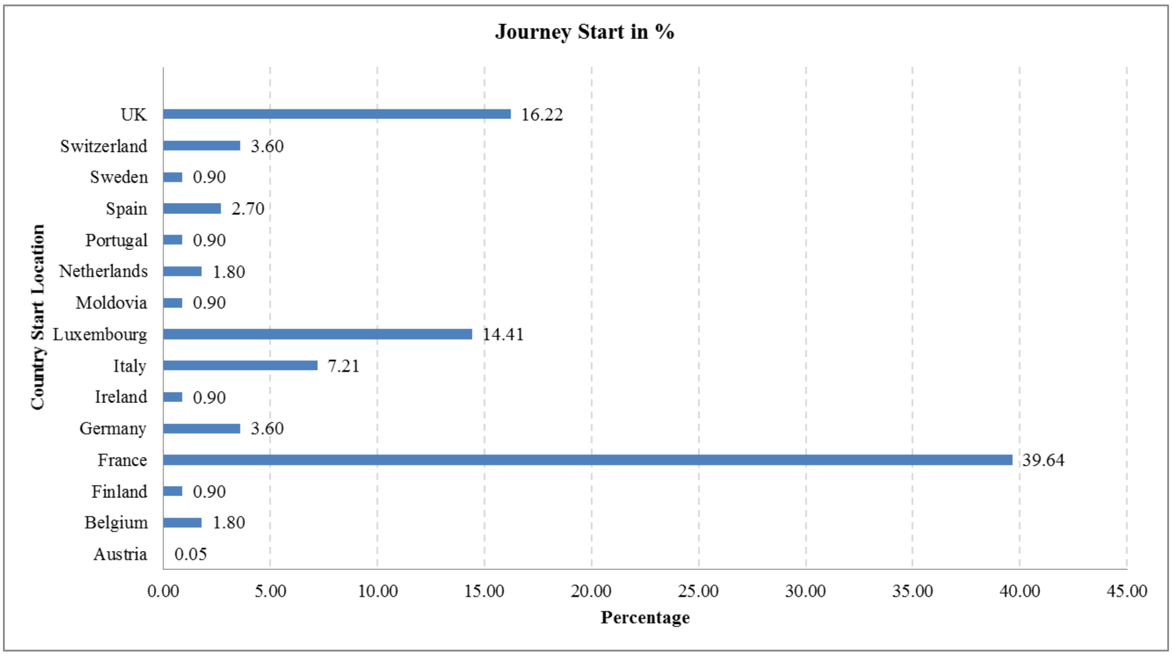

*Figure 7-25: Journey start location*

The modes used at each stage of the journey provided an indication of the access and main modes selected (Figure 7-26). For Stage 1, most of the respondents used car (42%) and taxi (18%) closely followed by local rail/metro as the modes of transport. Stage 2 of the journey, normally considered the main leg (the most distance travelled) was dominated by air with 53% and 26% being LDR. Most respondents for Stage 3 of the journey used taxi (27%) followed by metro/local rail (23%) and car (19%) as the final access modes to reach their destination. The access modes at the beginning and end of the journey vary slightly. This can be attributed to differences in the cost of modes at start and end destinations[48], and familiarity with specific routes at the start location vs.

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[48] For example car availability. If the own car is used as feeder to rail from the home end, then it is not available at the destination.

unfamiliarity at end destinations. For stage 2 and stage 3 there were 8% and 11% non-responses respectively, attributable to some journeys made throughout by car.

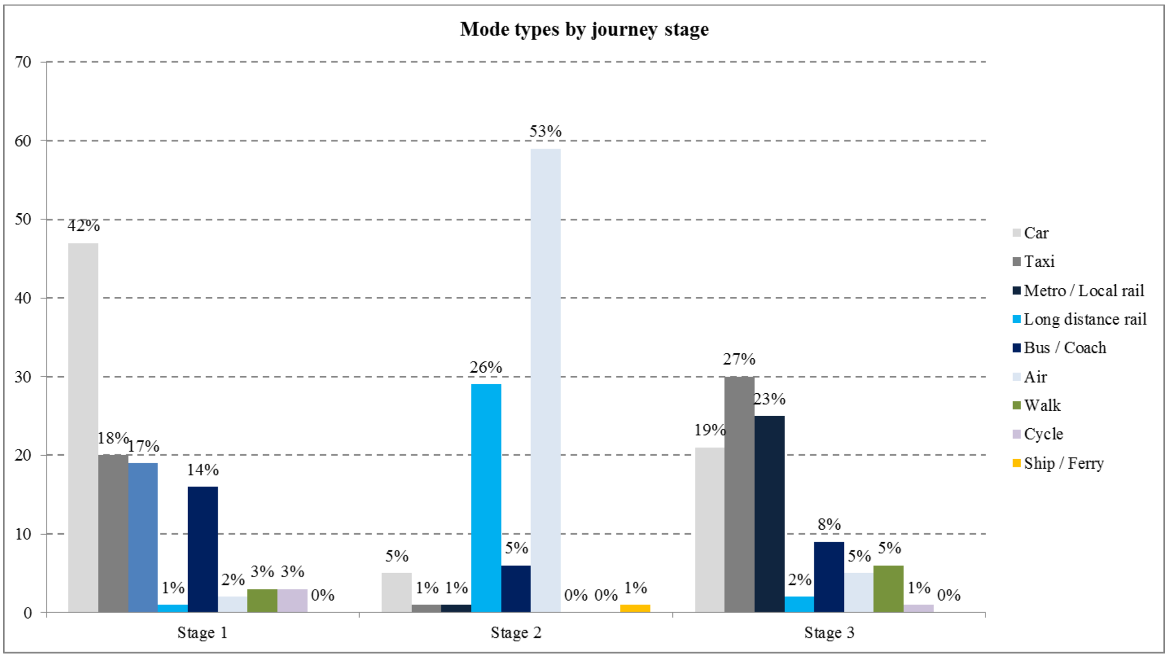


*Figure 7-26: Mode types by journey stage*

For the destinations, as with the start locations, due to the broad range of places it was necessary to classify according to country (Figure 7-27). Over 24% were in the UK, followed by nearly 21% in France, just under 10% in Germany and 7% in Italy. Of the remainder, the three next most frequent destinations were the Netherlands, Switzerland and Spain, each with about 16% of the total.

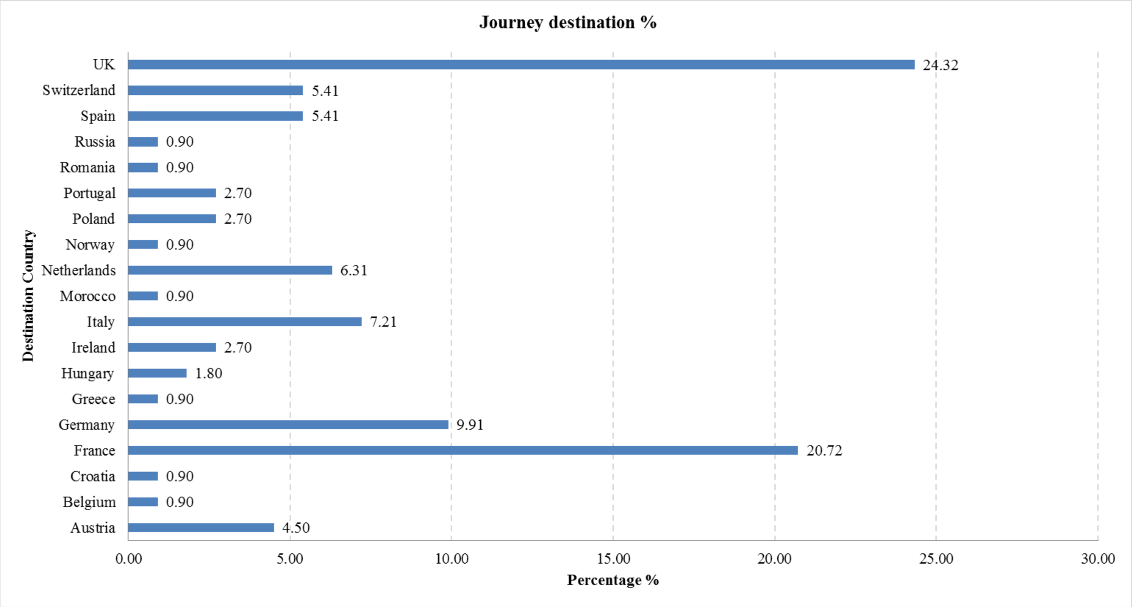


*Figure 7-27: Journey destinations*

Respondents were asked how often in the past 12 months they had made this journey between the same two points. Options given were weekly or more, monthly, several times per year or first time (Figure 7-28).

In 45% of cases, respondents travelled several times per year on the same route, suggesting some work related travel. A large proportion (41%) also noted that in the last 12 months they only travelled once on the route specified, suggesting that this could be to visit friends and relatives and for holiday purposes. 11% of the respondents travelled the same route on a monthly basis and 3% travelled weekly. The remaining 1% did not answer the question.

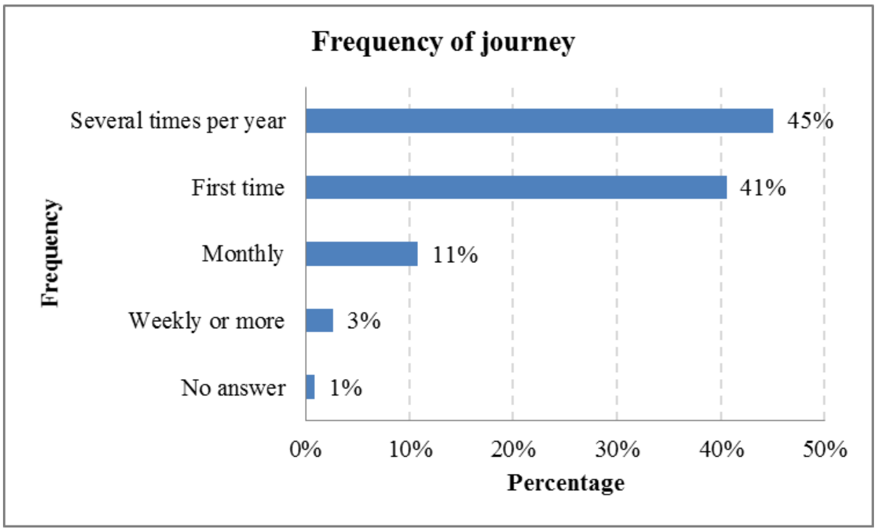


*Figure 7-28: Frequency of making the specific journey*

### Purpose of journey

Respondents were asked the main purpose of their journey (Figure 7-29). In this survey the main reason for travel was for work/business at 56%, secondly to visit friends and relatives at 23% and thirdly for holiday at 15%. This differs substantially from the **consumer***data* survey where the vast majority of travel was for purposes of leisure. It therefore allows a broader perspective on the prospects for modal switching for a wider range of journey purposes.

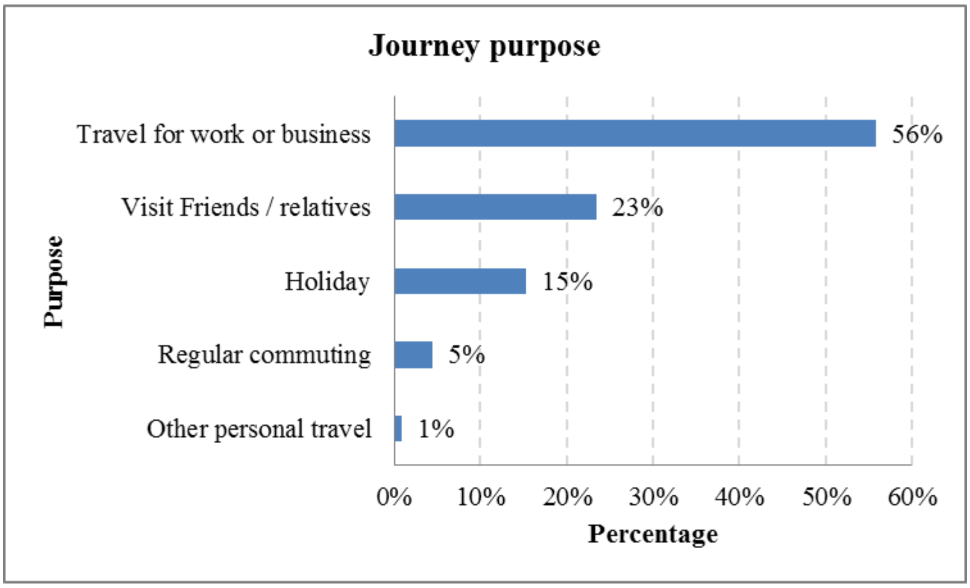


*Figure 7-29: Purpose of the journey for the snowball survey*

### 7.3.2 Potential for modal switching

**Consideration of alternative modes**

Respondents were asked when making journeys of the type described whether they normally consider alternative ways or methods of travelling for the main part of the journey. A Yes or No answer was requested (Figure 7-30).

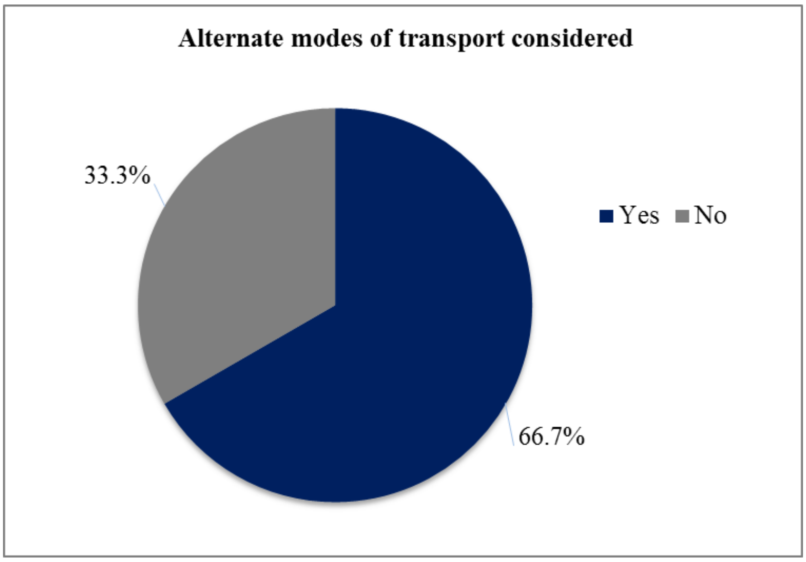


*Figure 7-30: Snowball survey respondents who considered alternative modes*

The aim of this question was to begin exploring the basis for CMS by asking directly whether respondents would consider alternative modes. The fact that 66.7% of respondents do consider an alternative mode suggests positive prospects for modal switching among this more business oriented population. The remaining 33.3% did not consider alternative options. This may be because for many of the long distance destinations there are limited or no alternatives. In particular, for the much longer distance air journeys there is rarely a viable alternative to air travel as the main mode for the journey, either on schedule or cost grounds. This was further supported by additional comments made by a number of respondents (comments listed in Appendix B-2 and B-3).

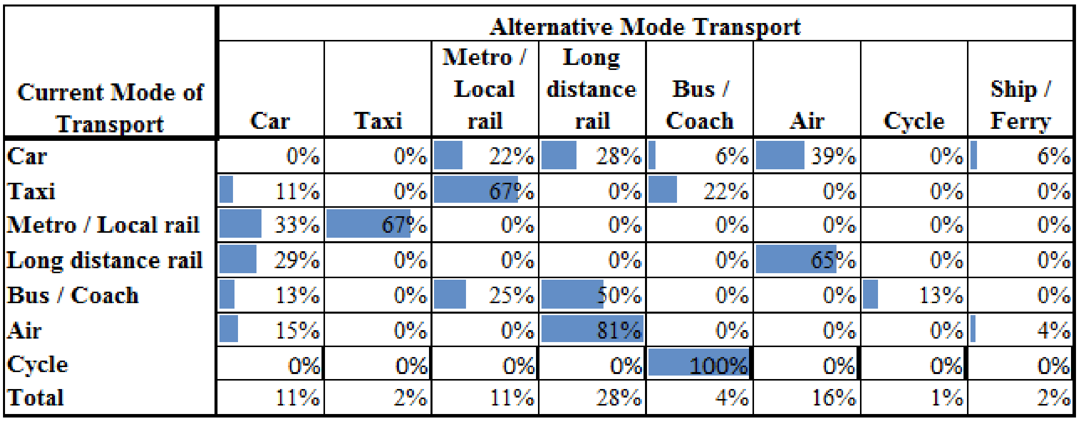
The alternative modes that were considered and the possible motivations for this switching are considered in the analysis of subsequent questions.

### Actual alternate modes considered and reasons

If respondents would have considered an alternative means of transport for any part of the journey described, they were asked to say what the transport type would have been and to indicate the reasons needed to select it.

Table 7-6 highlights the percentage of respondents willing to switch to alternative modes of transport and indicates the mode type they would switch to and from. 81% of air travellers willing to change mode would change from air to LDR and conversely 65% from LDR to air. As the journeys considered were of 200km or more within Europe, there is some choice from LDR as an alternate means to air for the main part of the journey, particularly for the journeys closer to the 200km distance. The second largest willingness to switch mode was from taxi to metro/local rail and vice versa, both at 67% as access modes for other parts of the journey. Bus/coach to LDR was significant at 50% (probably as a main mode) while bus/coach to metro/local rail was represented by 25% as access modes for shorter journey segments. The selection from using car to air was notable at 33% followed by 28% to LDR (travellers substituting car to air or car to LDR for the main journey segment) and 22% to metro/local rail (substitution for shorter journeys as access modes).

It should be noted that cycle to bus/coach is shown as 100% since there was only one respondent that wanted to shift from cycle to another mode of transport. 13% of bus/coach users would be willing to move to cycle.



| Current Mode of Transport | Alternative Mode Transport | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Car | Taxi | Metro / Local rail | Long distance rail | Bus / Coach | Air | Cycle | Ship / Ferry |
| **Car** | 0% | 0% | 22% | 28% | 6% | 39% | 0% | 6% |
| **Taxi** | 11% | 0% | 67% | 0% | 22% | 0% | 0% | 0% |
| **Metro / Local rail** | 33% | 67% | 0% | 0% | 0% | 0% | 0% | 0% |
| **Long distance rail** | 29% | 0% | 0% | 0% | 0% | 65% | 0% | 0% |
| **Bus / Coach** | 13% | 0% | 25% | 50% | 0% | 0% | 13% | 0% |
| **Air** | 15% | 0% | 0% | 81% | 0% | 0% | 0% | 4% |
| **Cycle** | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 0% |
| **Total** | 11% | 2% | 11% | 28% | 4% | 16% | 1% | 2% |

*Table 7-6: Specific alternative modes considered for snowball survey respondents*

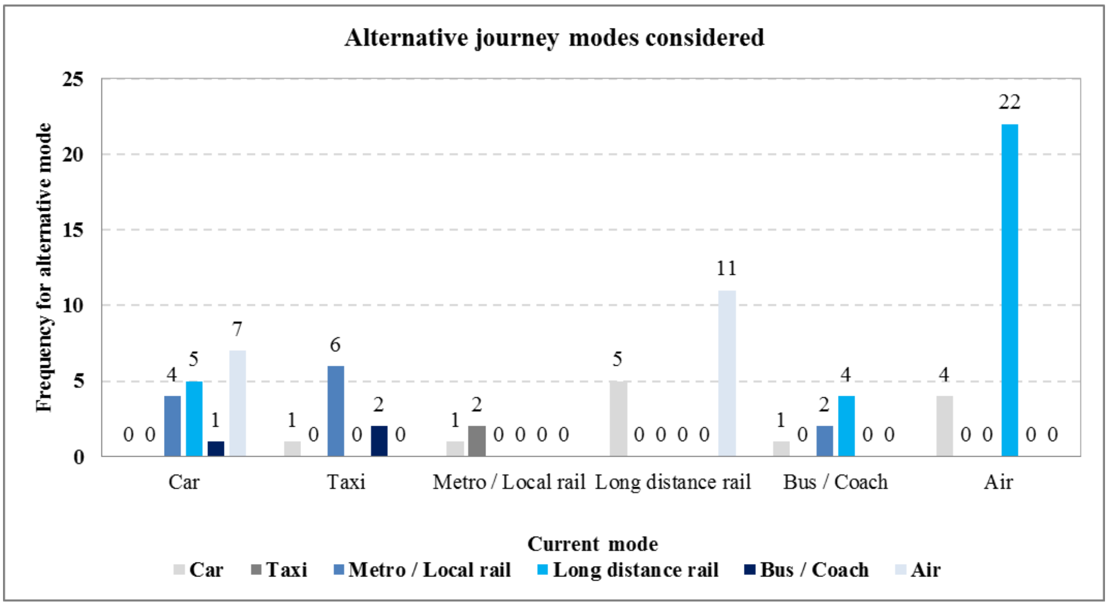


*Figure 7-31: Alternative journey modes considered*

From Table 7-6 and Figure 7-31 it is clear that there is a willingness for a sizeable number of respondents to switch cross modally. This seems reasonable as there are a number of alternative modes of transport available, especially for selected pairings such as air and LDR, car/taxi and metro/ local rail.

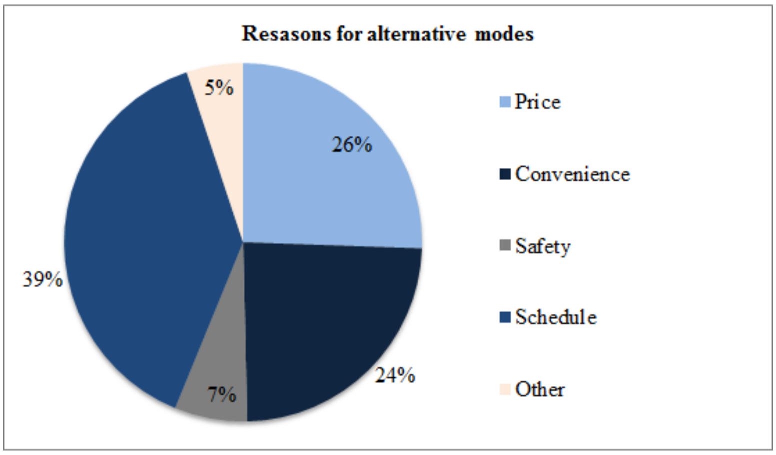


*Figure 7-32: Reasons for alternative modes being considered for the snowball survey*

The main reason given by respondents willing to swap modes was schedule of travel, at 39% (Figure 7-32). The number was linked using cross tabulation to travellers for work or business reasons. Secondary reasons were price and convenience at 26% and 24% respectively. Safety considerations were limited to 7% and other factors attributed to 5%.

### 7.3.3 Safety and accident risk perceptions

**Rank top issues important when deciding how to make your journey**

Table 7-7 shows the 5 most important issues considered by respondents when making a journey.

Figure 7-33 shows the breakdown of the factors specified as most important. Here, time taken has the highest frequency with 38% of responses giving this as the top importance. Price was the second highest importance at 32% and schedule was ranked third at 26%. Convenience and comfort were equal at 23%. Accident safety was specified as a top issue by 9% of cases, and 6% ranked personal safety as the highest importance.

Accident safety priorities were 3% as second and third priority, 2% for fourth priority and 4% and 11% for fifth priority. The other options were relatively evenly distributed with no major peaks at the second to fifth levels.

| Rank | Time taken | Accident safety | Personal security | Environmental concerns | Comfort | Price | Convenience | Schedule |
|---|---|---|---|---|---|---|---|---|
| **1** | 38% | 9% | 6% | 2% | 9% | 21% | 17% | 12% |
| **2** | 24% | 3% | 4% | 5% | 14% | 32% | 12% | 15% |
| **3** | 14% | 3% | 5% | 5% | 10% | 14% | 21% | 26% |
| **4** | 8% | 5% | 5% | 4% | 15% | 16% | 23% | 18% |
| **5** | 7% | 11% | 9% | 11% | 23% | 11% | 15% | 12% |
| **6** | 0% | 1% | 0% | 0% | 0% | 0% | 1% | 1% |
| **7** | 0% | 0% | 0% | 0% | 1% | 1% | 0% | 0% |
| **8** | 0% | 0% | 0% | 2% | 0% | 0% | 0% | 0% |
| **No answer** | 8% | 69% | 71% | 71% | 28% | 5% | 12% | 16% |

*Table 7-7: Ranking of top 5 issues when deciding to make a journey*

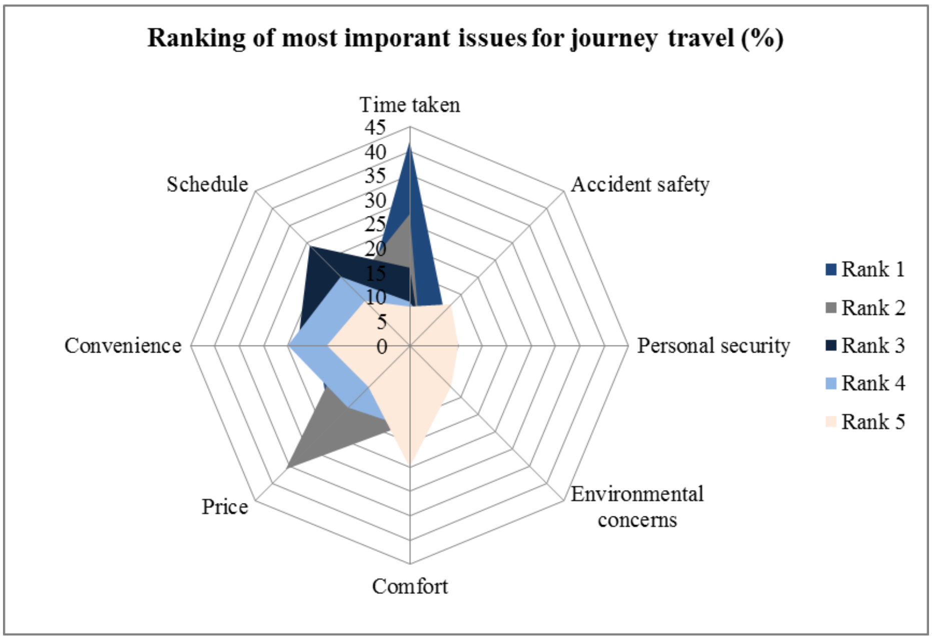


*Figure 7-33: Most important issues for journey travel*

### Causes of modal changes

Figure 7-34 highlights the main reasons travellers would be willing to change mode due to unforeseen circumstances. The main reasons selected for change were severe delays (42%) and bad weather (41%). Travellers would be less likely to change mode on the basis of security measures (21%) and long queues (24%). Where travellers are subject to security measures at airports it is not possible at that stage of their journey to change mode of travel, as they would normally incur penalties or would not have any reimbursements for their flight/s[49]. Nevertheless, bad experiences of delays or objections in principle to being searched could lead to the selection of alternatives.

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[49] This is dependent on the type of luggage (e.g. with liquids)

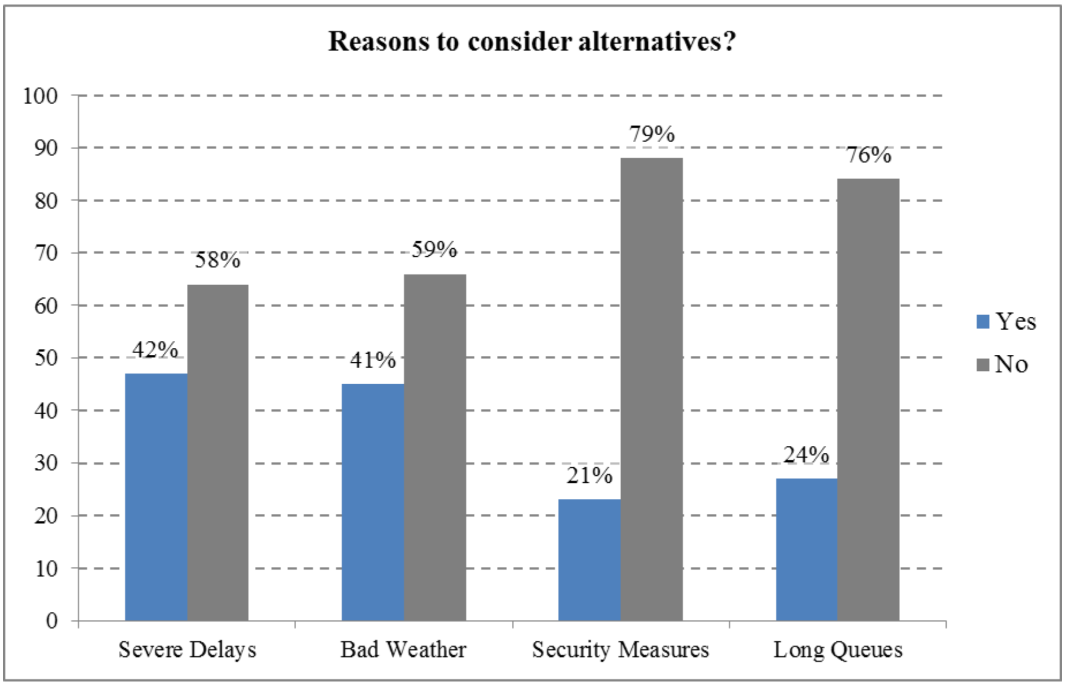

*Figure 7-34: Percentages considering suggested reasons for alternative modes survey*

**Personal security as a deciding factor**

Personal security was an issue for 11% of air passengers, 18% of local rail/metro travellers, 10% of LDR and bus/coach travellers, 14% of car/taxi passenger and 8% of ship/ferry travellers (Figure 7-35).

Similar to the findings in the **consumer***data* survey, the level of concern for air was presumably centred on terrorism while concerns regarding other public modes of transport were more likely to be motivated by more conventional forms of violence (e.g. muggings).

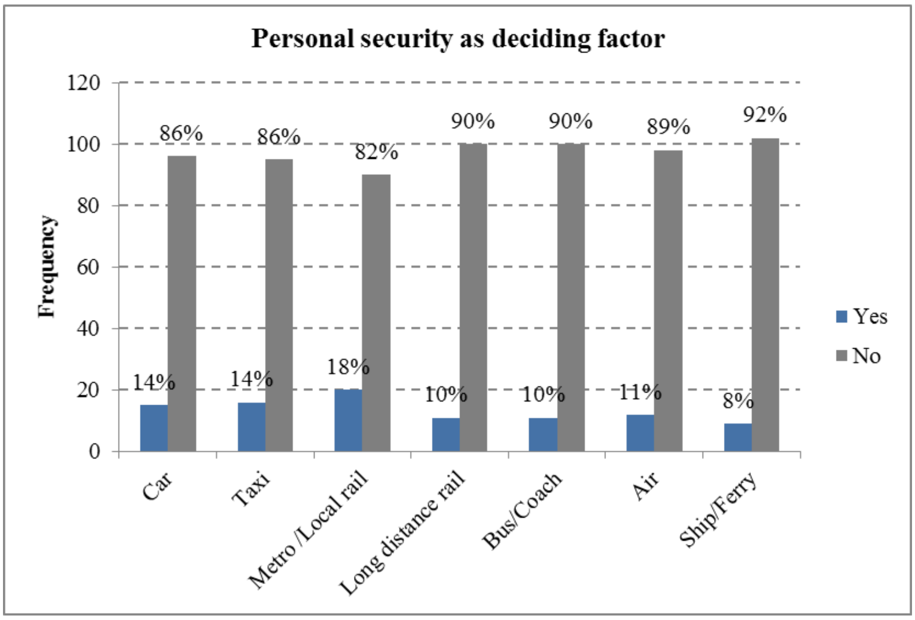

*Figure 7-35: Personal security as a deciding factor, by mode – for snowball survey*

**Risk of accident as a deciding factor**

The outcomes for risk of accident as a deciding factor (Figure 7-36) were 17% for air, 8% for LDR and ship/ferry, 11% for bus/coach, 7% for taxi and perhaps not surprisingly 34% for car. These levels of concern also mirror the British Social Attitudes Survey (DfT, 2013f) results of expected levels of perceived risk, with car use being highest and taxi and metro/local rail the lowest.

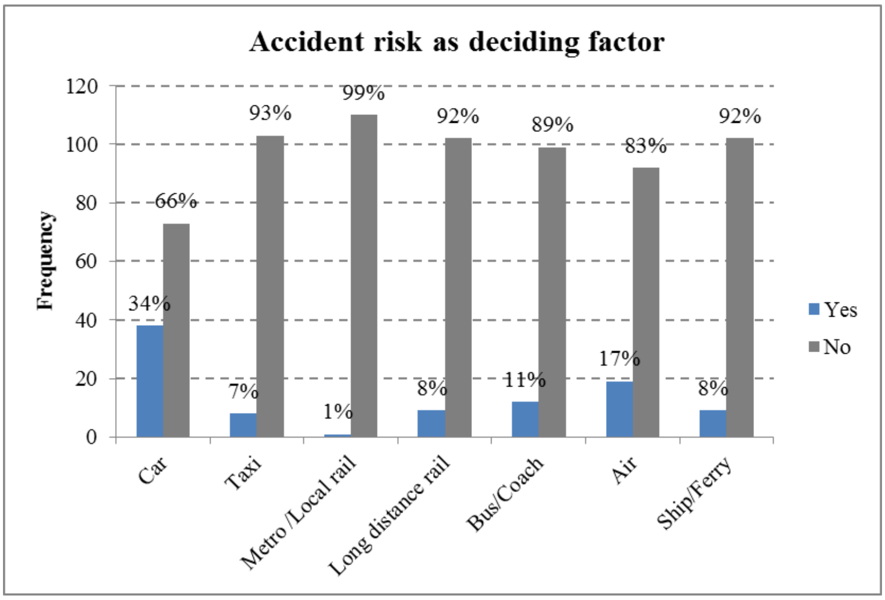

*Figure 7-36: Accident risk as a deciding factor, by mode – for snowball survey*

### Impact of adverse weather

The key interest in Figure 7-37 is the ‘no’ response, which was 51% for ship transport (although only one respondent used this as a main mode travel, it would appear that others are providing a ‘no’ response on the basis of risk perception) and 39% for air: the two modes where this issue would have been most expected because of the direct impact on passenger comfort. The bus/coach response at 25% is perhaps more surprising, though not so far ahead of taxi at 30% and car at 29%. Rail and metro are least impacted at 13% and 11% respectively.

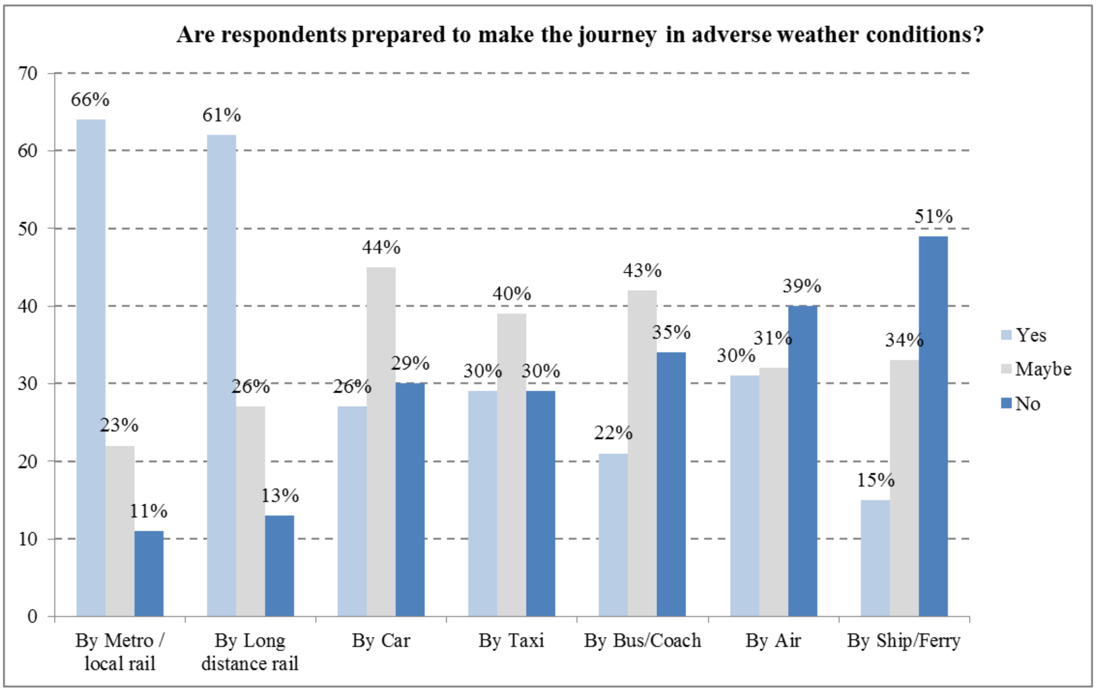

*Figure 7-37: Impacts of adverse weather on journey choices by mode*

### Most important selection factors

Respondents were asked, of the two types of risk mentioned (personal security/accident risk), which they personally considered more likely to affect their decision to travel by a particular transport type.

The main perceived risk for this survey was accident risk at 59%, while personal security risk represented only 33% of respondents and 7% did not respond to the question.

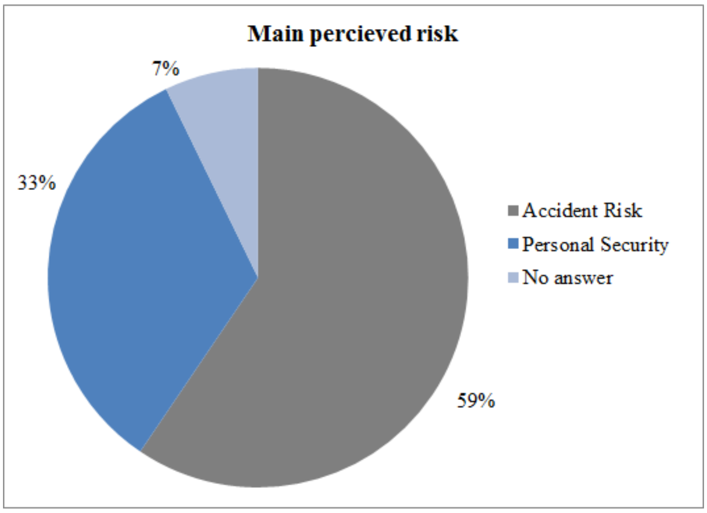

*Figure 7-38: Main perceived risk type*

**Modes used for journey considered safest (used and overall)**

Respondents were asked, of the transport types used on the specific journey described in question 2, which they thought were the safest (i.e. with the least risk of accident). These were ranked from 1 to 3, with 1 being the safest, as shown in Figure 7-39.

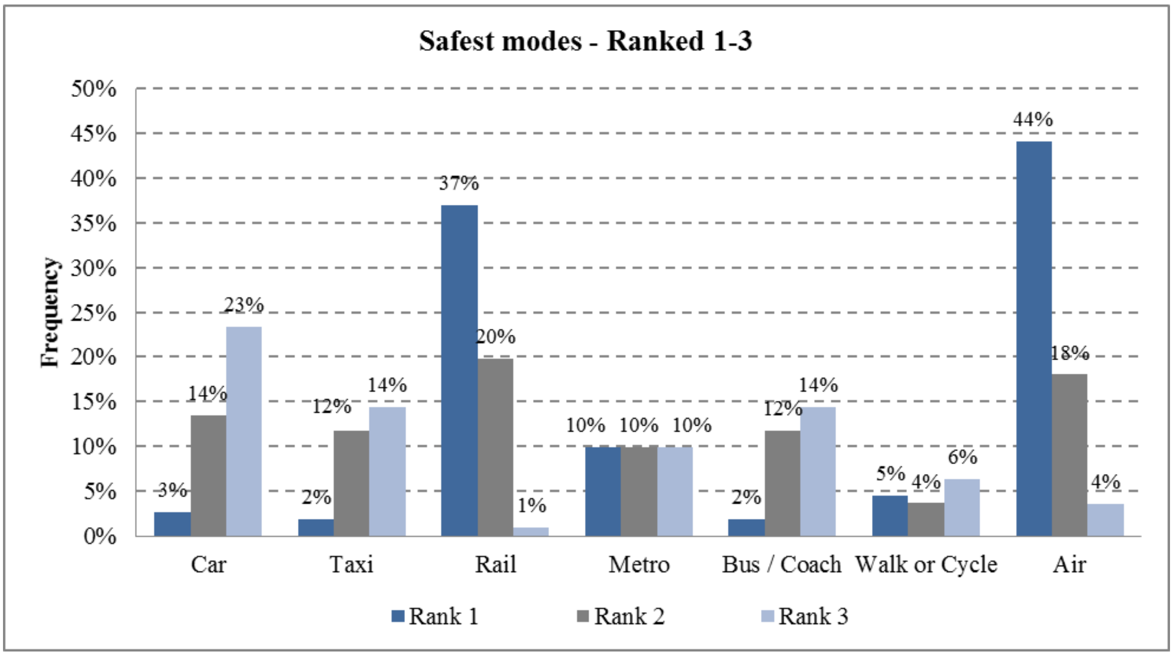

*Figure 7-39: Safest modes as defined by snowball survey respondents*

Air with 44% is considered to be the safest mode by quite a margin. The next highest was rail with 37% while metro was third with 10%. Bus/coach travel and taxi were only seen as safest by 2%; worse than walking or cycling at 5% and car at 3%.

For the second safest mode of transport, the split here between car/taxi and rail/metro is much different. Rail is considered safest of the remainder by 20%, air by 18% while car/taxi was selected only by 14% and 12% respectively. Bus/coach is 12%, only just ahead of metro which is lower at 10%.

**Demographic information**

For this survey respondents were asked to provide personal information covering occupation, gender, residence/nationality and age range (Figure 7-40 to Figure 7-43). Most respondents (72%) were from the private sector followed by the public sector (20%). There was a skew towards male respondents (also reported in CAA passenger surveys) while the residence or nationality of the respondents was mainly France, UK, Luxembourg and Italy. As this survey was based on respondents contacted through extended networks there is a bias in terms of their residence and nationality, since random sampling was not possible for this survey.

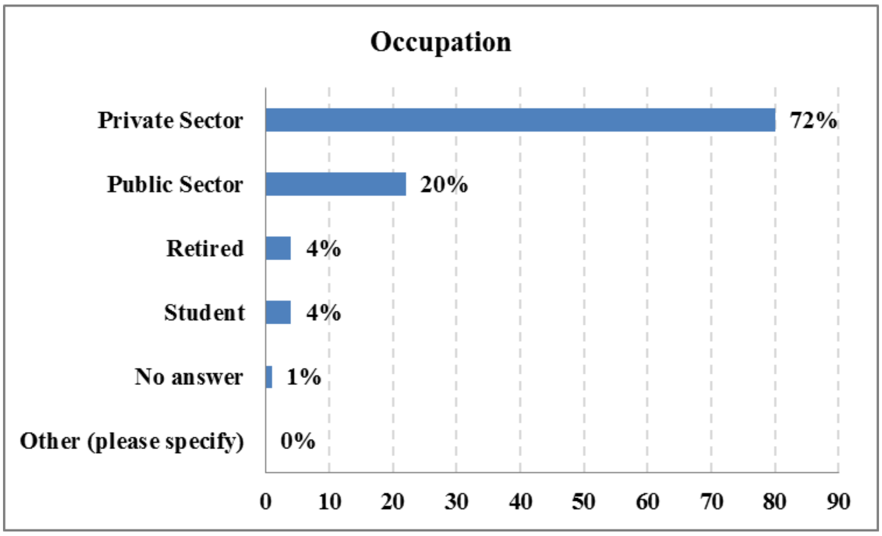

*Figure 7-40: Occupation of respondents*

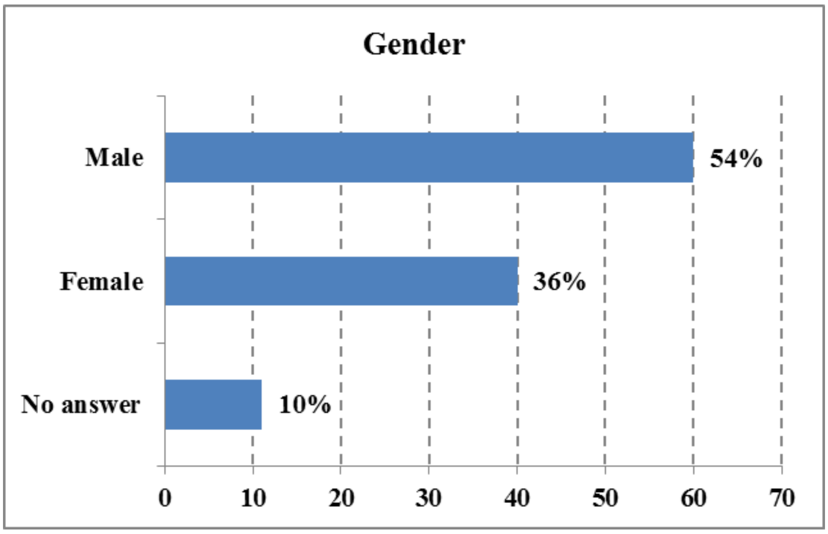

*Figure 7-41: Survey respondent gender*

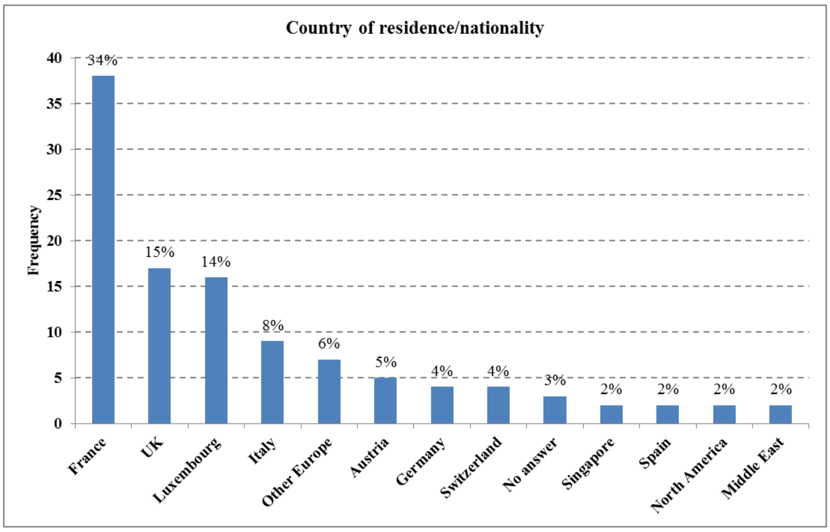

*Figure 7-42: Respondent country of residence/nationality*

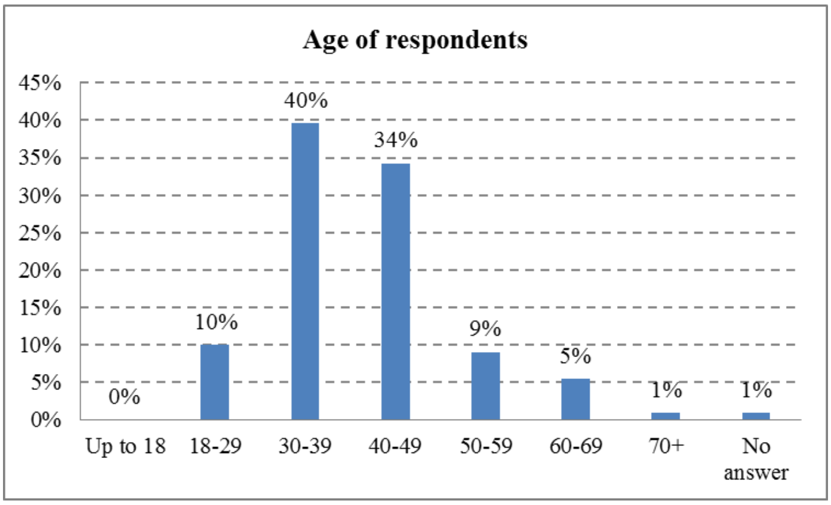

*Figure 7-43: Age of respondents*

The age of the respondents is predominantly clustered around the 30-39 and 40-49 group. This again can be attributable to the selection bias inherent within the survey, but also due to the fact that most respondents were business/work travellers and hence the working population rather than the under 18 age group or the older population over 60.

### 7.3.4 Significance testing

A range of cross tabulations was carried out for the snowball questionnaire to test the significance (using Pearson Chi-Square) of relationships between key variables. The aim of this was to understand the patterns within the data (using demographics such as age and gender) and also to support possible implementation measures designed to encourage modal switching (stated preferences against demographics). In doing this it should be noted that the snowball questionnaire sampling used a non-probability method with extended associations, meaning that the sample is not fully random and may thus have an element of bias. Any such bias will be acknowledged in the analysis. More detailed observed and expected frequencies are provided in Appendix B.5 (Tables B.1 to B.5).

The relationship between the age of the respondent and the frequency of his or her travel, which could be useful in targeting modal switching incentives, was tested. A chi-square test was performed and no relationship was found: chi-square (8, N = 111) = 6.57, p =.58. The observed count in 9 out of 15 cells exceeded the expected count as indicated in Table B.1. The largest observed frequencies were in the 30-39 and 40-49 age groups; but this could be attributed to sample selection bias. Most respondents travelled several times per year or were travelling for the first time to a specific journey or destination, i.e. few were regular commuters.

Significance of relationships between the age and gender of the respondent was examined. Although this has no direct bearing on modal choice, the test helps to understand the characteristics of the dataset used. A chi-square test was performed and no relationship was found: chi-square (4, N = 111) = 9.06, p =.06. The observed count in 4 out of 10 cells exceeded the expected count as indicated in Table B.2.

Table 7-8 displays the significance of the relationship between the frequency and purpose of travel. A chi-square test was performed and a highly significant relationship was found: chi-square (2, N = 111) = 13.85, p =.001. The results suggest that a fairly large proportion of those surveyed travelled several times a year for work/business. However a number of respondents who travelled for leisure or to visit friends and relatives were doing so for the first time. There were also leisure travellers who were making journeys several times. These findings seem to align with general transport survey trends on purpose and frequency of travel.

**Chi-Square Tests**

| | Value | df | Asymp. Sig. (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 13.851[a] | 2 | .001 |
| Likelihood Ratio | 15.516 | 2 | .000 |
| Linear-by-Linear Association | 13.714 | 1 | .000 |
| N of Valid Cases | 111 | | |

**a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.95.**

*Table 7-8: Frequency and purpose of travel*

Regarding the significance of links between the gender of respondents and their purpose of travel, a chi-square test was performed but no relationship was found.

Accident and personal security risks (personal security risk associated during the course of travel) were explored against the purpose of travel and age. The significance between the types of risk and the purpose of travel was examined. A chi-square test was performed and no relationship was found: chi-square (2, N = 111) = 0.77, p =.68. The observed count in 3 out of 6 cells exceeded the expected count as indicated in Table B.4. Two of the observed cell counts were very close to the expected cell counts.

Table 7-9 examined the significance of relationships between the types of risk and age. A chi-square test was performed, and a highly significant relationship was found: chi-square (8, N = 111) = 20.93, p =.007. A number of the observed cell counts were very close to the expected cell counts. The significance in this instance could be attributable to varying perceptions of personal security and accident risk within different age groups. For example, the level of concern regarding accident risk seems to increase up to the 40-49 age group; however the 50-59 age group were not found to be as concerned about accident risk. These findings could be used to target incentives more effectively by addressing different age groups in the most appropriate way. The main difference between observed and expected cell values are in personal security for the 0-29 age group, with a higher than expected regard for personal security (observed 7 vs expected 3.7) and less regard for accident risk than expected (observed 4 vs. expected 6.5). The concern for personal security is lower than expected (observed 9 vs. expected 12.7) for the 40-49 age group and higher than expected for accident risk (observed 25 vs. expected 22.6). Note however that conclusions cannot be drawn for expected values lower than 5, as was the case for personal security for 0-29 age group.

**Chi-Square Tests**

| | Value | df | Asymp. Sig. (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 20.925[a] | 8 | .007 |
| Likelihood Ratio | 14.880 | 8 | .062 |
| Linear-by-Linear Association | 12.808 | 1 | .000 |
| N of Valid Cases | 111 | | |

8 cells (53.3%) have expected count less than 5. The minimum expected count is .07.

*Table 7-9: Risk type and age*

Specific comments made by respondents are given in Appendix B-3.

## 7.4 EXPERT SURVEY

This section considers the survey findings from the expert survey which was completed between June and July 2014 (***n=20***). The expert survey is provided in Appendix B.1.3. Similar to the other user surveys a short email summarising the aims of the survey was sent to participants in advance, including confidentiality assurances to increase respondent interest in the survey. The transport experts were mainly specialising in air transport (with roles ranging from engineers, safety specialist/analysts, flight/planning analysts to commercial and strategic) with some limited specialists in rail (strategy and safety) and in maritime transport (safety systems engineer). The experts worked or specialised in various geographies (Japan, Thailand, Asia, Mexico and Venezuela), although predominantly Western Europe (Belgium, France, Germany, Italy, Netherlands, Portugal and UK) and Albania, Poland and Turkey.

### 7.4.1 Impacts of major accidents

Respondents were asked about how major accidents impact public travel behaviour. They could respond on a scale from ‘strongly agree’ to ‘strongly disagree’ as shown in Figure 7-44. Overall, this confirms expert agreement that there is an impact on public travel behaviour. Although there was some disagreement (3 cases), there were 14 cases where experts either agreed or strongly agreed with the statement.

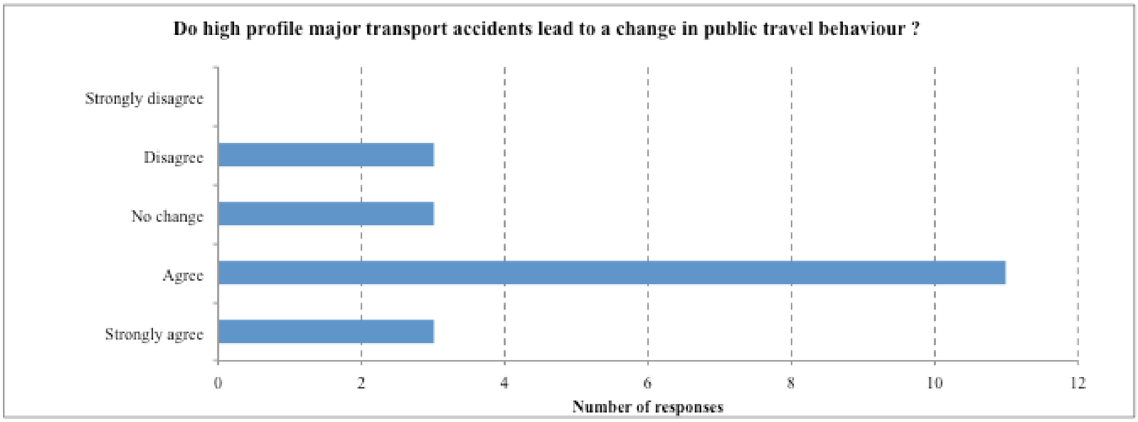

*Figure 7-44: Do high profile major transport accidents lead to a change in public travel behaviour*

The experts were also asked to state, where there is a change due to high profile accidents, whether this involves a change in transport mode and/or a change in operator.

Some expressed that individual behaviour would impact both mode and operator while others indicated only modal shift. Temporary suspension from long distance travel was also cited as a possibility. One respondent suggested that there would also be some *"staycation' promotions encouraging passengers to holiday domestically who are more likely to drive or use public transport*".

Respondents cited limited modal shift due to the fact that often there is no other mode realistically available for the trips in question. After a major accident people may travel less: for example, the impact on air travel after the 11 September 2001 and Malaysian Airlines accident in 2014. In both cases there was a dramatic drop in air travel; however, it was only sustained temporarily, as air is the only mode available between Europe and USA and Europe and Asia.

Major accidents also lead to new analysis of the specific transport mode processes and consequences which would have an impact on traveller behaviour, as well as longer term safety regulations changes on design.

Three respondents suggested no change in behaviour except for a short term impact on operator selected. One respondent indicated that a single accident would not have any impact on mode or operator; however, a series of accidents by the same operator may lead to a change. For certain geographical markets for example safety has a higher profile and therefore it could have a more noticeable effect. The 787 Boeing aircraft battery issues caused a drop off in flights involving 787 for a period of time though no accidents occurred. A further three respondents suggested that there would not be any change other than in extreme circumstances.

The experts were asked how long a behavioural change would be sustained either for a modal shift (Figure 7-45) or change in operator (Figure 7-46). They could respond on a scale from few weeks to permanent.

For a modal shift it is suggested that the impact is expected to be temporary with the majority considering a persistence of weeks or months rather than years. There was only one case in which a permanent modal shift was anticipated.

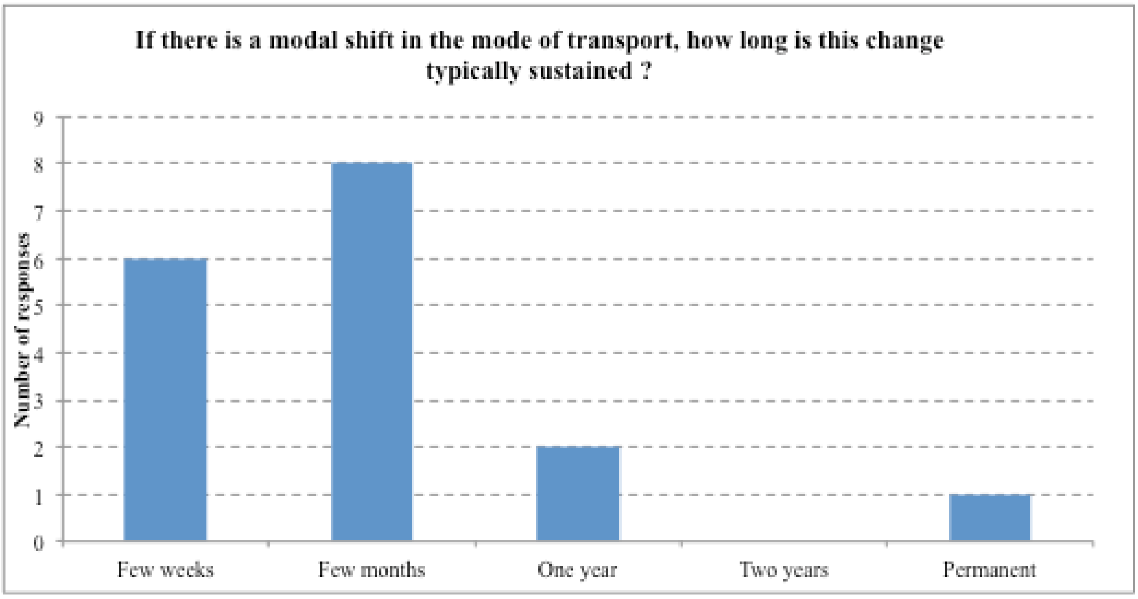

*Figure 7-45: Sustainability of modal shift in transport*

For a change in operator in general this would be expected to refer to aviation where there is the greatest choice of carriers, though it could also refer to bus and perhaps ferry travel. The responses here were markedly different to the modal shift case, with a much greater emphasis on long term or permanent changes. 50% of the respondents considered a change of two years or permanent change likely and only 2 of the 16 respondents considered an impact only to last a few weeks.

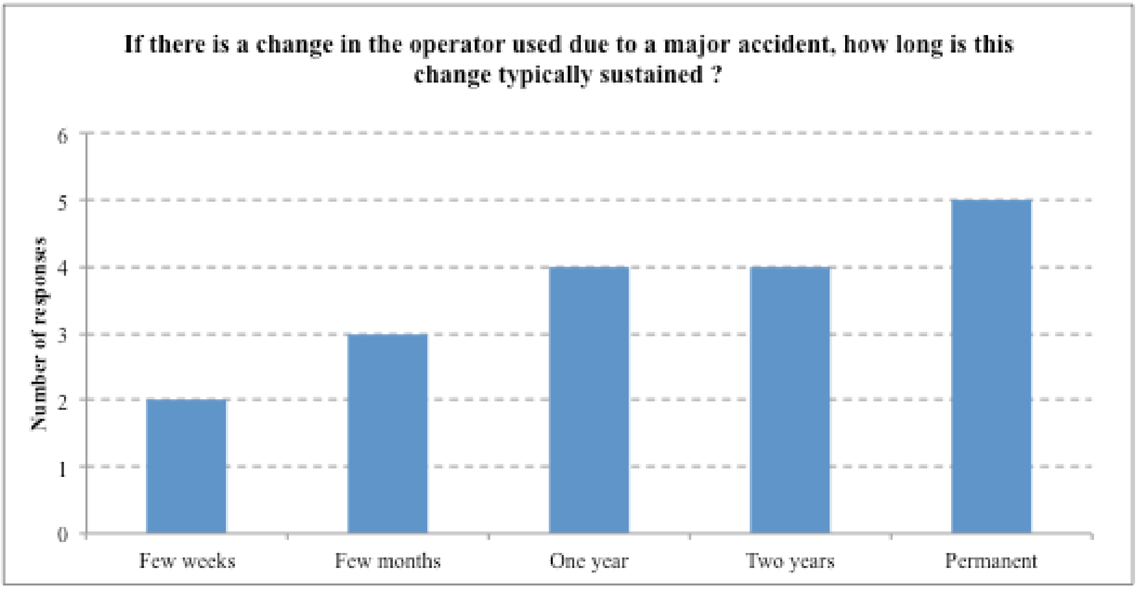

*Figure 7-46: Sustainability of change in operator in transport*

### 7.4.2 Modal choice and accident risk perceptions

Respondents were asked if there was any evidence that the public considered accident safety issues when selecting transport modes. A scale was provided from 'very strong evidence' to 'no evidence'.

This is a key question for the thesis, covering the expected public perception of safety issues and the extent to which these are accounted for in planning travel. The responses to this are given in Figure 7-47. There is a relatively even distribution centred on 'limited evidence' rather than 'some evidence', with no experts citing 'very strong evidence' but two citing 'no evidence'. Three cited strong evidence. This can be taken as confirmation that safety is considered to some extent, though is perhaps not the top priority for many people.

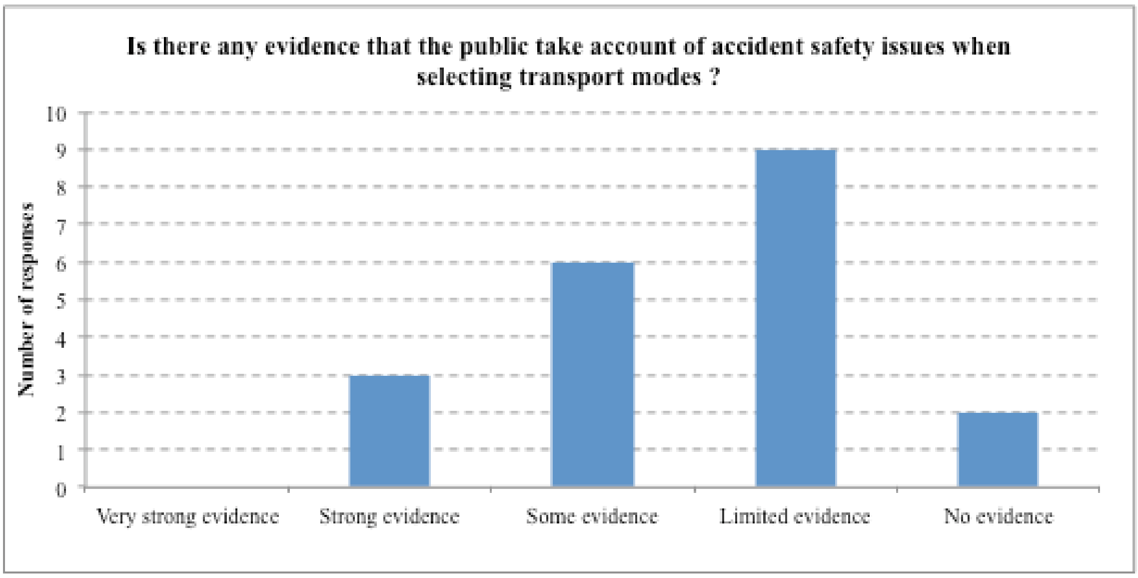

*Figure 7-47: Public consideration of accident safety issues in mode selection*

Respondents were also asked if there was any evidence that the public considers accident safety issues when selecting individual carriers/operators for a specific mode of transport (Figure 7-48). This indicates slightly stronger evidence than the mode version of this question, but only marginally. In this case, one expert cited 'very strong evidence' and none stated 'no evidence'; but the emphasis here is on 'some evidence' rather than 'limited evidence' as was the case with the mode question.

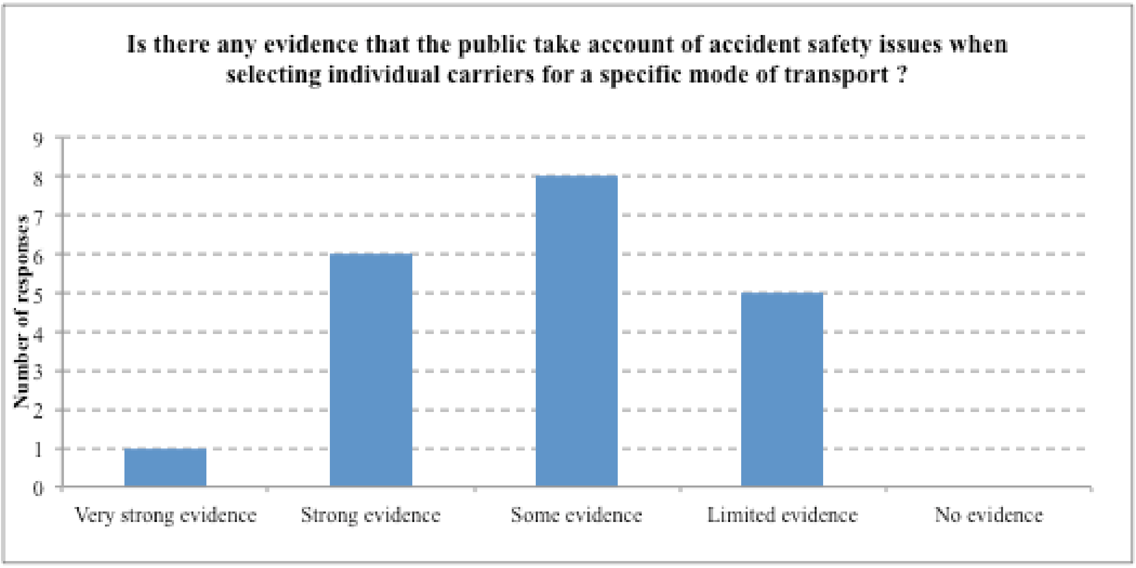

*Figure 7-48: Public consideration of accident safety issues in operator selection*

The modes most affected by accident safety considerations were noted by the experts. The key mode, which experts felt would be most affected by safety, was air; followed by rail, road (car, bus, coach, cycle) and shipping. Air was considered since most of the experts are working in aviation but some indicated the media influence. Rail was also considered with one respondent indicating that in developing countries such as India safety was an issue. Bus was also considered to be affected by accident safety considerations for countries such as India and Thailand. Most answers were limited in explanation as the experts indicated the mode only (e.g. air, rail).

The respondents were asked if there was any evidence that accident safety is, or has been, a higher priority than price, comfort, quality factors, particularly for longer distance journeys. The objective was to relate accident safety concerns to other priorities in travel selection, although this question is not precise since it compares accident safety to multiple factors. The scale of options available to respond ranged from very strong evidence to no evidence.

Figure 7-49 shows a response centred on 'some evidence' but skewed towards limited or no evidence. Only one respondent cited strong evidence and none said very strong evidence. This is consistent with the responses to the user surveys undertaken in the thesis.

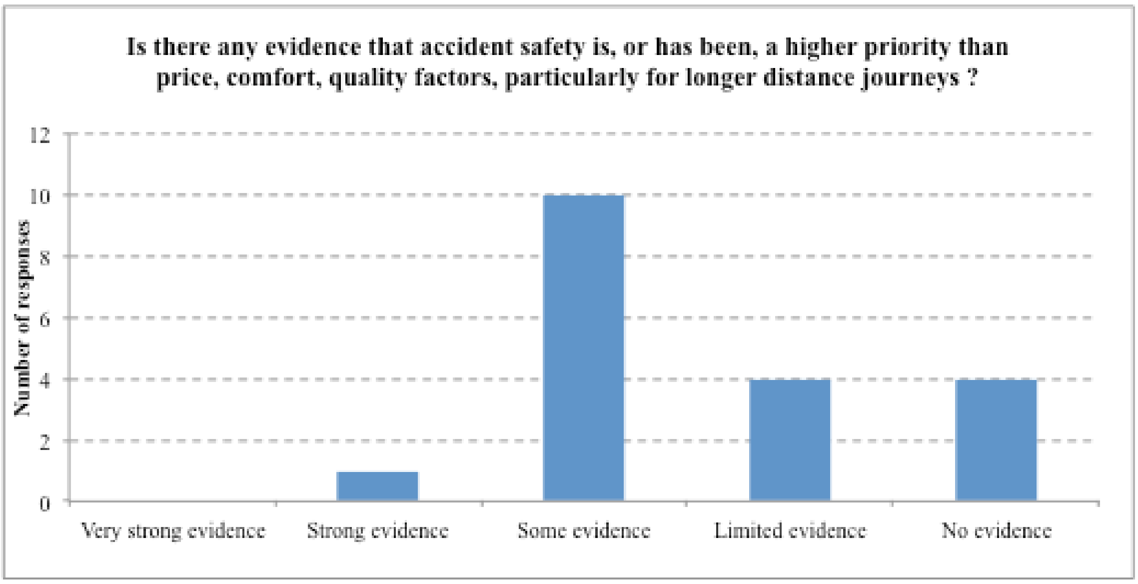

*Figure 7-49: Safety importance in relation to other factors*

Experts were asked if governments can influence transport modal change – an important issue for this work. Accordingly this question explored the level of government influence using options from strong influence to no influence. The responses centred on 'influential', with three responses of 'strong influence''. No respondents said that there was no influence (Figure 7-50).

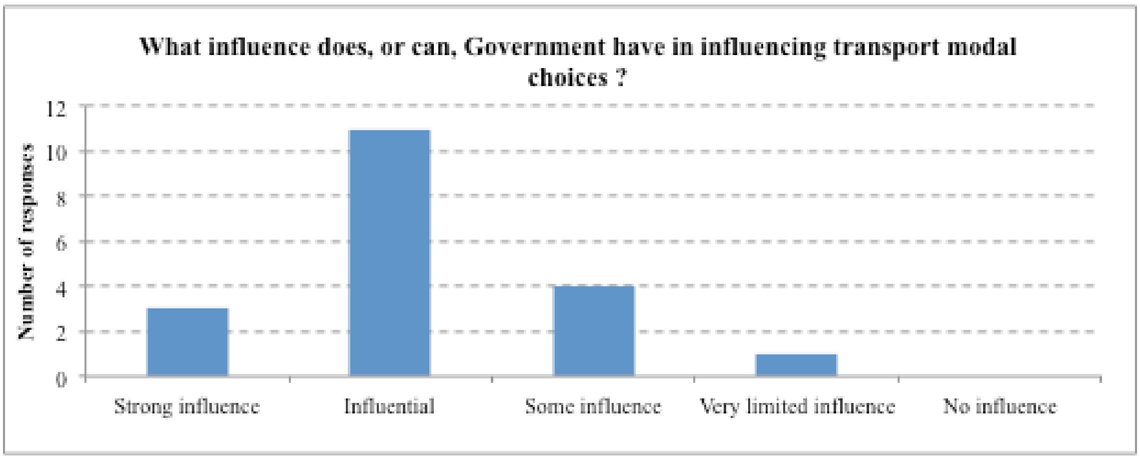

*Figure 7-50: Government influence*

Experts were asked how age and gender affect choices of transport mode and whether it is necessary to take account of these aspects when proposing safety improvements.

Respondents mainly commented on the impact of age rather than gender affecting modal choice. There was limited response as to whether age or gender should be considered when planning improvements in safety.

Age was cited to have a small or minor effect on modal choice due to accessibility issues. It is considered important for air and rail travel since time and accessibility are important factors for those modes. It was thought that younger travellers would be more inclined to make more complex journeys and fly more often. Younger travellers would also be more likely to take cheaper options, e.g. coaches/public transport, over long distances. Age was also thought to impact choice of transport mode: younger people may want to go by train instead of air transport because it is more interesting and cheaper. The issues regarding safety improvements impact all passengers, aircraft and crew, and are not related to passengers' age or gender.

Gender was considered for urban train travel; for example, women only carriages in Japan and waiting rooms in the UK. Modal choice would impact women travelling alone who perhaps would not take long international coach journeys, dependant on the route and location. A respondent noted that women may be more aware of personal safety when travelling at night.

One respondent expressed that age or gender was not relevant in making transport modal choice, but rather that travellers' familiarity with the travel routes would make the difference. A single expert noted that age or gender did not have any impact on modal choice.

All modes of transportation should be suitable for all passenger types, ages and genders. Those aspects should be accounted for given that certain passenger types may refrain from using a transportation mode, or making the journey at all, as a result of any discomfort.

Five experts did not respond to the impact of age, gender and whether it was necessary to take these into consideration in developing safety enhancements.

### 7.4.3 Travel behaviour

To ascertain behaviour of the public, experts were asked to convey what they thought were the top 3 considerations for travellers when making their modal choice for long distance journeys in excess of 200km. They were asked to rank the most important consideration to the third most important consideration on a scale of 1-3 (Figure 7-51).

The dominant responses were price followed by time taken, with accident safety registering as a 2 or 3 level of importance respectively. Overall, the third most prominent factor was convenience, which is closely linked to time taken and schedule. Comfort registers as a prominent third level priority.

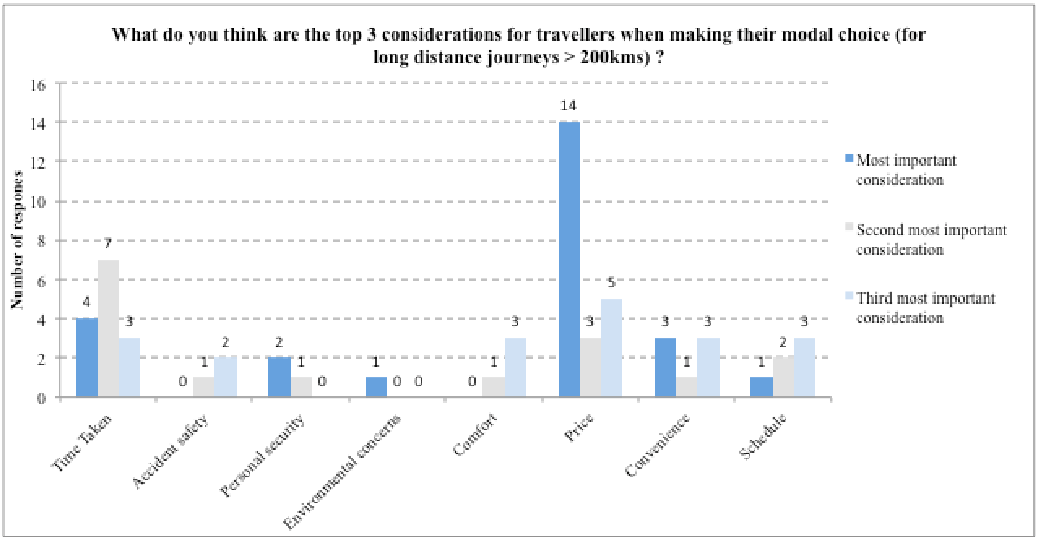

*Figure 7-51: Main considerations for travellers*

The frequency with which travellers consider alternative modes was asked of the respondents. The available options were: making a journey for the first time; when substantial changes occur in the service offered (price, frequency, speed, etc.); rarely or never; when personal changes affect travel patterns (e.g. change of employer); in response to concerns regarding safety or security; or other.

The responses in Figure 7-52 indicate that substantial changes in the service is the most prominent driver for alternatives to be considered (16 cases) while making a journey for the first time (8 cases) and personal changes (7 cases) are the next most frequent selections.

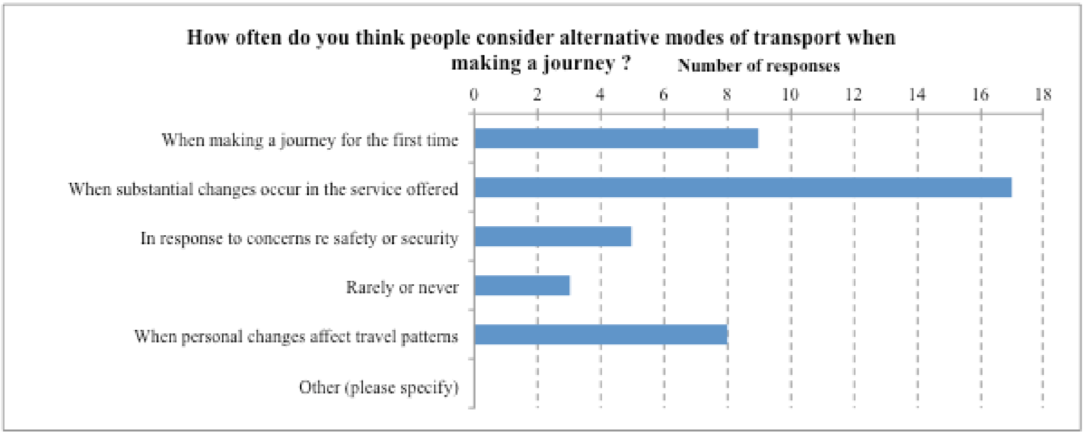

*Figure 7-52: Consideration of alternative modes of transport when making a journey*

Experts were requested to provide their view on the public perception of modal safety, something which is also compared to the results of the user surveys earlier in this chapter. The options were car, taxi, rail, metro, bus/coach, walk or cycle or other to specify.

The results are given in Figure 7-53. The results are presented by mode with the responses from safest to least safe shown from left to right in each case. Air travel received the strongest support as the safest mode, with rail and metro also showing relatively high support. Perhaps surprisingly, there is some support for all the modes being safest or second safest. This could reflect that some respondents, for example, separated walking from cycling. Car travel also received more safest or second safest support than might have been expected.

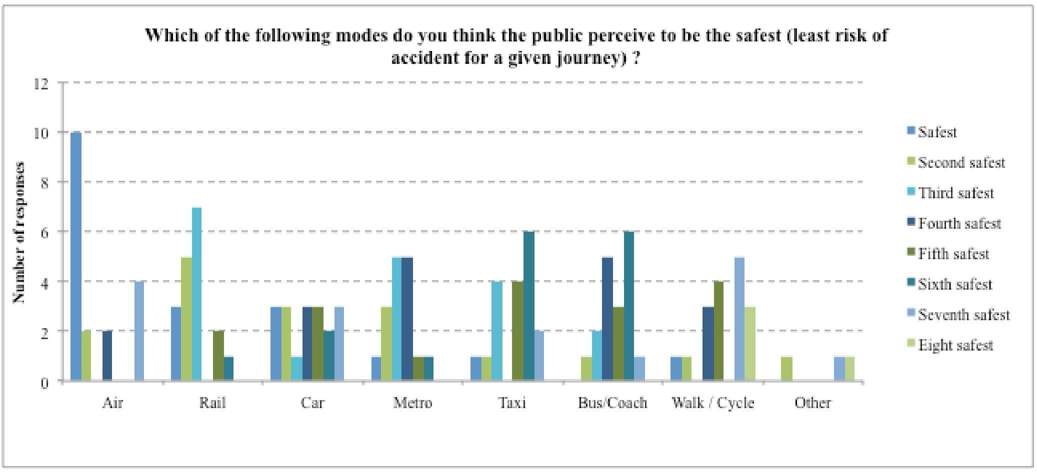

*Figure 7-53: Public perception of safest modes*

A general question was posed on whether in the long run there would be more or less emphasis on safety as a modal choice factor (e.g. in developing countries where perceptions change with higher levels of income or increasing modal choice options). Most respondents indicated that there would be more of an emphasis on safety in the long run, with a few expressing that there would not be a change in developed regions. It was noted that, *"their mode of transport may change as more choices are available and adequate information about safety of modes is given, comparing statistics, etc. (for instance different than from newspapers which look for spectacular accidents like "200 casualties in plane crash!!!)"*. A few respondents commented that in developing countries (India, China, Thailand) air is considered a safe form of transport but that cost is the main factor determining modal choice. In ascending order of preference related to income, bus, rail and air would be considered. It was commented that undoubtedly people become more concerned with safety matters as they become more affluent, but that cultural differences also exist in attitudes to risk and in particular, regarding transport, safety risks also play a role. One respondent also stated that, *"safety is a luxury of higher incomes, usually in developed countries"*, while others noted more emphasis on safety as a modal choice factor and that developing countries need to give more priority to this issue.

An expert also expressed uncertainty that higher income would change the safety awareness in developing countries, at least not in the short term, and cited that travellers would only use established carriers in such regions.

### 7.4.4 Comments from respondents

A key comment from the respondents was that individuals' safety perceptions are guided by geographical and political considerations and media response. For example, they note that air accidents are usually reported globally, while (in India and China) national train and bus accidents are only reported nationally unless there are foreign nationals involved or there is political interest. *"…[F]or aircraft and trains it is the incidents that can damage the perception of transport, rather than the actual quantifiable safety. For airlines it is more the Airline that is affected, e.g. 9/11, Air France 447, Malaysia airlines 370, Madrid train bombing, London underground bombing*".

### 7.4.5 Implications of expert survey

This survey provides insights into perception of public from the observations of experts working in the modal sectors on factors influencing modal choice and travel behaviour. The findings are important for this study in terms of how modal shift can be encouraged (i.e. through individual behaviour or government influence), the constraints that can limit modal shift and the perception of safety from experts' view of public behaviour.

The survey findings suggest that modal shift is influenced by governments and by substantial changes in the service offered by an alternative mode or travellers considering more modal choice when undertaking a journey for the first time.

Behavioural change does occur after major accidents although this temporary change is in operator rather than mode due to limited alternatives available (this result may be biased as the main expert respondents are from the aviation sector). Safety consideration as a factor of modal choice is limited, with price (especially in developing countries) and time taken being more dominant factors although the safety aspect is thought to become more important over time. The experts conveyed that individual safety is influenced by geographical, political and media responses.

## 7.5 QUALITATIVE INTERVIEWS

Qualitative interviews were carried out with a sample of 5 experts and 5 users to augment the overall findings from the expert and snowball questionnaires respectively.

The aim of these interviews was to complement the explanations provided in the main questionnaire responses and to add depth by discussing answers in more detail.

Accordingly the interview structures were aligned with the questionnaires. A corresponding limitation of this approach was that wider themes were not explored in as much detail.

### 7.5.1 Method

Interviews were approximately one hour long and were carried out using an outline to provide a structure for the interview. The structures used are provided in Appendices B.4.1 and B.4.2, which also provides the interview transcripts. The interviews were analysed by grouping responses into common themes and key observations.

**Expert questionnaire interviews**

From the analysis of the interviews 10 main themes emerged and the observations from the interviews are therefore discussed below under these headings.

**Experience in transport mode/countries**

The 5 experts interviewed had experience covering commercial aviation, rail, shipping and aerospace engineering. Functionally their remits covered forecasting and statistics, air traffic management, flight delay analysis and exploring modal shift between air and rail. Geographically interviewees were Europe based but also had experience of travel issues in Asia, USA, Africa and Middle East.

**Modal choice factors**

Together with the factors already identified such as price, schedule and convenience one of the experts noted that the level of stress involved on a journey could also influence modal choice.

Factors influencing the mode chosen could include the journey purpose, i.e. business, leisure, VFR or multi-purpose as well as the availability of options for route and access modes depending on journey origin. Experts highlighted that urban areas had more modal options than rural areas and that this also depended on the specific region or in some cases country, for example between the US and Europe. The frequency of available alternate modes was considered important, as was a preference for fewer transfers during the journey. The level of connections between modes would influence modal choice, especially from access mode to main mode: local bus or local rail connections to a main line rail station. Unreliability can also prevent a mode being chosen with an example given as the Brussels to Amsterdam air route which is subject to frequent cancellations. Most interviewees emphasised seasonality and time of travel as factors.

Regarding travellers themselves, age was considered relevant to the modes used for reasons such as time and comfort rather than price.

**Personal security considerations**

Two interviewees stressed that for air travel it is important to use reputable carriers and not those on the blacklist [i.e. the EU Air Safety List of banned carriers][50] although it was acknowledged that in general security at airports is high with limited exceptions where the security check was not so thorough. Specific concerns regarding personal security were noted in some countries, for example when driving in certain parts of South Africa, though this is not an area considered by this thesis.

**Accident safety considerations and priorities**

It was recognised that some risk is implicit in all transport modes. Air, rail and ship were modes considered to be most affected by large accidents, though their day to day average safety levels are high. For air travel it was observed that pilots' self-preservation instincts indirectly assured passenger safety. Using reputable carriers for air travel was considered important for accident safety as noted under personal security. Safety concerns regarding LCCs were raised because of the need for them to reduce costs for commercial reasons. The negative impact of air accidents on air manufacturers was noted. One interviewee stated that approximately 95% of accidents are attributable to human error, though this was not backed up with a source.

The issue of safety awareness for public VFR traffic was considered to be important as public misperception could limit use of certain modes. VFR users travel less frequently than others such as business travellers and therefore were thought to be less well informed. Road safety concerns were highlighted due to the risky behaviour of other road users and driving in unfamiliar environments. Safety variances between modes controlled by individuals and those controlled by specialists were also noted. In some cases accessing a relatively safe main mode such as air may involve using riskier access modes such as car or walking.

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[50] http://ec.europa.eu/transport/modes/air/safety/air-ban/index_en.htm

Attitudes to transport safety were seen as reliant on cultural background and reason for travelling, i.e. business or leisure, as well as individual attitudes to risk. Safety was viewed differently when considering long or short distance journeys because there are sometimes limited options on longer routes, for example only air. The public may consider modal options on the grounds of safety for shorter routes simply because more alternatives are available.

Safety was considered to be a higher priority for those with a specific aversion to a particular mode, particularly fear of flying, those travelling in regions with consistently high accident risk rates, or where seasonal or diurnal factors cause temporary increases in accident risk. Noteworthy was one observation that developed countries tolerate only enhancements in safety but not increased risks.

### Impacts of major accidents on public behaviour

The impact of media portrayal of major accidents affects user perceptions. In particular, the length of exposure given to a specific accident and distortions to the public image of aviation were commented on by most experts. It was accepted that public reactions are not usually based on full or accurate information, as a result of media distortions; or conversely in some cases the public are simply not aware of certain large scale events.

In the aftermath of an accident there may be short term (1 week to 6 months) behavioural changes such as switching operators (mainly for air where options are available) and occasionally a change in mode. For road travel however there is normally no impact on those not directly involved: drivers do not stop driving unless they have had direct experience of an accident themselves. Changes in public behaviour as a result of major accidents are therefore a function of the mode affected as well as the type of accident and available alternatives.

One reaction commented on was that for a limited time period the impacts of changes in travel behaviour could be counter-intuitive. A particular example quoted was that the closure of airspace in the US after the 11 September 2001 terrorist attacks led to more fatalities on the roads than those resulting directly from the attacks.

### Government influence on mode of transport

All the interviewees recognised that the government can influence the mode used because it has accurate information on modal safety and can inform the public of genuine safety concerns through safety campaigns. Taxation was stated to be a key instrument governments can use to influence modal choice. Current examples range from carbon taxes to ticket taxes on air travel. The latter are used in the Netherlands and Germany and have resulted in large numbers using alternative modes or airports in a neighbouring country. Other passenger taxes and even visa restrictions can also be used. Another example mentioned was the enhancement of road safety by transferring freight from road to rail and in some cases sea.

Reluctance of government to intervene was also noted. In particular under-investment in transport infrastructures can restrict use of certain modes.

### Public perceptions of the safest mode

There were mixed comments on what the public would perceive to be the safest form of transport. Some stated that air was perceived to be the safest because communication between aircraft allows collision warnings to be provided, compared with cars where there was no such provision. Others noted that car would be perceived as safest due to the heightened perception of control. One noted that buses and other urban transport would be safest because of the lower speeds used. One interviewee said rail would be the safest in view of the statistics but did not clarify if the public would perceive it as such.

### Alternative modes considered

More modal options are considered when undertaking a journey for the first time as all available options are explored at this stage. After this the individual tends not to change unless difficulties are experienced. Limited availability of options for longer distance journeys was also noted as a factor.

### Perception in developing countries

From the experience of interviewees, comments were provided on perceptions in developing countries. Cultural differences were identified as impacting safety perceptions and modal choice. Safety concerns in developing countries are not as high as in Europe or the US because people are normally more exposed to risks. Public behaviour is therefore less impacted by major accidents.

Limited availability of alternatives for certain modes in developing countries such as long distance bus/coach and rail travel was noted. Travel by air was considered the only viable option over large parts of Africa, with a reluctance of governments to develop other modes, since national airlines imply a certain “status” fostering national pride. The safety and the cost effectiveness of high speed trains in China as a mode increasingly chosen between large cities were also commented on.

**Other**

The views of interviewees not covered under the above headings are outlined here.

One expert noted that in some countries there is trade-off between safety and speed. The example cited was German autobahns where some parts have no speed restrictions and where this higher risk is known and accepted both by the public and government to a certain extent.

Passenger perceptions on board ships have also changed, which has an implication for safety. For example, on board ships passengers are now referred to as guests and cabins referred to as state rooms, thus making them feel they are in a hotel (unrealistic environment) rather than on a ship. This reduces their environmental awareness so that in the event of an emergency they may not have prepared themselves properly to know how to react.

### 7.5.2 Snowball questionnaire interviews

From the analysis of the snowball interviewees 6 dominant themes emerged. These outcomes and observations are discussed below under the corresponding headings.

**Mode of choice and journey purpose**

An interviewee stated that modal preference depends on socio-demographics and that as these change over time, this affects attitudes to price, accessibility and availability of mode. Modal preferences varied between interviewees. There was a general preference for air travel although cost and flexibility would mean that car would be the alternative mode most used. Air travel particularly dominated for leisure, VFR and business travel but users would prefer rail and coach if time allowed.

There was a preference to use public transport where possible, particularly for environmental reasons, especially in major hubs where it is widely accessible. For some it is not an option due to limited accessibility and availability, especially for commuting purposes. Car travel was preferred because of its flexibility for multi-destination leisure trips, long VFR journeys and when a number of people are travelling together. Some limitations were expressed such as the cost of parking and tolls.

### Modal choice factors

Significant modal choice factors noted were price, convenience, schedule, time, safety, security, comfort and flexibility. For business travel the modal choice is often determined by the company which determines price and available working time when travelling. As with the expert interviews, the choice of mode is influenced by journey purpose, particularly whether for business or leisure. The access modes used are related to availability and accessibility.

### Safety considerations/perceptions

The interviewees perceived accident risk as more important than personal security and mode used more significant than the operator, though there were still some safety concerns within a mode. All interviewees thought safety was implicit to a certain extent in developed countries. One-off accidents in air or rail were not considered to induce modal shift. Rail and air were perceived as safe modes but road safety raised some concern.

The choice of car type is an important consideration in terms of safety expressed by one interviewee, i.e. selecting a vehicle with good passenger safety characteristics (size, strength, design and overall safety ratings). Others noted safety concerns associated with some airlines, particularly trade-offs between using operators/carriers with differing reputations. It was also perceived that safety was not normally a concern when related to travel for business/work purposes. As with expert interviewees, safety was considered important when travelling in developing countries using certain modes, particularly car, buses and airlines. The preference was also to use slower public transport modes such as bus or rail than cars in such countries.

### Alternative modes

From the interviews it was clear that for longer distance travel from the UK and Ireland there are limited modal options with air travel being the main mode. Users expressed their preference for rail on city centre to city centre routes for convenience, ease of boarding and access to luggage. Rail was particularly preferred when the higher prices and longer duration often associated with long rail journeys were less important. In many cases rail was not considered viable because of the additional time taken compared to air travel.

Car as an alternative mode was considered a flexible option especially with more than one person travelling. Car sharing for long distance was also recognised as an option on the basis that the journey is more comfortable but does not represent a modal change.

On some routes in Europe which are covered adequately by rail, air was not regarded as an alternative for those living close to city centres since door to door rail was faster, cost effective and avoided the discomfort factor associated with airport security checks.

**Personal security**

The question of personal security mainly seemed to be related to unfamiliar environments in which there is a preference for taxi rather than public transport. It was suggested that there is trade-off between personal security and safety especially at night and also when in less secure environments or countries; for example, there is a fear of driving and of carjacking in some countries.

A key factor for personal security was gender, i.e. for females, particularly those travelling alone, at night or in unfamiliar environments. In certain locations both gender and age of accompanying persons was thought to be important.

**Choices in adverse weather**

In adverse weather most interviewees stated that they mainly relied on the judgement of operators to determine whether to travel or not. It was also suggested that delays and cancellations on public transport are a form of accident prevention as operators do not take unnecessary risks.

Regarding road safety, the type of roads used and speeds allowed/possible on these roads were recognised as determining choice of whether to travel.

The age of travellers was an important consideration in travelling in adverse weather. There is increasing concern as age increases.

### 7.5.3 Implications of further insights and explanation from qualitative interviews

The additional insights and detailed explanation provided by the qualitative interviews are valuable for this thesis because they provide a more complete understanding of the decision processes behind modal choices. For example, schemes to incentivise modal transfer, such as price subsidies for alternate modes, may not yield a large scale modal shift if other factors outweigh them. Availability of options, accessibility, unreliability, seasonality, time of travel, type of transport infrastructures and socio-demographic factors can all restrict the scale of modal transfer, even if travellers had preferences to use another mode.

## 7.6 SUMMARY

This chapter has reported the three surveys undertaken for this thesis to help determine individuals' willingness to switch modes, and to understand their views on related topics such as risk and modal selection. The questionnaires captured the views of leisure and business user groups respectively. A third survey also sought the views of experts on travellers' attitudes and perceptions to risk to augment the user surveys. All surveys provided useful contextual information on risk perception.

The surveys revealed characteristics of travel behaviour and modal choice and preferences that will help to determine the applicability of a modal switching policy and to influence how it can be applied. The outcomes revealed the following:

**Risk perceptions and willingness to change modes**

- Perceived accident risk was considered to be higher than personal security risk by 59% of snowball travel survey respondents (business travellers) while in the **consumer***data* survey (leisure travellers) 48% considered safety to be an important issue for the main part of the journey. For snowball respondents, accident risk as a deciding factor for modal choice was highest for car at 28% followed by 17% for air and 11% for bus/coach. For **consumer***data* survey travellers the outcome was highest for cycling (25.1%) followed by car/taxi (12.3%), air (10.8%) and bus/coach (also 10.8%).
- Safety was implicit rather than explicit when users considered the modes they would use for a specific journey. Other factors, particularly convenience, price, schedule, availability and time taken ranked more highly as priorities.
- For overall modal safety, air was considered the safest in both user surveys. This was followed by car/taxi and rail/metro in the **consumer***data* survey and in the snowball survey by rail and metro.
- The expert survey provided insights into the perception of the public from the observations of experts working in the modal sectors on factors influencing modal

choice and travel behaviour. This survey also helps in understanding how modal shift can be encouraged and also factors that could limit a shift.

- Safety consideration as a factor in modal choice is limited, with price (especially in developing countries) and time taken being more important factors. Nevertheless safety is thought likely to become more important over time as standards improve, particularly in developing countries. The experts confirmed that individual safety is influenced by geographical, political and media responses.

The additional insights and detailed explanation provided by the qualitative interviews are also valuable for this thesis because they provide a more complete understanding of the decision processes behind modal choices and provide further explanation as to why – even through incentivising modal transfer – the scale of the transfer may not be realised, as there other factors which may outweigh the incentive (availability of options, accessibility, unreliability etc.).

# 8 EVIDENCE ON CROSS-PRICE ELASTICITIES (CPE) AND PRICING IN CONSUMER DECISIONS

A key factor underpinning modal choice (and hence substitutability) identified by the two user surveys described in Chapter 7 is price. This chapter therefore reviews the impacts of price as identified by the surveys and in particular measures of the CPE of demand, which relates price to the mode selection process. Prior to this, the approaches to CPEs are discussed and findings from published literature in the field are also identified.

## 8.1 ANALYTICAL MEASURES OF CROSS-MODAL SUBSTITUTABILITY

The main analytical measure of substitutability, at least in principle, is the CPE of demand between any two modes. Positive and significant CPE measures provide a basis in principle for the use of modal switch as a policy tool for certain routes.

Inspection of existing literature in this area suggests that there are few estimates of such CPEs among transport modes, partly because of the complexity of doing so. An empirical approach is to infer CPEs from an observed shift between modes when price variation is known. Balcombe et al. (2004)[51] in their guidance manual on factors affecting demand for public transport examine urban and regional CPEs. In cases where travellers have never considered switching modes, perhaps due to imperfect information, then a survey is needed to gauge willingness to consider modal switch in response to various incentives. The results of the two user surveys described in Chapter 7 relating to price are presented here and explore in detail the influence of elements relevant to modal choice by the marginal consumer: that is to say, a consumer just at the point of indifference between which modes to use for a journey.

That there is at least a small degree of substitutability among the various modes of transport is evident; consumers considering certain trips clearly give thought to the question of which mode to use. What is not immediately clear is the degree of this substitutability or how it may vary between destinations[52], routes and modes. Consequently, measuring the degree of substitutability and demonstrating that it is of sufficient magnitude to support safety policy are important factors in this study. Two

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[51] Section 9.

[52] For LCCs in some instances this can be a different destination (some distance from final destination for the traveller).

approaches can be used to establish the level of substitutability between the different modes:

(1) Using directly calculated CPE of demand in transport from published studies;

(2) Directly calculating CPE of demand in transport.

## 8.2 EVIDENCE OF CROSS-PRICE ELASTICITIES DERIVED FROM PUBLISHED STUDIES

### Overview

For this study one approach was to review and consider using relevant CPEs from published studies.

There have been extensive reviews of various price elasticities in the published literature (Bly, 1976; TRRL, 1980; Goodwin, 1992; Oum et al, 1992; Halcrow Fox et al., 1993; Wardman, 1997a; Nijkamp et al., 1998; Pratt, 2000; De Jong and Gunn, 2001; Graham and Glaister, 2001; VTPI, 2003). The type of CPEs examined for transport in Great Britain is summarised in Table 8-1.

| Article | Year | Type of cross-price elasticity |
|---|---|---|
| Accent Marketing et al | 1989 | Presents evidence on intercity business travel CPEs for Britain. |
| Acutt and Dodgson | 1995 | Provides a set of CPEs of demand at the national level for travel in Great Britain. These consist of CPE between car travel and the fares on six different public transport modes, and between travel on these six modes and the price of petrol. |
| Clark | 1996 | Provides cross-price estimates from studies that employ aggregate models based on collective behaviour, such as market share or travel volumes. |
| Whelan | 1997 | Reviews CPE estimates in relation to car ownership modelling and forecasting. |
| Wardman | 1997a | Provides urban CPE estimates for rail and car, rail and bus, and car and bus. |
| Wardman | 1997b | Reviews estimates from inter-urban studies of Great Britain using disaggregate mode choice models. Covers rail and car as well as rail and coach and considers the demand for both business and leisure travel. |
| Wardman et al. | 1997c | Provides evidence of rail and car CPEs in the inter-urban leisure travel market in Britain. |
| Halcrow Fox and TRL | 2000 | Presents a comprehensive review of road/rail CPEs with suggested values. |
| Glaister/Grayling & Glaister | 2001 and 2000 | Provides geographical information for the conurbations for intra-urban CPEs, including values for the London Underground. |
| Balcombe et al. | 2004 | Reviews CPEs between private and public transport for urban and inter-urban short distance (Table 9.13) for London and the rest of Great Britain. Includes a review from other countries. |
| Dargay | 2010 | Provides own and CPEs for long distance travel in Britain by domestic coach, rail, air and car (Tables 23 and 27). |

**Source: Adapted from Graham and Glaister 2001 and updated to include more recent studies**

*Table 8-1: Cross-price elasticities for transport in Great Britain*

CPEs are generally considered to be strongly dependent on the competitive situation between modes. It is therefore difficult to characterise markets by a single set of CPEs (Wardman, 1997b) because they can vary according to relative market modal shares and diversion factors[53]. Diversion factors are the number of individuals using a particular mode who say they would be willing to switch to another specified mode[54] (Dargay, 2010).

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[53] Wardman (1997b) suggests the models reported often assume that users of transport have “a real choice between the modes in question” and therefore should not be applied to particular users (e.g. rail users who do not have a car should not be included in a rail-car choice model).

[54] For example, a diversion factor of 0.37 from car to rail of for a specific route would suggest that 37% of car users would switch to rail, if the cost of using the car became too expensive.

Balcombe et al. (2004, Table 9.13) cite inter-urban deduced elasticity (derived from Wardman (1997b)) of car cost with respect to rail use as 0.25, and coach use as 0.34.

Bearing this in mind, the CPEs presented in Table 8-2 illustrate the range of CPEs for car travel with respect to rail fare, and rail trips with respect to car fuel cost.

| Inter-Urban Cross-Price Elasticities | | |
|---|---|---|
| | Car trips with respect to rail fares | Rail trips with respect to car fuel cost |
| Suggested range of values from comprehensive review by Halcrow Fox and TRL (2000) on Road/Rail cross-elasticities | 0.02 to 0.03 | 0.15 to 0.25 |
| National Transport Model Working Paper 3 (2003) High/Low Travel Demand | 0.02 | 0.12 |
| Acutt and Dodgson (1995) | 0.04 (over 50 miles) | - |

**Source: Adapted from DfT (2003)**

*Table 8-2: Comparison of inter-urban cross-price elasticities*

DfT (2003) provides CPEs extracted from their demand model for inter-urban road/rail travel. Comparing their CPEs with suggested values from a review conducted by Halcrow Fox and TRL (2000) shows limited substitution between rail and car, especially when car travel is compared to rail prices. There seems to be more substitutability when rail trips are examined in relation to car fuel costs. This may simply be a function of market shares, e.g. if rail comprises 20% and car 80%, a given absolute shift represents a much larger percentage change in rail travel as such. The CPEs of car travel with respect to rail estimated by Acutt and Dodgson (1995) for journeys over 50 miles also seems to indicate substitutability, which is higher than the other estimations. A possible explanation is that for longer distance travel there is a greater level of competition and hence substitutability. Overall, for the UK, there is a tendency for CPEs of car travel demand with respect to the price for rail to be low for inter-urban leisure travel (Wardman et al, 1997c). Some care is needed in interpreting these figures because of the change in transport costs over this period[55] and, given that car represents a much higher share for all travel than rail, a given absolute shift would represent a much larger percentage of rail travel than of car travel.

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[55] For example, see ORR (2015) Rail Finance: Rail Fares Index (January 2015) Statistical Release. Index showing average change in price of rail fares by ticket type - Table 1.8.

**Dargay Study 2010**

Dargay (2010) has conducted a study on behalf of the Independent Transport Commission developing a forecasting model up to 2030 to examine the prospects for long distance travel in Great Britain by car, rail, coach and air. The model is based on elasticity framework and CPEs are derived from own elasticities using market shares, diversion factors and transfer costs questions.

Journey purpose was categorised into five segments (business, commuting, leisure day trips, VFR and holiday) to allow for the differences in the demand relationships. A further division was provided by providing two distance bands (50 to 150 and >150 miles) for car, rail and coach, as the competition between modes may vary according to distance; air was only considered for trips greater than 150 miles. The forecasting model was specified as a system of 35 demand equations where all elasticities varied by purpose, distance and mode. The substitution between modes is captured through CPEs for travel cost and time, which are key features of the forecasting model developed.

The elasticities were derived (due to the limitations of NTS data such as lack of cost and time information) from data collected in a new survey carried out in the work of Dargay. The survey was targeted at the long distance traveller using a sample size of 1000 individuals for each mode, so that the type of long distance travel and journey costs and time elasticities by mode could be estimated. Interviews were undertaken at motorway services, on board trains for rail travellers, at coach stations and at airports. A minimum of 3 different locations were selected for each mode.

Part of the survey entailed respondents being asked to provide details of the times and costs of the modes available to them. From the 4092 returned questionnaires, only 1101 provided sufficient information for purposes of modelling. This included time and cost information for their current mode and at least one available alternative. It was commented that for such interviews the number of responses would be higher but that the limited frequency of long distance travel meant that individuals were not aware of the costs and time of those modes not used regularly.

The anticipated behaviour questions were used to estimate diversion factors, from which CPE could be derived with respect to journey cost and journey time. Transfer price and time questions enabled the estimation of own-elasticities with respect to journey cost and journey time.

These values were used as dependences to determine journey cost and time elasticities by mode, purpose and distance band from elasticities obtained from aggregate data.

The work of Dargay represents a useful contribution to the literature on this subject as it provides a set of journey cost and time elasticities for long distance travel by mode, journey purpose and distance band not available from other sources.

## 8.3 MEASURING CROSS-PRICE ELASTICITIES OF DEMAND IN TRANSPORT

### 8.3.1 Directly calculating cross-elasticities of demand in transport

Another approach was to calculate CPEs directly from the **consumer***data* and snowball surveys, using data from pricing questions posed in the survey. Questions were asked on the cost at each stage of the journey and respondents' willingness to transfer to an alternative mode given a specific % price reduction, to examine and measure the CPE of demand between modes on the basis of the responses in this survey.

### 8.3.2 Pricing and impact on modal switching consumer*data* survey

The price question covered the cost of individual journey stages. For return tickets, the return fare for each segment was requested (£ sterling). The modes for each part of the journey were cross referenced by the respective cost segment to which they referred. For the purpose of this analysis, the costs provided have been banded to give a relatively even distribution of the costs. The banding is not at equal intervals, but is skewed towards the low price end to accommodate the granularity of the responses provided. It would be reasonable to assume that the banding 100-500 would be air. Overall, the charts (Figure 8-1 to Figure 8-4) show that cost of each part of the journey reflects the modes used. Cost segment 1 is largely the access modes such as car/taxi, rail/metro and bus and coach, whereas cost segment 2 is the main mode of the journey which is primarily air. Cost segments 3 and 4 are mainly access modes, although there is some element of main modes where interconnecting air services are used. The high figures for car/taxi may reflect an element of taxi travel within the total, and also costs of car parking at airports, especially for leisure trips (although it has not been possible to test this directly, as there may be a difficulty for car users in estimating costs such as petrol for a relatively short feeder trip).

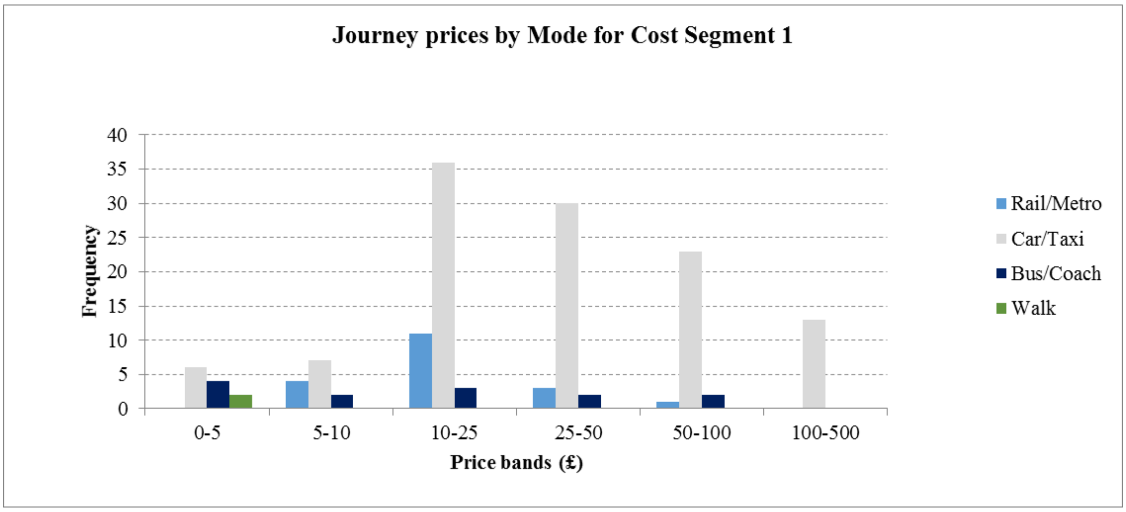

Figure 8-1: Journey prices by mode for cost segment 1 (as given by respondents)

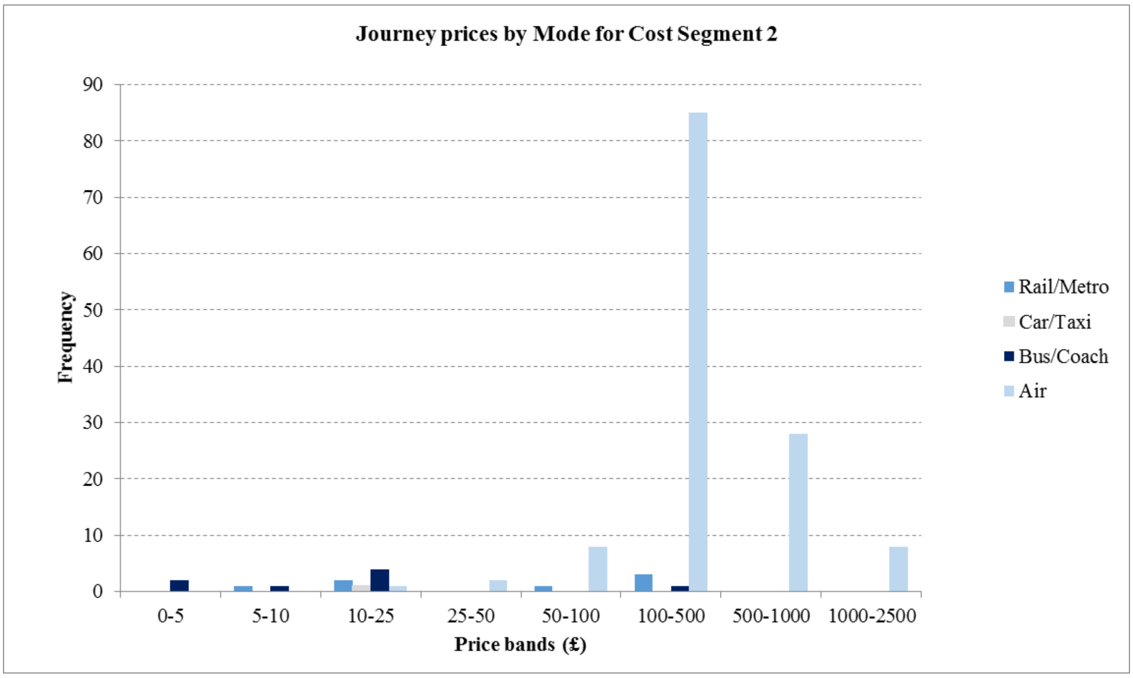

Figure 8-2: Journey prices by mode for cost segment 2 (as given by respondents)

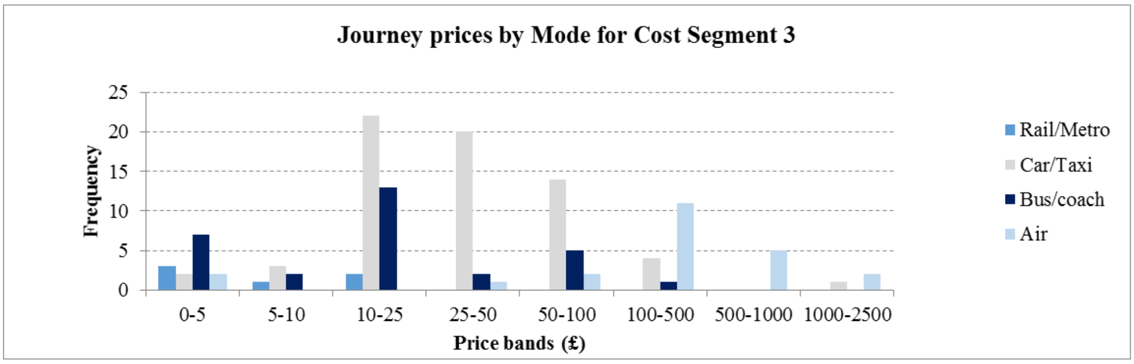

Figure 8-3: Journey prices by mode for cost segment 3 (as given by respondents)

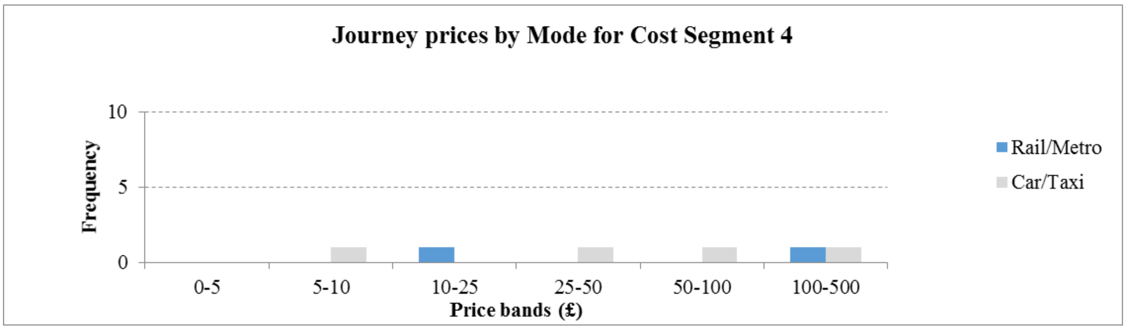

*Figure 8-4: Journey prices by mode for cost segment 4 (as given by respondents)*

**Cross-price elasticity implications consumer*data***

Of the reasons for modal switching it was expected that one of the most prominent was likely to be the cost of alternative modes. A further question was therefore asked to see if respondents would consider switching at different price levels between two modes that they themselves specified. The answers to this were considered in relation to the numbers giving price as a reason for switching in the earlier question on alternative modes, i.e. the 34% who said they would consider alternatives more generally, and of these the 23% who said price was a primary factor in this decision.

The question asked was, "*if cost would cause you to consider an alternative mode for any part of your journey (e.g. selecting a slower mode to save money), please say how much lower the cost would have to be for you to change to the alternative mode?*" The response grid was as follows:

| Transport Type | Alternative Type | -5% | -10% | -25% | -50% | - more than 50% |
|---|---|---|---|---|---|---|
| | | | | | | |

A particular advantage of this question is that it enables direct estimates of CPE of demand for the different transport modes. For this reason it is of considerable value to the core objectives of the thesis. The overall outcomes and analysis are summarised in Appendix B.6.1. This question was also asked in the snowball survey and the combined findings are analysed in a separate Section 8.4 within this chapter.

### 8.3.3 Pricing and impact of modal switching snowball survey

Respondents were asked approximately how much each stage of the trip cost, and asked which mode had been used[56].

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[56] The respondents gave the cost per segment for each stage of the journey so it was not possible to determine if they had factored in costs other than fuel such as parking and toll costs.

The fare for each segment was requested in the currency used and the answers converted to Euros. Return journey fares were divided by two as the question covered the cost of individual journey legs. The modes for each part of the journey were cross referenced by the respective cost segment to which they referred.

Similar to the **consumer***data* the costs have been banded to give a relatively even distribution of costs provided.

Overall, Figure 8-5 and Figure 8-6 show that cost of each part of the journey reflects the modes used.

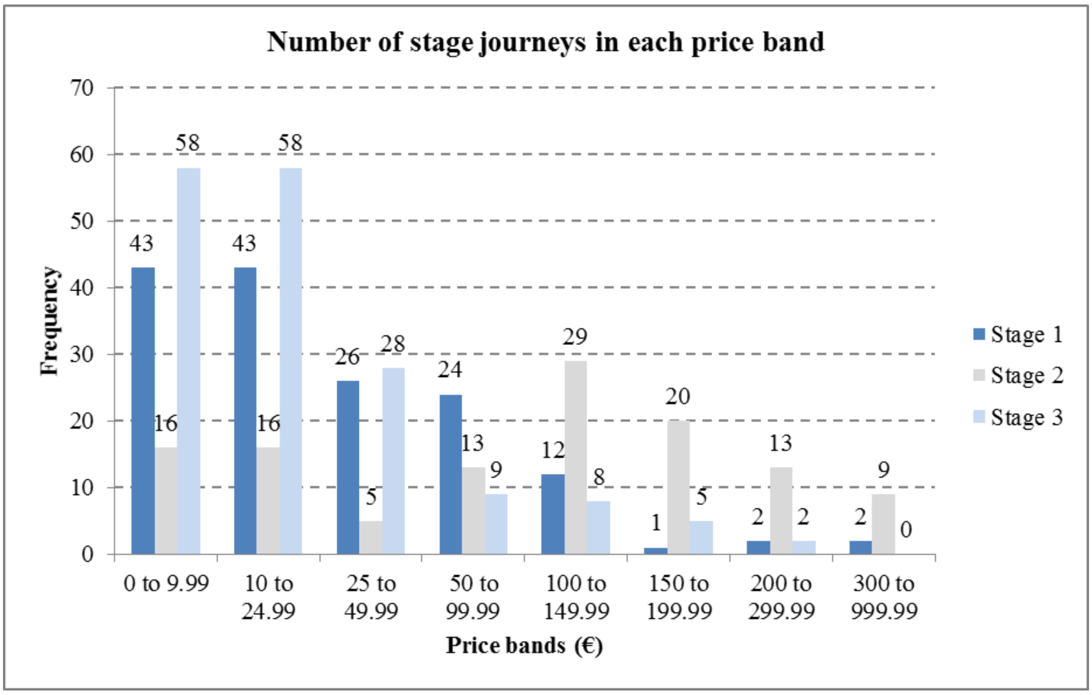

*Figure 8-5: Number of stage journeys in each price band*

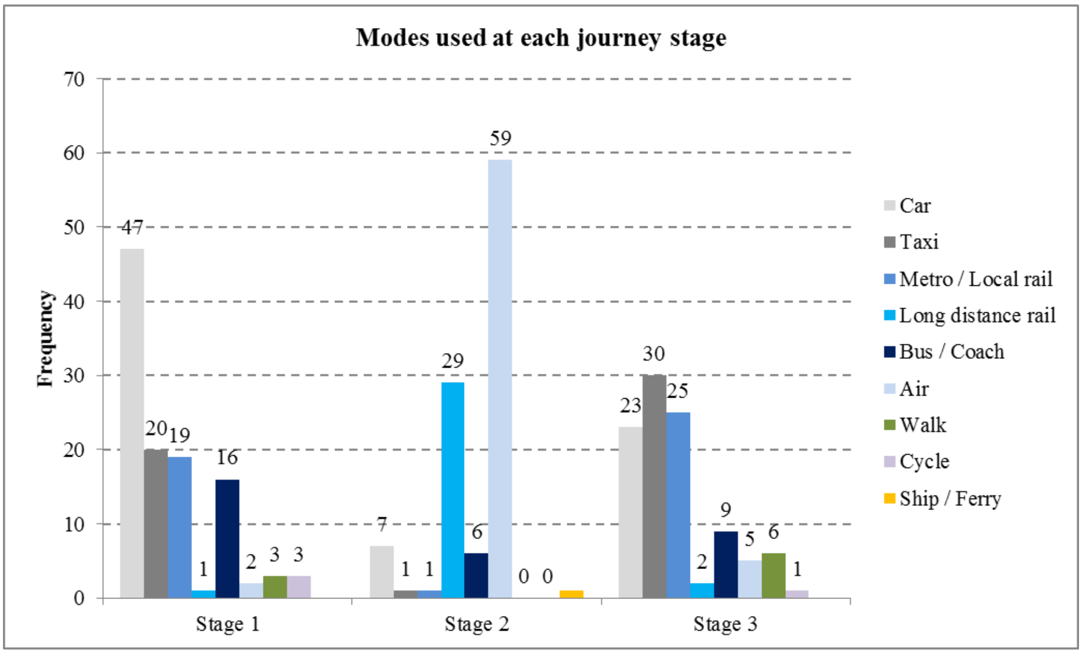

*Figure 8-6: Modes used at each stage*

**Cross-price elasticity implications of snowball survey**

Respondents were asked if the cost of the journey would have caused them to consider an alternative transport type for any part of the journey, to indicate the current and alternative transport type and to specify the fare reduction necessary for them to change to the alternative transport type. Similar to the **consumer***data* survey the answers were considered in relation to the numbers giving price as a reason for switching in the earlier question on alternative modes, i.e. the 77% who said they would consider alternatives more generally and of these the 47% who said price was a primary factor in this decision.

The overall outcomes are summarised in Appendix B.6.2. The combined findings are analysed in Section 8.4 of this chapter.

## 8.4 CROSS-PRICE ELASTICTY IMPLICATIONS FROM COMBINED SURVEYS

A key objective of the surveys was to help understand the CPE of demand between different transport modes and how this would impact measures to improve accident safety through CMS.

Using the responses from the surveys, CPEs were calculated to understand how specific price reductions in a particular mode resulted in demand responsiveness of other modes, and to gauge the level of elasticity of the modes. As mentioned in earlier sections ( 8.3.2

and 8.3.3 ) the detailed analysis of the question pertaining to CPEs from the **consumer***data* and the snowball survey is provided in Appendix B.6.1 and B.6.2 respectively. This section deals with the combined surveys as the identical question was posed in each survey. For the **consumer***data* questionnaire the sample size was 69 out of a total of 203 (34%) responses overall, while for the snowball questionnaire it was 86 out of 111 (77%). Taking the combined questionnaire responses from both surveys gave 155 responses out of 314 in total, resulting in a 49% response rate. All responses, including no responses (those not indicating price sensitivity) and those that included an alternative mode indicating price sensitivity, were considered in the analysis.

The results of the CPE assessments for the combined survey are provided with some general analysis. It has been decided to use only 3 specific price reduction levels (i.e., -25%, -50% and -60%) to ensure sufficient samples in each cell. Prior to the combined analysis some mention should be made of the differences in definitions between each data set. The **consumer***data* participants largely comprised users whose main trip purpose was for leisure/holiday while in the snowball group the purpose was more business/work travel. The length of the trip for the leisure/holiday group was longer distance in general than the business/work which was more focused on distances within Western Europe. Within the **consumer***data* group the treatment of LDR was classified under rail/metro category and car and taxi modes were combined as car/taxi category. For the snowball survey rail/metro was split into local rail/metro and LDR and car and taxi were treated as separate categories. Nevertheless, it was deemed appropriate to analyse the combined responses to better understand CPEs and compare with published data.

Table 8-3, Table 8-5, Table 8-7 and Table 8-9 show the CPEs derived from the combined datasets at specific price reductions for the specific modes and the corresponding combined base numbers in separate tables (Table 8-4, Table 8-6, Table 8-8 and Table 8-10). This is compared to the CPEs indicated in Dargay's (2010) work: for Business/Holiday purposes and with distances greater than 150 miles (240kms). Although the elasticities are not directly comparable (due to differences in Dargay's methods, such as derivation of indirect CPEs calculated from own elasticities, inclusion of modal market shares and diversion factors), the degree of CPE is similar to the results indicated in the Dargay study. A ranking (1-3) is provided in the tables to show the degree of elasticity in each case. For example, in Table 8-3 Dargay observes higher elasticities for rail/metro compared to the other modes of transport, followed by car/taxi and then bus/coach. The first value in Dargay's CPE values refers to travel for business purposes, the second for holiday purposes.

| | **With respect to the cost of Air** | | | | | | |
|---|---|---|---|---|---|---|---|
| | | **-25%** | **-50%** | **-60%** | **Ranking of combined Surveys** | **CPEs Dargay 2010 *** | **Ranking Dargay** |
| | Rail/Metro | 0.14 | 0.08 | 0.08 | 1 | 0.18/0.48 | 1 |
| **Current Mode** | Car/Taxi | 0.05 | 0.03 | 0.03 | 2 | 0.03/0.05 | 2 |
| | Bus/Coach | 0.00 | 0.00 | 0.00 | 3 | 0.00/0.02 | 3 |
| | Air | 0.03 | 0.01 | 0.01 | | N/A | |
| | Ferry / Ship | 0.00 | 0.00 | 0.00 | | | |

** Comparison for Business/Holiday 150 miles +*

*Table 8-3: Cross-price elasticities for current mode with respect to % price reductions in air*

**Selected alternate mode of transport at various price reductions (no.of observations)**

| | | **Air** | | |
|---|---|---|---|---|
| | | **-25%** | **-50%** | **-60%** |
| **Current Mode** | Rail/Metro | 11 | 1 | 4 |
| | Car/Taxi | 4 | 1 | 1 |
| | Bus/Coach | 0 | 0 | 0 |
| | Air | 2 | 0 | 0 |
| | Ferry/ Ship | 0 | 0 | 0 |

*Table 8-4: Change in current mode with respect to % price reductions in air*[57]

In the combined surveys (Table *8-5*), air to rail/metro has higher CPEs (attributable to the more elastic demand between air and LDR trips) followed by car/taxi and Bus/Coach. The latter obtain the same ranking as in Dargay's work, although the absolute values are noticeably lower. For ferry there was no comparison available since this mode was not considered by Dargay and therefore eliminated from the analysis.

The rankings vary from the combined surveys in that bus/coach have higher elasticities (as would be expected) followed by air and car/taxi in Dargay's work, while this work has higher elasticities for Air followed by car/taxi and then bus/coach. The existence of a CPE within the rail/metro category looks unusual in this work. This can be explained by

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[57] Base numbers are additive, that is to say that one further person would shift from Rail/Metro to Air if the price was reduced from -25 to -50, and a further four if the price was reduced to -60%. Therefore at 60% there is a total of 16 in base numbers.

the complications arising here from the role of rail as a feeder as well as main leg mode. For example rail/metro price changes influence transfers from both air (long distance) and Taxi (short distance access mode). This is attributable to the fact that in the **consumer***data* survey rail/metro and car/taxi were not separate modal categories (although they were in the snowball survey) and therefore could imply either a long distance or shorter distance modal transfer. For the combined surveys the broad categories had to be used to make comparisons.

| | **With respect to the cost of Rail/ Metro** | | | | | | |
|---|---|---|---|---|---|---|---|
| | | **-25%** | **-50%** | **-60%** | **Ranking of combined Surveys** | **CPEs Dargay 2010 *** | **Ranking Dargay** |
| | Rail/Metro | 0.00 | 0.01 | 0.01 | | N/A | |
| **Current Mode** | Car/Taxi | 0.13 | 0.11 | 0.14 | 2 | 0.10/0.11 | 3 |
| | Bus/Coach | 0.03 | 0.03 | 0.02 | 3 | 0.31/0.36 | 1 |
| | Air | 0.19 | 0.17 | 0.19 | 1 | 0.06/0.21 | 2 |
| | Ferry / Ship | 0.00 | 0.00 | 0.00 | | N/A | |

** Comparison for Business/Holiday 150 miles +*

*Table 8-5: Cross-price elasticities for current mode with respect to % price reductions in rail/metro*

**Selected alternate mode of transport at various price reductions (no.of observations)**

| | | **Rail/ Metro** | | |
|---|---|---|---|---|
| | | **-25%** | **-50%** | **-60%** |
| **Current Mode** | Rail/Metro | 0 | 1 | 0 |
| | Car/Taxi | 10 | 8 | 9 |
| | Bus/Coach | 2 | 2 | 0 |
| | Air | 15 | 12 | 8 |
| | Ferry/ Ship | 0 | 0 | 0 |

*Table 8-6: Current mode with respect to % price reductions in rail/metro (base numbers)*

Table 8-7 show a variation in the second and third placed rankings (air vs. bus/coach). The elasticity values for the highest-ranked rail/metro moving to car/taxi are relatively high and so the ranking is the same as in Dargay's work; but there are noticeably less reliable CPE values in the combined surveys. This is attributable to the small sample sizes.

| | With respect to the cost of Car/Taxi | | | | | | |
|---|---|---|---|---|---|---|---|
| | | -25% | -50% | -60% | Ranking of combined Surveys | CPEs Dargay 2010 * | Ranking Dargay |
| | Rail/Metro | 0.13 | 0.08 | 0.07 | 1 | 0.25/0.79 | 1 |
| **Current** | Car/Taxi | 0.08 | 0.04 | 0.05 | | N/A | |
| **Mode** | Bus/Coach | 0.00 | 0.00 | 0.01 | 3 | 0.17/0.25 | 2 |
| | Air | 0.05 | 0.03 | 0.04 | 2 | 0.02/0.08 | 3 |
| | Ferry / Ship | 0.00 | 0.00 | 0.00 | | N/A | |

** Comparison for Business/Holiday 150 miles +*

*Table 8-7: Cross-price elasticities for current mode with respect to % price reductions in car/taxi*

**Selected alternate mode of transport at various price reductions (no.of observations)**

| | | Car/Taxi | | |
|---|---|---|---|---|
| | | -25% | -50% | -60% |
| **Current Mode** | Rail/Metro | 10 | 2 | 2 |
| | Car/Taxi | 6 | 1 | 2 |
| | Bus/Coach | 0 | 0 | 2 |
| | Air | 4 | 0 | 4 |
| | Ferry / Ship | 0 | 0 | 0 |

*Table 8-8: Current mode with respect to % price reductions in car/taxi (base numbers)*

In Table 8-9, Dargay’s work observes higher elasticities for rail/metro whereas this work observes higher car/taxi elasticities. For Air the ranking is the same as for rail/metro in the combined surveys (2) and ranked 3 for Dargay’s work. It should be noted that that Dargay’s work is concerned with long-distance rail only, whereas the combined surveys undertaken also cover rail/metro as an access mode. This can potentially have contributed to the differences in ranking.

| | With respect to the cost of Bus/Coach | | | | | | |
|---|---|---|---|---|---|---|---|
| | | -25% | -50% | -60% | Ranking of combined Surveys | CPEs Dargay 2010 * | Ranking Dargay |
| **Current Mode** | Rail/Metro | 0.01 | 0.01 | 0.01 | 2 | 0.01/0.44 | 1 |
| | Car/Taxi | 0.09 | 0.06 | 0.08 | 1 | 0.00/0.06 | 2 |
| | Bus/Coach | 0.01 | 0.01 | 0.01 | | N/A | |
| | Air | 0.01 | 0.01 | 0.01 | 2 | 0.00/0.01 | 3 |
| | Ferry / Ship | 0.00 | 0.00 | 0.00 | | N/A | |

** Comparison for Business/Holiday 150 miles +*

*Table 8-9: Cross-price elasticities for current mode with respect to % price reductions in bus/coach*

**Selected alternate mode of transport at various price reductions (no.of observations)**

| | | Bus/ Coach | | |
|---|---|---|---|---|
| | | -25% | -50% | -60% |
| **Current Mode** | Rail/Metro | 1 | 0 | 1 |
| | Car/Taxi | 7 | 2 | 6 |
| | Bus/Coach | 1 | 0 | 0 |
| | Air | 1 | 0 | 1 |
| | Ferry / Ship | 0 | 0 | 0 |

*Table 8-10: Current mode with respect to % price reductions in bus/coach (base numbers)*

The aim of the CPE question in the two user surveys was to quantify demand at various price reductions for alternative modes of transport. For the combined survey responses, a ranking was developed (as explained above) under each alternative mode to assess the degree of elasticity for certain modes. The results were generally consistent with Dargay's findings, although the absolute CPE values in Dargay's work are higher. The differences can be explained by the design of the questionnaires. While Dargay applied diversion factors to reflect the ability and willingness to shift between various modes of transport, the design of the questionnaires vary and overall the combined surveys have smaller sample sizes than the work undertaken by Dargay. Additionally, this study also considers access modes used mainly for shorter distances (e.g. rail/metro/taxi etc.) while Dargay's study concentrates on long distances and hence the differences in values could be attributable to this.

## 8.5 SUMMARY

This chapter has reported the evidence from published data on CPEs and directly measured CPEs. The latter made use of the respondent data from the two user surveys undertaken for this thesis to help determine individuals' willingness to switch modes, and the specific price reductions at which they may do this.

The findings revealed the following:

**Willingness to change modes**

For both main surveys there was a willingness to switch to an alternative mode. In the **consumer***data* survey 34% of all respondents indicated that they would switch to an alternate mode while in the snowball questionnaire 77% of total respondents would consider an alternative. Combining the responses from both surveys gave 49% willingness to switch.

**Cross-price elasticity**

Arc CPEs were calculated directly using the responses from the survey. This was based on respondents' willingness to switch modes at specific % reductions in price. For the combined survey responses, a ranking was developed for each alternative mode to arrive at an estimate of the degree of CPE. The result was generally consistent with Dargay's (2010) findings on long distance travel, although the absolute CPE values in Dargay's work are higher.

The differences can be explained by the design of the questionnaires, types of modes considered (access/long distance) and sample size.

The implication for this study is that Dargay's CPE values would be more appropriate to use in the net benefit calculations only for long distance trips (150 miles or more) since the relatively small sample size means that the CPEs derived in this study are potentially less reliable and robust to be used robustly in net benefit calculations. Even if the CPEs from the survey were robust enough to use in the net benefit calculation, the data is derived from long distance travel (as investigated in surveys) and therefore only applicable for similar journeys.

# 9 ASSESSMENT OF RISK PERCEPTIONS AND ESTIMATING NET BENEFITS FROM CMS

Initially this chapter evaluates the significance of differences between actual and perceived risks and the implications for CMS, building on Chapters 7 and 8 respectively. The main part of the chapter then uses CBA to provide net benefit assessments which compare monetised safety and related economic benefits from modal shifts on sample journeys to the cost of realising these shifts, for example through subsidies. These CBA calculations test the concept of promoting modal switching and hence draw the analytical elements of the thesis towards a conclusion.

## 9.1 ACTUAL (AGGREGATE AVERAGE) RISKS COMPARED TO PERCEIVED RISKS

Earlier in this work it was noted that there is variation between actual risks reported statistically by official government sources (i.e. aggregate average risks) and the risks perceived by the public (ReStarts, 2012). Individual travellers can, for example, overestimate specific risks in the aftermath of a high profile incident with extensive media coverage (for example large air and rail accidents) despite the risk or probability of a casualty occurring on those modes remaining very low (Carlsson et al., 2004).

Rundmo et al. (2011) observe that there is also a variation between the public perception of private and public transport modes. Users of private modes of transport, which tend to be under their own control (i.e. own car, motorcycle, etc.), often consider these to be safer compared to public modes of transport. Drivers, in particular, tend to assume that they can better control dangers compared to a public mode of transport where they do not have control of the transport mode.

This is important because perceived more than actual risks are a key factor in determining modal choice and will therefore determine the response to efforts to encourage modal switching. To analyse this issue in more detail, the averaged actual risks as defined in the Transport Statistics Great Britain have been compared with the perceptions of risks gained from the travel surveys conducted as part of this work.

### 9.1.1 Actual (Aggregate Average) Risks

The aggregate average risks of being Killed (K) and Seriously Injured (SI) for varying modes of transport per 1000M person km are presented using a log scale in Figure 9-1 as an average between 2004 and 2013 using DfT (2014, Table TSGB0107) statistics on passenger casualty rates by mode. For most modes the casualty risk rates have been falling over time due to technological advancements, improvement in standards in individual modes and increased awareness of safety aspects in some modes.

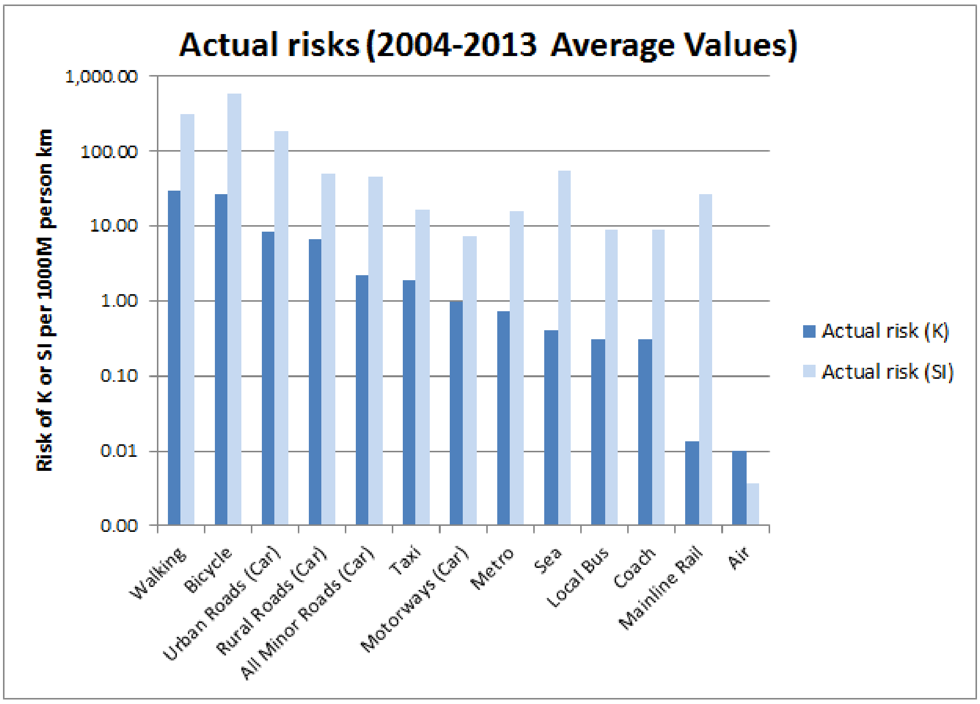

*Figure 9-1: Aggregate average risks per mode (2004 to 2013 averages on log. scale)*

### 9.1.2 Method for perceived risks

The aggregate average risks described above are compared with the perceived risks derived from all three travel surveys: **consumer***data*, snowball and expert. The perceived risks identified by respondents to each question were ranked to allow direct comparison with the actual risks. The safest mode was allocated a rank of 1 with less safe modes having higher number ranks. The results are now considered in the context of each survey.

### 9.1.3 consumer*data* survey questions

Users were asked, *"Has accident risk ever been a deciding factor in your choice of type of transport for a journey (please indicate yes/no for each type)?"*[58] The types of modes provided were air, rail/metro, bus/coach, car/taxi, walk and cycle. Table 9-1 shows the responses (Yes, No or No Response) expressed as a percentage of the total 203 respondents.

| Ranking of perceived risk (safest to least safe) | Mode | Yes (as a % of overall total) | No (as a % of overall total) | No response (as a % of overall total) |
|---|---|---|---|---|
| **1** | Rail/Metro | 4.9% | 83.7% | 11.3% |
| **2** | Walk | 9.9% | 71.9% | 18.2% |
| **3** | Air | 10.8% | 87.2% | 2.0% |
| **3** | Bus/Coach | 10.8% | 78.8% | 10.3% |
| **4** | Car/Taxi | 12.3% | 78.3% | 9.4% |
| **5** | Cycle | 25.1% | 54.2% | 20.7% |

*Table 9-1: Was accident risk a factor in modal choice?*

The highest percentage considering safety as a factor in mode choice is cycle at 25.1% and the lowest is rail/metro where only 4.9% considered it a safety issue. The ranking derived from these results used a scale of 1-5 with the lowest value (rail/metro) representing the safest perceived mode. Walking was also perceived to be safer (9.9%) than most other modes except rail. air and bus/coach are ranked joint third with the same percentage. For all modes of transport a sizable proportion (from 54.2% to 83.7%) indicated that accident risk was not a factor in their modal choice.

Users were also asked, *"Considering the types of transport you have used for this journey which do you think were the safest (less risk of accident)?"*[59] The choices provided were air, rail/metro, car/taxi, walk and cycle. They could select a maximum of two modes which meant a maximum of 406 responses and a minimum of 203, assuming all answered the question correctly. The actual number of responses was 338. In this case, respondents were limited to the modes they had actually used and hence some modes, such as cycling, had a limited response rate.

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[58] Q14b Consumer Data Survey Appendix B.1.1.

[59] Q18 Consumer Data Survey Appendix B.1.1.

For the journey specific question and taking the ranked outcomes at face value, the safest was perceived to be air with cycle being the least safe as shown in Table 9-2.

| Ranking of perceived risk (safest to least safe) | Mode | Number identifying the safest mode | Number who actually used the mode for the journey they specified |
|---|---|---|---|
| **1** | Air | 177 | 199 |
| **2** | Car/Taxi | 63 | 180 |
| **3** | Rail/Metro | 62 | 41 |
| **4** | Walk | 17 | 4 |
| **5** | Bus/Coach | 16 | 75 |
| **6** | Cycle | 3 | 0 |
| **Maximum of 2 modes selected per respondent** | | | |

*Table 9-2: Transport modes considered safest for the actual journey undertaken*

Thirdly users were asked *"Which type of transport do you think in general the safest (less risk of accident) to travel?"*[60] The choices provided were air, rail/metro, car/taxi, walk and cycle. They could select a maximum of two modes and, as in the previous question, a maximum of 406 responses and a minimum of 203 responses were possible assuming all answered the question correctly. In this case, 104 provided two answers and 99 only one, leading to a total of 307 responses. Air was ranked the safest followed closely by rail/metro and car/taxi while cycling was ranked the least safe.

### 9.1.4 Snowball survey questions

In the snowball survey, questions comparable to those in the **consumer***data* survey were asked of a wider group, including users from other European countries. Users were asked, *"Has risk of accident ever been a deciding factor in your choice of transport type for a journey? Please tick if it has for all types of transport for which this has been the case."*[61] Choices presented were car, taxi, metro/local rail, LDR, bus/coach, air and ship/ferry. This differed from the **consumer***data* survey in that car/taxi and rail/metro were treated as separate modes. Car is considered to be the largest concern for accident risk at 34% while, surprisingly, Air at 17% is considered to have the second highest level of concern.

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[60] Q19 Consumer Data Survey Appendix B.1.1.
[61] Q11 Snowball Survey Appendix B.1.2.

| Ranking of Perceived Risk (Safest to least safe) | Mode | Number of responses which indicated accident risk as a factor in modal choice | % responses which indicated accident risk as a factor in modal choice[62] |
|---|---|---|---|
| **1** | Metro/Local rail | 1 | 1% |
| **2** | Taxi | 8 | 7% |
| **3** | Long distance rail | 9 | 8% |
| **3** | Ship/Ferry | 9 | 8% |
| **5** | Bus/Coach | 12 | 11% |
| **6** | Air | 19 | 17% |
| **7** | Car | 38 | 34% |
| **Maximum of 7 modes selected per respondent** | | | |

*Table 9-3: Accident risk as a factor in modal choice*

For the snowball survey users were also asked, *"Considering the transport types you have used for the specific journey described in question 2 which do you think were the safest (least risk of accident)? Please rank from 1 to 3, with 1 being the safest*"[63]. The choices provided were car, taxi, rail, metro, bus/coach, walk/cycle and air. As there was a ranking in the question itself, a weighting was applied to the results to allow the answers to this question to be combined. The weightings applied to rankings 1, 2 and 3 were respectively 1, 0.5 and 0.25 in order to up weight the selection of higher priorities. The outcomes are shown in Table 9-4. The perceived rankings in this question approximately correspond to the actual aggregate risks rankings in Table 9-6.

| Rank | Car | Taxi | Rail | Metro | Bus/Coach | Walk/Cycle | Air |
|---|---|---|---|---|---|---|---|
| **1** | 3 | 2 | 41 | 11 | 2 | 5 | 49 |
| **2** | 7.5 | 6.5 | 11 | 5.5 | 6.5 | 2 | 10 |
| **3** | 6.5 | 4 | 0.25 | 2.75 | 4 | 1.75 | 1 |
| **Totals** | **17** | **12.5** | **52.25** | **19.25** | **12.5** | **8.75** | **60** |
| Weighting: Rank 1 = 1, Rank 2 = 0.5 and Rank 3 = 0.25 | | | | | | | |

*Table 9-4: Weighted safest modes considered for an actual journey undertaken*

### 9.1.5 Expert survey questions

In the Expert Survey the experts were asked about public perceptions of safety as follows: "*Which of the following modes do you think the public perceive to be the safest (least risk*

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[62] Note that the percentages do not sum to 100%, as the number of yes respondents is expressed as a percentage of the total number of responses and therefore varies by mode of transport. Only the sum of yes and no by definition add up to 100%.

[63] Q14 Snowball Survey Appendix B.1.2.

*of accident for a given journey)? Please rank from 1 to 8, with 1 being the safest."*[64] The choices provided were air, car, rail, taxi, metro, bus/coach, walk/cycle and other.

The outcomes are set out in Table 9-5. Rankings were determined by applying weighting factors to the first three ranks, adding the results for the three top ranks of each mode and sorting the total by mode. The values in each column of Table 9-5 are thus as follows:

- Ranked 1 column: number giving rank 1 to that mode multiplied by 5
- Ranked 2 column: number giving rank 2 to that mode multiplied by 2
- Ranked 3 column: number giving rank 3 to that mode multiplied by 1
- TOTAL: sum of the results for Ranked 1, Ranked 2 and Ranked 3

The results were sorted on the basis of the TOTAL column to give the ranks in the first column. Based on this, air emerges as safest and cycle as least safe.[65]

| Ranking of perceived risk | Mode | Ranked 1 | Ranked 2 | Ranked 3 | TOTAL |
|---|---|---|---|---|---|
| **1** | Air | 50 | 4 | 0 | 54 |
| **2** | Rail | 15 | 10 | 7 | 32 |
| **3** | Car | 15 | 6 | 1 | 22 |
| **4** | Metro | 5 | 6 | 5 | 16 |
| **5** | Taxi | 5 | 2 | 4 | 11 |
| **6** | Bus/Coach | 0 | 2 | 2 | 4 |
| **7** | Walk/Cycle | 5 | 2 | 0 | 7 |
| **8** | Other | 0 | 2 | 0 | 2 |
| Weighting: Rank 1 = 5, Rank 2 = 2 and Rank 3 = 1 | | | | | |

*Table 9-5: Experts' view of public perceptions of safest modes*

### 9.1.6 Comparison of Actual versus Perceived Risks

All the rankings shown in Table 9-1 to Table 9-5 are combined and compared in Table 9-6. This is ordered according to the actual risks for K in deaths per 1000M person km. The actual risks have also been ranked from 1 (safest) to 8 (least safe) mode.[66]

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[64] Q13 Expert Survey Appendix B.1.3

[65] Since only a single respondent noted ferry this has not been included.

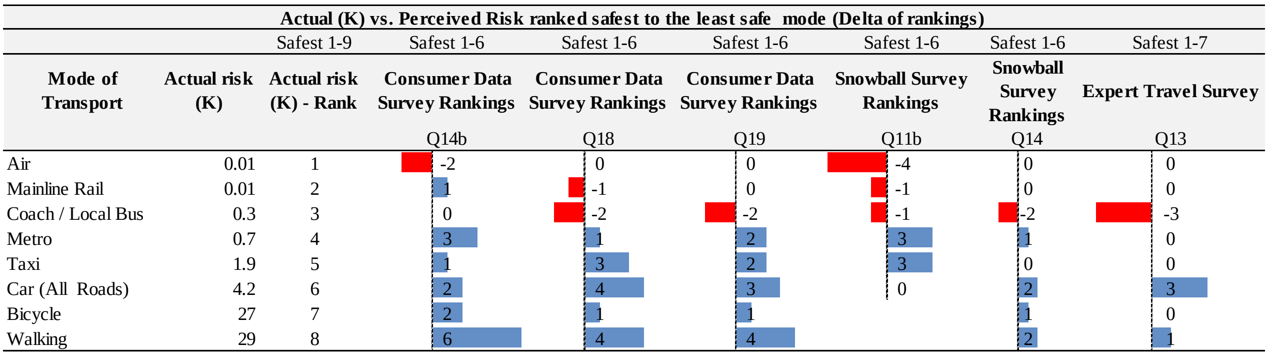
[66] Sea transport has been omitted as it was only noted in the snowball survey.

| Actual Risk vs. Perceived Risk from Surveys (K) Ranked safest to the least safe mode | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Safest 1-8 | Safest 1-5 | Safest 1-6 | Safest 1-6 | Safest 1-6 | Safest 1-6 | Safest 1-7 |
| | Actual risk (K) | Actual risk (K) - Rank | Consumer Data Survey perceived risk rankings | | | Snowball Survey perceived risk rankings | | Expert Travel Survey |
| Air | 0.01 | 1 | 3 | 1 | 1 | 5 | 1 | 1 |
| Mainline Rail | 0.01 | 2 | 1 | 3 | 2 | 3 | 2 | 2 |
| Coach/Local Bus | 0.3 | 3 | 3 | 5 | 5 | 4 | 5 | 6 |
| Metro | 0.7 | 4 | 1 | 3 | 2 | 1 | 3 | 4 |
| Taxi | 1.9 | 5 | 4 | 2 | 3 | 2 | 5 | 5 |
| Car (All Roads) | 4.2 | 6 | 4 | 2 | 3 | 6 | 4 | 3 |
| Bicycle | 27 | 7 | 5 | 6 | 6 | | 6 | 7 |
| Walking | 29 | 8 | 2 | 4 | 4 | | 6 | 7 |

*Table 9-6: Aggregate average risk compared with perceived risk survey questions*

The aggregate average risks are presented side by side with the perceived risks from the survey question rankings. To provide a clear comparison, the original information for actual road values of K, which were given per road type, have been combined into a single all-road category. This was created using a weighted average for the different road types (Motorway, Rural A Roads, Urban A Roads and All Minor Roads) with weights determined according to total distance travelled on that road type. Distances were taken from the DfT (2013a, Table TSGB0703/TRA0102).

The variation between actual and perceived risks is shown in Table 9-7 below. The red boxes indicate instances where the ranked perception of risk is higher than the actual rank; the blue boxes where it is lower. The black dotted lines show the case where the actual and perceived ranks are the same. It should be noted that Table 9-7 shows actual versus perceived risk only for K (killed) and does not include SI (seriously injured).



| Actual (K) vs. Perceived Risk ranked safest to the least safe mode (Delta of rankings) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Safest 1-9 | Safest 1-6 | Safest 1-6 | Safest 1-6 | Safest 1-6 | Safest 1-6 | Safest 1-7 |
| Mode of Transport | Actual risk (K) | Actual risk (K) - Rank | Consumer Data Survey Rankings Q14b | Consumer Data Survey Rankings Q18 | Consumer Data Survey Rankings Q19 | Snowball Survey Rankings Q11b | Snowball Survey Rankings Q14 | Expert Travel Survey Q13 |
| Air | 0.01 | 1 | -2 | 0 | 0 | -4 | 0 | 0 |
| Mainline Rail | 0.01 | 2 | 1 | -1 | 0 | -1 | 0 | 0 |
| Coach / Local Bus | 0.3 | 3 | 0 | -2 | -2 | -1 | -2 | -3 |
| Metro | 0.7 | 4 | 3 | 1 | 2 | 3 | 1 | 0 |
| Taxi | 1.9 | 5 | 1 | 3 | 2 | 3 | 0 | 0 |
| Car (All Roads) | 4.2 | 6 | 2 | 4 | 3 | 0 | 2 | 3 |
| Bicycle | 27 | 7 | 2 | 1 | 1 | | 1 | 0 |
| Walking | 29 | 8 | 6 | 4 | 4 | | 2 | 1 |

*Table 9-7: Actual versus perceived risk (K) ranked safest to the least safe modes (delta of rankings)*

The perception of air is generally aligned with the low actual ranked risk except in two instances: (Q14b) in **consumer***data* and (Q11b) in the Snowball Survey where in both cases Air is ranked as having a higher risk than the actual. Even though statistics and data show modes such as air travel to be a safe form of transport, some respondents are still "fearful" and use air transport only when they have no alternative for certain journeys, perceiving it to be more risky than walking or rail. Following the crashes of the Malaysia MH370, Air Asia and Germanwings for a variety of reasons the perception of risk for users in the cruise stage for air may have changed although the surveys in this thesis were conducted prior to these events.

Similarly, perceived LDR risk is in accordance with the actual ranked risk and close in ranking to Air. There is a slight divergence between actual ranked and perceived risks in the **consumer***data* survey, where the perceived ranked risk is slightly lower than actual ranked risk (Q14b) and slightly higher than actual ranked risk (Q18). What is notable is that perceived risk of long-distance rail is considered higher than car, which is the opposite of the objective risk. This confirms the expectation that travellers in control of their transport perceive themselves to be safest since they are in charge. LDR is also perceived to be less safe than metro in **consumer***data* survey Q18.

In one case for the **consumer***data* survey (Q18,), car is perceived to be safer than long-distance rail. In some cases this can be attributed to instances of large accidents on long distance trains with major casualties from a single incident well in excess of one vehicle accident on the road. In the Expert Survey (Q13), car is still considered to be in the top 3 ranked as safest. The experts were asked to rank the safest modes according to how the public would rank safety. Experts suggested that the car users felt more in control of the vehicle compared to public transport modes.

Bus and coach have considerably lower actual risk than cars yet are only once perceived to be safer than car in the snowball survey (Q11b). This perception could be attributed to a large number of travellers who travel to different regions for holiday/business and perceive the risks for local bus/coach used as a feeder to get to their destinations having higher risk rates. It could also be linked to risks associated with getting to the bus/coach terminus, which can involve walking which carries a different risk profile. Berntman et al. (2010) note this risk type in their work, stating that although the risk for occupants while travelling on buses is low, a door to door journey involving buses is associated with a higher risk, as there are notable casualties to and from the bus stops (which also involve a large number of older persons). Perception of risk can vary and differ in origin and destination locations. This is supported by the Expert Survey where it was commented that local bus can be considered to be affected by accident safety considerations especially for countries such as India and Thailand.

Walking carries a relatively high actual probability of being killed or seriously injured compared to other modes; however, for the **consumer***data* Survey Q14b it was perceived as the second safest transport mode after LDR, and overall it is perceived to be a safe mode despite a very high actual risk relative to other modes. Again this suggests that people perceive themselves better able to control risk than a third party or operator. The low public perception of walking risk may also be because they do not associate safety with distance travelled but assess it against some other parameter such as per journey made. They may also consider that risks are highly dependent on the specifics of a particular journey so that in most cases walking is perceived to be safe, and may actually be so, for example if no dangerous road crossings are required.

In summary, from the analysis it can be said that there are certain variations between perceived and actual ranked risks (car and rail) which could be attributed to factors such as media exposure, origin and destination locations, and private versus public transport modes. There are also variations between modes such as walk and car versus coach/bus, air and rail, the former being perceived to be safer. A possible explanation is the perception of control and overweighting of low probabilities which is consistent with prospect theory mentioned in Chapter 3. This seems to be the case for Air and Bus/Coach travel as shown in Table 9-7. The practical implication of the gaps between perceived and actual levels of risks is that it would be important to complement CMS incentives with an information campaign to try to convey the actual safety risks. In addition to promoting CMS this could also help reduce anxiety for some people, particularly for air travel. The net monetised safety benefits of CMS applied to key journey types, where the modal switch policy is promoted by using a fare subsidy as the main tool, and associated costs are estimated in the following section.

## 9.2 ASSESSMENT OF NET BENEFITS FROM CMS

### 9.2.1 Approach to net benefit assessment

CBA was selected as the appraisal method for assessing potential improvements in safety from CMS. Using the information from earlier chapters, CBA is now applied to examine the potential monetised safety and other economic benefits from the application of CMS to different journey profiles as compared to the costs of achieving the modal switches. Three journey scenarios were selected for the net benefit calculation:

a) A long distance journey with distance beyond the likelihood of regular commuting (London to Glasgow)

b) A relatively long journey dominated by inter-regional traffic but which is also commutable (London to Birmingham)

c) A short distance commute dominated by regular commuting (Kingston to Guildford)

The use of this varied selection of journeys was designed not only to compare the benefits of applying CMS, but also to consider which type of journey would be most amenable to the use of incentives to switch modes. For this reason, the examples chosen are regarded as being 'high volume' examples of their journey type. This means that if there is a net benefit from incentivising modal switch, that benefit could be realised for a large number of travellers. This would depend on sufficient additional capacity being available on the recipient mode. For each of the examples chosen, the high volumes are made possible by frequent rail services, good road connections and, on the long distance London to Glasgow example, air services as well. For London to Birmingham air travel is not considered because it is not quite far enough to justify the fixed time elements of air travel needed for this mode.

The calculations for each journey were quantified as follows:

- Take an assumed target year by which changes in policy measures and user responses would have matured towards equilibrium.
- Apply subsidised prices as the policy tool intended to achieve modal shift. Other incentives could also be used, such as infrastructure investments to improve capacity or marketing campaigns, but in this case the analysis for these particular scenarios is limited to price subsidy only.

- Data on passenger traffic flows and regional movements by different modes are used to help calculate the numbers of passengers willing to transfer from one mode to another. There are problems of consistency in the data and definitions of data sources that have to be controlled.
    - These data were obtained from press release by the Train Operating Companies (TOCs), via 2011 Census Data on Nomis and ORR published reports available modal shares data (along specific rail/air corridors and general market shares according to distances travelled) and press releases, etc.
    - For the point to point journeys it should be noted that where specific data is not available, approximations from regional or national data have been used.
- Aggregate actual risk rates and monetised valuations for K and SI have been obtained from published data as discussed earlier in this thesis.
- CPEs over short and long distances has been estimated based on the findings in Dargay (2010) and in Balcombe et al. (2004) on the demand for public transport.

Distance travelled per mode is combined with monetised risk per mode to provide an overall per person whole journey risk for each modal combination. The reduction in risk per person as a result of the switch is then multiplied by total traveller numbers switching to provide the benefits for safety. Consumer surplus, time savings and environmental impact are also taken into consideration as complementary benefits.

### 9.2.2 Description of scenarios

As the journey types are varied, the general assumptions and the sources that are applicable in each case are provided in the specific journey discussions and corresponding tables. A summary of the approach is provided in Table 9-8 which presents the modes used, origin and destination locations and rationale for each of the three scenarios.

| | **Glasgow to London (point to point)** | **Kingston upon Thames to Guildford (point to point)** | **Birmingham (15 km radius) to London (15 km radius) (catchment area to catchment area)** |
|---|---|---|---|
| Current & Alternative Modes | **Car to Long Distance Rail (LDR)**<br>Journey Type 1 Car, Walk<br>Journey Type 2 Local Bus, LDR, Taxi | **Car to Local Rail**<br>Journey Type 1 Car, Walk<br>Journey Type 2 Local Bus, Rail, Walk | **Car to Rail**<br>Journey Type 1 Car<br>Journey Type 2 Rail, Bus, Underground |
| Scenario | This scenario is a journey from Glasgow to London including access modes with the modal shift from car to LDR to give an illustration of a regularly used, long distance, non-commutable route within Great Britain. | This scenario is a suburban journey dominated by commuting with access modes, from Kingston upon Thames Local Authority District to Guildford Local Authority District with the modal shift from car to rail. | This scenario is a journey originating from Birmingham within a 15 km radius to a destination in London within a 15 km radius with the modal shift from car to LDR. The objective here was to consider a journey with its origin as a regional catchment area and a destination in the central London region, i.e. not a point to point journey. |
| Origin and Destination | The origin and destination points for both modes are assumed to be a residential location just to the north of Glasgow and a central London location just over a mile from the main terminus at Euston. | The origin and destination points for both modes are assumed to be Surbiton Crescent, Kingston via Surbiton Station, and Castle Street, Guildford. This is a point to point journey which considers different access modes. The access mode for Journey 1 is walk followed car as the main mode, while for Journey 2, local bus and walk are the access modes and rail is the main mode. | This journey considers various access modes within the catchment area of both cities. |
| Rationale | The car to rail scenario has been chosen based on the revealed and attitudinal preference information from the travel surveys undertaken for this thesis and CPEs taken from published literature (Dargay et al., 2010)[67]. These suggest willingness to shift from car to rail in response to certain reductions in price of rail, and identify thresholds for modal substitution between certain modes. The timescale considered for this illustrative calculation will only be the year in which the modal shift has been made, assumed to be 2014 | The car to rail modal switch scenario has been chosen as it represents a short suburban commute and contrasts with the much longer-distance Glasgow to London scenario. The modal shares are much more dominated by rail compared to long distance journeys, as are the own and CPEs, which for this scenario have been taken from Balcombe et al. (2004, Table 6-10 and Table 9-11 respectively) using suburban own and cross-price elasticity | The car to rail scenario has been chosen based on the revealed and attitudinal preference information from the travel surveys undertaken for this thesis and CPEs taken from published literature (Dargay et al., 2010)[67]. These suggest willingness to shift from car to rail in response to certain reductions in price of rail, and identify thresholds for modal substitution between certain modes. The timescale considered for this illustrative calculation is the year in which the modal shift has been made, i.e. 2014, implicitly |

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[67] Table 23 and 27 own and cross-price elasticities respectively.

|  | **Glasgow to London (point to point)** | **Kingston upon Thames to Guildford (point to point)** | **Birmingham (15 km radius) to London (15 km radius) (catchment area to catchment area)** |
|---|---|---|---|
|  | with the actual policy introduced a few years previously.<br>The data values for traveller numbers are estimates because specific data for individual point to point journeys are not available. Some of the published data also has limitations which allow only approximate values to be extrapolated. The exception is Virgin rail passenger traffic on this route which is available and used. | values. | assuming that the actual policy was introduced a few years previously.<br>The data values provided for user numbers are estimates which have been derived from MVA Consultancy et al. (2012)[68]. |

*Table 9-8: Description of scenarios*

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[68] The estimates are from Table 3.1. PLANET Long distance: Average weekdays rail trips and growth, between London and City Council areas without HS2.

| Baseline Scenarios: Journey Specific Inputs | | |
|---|---|---|
| **Glasgow to London (point to point)** | **Kingston upon Thames to Guildford (point to point)** | **Birmingham (15 km radius) to London (15 km radius) (catchment area to catchment area)** |
| This is a journey which considers different access modes. The origin and destination point for both modes is Torrance, near Glasgow, to just over a mile from the main arrival terminus at Euston, London. The access mode for Journey Type 1 is car, this being the main mode followed by a small amount of walking as an access mode on arrival in London from car park to destination. For Journey Type 2, rail is the main mode with local bus as the initial access mode to Glasgow Central Station followed by taxi to reach the final destination from London Euston.<br>The journey distance is approximately 654 km/407 miles. The number of rail users on the Glasgow to London route (600,000 in a one year period in 2013/4) was derived from the Virgin Trains press notification. The number of car trips on this route during the same period is derived from market share data applied to the rail traffic numbers, again because car trip information was not available[69].<br>The car-rail market shares for the Glasgow to London route were based on NTS data. The published NTS data are specific to all journeys over 350 miles, and hence are assumed to be applicable in this case. Car journeys covered 34%, rail 13% and air travel 44%. Bus and other modes were only 5% and 2% respectively. Rail share on the specific route (Glasgow-London) would probably be higher (even one third) than for Scotland as a whole to the South East of England. It should | The data values provided for rail user numbers and car driver and passenger numbers are estimates collated from the Census Survey 2011 Nomis database conducted by the Office of National Statistics (ONS). This data was used because specific data for the point to point journey was not available from other sources. The census data contains information on the location of usual residence (origin), place of work (destination) and method of travel to work and this information was extracted using Nomis at local authority district level. Not all residents replied to the Census (Kingston upon Thames had an average response of 93% (ONS, 2012) and not all respondents answered the journey to work question, so the traveller numbers are considered to be under-represented. Accordingly an adjustment was applied to reflect the average response rate for the local authority of origin). The number of travellers by car per day was 521 and by rail 105. These were multiplied by 255 working days and adjusted to reflect the 93% Nomis response rate, resulting in 142,855 trips by car and 28,790 trips by rail. Table 9-10 outlines the key journey inputs and provides the relevant sources used. | The journey distance is approximately 181 km/112 miles for car and 173 km/108 miles for rail. The number of rail users on the Birmingham to London route was 4,472,000 in the period in 2013/4. The number of car trips on this route during the same period is derived from market share data applied to the rail traffic numbers, again because car trip information was not available[69].<br>The car-rail market shares for the Birmingham to London route were based on National Travel Survey data. This was from (DfT, 2013a, NTS0317, edited). The specific medium range car journeys covered 77% with rail at 14%. Table 9-10 outlines the key journey inputs and provides the relevant sources used.<br>For this assessment car to rail modal shift has been considered but not air/rail or car/air given the relatively short distance.<br>The person kilometres were calculated based on 8,600 weekly one-way trips per business day for a 52 week period (i.e. one year) which results in 4,472,000 trips per year. |

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[69] Table NTS0317 Long distance trips within Great Britain by main mode and length: England, 2009/2013 (five survey years combined) was provided as an edited version by NTS in April 2015.

| Baseline Scenarios: Journey Specific Inputs | | |
|---|---|---|
| Glasgow to London (point to point) | Kingston upon Thames to Guildford (point to point) | Birmingham (15 km radius) to London (15 km radius) (catchment area to catchment area) |
| also be noted that NTS data excludes an air interline component. Table 9-10 outlines the key journey inputs and provides the relevant sources used.<br>For this assessment car to rail modal shift has been considered but not air/rail or car/air. The reason in the first case is that air and rail have very similar risk rates (although the air SI risk rate is comparatively lower) and encouraging modal shift would not necessarily lead to net safety benefit or improvement. The car to air scenario has been excluded because of uncertainties about the air market share. This share is difficult to assess since the NTS data excludes transfers at London which, if included, would approximately double market share for air. Hence, the origin and destination of air passengers is unclear because some passengers may transfer on to another destination, or start journeys, for example, elsewhere in the west of Scotland and include other access modes. In view of NTS understating the air market[70] and the corresponding data being ambiguous due to it being based on broad averages, only car to LDR has been considered.<br>The person kilometres were calculated based on the distance and the number of trips estimated in each mode and expressed in units as per 1000M kilometres. | The distances include the access mode distances. Journey 1 has a 33.2 km car journey and assumes a 1.5 km walk in Guildford from car park to the destination. Journey 2 involves 2 km of bus travel at the origin and a 5 km walk to the destination from Guildford station. | |

*Table 9-9: Details of the baseline scenarios for the net benefit calculation*

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[70] CAA air trip data is available, but consideration would then have to be given to journey times to Heathrow via rail in respect of interline trips and therefore NTS may be a better proxy for purely domestic travel.

Following from Table 9-9, Table 9-10 provides quantitative information for each of the main scenarios. In addition to the basic distances for the car journeys and LDR, this also includes contextual information on the number of persons and passenger km travelled on each route annually.

| Journey specific inputs | | | |
|---|---|---|---|
| | Glasgow - London[71] | Kingston – Guildford[72] | Birmingham - London[73] |
| Distance Car (km) | 654 | 34.7 | 180.9 |
| Distance Rail (km) | 648 | 31.1 | 172.9 |
| Persons travelling Journey Type 1 in Y 2014 (trips) | 1,600,000 | 142,855 | 24,596,000 |
| Persons travelling Journey Type 2 in Y 2014 (trips) | 600,000 | 28,790 | 4,472,000 |
| Person kilometres current mode (1000M km) | 1.047 | 0.005 | 4.450 |
| Person kilometres alternative mode (1000M km) | 0.385 | 0.001 | 0.773 |

*Table 9-10: Journey specific inputs for all 3 scenarios*

### 9.2.3 Monetary valuation and risk rates

The weighted risk rates are provided below for each scenario followed by a comparative summary table at the end of this section.

The monetary values for the VSL and VSI for all three scenarios were taken from the WebTAG Data book and are shown below in Table 9-11. There are some variations in the monetised values for life and seriously injured for individual modes, although to ensure consistency in the data the recommended statistics from WebTAG November 2014, Table A 4.1.1: Average value of prevention per casualty by severity and element of cost have been used. The 2010 values have been adjusted to 2014 values and prices to include changes in monetary inflation and GDP[74].

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[71] Sources: National Travel Survey 2013-4: Car Market share 34% (car driver and passengers for distances over 350 miles). Rail Market Share 13%. Edited tables provided by NTS to include Scotland: http://www.mynewsdesk.com/uk/virgintrains/pressreleases/virgin-trains-sees-surge-in-anglo-scottish-rail-travel-1104955, Google Maps

[72] Sources: Census Survey ONS 2011, Nomis database. Correction factor applied to reflect response rate for the survey. https://www.virgintrainseastcoast.com/rail-travel/the-best-way-to-travel/carbon-calculator/

[73] Sources: National Travel Survey 2013-4: Table NTS0302 (edit) Mode share - average distance travelled: England, 2013. Car Market share 77% (car driver and passengers). Rail Market Share 14%. MVA Consultancy et al., (2012, Table 3.1).

[74] In the Web Tag Databook under the user parameters the price year and the value year has been set to 2014.

| Monetary valuation | | | |
|---|---|---|---|
| Statistical Value of Life (VSL) | **1,836,054** | GBP | WebTAG: TAG data book, November 2014 (Table A 4.1.1), 2010 values adjusted for real GDP growth and inflation until 2014. |
| Value of Seriously Injured (VSI) | **206,321** | GBP | WebTAG: TAG data book, November 2014 (Table A 4.1.1), 2010 values adjusted for real GDP growth until 2014. |

*Table 9-11: Monetary valuation*

For all three scenarios, data for aggregate risk rates for K and SI per 1000M person km for car and rail were taken from Transport Statistics Great Britain, Road Casualties, Road Traffic Statistics and Rail Accidents and Safety as shown in Table 9-12 to Table 9-18.

### Glasgow to London

For the car risk, it was assumed that the main part of the journey (93.8%) was on motorways, a small proportion (6%) on urban roads and walk (0.2%). Table 9-12 shows the weighted calculation.

| **Weighted risk calculation of Journey Type 1** | | |
|---|---|---|
| Conversion | 1.60934 | km/mile |
| Urban journey part LON | 20.1 | miles from junction M 40 to location few km from Euston, London |
| Urban journey part GLA | 5.1 | miles from Torrance, Glasgow to Junction 2 onto M80 |
| Motorway | 632.5 | km from Motorway M80 Junction 2 to Junction M40/M4 |
| Walk LON | 1 | km from parking to destination |
| Aggregate Urban journey Share **[A]** | 6.0% | of total journey |
| Motorway Share **[B]** | 93.8% | of total journey |
| Walk Share **[C]** | 0.2% | of total journey |
| Risk of killed Urban **[D]** | 8.33 | per 1000M person km |
| Risk of killed Motorway **[E]** | 0.97 | per 1000M person km |
| Risk of killed Walking **[F]** | 29.00 | per 1000M person km |
| **Calculation** | = | **A*D+B*E+C*F** |
| **Weighted average journey specific risk of being K** | **1.45** | **per 1000M person km** |
| Risk of SI Urban **[G]** | 183.69 | per 1000M person km |
| Risk of SI Motorway **[H]** | 7.24 | per 1000M person km |
| Risk of SI Walking **[I]** | 313.00 | per 1000M person km |
| **Calculation** | = | **A*G+B*H+C*I** |
| **Weighted average journey specific risk of being SI** | **18.31** | **per 1000M person km** |

*Table 9-12: Weighted risk calculation Journey Type 1 - Glasgow to London*

For the risk of alternative modes to car, i.e. bus, LDR and taxi, Table 9-13 shows the calculation.

| **Weighted risk calculation of Journey Type 2** | | |
|---|---|---|
| Conversion | 1.60934 | km/mile |
| Urban journey part GLA | 12.9 | km bus from Torrance., Glasgow to Glasgow Central |
| LDR | 641.6 | km from GLA to EUS |
| Urban journey part LON | 2.9 | km taxi from EUS to few km, London |
| Aggregate Urban journey Share [A] | 2.0% | of total journey |
| LDR Share [B] | 97.6% | of total journey |
| Taxi Share [C] | 0.4% | of total journey |
| Risk of killed Bus [D] | 0.30 | per 1000M person km |
| Risk of killed LDR [E] | 0.01 | per 1000M person km |
| Risk of killed Taxi [F] | 1.90 | per 1000M person km |
| **Calculation** | **=** | **A*D+B*E+C*F** |
| **Weighted average journey specific risk of being K** | **0.02** | **per 1000M person km** |
| Risk of SI Bus [G] | 8.70 | per 1000Mperson km |
| Risk of SI LDR [H] | 0.90 | per 1000M person km |
| Risk of SI Taxi [I] | 16.10 | per 1000M person km |
| **Calculation** | **=** | **A*G+B*H+C*I** |
| **Weighted average journey specific risk of being SI** | **1.12** | **per 1000M person km** |

*Table 9-13: Weighted risk calculation Journey Type 2 - Glasgow to London*

There is, however, a slight difference in the definitions for SI between car[75] and rail travel (known as major injury)[76]. Both definitions refer to injuries requiring hospital in-patient treatment. For rail it is defined as being hospitalised for more than 24 hours; while for road serious injuries refer to being an in-patient shortly after an accident, which suggests similarity to the '24 hours in hospital' approach. The definition of SI for road suggests that some less serious injuries are included as well as those which require a hospital stay. This implies that road related "serious injuries" have a wider definition and rail "major injuries" have a more narrow definition. The differences are not considered sufficient to prevent the statistics being used comparatively.

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[75] Serious injury: An injury for which a person is detained in hospital as an "in-patient", or any of the following injuries whether or not they are detained in hospital: fractures, concussion, internal injuries, crushings, burns (excluding friction burns), severe cuts, severe general shock requiring medical treatment and injuries causing death 30 or more days after the accident. An injured casualty is recorded as seriously or slightly injured by the police on the basis of information available within a short time of the accident. This generally will not reflect the results of a medical examination, but may be influenced according to whether the casualty is hospitalised or not. Hospitalisation procedures will vary regionally.

[76] Major injury: Injuries to passengers, staff or members of the public as defined in schedule 1 to RIDDOR 1995 amended April 2012. This includes losing consciousness, most fractures, major dislocations, loss of sight (temporary or permanent) and other injuries that resulted in hospital attendance for more than 24 hours.

### Kingston to Guildford

As there was more than one mode in both journeys, composite risks were calculated and weighted according to the distance. Table 9-14 and Table 9-15 show the calculation.

| **Weighted risk calculation of Journey Type 1** | | |
|---|---|---|
| Conversion | 1.60934 | km/mile |
| Car | 33.2 | km |
| Walk | 1.5 | km |
| Share Car **[A]** | 95.7% | of total journey |
| Share Walk **[B]** | 4.3% | of total journey |
| Risk of killed Car **[C]** | 8.33 | per 1000M person km |
| Risk of killed Walk **[D]** | 29.00 | per 1000M person km |
| **Calculation** | = | **A*C+B*D** |
| **Weighted average journey specific risk of being K** | **9.22** | **per 1000M person km** |
| Risk of SI Car **[E]** | 183.69 | per 1000M person km |
| Risk of SI Walk **[F]** | 313.00 | per 1000M person km |
| **Calculation** | = | **A*E+B*F** |
| **Weighted average journey specific risk of being SI** | **189.29** | **per 1000M person km** |

*Table 9-14: Weighted risk calculation Journey Type 1 - Kingston to Guildford*

| **Weighted risk calculation of Journey Type 2** | | |
|---|---|---|
| Conversion | 1.60934 | km/mile |
| Local Bus | 2.0 | km |
| Rail | 27.6 | km |
| Walk | 1.5 | km |
| Share Local Bus [A] | 6.4% | of total journey |
| Share Rail [B] | 88.7% | of total journey |
| Share Walk [C] | 4.8% | of total journey |
| Risk of killed Bus [D] | 0.30 | per 1000M person km |
| Risk of killed Rail [E] | 0.01 | per 1000M person km |
| Risk of killed Walk [F] | 29.00 | per 1000M person km |
| **Calculation** | = | **A*D+B*E+C*F** |
| **Weighted average journey specific risk of being K** | **1.43** | **per 1000M person km** |
| Risk of SI Bus [G] | 8.70 | per 1000M person km |
| Risk of SI Rail [H] | 0.90 | per 1000M person km |
| Risk of SI Walk [I] | 313.00 | per 1000M person km |
| **Calculation** | = | **A*G+B*H+C*I** |
| **Weighted average journey specific risk of being SI** | **16.47** | **per 1000M person km** |

*Table 9-15: Weighted risk calculation Journey Type 2 - Kingston to Guildford*

### Birmingham to London

For the car risk, it was assumed that the main part of the journey (89%) was on motorways and a very small proportion (11%) on urban roads. Table 9-16 and Table 9-17 show the calculation.

| Weighted risk calculation of Journey Type 1 | | |
|---|---|---|
| Conversion | 1.60934 | km/mile |
| Car Motorway | 160.9 | km |
| Car Urban | 20.0 | km |
| Share Car Motorway **[A]** | 88.9% | of total journey |
| Share Car Urban **[B]** | 11.1% | of total journey |
| Risk of killed Car Motorway **[C]** | 0.97 | per 1000M person km |
| Risk of killed Car Urban **[D]** | 7.91 | per 1000M person km |
| **Calculation** | = | **A*C+B*D** |
| **Weighted average journey specific risk of being K** | **1.74** | **per 1000M person km** |
| Risk of SI Car Motorway**[E]** | 7.24 | per 1000M person km |
| Risk of SI Car Urban **[F]** | 149.98 | per 1000M person km |
| **Calculation** | = | **A*C+B*D** |
| **Weighted average journey specific risk of being SI** | **23.02** | **per 1000M person km** |

*Table 9-16: Weighted risk calculation Journey Type 1 - Birmingham to London*

| Weighted risk calculation of Journey Type 2 | | |
|---|---|---|
| Conversion | 1.60934 | km/mile |
| Local Bus | 4.0 | km |
| Rail | 160.9 | km |
| Underground | 8.0 | Km |
| Share Local Bus [A] | 2.3% | of total journey |
| Share Rail [B] | 93.1% | of total journey |
| Share Underground [C] | 4.6% | of total journey |
| Risk of killed Bus [D] | 0.30 | per 1000M person km |
| Risk of killed Rail [E] | 0.01 | per 1000M person km |
| Risk of killed Underground [F] | 0.39 | per 1000M person km |
| **Calculation** | = | **A*D+B*E+C*F** |
| **Weighted average journey specific risk of being K** | **0.04** | **per 1000M person km** |
| Risk of SI Bus [G] | 8.70 | per 1000M person km |
| Risk of SI Rail [H] | 0.90 | per 1000M person km |
| Risk of SI Underground [I] | 16.86 | per 1000M person km |
| **Calculation** | = | **A*G+B*H+C*I** |
| **Weighted average journey specific risk of being SI** | **1.82** | **per 1000M person km** |

*Table 9-17: Weighted risk calculation Journey Type 2 - Birmingham to London*

### Comparative risk rates

The resulting risk rates for all three scenarios are shown in Table 9-18.

| Risk Rates Summary[77]<br>(per 1000M person km) | Glasgow - London | Kingston – Guildford | Birmingham - London |
|---|---|---|---|
| Probability of being K – Journey Type 1 | **1.45** | **9.22** | **1.74** |
| Probability of being SI – Journey Type 1 | **18.31** | **189.29** | **23.02** |
| Probability of being K – Journey Type 2 | **0.02** | **1.43** | **0.04** |
| Probability of being SI – Journey Type 2 | **1.12** | **16.47** | **1.82** |

*Table 9-18: Comparative risk rates for all three scenarios*

### 9.2.4 Subsidy, cross price elasticity and rail fares

The incentive used to encourage modal shift in all three scenarios is a price subsidy resulting in a fare decrease of 10% for rail travel on the route.

### Glasgow to London

A CPE value of 0.10 has been derived from an average of varying purpose of travel (business, commuting, holiday, leisure and VFR) is used from Dargay (2010, Table 27) for long distance travel demand (greater than 150 miles) to determine the extent of the modal shift from car to rail, as this is considered to be appropriate to the demand on this route. The resulting shift corresponding to this rail price decrease from the subsidy is 1% of car users changing to rail. Although the percentage is low, given the high market share of car travel the amount of transfers is large in absolute terms.

The representative rail ticket fare between Glasgow Central and London Euston was obtained from the ORR (Table 12-10) using average revenue per franchised passenger kilometre (pence/km) for 2013/2014 which showed 13.74 pence/km. This was multiplied by the rail distance, resulting in a fare of £90.30. This is similar to the average fare by West Coast TOC as noted in the article by Steel (2015, p59).

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[77] DfT (2014a, Table RAS30017), DfT (2013d, Table TRA0204); DfT (2014c, Table RAS3001-TSGB0107- average 2003/4 - 2013/4); DfT (2014c, Table RAI0502 - TSGB0806 - average 2001/2-2012/13)

**Kingston to Guildford**

An illustrative CPE of 0.03 was used, derived from Balcombe et al. (2004, see Tables 9.6, 9.8 and 9.12). These tables respectively gave CPEs for car use with respect to underground fare (0.02), CPE of car use with respect to rail fare (0.05), and urban deduced cross elasticities (0.054) for car use with respect to rail cost in London and surrounding areas. The 0.03 CPE value used, which is within the range of values given by Balcombe et al., is considered to be appropriate to the demand on the Kingston to Guildford route. The resulting shift corresponding to the 10% reduction in rail price from the subsidy is 0.3% of car users changing to rail as shown in Table 9 19 (i.e. 10% of 0.03).

The representative rail fare between Kingston and Guildford was an average rate obtained from thetrainline.com using the Any Time day return fare of £17 divided by 2 to represent a one way rail fare and from an average of season ticket price from National Rail (assuming 50:50 split). This would be the fare used by peak hour commuters.

**Birmingham to London**

A CPE value of 0.06 has been derived from an average of varying purpose of travel (business, commuting, holiday, leisure and VFR) is used from Dargay (2010, Table 27) for long distance travel demand (0-150 miles) to determine the extent of the modal shift from car to rail as this is considered to be appropriate to the demand on the Birmingham to London route. The resulting shift corresponding to the 10% rail price decrease from the subsidy is 0.06% of car users changing to rail. Although the percentage is low, given the high market share of car travel, the number of transfers is large in absolute terms. The representative rail ticket fare between Birmingham and London Euston was obtained from the ORR Statistics (2014, Table 12-10) using revenue per franchised passenger kilometre (pence/km) for 2013/2014 which showed 13.74 pence/km. This was multiplied by the rail distance, resulting in a fare of £22.11. This is similar to the average fare by West Coast TOC as noted in the article by Steel (2015, p59).

The overall price reduction and CPE factors are summarised in Table 9-19.

| Summary of Subsidy, cross-price elasticity and rail fares | | | |
|---|---|---|---|
| | **Glasgow - London**[78] | **Kingston – Guildford**[79] | **Birmingham - London**[80] |
| Cost of Subsidies per person/per trip (GBP) | -9.03 | -0.76 | -2.21 |
| Cross-price elasticity Car towards LDR | **0.10** | **0.03** | 0.06 |
| Percentage change in Price for Rail (%) subsidy assumption | **-10.00%** | **-10.00%** | **-10.00%** |
| Percentage change in demand for Car (%) as a result of CPE and assumed price reduction | -1.0% | -0.3% | -0.6% |
| Rail ticket price London Euston - Glasgow Central one-way (GBP) | **90.3** | **7.61** | 22.11 |

*Table 9-19: Price reduction and cross-price elasticity*

### 9.2.5 Safety benefits

#### Glasgow to London

The impact of the modal shift from car to rail resulted in the benefits shown in Table 9-20. In absolute numbers the fare adjustment incentive would result in 15,604 trips moving to rail rather than travelling by car. This was calculated by multiplying the persons making the journey by rail annually by the % increase in demand for rail resulting from the rail price drop, acting on the CPE relationship established between car and rail. Table 9-20 shows how the total safety benefit of **£64,997** was calculated.

| Calculation of safety benefits | | |
|---|---|---|
| Number of trip changes from Car to Rail **[A]** | 15,604 | trips |
| Reduction in person km due to switch from car to public transport Glasgow - London **[B=A*674km/1,000,000]** | 0.0105 | 1000M person km |
| Increase in person km on rail due to switch on Glasgow - London **[C=A*657.4km/1,000,000]** | 0.0103 | 1000M person km |
| Reduction of persons killed in journey type 1 **[D=B*1.45]** | 0.0153 | persons |
| Persons killed in journey type 2 **[E=C*0.02]** | 0.0002 | persons |
| **Lives saved due to switch [F=D-E]** | **0.0151** | persons |

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[78] Based on ticket price and price reduction assumption, Average Cross Price Elasticity over 150 miles Dargay, 2010 (Table 27), ORR Statistical table 12.10: Based on revenue per franchised passenger kilometre (13.74 pence/km) 2013/14.

[79] Based on ticket price and price reduction assumption, Demand for Public Transport (Balcombe et al., 2004), Table 9.11, http://ojp.nationalrail.co.uk/service/seasonticket/tickets and www.thetrainline.com.

[80] Based on ticket price and price reduction assumption, Average CPEs for distances below 150 miles (Dargay, 2010, Table 27), Source: ORR Statistical table 12.10: Based on revenue per franchised passenger kilometre (13.74 pence/km) 2013/14.

| Calculation of safety benefits | | |
|---|---|---|
| Reduction of persons seriously injured in journey type 1 **[G=B*18.31]** | 0.1926 | persons |
| Increase in persons seriously injured in journey type 2 **[H=C*1.12]** | 0.0115 | persons |
| **Reduction in injuries due to switch [I=G-H]** | **0.1811** | persons |
| Monetised values lives saved due to switch **[J=F*VSL]** | 27,634 | GBP |
| Monetised values of injuries prevented due to switch **[K=I*VSI]** | 37,364 | GBP |
| **Total Safety Benefit [L=J+K]** | **64,997** | **GBP** |

*Table 9-20: Safety benefits calculations Glasgow to London*

### Kingston to Guildford

The benefits of the modal shift from car to rail safety are now considered. In absolute numbers the fare adjustment incentive would result in 429 trips moving to rail from car. This was calculated by multiplying the persons making the journey by rail annually by the percentage increase in demand for rail resulting from the rail price drop, acting on the CPE relationship established between car and rail. Table 9-21 shows how the total safety benefit of **£751** was calculated.

| Calculation of safety benefits | | |
|---|---|---|
| Number of trip changes from Car to Rail **[A]** | 429 | trips |
| Reduction in person km due to switch from car to public transport Kingston - Guildford **[B=A*34.7km/1,000,000]** | 0.00001 | 1000M person km |
| Increase in person km on rail due to switch on Kingston - Guildford **[C=A*31.1km/1,000,000]** | 0.00001 | 1000M person km |
| Reduction of persons killed in journey type 1 **[D=B*9.22]** | 0.0001 | persons |
| Persons killed in journey type 2 **[E=C*1.43]** | 0.0000 | persons |
| **Lives saved due to switch [F=D-E]** | **0.0001** | persons |
| Reduction of persons seriously injured in journey type 1 **[G=B*189.29]** | 0.0028 | persons |
| Increase in persons seriously injured in journey type 2 **[H=C*16.47]** | 0.0002 | persons |
| **Reduction in injuries due to switch [I=G-H]** | **0.0026** | persons |
| Monetised values lives saved due to switch **[J=F*VSL]** | 217 | GBP |
| Monetised values of injuries prevented due to switch **[K=I*VSI]** | 535 | GBP |
| **Total Safety Benefit [L=J+K]** | **751** | **GBP** |

*Table 9-21: Safety benefits calculation Kingston to Guildford*

### Birmingham to London

The impact of the modal shift from car to rail resulted in the benefits shown in Table 9-22. In absolute numbers the fare adjustment incentive would result in 157,414 trips moving to rail rather than car. This was calculated by multiplying the persons making the journey by rail annually by the percentage increase in demand for rail resulting from the rail price drop, acting on the CPE relationship established between car and rail. Table 9-22 shows how the total safety benefit of **£214,078** was calculated.

| Calculation of safety benefits | | |
|---|---|---|
| Number of trip changes from Car to Rail **[A]** | 157,414 | trips |
| Reduction in person km due to switch from car to public transport Birmingham - London **[B=A*180.9km/1,000,000]** | 0.0285 | 1000M person km |
| Increase in person km on rail due to switch on Birmingham - London **[C=A*172.9km/1,000,000]** | 0.0272 | 1000M person km |
| Reduction of persons killed in journey type 1 **[D=B*1.74]** | 0.0495 | persons |
| Persons killed in journey type 2 **[E=C*0.04]** | 0.0010 | persons |
| **Lives saved due to switch [F=D-E]** | **0.0485** | persons |
| Reduction of persons seriously injured in journey type 1 **[G=B*23.02]** | 0.6557 | persons |
| Increase in persons seriously injured in journey type 2 **[H=C*1.82]** | 0.0495 | persons |
| **Reduction in injuries due to switch [I=G-H]** | **0.6062** | persons |
| Monetised values lives saved due to switch **[J=F*VSL]** | 89,007 | GBP |
| Monetised values of injuries prevented due to switch **[K=I*VSI]** | 125,070 | GBP |
| **Total Safety Benefit [L=J+K]** | **214,078** | **GBP** |

*Table 9-22: Safety benefits calculation Birmingham to London*

### 9.2.6 Subsidy derived benefits

### Glasgow to London

In addition to the safety benefits, additional complementary benefits arise directly from the price subsidy.

As a result of the price subsidy of 10% the existing rail users (600,000) for the journey selected also benefit in terms of reduced rail fares. This amounts to approximately **£5.4 million** per annum. This benefit would be a transfer payment from tax payers in general and can be considered a re-distribution effect in favour of rail users.

Together with the benefits to existing rail users, there is additional demand generated by the "own-mode" demand for long-distance rail services which is fairly elastic (Dargay, 2010, Table 23). Table 9-23 highlights the own elasticity for rail from Dargay which is -0.83 and results in a change in demand of 8.30%. The total number of additional users due to the price reduction is 49,800, of which 34,196 are additional rail users due to own-mode elasticity of demand. A price reduction in rail would generate revenue from additional persons **(£4.0 million** per annum). The total consumer surplus (see Figure 9-2) gain for these users is **£ 295,374**.

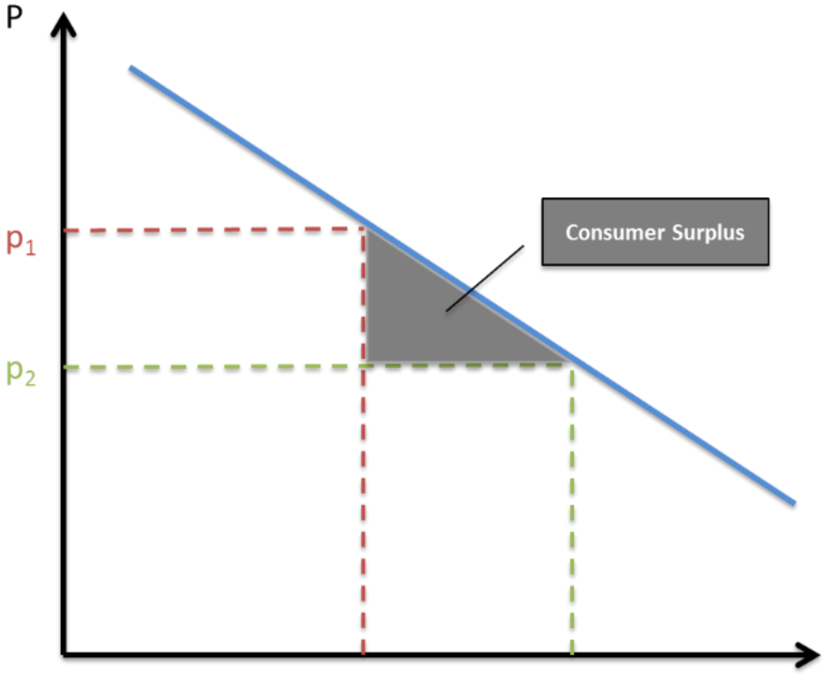


*Figure 9-2: Consumer surplus for additional users as a result of price subsidy*

From this figure the consumer surplus of persons switching from car to LDR has been deducted (to avoid double counting) resulting in a net consumer surplus gain of **£154,434** that can offset part of the subsidy. In this scenario the "rule of half" has been applied to evaluate the average consumer benefits to additional users that have been attracted through the price reduction but which are not those who have shifted modes, or were existing users.

| **Benefits of price reduction attracting new LDR passengers** | | | |
|---|---|---|---|
| Own elasticity of rail | -0.830 | | Dargay 2010, Table 23, Own elasticities with respect to travel cost |
| Price Reduction | -10.00% | | |
| Percentage change in demand for Rail (Own elasticity) | 8.30% | | |
| Number of additional trips using rail in total **[A=600,000 trips * 8.30%]** | 49,800 | | |
| Revenue generated from additional trips **[B=A*(90.3-9.03)]** | 4,048,270 | | |
| New trips due to price reduction (excl. modal shift car to LDR) **[C=A-15,604 trips]** | 34,196 | | |
| Consumer surplus of new trips applying rule of half **[D=C*9.03GBP/2]** | **154,434** | | Assumes "Rule of Half". |
| Number of persons switching from Car to LDR | 15,604 | | |
| Consumer surplus of trips switching from car to LDR **[E=15,604 trips*9.03GBP]** | **140,940** | | Assumes full benefit of price reduction. |
| **Consumer surplus due to price reduction [F=D+E]** | **295,374** | **GBP** | |

*Table 9-23: Benefits of price reduction attracting new LDR passengers*

### Kingston to Guildford

In addition to the safety benefits, there are additional benefits arising directly from the price subsidy. These are now considered on the same basis applied to the Glasgow to London case above.

As a result of the price subsidy of 10% the existing rail users (28,790) for the journey selected also benefit from reduced rail fares. This amounts to approximately **£21,895** per annum.

Together with the benefits to existing rail users there is additional demand generated by the “own-mode” demand for suburban rail services (Balcombe et al., 2004, Table 6-10). Table 9-24 highlights the own elasticity for rail which is -0.58 (short-run) and results in a change in demand of 5.8%. The number of additional rail users due to own-mode elasticity of demand is 1,670. A price reduction in rail would generate revenue from additional persons **(£11,429**). The total consumer surplus gain is **£798**. From this figure the consumer surplus of persons switching from car to rail has been deducted (to avoid double counting) resulting in a net consumer surplus of **£472** which, in this scenario, does offset a small part of the subsidy.

| **Benefits of price reduction attracting new rail passengers** | | |
|---|---|---|
| Own elasticity of rail | -0.580 | Demand for public transport, Balcombe et al., 2004, Table 6.10. |
| Price Reduction | -10.00% | |
| Percentage change in demand for rail (own elasticity) | 5.80% | |
| Number of additional trips using rail **[A=28,790 trips * 5.80%]** | 1,670 | |
| Revenues generated from additional trips [B=A*(7.61-7.76)] | 11,429 | GBP |
| New trips due to price reduction (excl. modal shift car to rail) **[C=A-429 trips]** | 1,241 | |
| Consumer surplus of new trips applying rule of half **[D=C*0.76GBP/2]** | **472** | Assumes "Rule of Half". |
| Number of persons switching from car to rail | 429 | |
| Consumer surplus of trips switching from car to rail **[E=429 trips*0.76GBP]** | **326** | Assumes full benefit of price reduction. |
| **Consumer surplus due to price reduction [F=D+E]** | **798** | **GBP** |

*Table 9-24: Benefits of price reduction attracting new rail passengers*

### Birmingham to London

There are additional benefits arising directly from the price subsidy as well as environmental improvements. These are now considered.

As a result of the price subsidy of 10% the existing rail users (4,472,000) for the journey selected also benefit in terms of reduced rail fares. This amounts to approximately **£9.9 million p.a**.

Together with the benefits to existing rail users there is additional demand generated by the “own-mode” demand for long-distance rail services (<150 miles) which is fairly elastic (Dargay’s 2010, Table 23). Table 9-25 shows the own elasticity for rail which is -0.81 and results in a change in demand of 8.10%. The total number of additional users due to price reduction is **362,232** of which **204,818** are additional rail users due to own-mode elasticity of demand. A price reduction in rail would generate revenue from additional persons **(£7.2 million**). The total consumer surplus gain is **£574,530**.

From this figure the consumer surplus of persons switching from car to rail has been deducted (to avoid double counting) resulting in a net consumer surplus gain of **£226,540** that can be compared with the subsidy to derive a BCR.

| Benefits of price reduction attracting new rail passengers | | | |
|---|---|---|---|
| Own elasticity of rail | -0.810 | | Demand for public transport, TRL 593, 2004. Table 6.10 |
| Price Reduction | -10.00% | | |
| Percentage change in demand for Rail (Own elasticity) | 8.10% | | |
| Number of additional trips using rail in total **[A=4,472,000 trips * 8.10%]** | 362,232 | | |
| Revenues generated from additional trips **[B=A*(22.11-2.21)]** | 7,208,815 | | |
| New trips due to price reduction (excl. modal shift car to rail) **[C=A-157,414 trips]** | 204,818 | | |
| **Consumer surplus of new trips applying rule of half [D=C*2.21GBP/2]** | **226,450** | | Assumes "Rule of Half". |
| Number of persons switching from car to rail | 157,414 | | |
| **Consumer surplus of trips switching from car to rail [E=157,414 trips*2.21GBP]** | **348,080** | | Assumes full benefit of price reduction. |
| **Consumer surplus due to price reduction [F=D+E]** | **574,530** | **GBP** | |

*Table 9-25: Benefits of price reduction attracting new rail passengers*

### 9.2.7 Gross cost

The cost here refers to the cost of encouraging the modal shift. The cost is defined in terms of the method used to achieve the modal switch, which in this scenario is a price subsidy for rail. The effectiveness of this method (i.e. how many persons are willing to switch from car to rail) is measured using CPE. It is assumed here that there are no infrastructure investments required. These are very costly and may not yield net benefits unless said benefits are significant. The only consideration in terms of cost is the subsidy provided for the price reduction to rail, at 10%. There could be some further costs if the increase in users required the addition of further capacity on rail, although considering the numbers shifting due to the CPEs, the impact would be marginal and unlikely to require additional capacity. This depends however on the time distribution for example, adding to Friday evening peak time.

| Summary of gross cost of subsidies | | | |
|---|---|---|---|
| | **Glasgow - London** | **Kingston – Guildford** | **Birmingham - London** |
| Gross cost of subsidies (£) | 5,560,311 | 22,221 | 10,236,715 |

*Table 9-26: Cost of subsidies for all scenarios*

### 9.2.8 Other economic benefits (Time savings and environmental)

#### Time savings

As there are some notable time savings between using car and rail the approximate value of the time savings has been calculated for using rail and shown in Table 9-27. For this scenario an approximate 2.0 hours of savings were considered taking into consideration the specific journey types. Values of non-working time and working time values were used in proportions of 60% and 40% and weighting applied respectively which approximately conforms to the findings of the work undertaken by Lyons et al. (2013) and Wardman and Lyons (2015). The value of the time savings is **£459,184**. Given the short distances for the Kingston to Guildford and Birmingham to London no time savings have been considered for these scenarios. Together with the time savings quantified here by using rail, there would also be some impact of time benefits to continuing car drivers from reduced congestion and potential vehicle cost savings while potentially there could be increased delays for rail travellers due to the increase in rail passengers.

| Other Economic Benefits (Time savings) | | | |
|---|---|---|---|
| **Time savings** | | | |
| Time LDR | 6.0 | hours | 4.5 hours LDR, 1h local bus, 30 min. Taxi |
| Time Car | 8.0 | hours | 7.0 hours net driving, 45 min. breaks, 15 min. Walking |
| Time saved per person by using rail | 2.0 | hours | |
| Value of time savings | 14.7 | GBP/hour | WebTAG November 2014: Table A.1.3.1 Value of Working/Non-working time by Mode (£ per hour, market prices adjusted for 2014) and weighted 60% applying non-working time values and 40% applying working time values. |
| Value of time saved per person | 29.43 | GBP | |
| Trips | 15,604 | trips | |
| **Total value of time savings** | **459,184** | **GBP** | |

*Table 9-27: Time savings Glasgow to London*

#### Environmental benefits for all three scenarios

One additional benefit is the environmental improvement of reducing the levels of carbon emissions from the car journeys now made by rail. This benefit has been calculated using average car emission rates and the avoided emissions multiplied by the social cost of carbon which provides an additional benefit. This is shown in Table *9-28*.

It should also be noted that there are potentially some ‘reverse benefits’ in that remaining road users could benefit – through the absence of those switching –through reduced congestion, and possibly some related vehicle cost savings, while those that do switch could suffer increased rail congestion.

| Summary of Environmental benefits | | | |
|---|---|---|---|
| | **Glasgow - London** | **Kingston – Guildford** | **Birmingham - London** |
| Environmental benefits (£) | 48,347 | 68 | 128,080 |

*Table 9-28: Environmental benefits in terms of reduction in $CO_2$ emissions*

Detailed calculations and assumptions for each scenario can be found in Appendix C.

### 9.2.9 Sensitivity analysis

**Glasgow to London**

The sensitivity of the estimated calculations to some of the assumptions made in the Glasgow to London scenario are examined. Sensitivity was calculated for:

- the reduction/increase in rail fare and its impact on safety benefits;
- changes in CPE and its impact on safety benefits;
- the reduction in rail fare and its impact on total economic benefits;
- changes in CPE and its impact on total economic benefits;
- rail price subsidy and its impact on BCRs.

These are shown in Table 9-29 to Table 9-31. Sensitivity of safety benefits (Table 9-29) suggests that as price for rail is reduced then the safety benefits increase. The reverse is also true: small reductions in the price of rail lead to smaller safety benefits. The central values in the sensitivity tables refer to each reference scenario for a given set of input variables.

Similarly if the CPE is higher, the safety benefits will also increase and, conversely, if the CPEs are lower the resulting safety benefits are also reduced.

| | | **Price Reduction Rail (%)** | | | | |
|---|---|---|---|---|---|---|
| | | **-5%** | **-7.5%** | **-10%** | **-15%** | **-20%** |
| | **0.06** | 19,169 | 28,754 | **38,339** | 57,508 | 76,677 |
| | **0.08** | 25,834 | 38,751 | **51,668** | 77,502 | 103,336 |
| **CPE** | **0.10** | **32,499** | **48,748** | **64,997** | **97,496** | **129,995** |
| | **0.20** | 65,822 | 98,733 | **131,644** | 197,466 | 263,289 |
| | **0.30** | 99,146 | 148,718 | **198,291** | 297,437 | 396,582 |

*Table 9-29: Sensitivity analysis of safety benefits (£ p.a.) Glasgow to London*

Sensitivity of total economic benefits (Table 9-30) suggests that as price for rail is reduced in % terms then the economic benefits increase accordingly and the reverse is true when % price reductions are smaller. For a given CPE value, it is self-evident that the relationship between price reduction and safety benefits follows a linear pattern.

This linear pattern is also observed with respect to sensitivity of total economic benefits and CPEs. Doubling the CPEs value from 0.1 to 0.2 could compensate a reduction of price decrease from -10% to -5%.

| | | **Price Reduction Rail (%)** | | | | |
|---|---|---|---|---|---|---|
| | | **-5%** | **-7.5%** | **-10%** | **-15%** | **-20%** |
| **CPE** | **0.06** | 214,687 | 356,406 | **521,042** | 919,066 | 1,408,759 |
| | **0.08** | 269,780 | 436,336 | **624,002** | 1,062,668 | 1,585,776 |
| | **0.10** | **324,873** | **516,265** | 726,962 | **1,206,269** | **1,762,792** |
| | **0.20** | 600,337 | 915,913 | **1,241,762** | 1,924,274 | 2,647,875 |
| | **0.30** | 875,801 | 1,315,561 | **1,756,561** | 2,642,280 | 3,532,957 |

*Table 9-30: Sensitivity analysis of total economic benefits Glasgow to London*

Table 9-31, providing the sensitivity on BCRs with respect to rail price subsidy and CPE, shows that doubling the subsidy does not proportionally increase the BCR and halving the subsidy also does not reduce the BCR by the same proportion. Overall the BCR ratio is very small and mainly related to the time savings gained from persons switching from car to rail.

| | | **Price Subsidy Rail (%)** | | | | |
|---|---|---|---|---|---|---|
| | | -5% | -7.5% | -10% | -15% | -20% |
| **CPE** | **0.06** | 1.08 | 1.09 | **1.09** | 1.11 | 1.13 |
| | **0.08** | 1.10 | 1.11 | **1.11** | 1.13 | 1.14 |
| | **0.10** | **1.12** | **1.12** | 1.13 | **1.14** | **1.15** |
| | **0.20** | 1.22 | 1.22 | **1.22** | 1.22 | 1.22 |
| | **0.30** | 1.31 | 1.31 | **1.30** | 1.29 | 1.28 |

*Table 9-31: Sensitivity analysis of BCRs for Glasgow to London*

### Kingston to Guildford

Traveller numbers for this scenario are limited and low CPE results in a minimal modal shift. A sensitivity analysis can still prove to be worthwhile if a larger CPEs is assumed (e.g. 0.06 instead of 0.03) given that there is a direct relationship between CPE values and safety benefits. Doubling the CPE as shown in

Table 9-32 leads to an increase in BCR (i.e. including cost of subsidy) of 30%. What is notable is that if higher CPEs values are observed (0.15), a small reduction in price (5%)

can lead to better results in terms of BCR as compared to a larger price reduction (15%). This is mainly due to the cost of subsidies which puts a limit on achievable BCR values. Alternatively higher price reductions are required at lower CPE values to improve BCRs.

| | | | | **Price Reduction Rail (%)** | | |
|---|---|---|---|---|---|---|
| | | **-5%** | **-7.5%** | **-10%** | **-15%** | **-20%** |
| | **0.03** | **1.04** | **1.05** | **1.06** | **1.07** | **1.08** |
| | **0.06** | 1.07 | 1.08 | **1.08** | 1.09 | 1.09 |
| **CPE** | **0.09** | 1.10 | 1.10 | **1.10** | 1.11 | 1.11 |
| | **0.12** | 1.13 | 1.13 | **1.13** | 1.12 | 1.12 |
| | **0.15** | 1.16 | 1.16 | **1.15** | 1.14 | 1.14 |
| | **0.18** | 1.19 | 1.18 | **1.17** | 1.16 | 1.15 |

*Table 9-32: Sensitivity analysis of BCRs for Kingston to Guildford*

### Birmingham to London

The sensitivity of the estimated calculations to some of the assumptions made in the Birmingham to London scenario are observed. Sensitivity was examined for:

- the reduction/increase in rail fare and its impact on safety benefits;
- changes in CPE and its impact on safety benefits;
- the reduction/increase in rail fare and its impact on total economic benefits;
- changes in CPE and its impact on total economic benefits.

Sensitivity of safety benefits as shown in Table 9-33 follows the same linear pattern as the other two scenarios.

| | | | | **Price Reduction Rail (%)** | | |
|---|---|---|---|---|---|---|
| | | **-5%** | **-7.5%** | **-10%** | **-15%** | **-20%** |
| | **0.02** | 40,140 | 60,209 | **80,279** | 120,419 | 160,558 |
| | **0.04** | 73,589 | 110,384 | **147,179** | 220,768 | 294,357 |
| **CPE** | **0.06** | **107,039** | **160,558** | 214,078 | **321,117** | **428,156** |
| | **0.12** | 207,388 | 311,082 | **414,776** | 622,164 | 829,552 |
| | **0.18** | 307,737 | 461,605 | **615,474** | 923,211 | 1,230,948 |

*Table 9-33: Sensitivity analysis of safety benefits Birmingham to London*

Table *9-34* shows that if price is reduced from 10% to 20% from the central value (568,607) then total economic benefits will increase by nearly 3 times.

|  |  |  |  | **Price Reduction Rail (%)** |  |  |
|---|---|---|---|---|---|---|
|  |  | **-5%** | **-7.5%** | **-10%** | **-15%** | **-20%** |
|  | **0.02** | 147,961 | 284,796 | **463,534** | 946,719 | 1,597,517 |
|  | **0.04** | 187,826 | 334,396 | **516,070** | 984,734 | 1,593,815 |
| **CPE** | **0.06** | **227,691** | **383,996** | **568,607** | **1,022,748** | **1,590,114** |
|  | **0.12** | 347,287 | 532,797 | **726,217** | 1,136,791 | 1,579,009 |
|  | **0.18** | 466,883 | 681,597 | **883,827** | 1,250,835 | 1,567,905 |

*Table 9-34: Sensitivity analysis of total economic benefits Birmingham to London*

## 9.3 SCENARIO FINDINGS AND DISCUSSION

Table 9-35 summarises all the safety and related economic benefits arising from the subsidised modal shift for all three scenarios. The economic benefits comprise cost saving benefits to existing rail users, revenues from additional rail users attracted by the subsidy, environmental benefits from reduced car use and time savings for new rail users. The total net benefits and the BCRs are also shown. The BCRs are calculated using the safety benefit but also include benefits resulting directly from the subsidy as shown in Table 9-35. The BCRs are 1.13 for Glasgow to London (benefits dominated by time savings from switching from car to rail) and 1.06 for the other two cases, and though positive are very small.

| **Key scenario findings (£)** |  |  |  |
|---|---|---|---|
|  | **Glasgow - London** | **Kingston – Guildford** | **Birmingham - London** |
| Safety Benefits **[A]** | 64,997 | 751 | 214,078 |
| Benefits of the price reduction to existing LDR passengers **[B]** | 5,419,371 | 21,895 | 9,888,635 |
| Consumer Surplus due to price reduction **[C]** | 295,374 | 798 | 574,530 |
| Total Cost of Price Reduction **[D]** | 5,560,311 | 22,221 | 10,236,715 |
| **Safety and subsidy derived benefits [E=A+B+C-D]** | **219,431** | **1,223** | **440,528** |
| Time savings **[F]** | 459,184 | N/A | N/A |
| Environmental benefits **[G]** | 48,347 | 68 | 128,080 |
| **Total Net Benefit [H=E+F+G]** | **726,962** | **1,292** | **568,607** |
| **BCR [I=(A+B+C+F+G)/D]** | **1.13** | **1.06** | **1.06** |

*Table 9-35: Comparison of key findings*

Table 9-36 shows the percentage composition of benefits within each scenario. Time savings for the Kingston to Guildford and Birmingham to London scenarios have not been calculated due to the short duration of the trips and hence negligible time savings when using rail.

| **Benefits from all scenarios ranked as a % of total benefits (excluding cost of subsidies)** | | **Glasgow to London** | **Kingston to Guildford** | **Birmingham to London** |
|---|---|---|---|---|
| | Economic benefit to existing rail users | 85% | 93% | 92% |
| | Time savings from modal diversion | 9% | N/A | N/A |
| | Benefits to additional users in the form of consumer surplus | 4% | 3% | 5% |
| | Safety benefits to car users who have transferred to rail | 1% | 3% | 2% |
| | Environmental benefits from reduction in $CO_2$ emissions | 1% | < 1% | 1% |

*Table 9-36: Benefits ranked as % of total benefits*

### 9.3.1 Safety benefits

The safety benefits for all scenarios are very limited, ranging from 3% of the total benefits in the Kingston to Guildford case to 1% on the London to Glasgow example. In absolute terms, the safety benefits are £64,997, £751 and £214,078 respectively. An explanation for this are low risks rates due to significant improvements in car safety and low CPE values which do not induce large numbers of travellers to switch from car to rail.

The total safety benefits (£64,997) for the Glasgow to London scenario are low compared to the travel time saving benefits (£459,184). Decision making over any pricing intervention for this case would therefore have to be based on economic/equity issues relating to travel time savings, with safety improvements as a by-product.

For Kingston to Guildford the safety benefits are slightly higher proportionally than the other two scenarios, at 3% of total benefits, but very small indeed in absolute terms (£751) such that they could be regarded as within the margin of error and in any case could easily be absorbed by administrative costs in any implementation.

The very low load factor here of 3% for train partly reflects the 'contra-peak' nature of the flow. This can be partially attributed to the fact that it does not account for additional passengers entering the train at stations during the journey (e.g. Waterloo to Guildford).

For the Birmingham to London case, the safety benefits are greatest in absolute terms at £214,078, though these are still only 2% of the total benefits gained. The larger relative safety benefit can be attributed to higher volume of trip switches.

### 9.3.2 Other economic benefits

For all three scenarios the majority of the benefits stem from advantages provided to existing rail users through the subsidy. This is 93% for the Birmingham to London case, 92% for Kingston to Guildford while for Glasgow to London this proportion of the total benefits is slightly lower at 85%. This could be considered as the largest form of transfer payments from the taxpayers to existing rail users and requires some care when looking at the balance between those paying and those receiving the benefits, as pointed out by Last (2013). He discusses the economic benefits generated by concessionary travel in relation to the costs for certain target groups. In his calculations only the consumer surplus benefits were considered. He summarises that of the net benefits to society as a whole arising from providing concessionary bus fares to older and disabled passengers, the largest part of the benefit is in the form of transfer payments from taxpayers to pass holders), and overall the BCRs are not very large (ranging from 1.24 for a zero fare to 1.56 where only 50% concession is provided). Caution should be exercised when looking at the equity balance between tax payers and those that benefit. Similarly, in the scenario calculations the distributional and possible equity effects of the subsidy should be carefully considered.

The economic benefits that accrue to existing LDR users based on time savings (only for the Glasgow to London due to the journey type) are a significant contributor to the overall benefits at 9%.

There is also a contribution of 3 to 5% to the overall benefits from the consumer surplus of additional users due to own-mode elasticity for rail, applying the “rule of half” in all scenarios.

Environmental benefits for the reduction in $CO_2$ emissions resulting from the modal switch to rail for car users have been estimated for all scenarios, although these are a negligible fraction of the total. This is 1% or less in each case.

In terms of the overall BCRs, for the Glasgow - London case the net financial cost is strongly affected by whether additional revenue from new rail users is included in calculations for BCRs and travel time savings or not. The environmental effects calculations appear to assume no extra energy generated from fossil sources (coal, oil, gas) being used by rail to carry the extra passengers. The estimate for the BCR ratio sensitivity tests (1.13) seems to be mainly sensitive to CPE assumptions.

CPEs were used from Dargay, as the CPEs calculated and measured in this work were not robust enough to use with a high level of confidence.

The findings from the three scenarios, although positive in terms of absolute safety benefits and BCRs, suggest a marginal case for CMS but not on the basis of safety *per se*. If other economic benefits are considered (time savings) then there may be a requirement for modal shift.

The results suggest further research needs to be undertaken particularly in instances where risks rates and CPE values are high.

# 10 CONCLUSIONS AND PRACTICAL RECOMMENDATIONS

This final chapter draws together the findings of the research, highlights its contributions and considers its limitations. The chapter also provides the overall conclusion and makes suggestions for further research.

This thesis set out to explore how overall safety could be further enhanced and encouraged through Cross Modal Switching (CMS). This could potentially provide safety gains for both urban and long distance passenger transport without large infrastructure investments, or more likely as a complement to such investments.

As a basis for the assessment of CMS, the work firstly explored the development of optimal transport safety policy across modes, advocating a more holistic rational approach working across all modes rather than the single mode-focused approach which has most often been the basis of transport safety policies. The literature on CMS to date largely concentrates on support for environmental objectives, time savings and sustainability rather than safety. The thesis therefore sought to answer the following main research question:

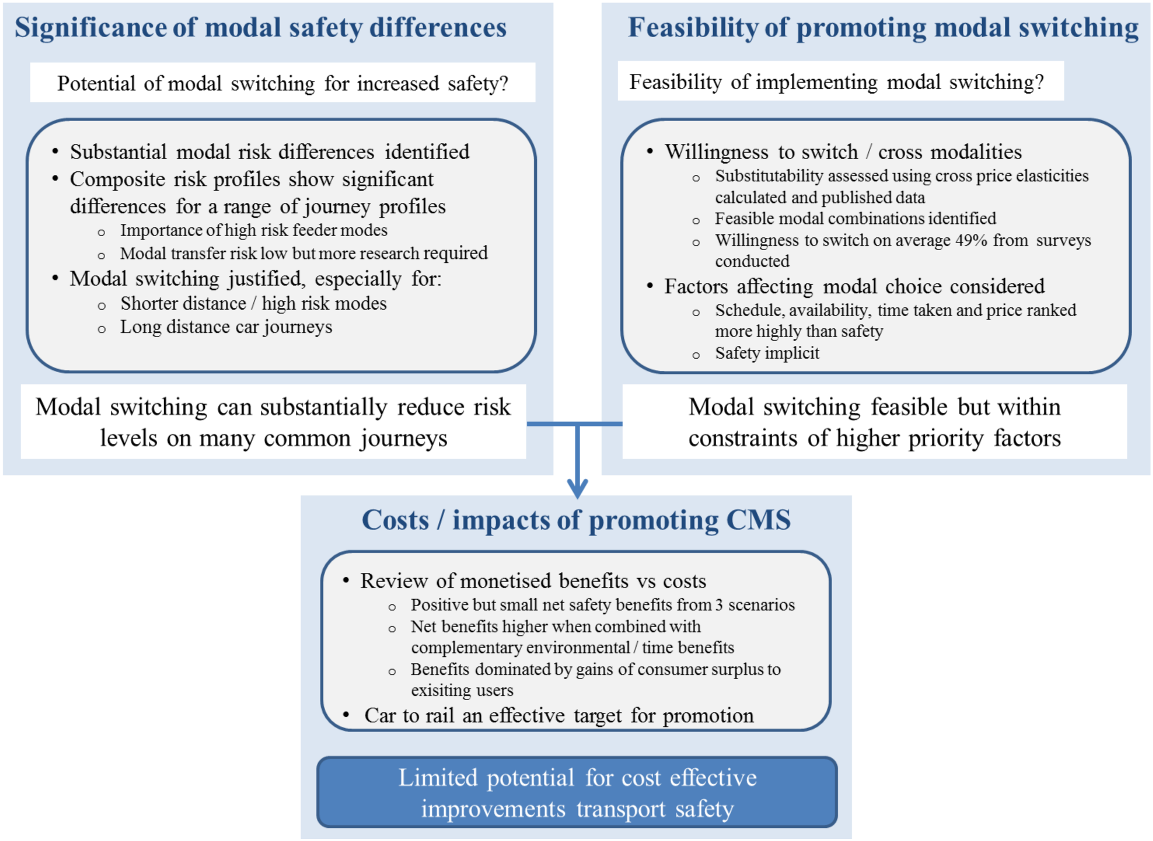
> *To what extent can CMS be used as an instrument (explicitly or implicitly) of transport safety policy to encourage users to transfer from less safe modes to safer modes of transport?*

Some supporting questions were also posed covering methods of appraisal and associated tools, the measurement of safety output and substitutability between modes, CPE of demand, policies deployed, the benefits realised and the routes where CMS could be applied. Journey safety considerations, it was noted, should include the whole end to end journey because use of a main mode with a good safety record can also entail use of feeder modes with considerably lower safety records.

The approach to address the main research question consisted of two stages:

- Could CMS provide net safety gains taking full account of the composite nature of most journeys?
- Would the promotion of CMS be practical and effective in changing travel behaviour and if so, what would be the most successful incentives?

This sequence is illustrated in Figure 10-1, which also summarises the key findings in each area. The answers to the first two questions were positive, but the overall monetised safety benefits were found to be very small for the journey scenarios considered. The BCRs were found to be positive, but only when taking account of related benefits derived from the subsidy in addition to safety.



**Significance of modal safety differences**

Potential of modal switching for increased safety?

- Substantial modal risk differences identified
- Composite risk profiles show significant differences for a range of journey profiles
    - Importance of high risk feeder modes
    - Modal transfer risk low but more research required
- Modal switching justified, especially for:
    - Shorter distance / high risk modes
    - Long distance car journeys

Modal switching can substantially reduce risk levels on many common journeys

**Feasibility of promoting modal switching**

Feasibility of implementing modal switching?

- Willingness to switch / cross modalities
    - Substitutability assessed using cross price elasticities calculated and published data
    - Feasible modal combinations identified
    - Willingness to switch on average 49% from surveys conducted
- Factors affecting modal choice considered
    - Schedule, availability, time taken and price ranked more highly than safety
    - Safety implicit

Modal switching feasible but within constraints of higher priority factors

**Costs / impacts of promoting CMS**

- Review of monetised benefits vs costs
    - Positive but small net safety benefits from 3 scenarios
    - Net benefits higher when combined with complementary environmental / time benefits
    - Benefits dominated by gains of consumer surplus to exisiting users
- Car to rail an effective target for promotion

Limited potential for cost effective improvements transport safety

*Figure 10-1: Overview of the research approach and summary of findings*

The main findings of the work overall are now assessed in more detail.

## 10.1 MAIN FINDINGS

This work suggests transport safety policy should be developed by adopting a rational approach while considering the varying perspectives of those concerned with safety (ranging from individual travellers to those determining and implementing policy measures). Such a rational approach, although implicit in the work examined by others in the field, has not been widely explicit in underpinning transport safety policy across modes. In practical terms this means resisting pressure to respond to major public transport incidents by diverting resources that might be more effectively deployed on other safety measures. If CMS is to be successful it is important that this approach is maintained because the impacts of CMS are likely to be more subtle than major infrastructure initiatives.

The discussion of safety policies in the thesis has been carried out within the framework of the utilitarian inspired Pareto norm which is considered the most relevant norm with which to address CMS as a tool of safety policy. Within Paretian analysis it is recognized that a market system will fail to allocate resources optimally resulting in market failures either in the presence of public non-excludable externalities and/or where there are significant asymmetries of information, or misinformation.

In relation to transport safety public non-excludable externalities arise when third parties who have no commercial relationship with a transport operator are impacted; and so on Paretian grounds there will be a case for state intervention to correct the resulting market failure/misallocation of resources. For this type of externalities the argument is strongest for road transport safety, where third parties are impacted due to the multiple use character of road networks.

Information asymmetries can result in the public being misinformed of the safety aspects of transport modes, which may give rise to sub-optimal modal choices. There is arguably a key role for the state to intervene to promote better-informed choices to consumers, and where necessary to incentivise such choices. The empirical results from the travel surveys undertaken in this work suggest that there are indeed imperfections in consumer information about the relative safety of the different modes. For example, the user surveys results show that the perception of lower risk modes (aviation and bus/coach) are overweighted (carrying a perception of higher than actual risk) which is consistent with prospect theory. Here in principle the case for intervention to transfer people to modes whose safety risks they are overstating can be justified.

Optimal safety has been debated with regard to the cost of safety provision and the value of safety to society and individuals. This can lead to friction between policy makers, who understand the potentially substantial costs of averting small risks in relation to small safety gains, and those advocating safety irrespective of cost. Within this thesis, it is advocated that safety gains are achievable without large investments through CMS, although marginal improvements with considerably lower associated costs could be considered to enhance safety. This contrasts with some infrastructure investments such as a £130 million in rail ATP systems to prevent two on-board rail fatalities (Evans and

Addison, 2009). It is notable that developed nations with already relatively high levels of safety are in a situation that makes additional improvements (marginal safety benefits) more difficult to achieve, though still important.

### 10.1.1 CMS framework

The discussion of CMS highlighted that transport safety policy has hitherto been considered on a mode-specific basis without considering policies set in other modes, and that this could result in the development of sub-optimal safety policies overall. The reason for this is a mixture of limited government funding, competition between modes, technical aspects of transport safety being necessarily mode-specific and because, although substitution factors have been considered to some extent for other applications, this has not been extended to safety policies. It has already been recognised in the literature that work on modal transfer on the grounds of safety is limited.

A contribution made by this thesis centres around the conceptual innovative framework advocating the move from single mode policies towards an optimal safety policy spanning all transport modes simultaneously. This would include but not be confined to CMS of passengers/persons from modes with lower levels of safety to those modes that yield the highest safety benefits as an instrument of safety promotion policy.

This approach is supported by the recent literature from Litman (2014, 2016). Litman recognises that that there can be multiple impacts emanating from a specific policy and advocates the modal shift to public transport from cars in North America to improve transport safety.

### 10.1.2 Composite risk assessments

Several composite risk assessments were completed for a wide range of journey profiles. The overall differences between pairs of modal combinations were calculated for all routes to assess the potential safety gains that could be achieved using CMS. The assessment provided a number of findings which indicate:

- Urban journeys are dominated by high risk modes, partly because shorter distances make more risky forms of travel such as walking and cycling practical. Rail is also a common component of urban journeys and is lower risk, but the regularity with which cycling and walking are used as feeders increases the composite risks of such journeys.

- Car journeys, which form the bulk of non-urban travel, carry relatively high risk. This applied to all types of road even though different risk rates were applied to different categories, i.e. urban roads, minor roads, trunk roads and motorways.
- The impact of feeder modes on safe long distance transport modes, notably air and rail, is still considerable. It is evident that journeys using higher risk feeder/access (modes other than those used for the main leg of the trip) often form a major component of the risk and must therefore be a target for CMS.
- Risks for the safer forms of transport, such as aviation and rail, are dominated by a very small number of specific incidents. In these cases, public policy needs to take account of the specific issues involved as well as the summary view provided by the statistics. It may also need to address the imbalanced perceptions that may emerge after media coverage of such events.

The results from the total journey risk calculations indicated that modal switching could lead to safety gains. For shorter distances on certain modes of transport the risk rates are significant per person km (walking and cycling) so that when considering the whole door-to-door journey the risk is substantially higher than for the main mode alone (often bus or train). Nevertheless, the distances involved are often short and in many cases the alternatives are limited. When evaluating longer distance journeys, modal switching is also valid to shift from high risk modes (car) to safer modes (rail or aviation) as highlighted in the outcome of the composite risk calculations. Both of these types of possibilities were therefore taken forward to the net benefit analysis later in the work.

### 10.1.3 Risk unrelated to distance

For aviation, bus and rail travel modal risks unrelated to distance were investigated in order to assess how risk should be addressed when considering journeys with transfers. The research reveals that at present there are no established transfer risk rates (for interchanges between routes or modes during one specified journey) that are readily available and can be applied. There are some statistical data on bus and coach casualties arising from boarding and alighting but this is not sufficient to derive transfer risk rates. This thesis provided an illustrative calculation applying an additional constant risk factor to the different transfer stages. Results showed that while there are changes in composite risk rates, including the transfer stages versus the original rates, these are not notable. For aviation there is no indication that the figures include boarding and alighting effects. It has been demonstrated that applying a risk factor to allow for the higher risk probabilities for the high risk phases of a flight yields marginal differences and hence require no specific treatment for comparative purposes.

Further research would be necessary to quantify the specific transfer-related risk per mode of transport, but in this work it has been shown that allowing for the additional risk factor for transfers does not change the total composite risks significantly.

### 10.1.4 Measurement of modal substitution

Direct arc CPEs were calculated using the results from the user survey, while many of the published CPEs are derived from own price elasticities. This was based on the respondents' willingness to switch modes at specific percentage reductions in price. For the combined survey responses, a ranking was developed under each alternative mode to get an estimate of the degree of CPE. The results are generally consistent with Dargay's (2010) findings on long distance travel, although the absolute CPE values in Dargay's work are higher.

The findings suggest that in measuring substitutability the most important factors are the market shares of the respective transport modes being considered, the diversion factors and own price elasticity (as CPE in the published literature has been derived using these factors to a large extent); hence the effects of relative market size and direction of change are the critical factors determining the extent of the modal shift. Additionally, it is apparent that modal choice availability (the extent to which alternative modes are easily available for a user) impacts the extent of the modal transfer.

Long distance CPEs were used from Dargay (2010) and short distance from Balcombe et al. (2004) as the CPEs calculated and measured in this work were not robust enough to use with a certain level of confidence, given the high degree of granularity of various modal alternatives analysed and hence the small sample population for specific modal shifts (e.g. car to rail/metro, car to air, car to walking, car to local bus etc.).

### 10.1.5 Empirical surveys

Three surveys undertaken for this thesis helped to capture the views of leisure and business user groups respectively. A third survey revealed views of experts on travellers' attitudes and perceptions to risk, to augment the user surveys.

The outcomes revealed the following:

- There is a difference between those selecting accident risk as opposed to personal safety as a priority in the snowball survey (59%) compared to the **consumer***data* survey (48%) combined with respondents in the snowball survey perceiving air risk to be greater (17%) than those in the consumer data survey (10.8%). This could be attributable to journey purpose. Those in the snowball survey used different modes for the main leg (car, rail, air) while in the **consumer***data* survey most journeys were for leisure travel and the main part of the journey was completed by air which respondents regarded as a safe mode. The fact that personal safety was not highly ranked in both user surveys (as commented by respondents for travel in Europe) suggests that it is intrinsically provided for by modes (implicit rather than explicit) compared to other factors ranked as higher priorities. In line with responses from the expert survey, respondents from the user surveys also confirmed that individual safety is influenced by geography when travelling outside Europe.
- Both **consumer***data* (34%) and snowball (77%) survey respondents' willingness to switch to alternative modes provided a good indication of modal substitutability and insights into the specific modes that would be considered. The willingness to switch was considerably lower in the **consumer***data* survey indicating perhaps a lack of alternative options. For long distance air routes there are indeed limited alternatives.
- The expert survey provided insights into perceptions of public behaviour on factors influencing modal choice and travel behaviour, from the observations of experts working in the modal sectors. This survey also helped in understanding how modal shift can be encouraged and also factors that could limit a shift.
- The qualitative interviews are valuable for this thesis because they provide a more complete understanding of the decision processes behind modal choices. They also provide further explanation as to why, even if modal transfer is incentivised, its potential may not be realised due to other factors which may outweigh the incentive (such as availability of options, accessibility and unreliability).

### 10.1.6 CBA calculations

These calculations thus tested the concept of promoting CMS and helped to draw together the analytical elements of the thesis towards a conclusion. They illustrate the effects of

CMS for selected urban to long distance journeys of different distances. The detailed findings are provided in Chapter 9.

It is evident from all three scenarios, although the findings are positive in terms of absolute safety benefits, that there are only marginal monetary safety benefits in each. This is possibly due to improvements in vehicle safety and road infrastructure and low CPE values reducing the modal transfer.

For the Glasgow to London scenario, safety gains are marginal compared to the travel time saving benefits. Decision making over any pricing intervention for this case would therefore have to be based on economic/equity issues relating to travel time savings with safety improvements as a by-product.

While the associated safety benefits are not dramatic, it might be a better proposition to encourage modal transfer at existing risk rates rather than investing in very high cost technology to reduce already low risk rates for marginal safety improvements. An example includes the introduction of an ATP system for rail.

In all cases the importance of the modal share, direction of the change, the level of subsidy and CPEs are critical in determining the impact of the modal switch. The higher the CPE and modal share of the current mode, the larger the modal transfer potential to another mode with lower market share (e.g. car and rail on suburban commute).
The results suggest that further research needs to be undertaken particularly in instances where risk rates and CPE values are high. A greater number of composite journeys and more detailed assessments of the overall benefits and costs would be needed to establish the specifics of modal switching policy measures.

### 10.1.7 Alternative interpretation of scenario findings

Another way to view the net benefit calculations might be to consider the ***net* cost** of the policy measure to be the subsidy minus the consumer surplus gains to existing users, since the latter are a kind of transfer that almost cancels out with the subsidy (Table *10-1*). The net cost can then be related to the net safety benefit achieved, i.e. excluding from the benefit side the transfer payment benefit represented by lower fares for all existing users.

**Summary of findings from alternative interpretation (net benefits/net costs)**

| | Glasgow-London Long Distance | Kingston-Guildford Suburban | Birmingham-London Inter-urban |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Net Benefits excluding other economic benefits (£) **[A]** | 219,431 | 1,223 | 440,528 |
| Net cost (£) **[B]** | 140,940 | 326 | 348,080 |
| **Net BCR excl. other economic benefits [ (A+B)/B ]** | **2.56** | **4.75** | **2.27** |
| Other economic benefits (£) **[C]** | 507,531 | 68 | 128,080 |
| **Net BCR incl. other economic benefits [ (A+B+C)/B ]** | **6.16** | **4.96** | **2.63** |

*Table 10-1: Summary of findings from net benefit/net cost calculations*

The main benefit (consumer surplus to existing rail users) should be a mirror image of that part of the subsidy which represents a simple transfer to the existing rail users. Cancelling these gains, both on the cost and the benefit side, the resulting net BCRs range from 2.27 (Birmingham to London) to 4.75 (Kingston to Guildford). These BCR values include benefits and costs of subsidy to those people switching from car to rail; and the benefits to new rail users attracted by the now lower price.

Additionally, if other economic benefits are included then the case for modal shift is further strengthened with BCRs varying from 6.16 (Glasgow to London) to 2.63 (Birmingham to London). The large BCR of 6.16 for the Glasgow to London scenario can be attributed to the sizeable time savings that are assumed to be gained from using rail.

## 10.2 LIMITATIONS OF THE STUDY

The study has evaluated how to enhance safety through CMS and was conducted through use of primary and secondary data, information sources and surveys. As a direct consequence of this methodology, the study encountered a number of problems which need to be considered along with their implications for the thesis.

### 10.2.1 Fares data limitations

Initially three approaches were considered to be suitable to measure the level of substitutability between the different modes:

1. Calculation of CPEs of demand in transport using primary fares data collated with associated load factors or ridership;

2. Calculation of CPEs through the results from the user surveys;

3. Through existing published data on CPEs.

Fares were collated for 16 months in order to calculate actual CPEs for specific journeys over a given time frame. However, data on passenger volumes were not available for commercial confidentiality reasons. From the user travel surveys conducted it was possible to infer arc CPE of modes, although the sample was not robust enough to use in net benefit calculations.

The lack of suitable/adequate data collated or accessed has meant that the results cannot be used to contribute to other work in the field or be considered with a high level of confidence. It suggests that further research would be required to derive more measurements that can be used in the net benefit calculations rather than relying on existing published studies.

### 10.2.2 Questionnaire survey limitations

There were some limitations and constraints in the surveys process. Firstly there was a lack of random sampling as the questionnaires were conducted using online and electronic surveys, meaning that some of the results can have some bias in terms of the sample respondents for both surveys.

Secondly, direct face to face interviews were not possible due to reluctance of operators to allow access to travellers, especially at airports. This was mainly because of security concerns. SNCF initially agreed in principle to questionnaires being distributed on the Paris-Frankfurt and Paris-London routes, but in practice stalled and failed to respond. This meant that in the end no permission was given. Direct face to face interviews would have provided this work with more valuable insights from travellers, removed sample bias and potentially provided a larger sample of respondents than online/electronic surveys.

The **consumer***data* survey was mainly based on leisure travellers from the UK to other countries; this meant that the main mode alternatives for many of these travellers were very limited. This could have affected the sample of respondents citing alternatives, which will have impacted the CPE calculations and hence the granularity of the results.

Finally, it was not possible to obtain any socio-demographic data from the **consumer***dat*a sample. That could have enabled more detailed analysis such as age specific risks.

### 10.2.3 CBA calculations

Rail passenger volume data was requested from ATOC for specific routes but was not forthcoming due to commercial sensitivity concerns. Notwithstanding the limitations in data availability, an indicative cost-benefit analysis was carried out and it was noted that the results were quite sensitive to the precise methodological assumptions made in respect of consumer surplus. Nonetheless, since the benefits (although marginal) outweigh the costs in modal switching in both of the suggested approaches to treatment of consumer surplus, it can be said that CMS for purposes of safety improvement yields positive net benefit (potential Pareto improvement). Therefore, it may be used explicitly or implicitly as an instrument of transport safety policy. Further analysis of a wider range of journey net benefits calculations is necessary to suggest this as a viable option that can be implemented practically.

## 10.3 POLICY IMPLICATIONS

Positive net benefit outcomes for the specific routes suggest that the CMS approach is potentially of value in specific cases, although further research and investigation is required to substantiate this through net benefit calculation for large quantity of different journeys. This would be necessary as policies are implemented on a regional or national scale. From a policy perspective, safety promotion using CMS might be a more cost-effective proposition than larger infrastructure investments that only yield marginal safety improvements, particularly in existing low risk modes. For example in the case of diverting road travel to rail, significant reductions in environmental pollution occur, especially where the railways in question are electrified. This suggests that safety benefits should be considered as part of a wider multi-objective policy approach (also suggested by Litman (2014)) to promote modal transfer and investment in public infrastructure simultaneously.

The CBA net benefit calculations can also potentially provide a basis for prioritising the allocation of resources to the promotion of CMS by identifying the more promising routes, e.g. long distance or short commuter journeys. From the scenarios reviewed this prioritising cannot be undertaken since all BCRs calculated are similar. It was observed however that this was less the case when using the alternative BCR calculation based on net benefits/costs. As a result the method would not be as limited with regard to route prioritisation if the alternative BCR calculation was used.

It is also important to note that this work has been undertaken during a period where there has been a significant attempt to promote modal change in urban travel, notably towards cycling and walking. The effects of this shift need to be monitored from a safety perspective because in some respects the overall benefits of this shift in terms of reduced congestion, environmental improvements and health benefits do not always align with the safety perspective.

## 10.4 RECOMMENDATIONS FOR FUTURE RESEARCH

### 10.4.1 General

Since the subject of CMS is wide ranging and sensitive to CPE levels, further research work could be conducted on the extent of travellers' willingness to use alternate modes, i.e. diversion factors, and the research could be extended to include specific socio-demographic groups. This should be undertaken through direct face to face interviews in specific regions where alternative modes are available. The practical difficulty with this is obtaining the necessary permission from the relevant authorities to conduct such interviews at major transport hubs, at a time when security is a major concern.

More primary research is also needed to confirm the substitutability preferences, particularly in support of targeted journeys or regions, using the stated preference method. This would provide a more reliable understanding of consumer preferences and CPE estimates, allowing full optimisation of the target subsidies. The work undertaken could also be applied in developing countries to compare differences in attitudes to safety, modal switching and travel preferences since the benefits of modal switching may be greater in these regions.

### 10.4.2 Specific research

Specific topics for additional research are proposed as follows:

- Extend the research to age-specific accident risks could be considered, highlighting higher risks: for example older/younger populations on certain modes.
- Examine how transfer risk unrelated to distance can be calculated with a high level of confidence.

- Investigate the impact of new transport technologies and infrastructure and its implications for modal transfer on safety grounds.
- Investigate the national or regional impact of policy measures, aggregating the outcomes of groups of journey-specific modal transfers from high risk to low risk modes in the UK. This would mean expanding the net benefit assessment approach used in this thesis to cover a wider set of regional transfers, rather than mainly the point to point examples assessed here.
- Analyse journeys/regions where CMS is promoted for reasons other than safety, and evaluate the safety impact in such cases. For example the move to walking and cycling from other road transport modes could be considered.
- Identify and investigate the effect on safety of modal transfer from high risk modes in developing countries or regions. One example could be transfers from car to air in India for specific longer distance routes. This would need to consider issues of capacity and affordability to a greater extent than the work conducted here in the UK and Europe.

## 10.5 CONCLUSION

This thesis shows that there is a marginal justification for CMS as a tool within an overall integrated transport policy that considers safety in all modes simultaneously. This must recognise that the absolute safety benefits are not very large relative to other benefits, although the relative size depends on the manner in which changes of consumer surplus are treated in the CBA. Safety promotion through CMS can be demonstrated to be cost effective in low risk modes, relative to larger infrastructure investments that may only yield marginal safety improvements. In evaluating safety policy in this manner using CMS, policy could be targeted towards specific regions or journeys, both in developed and developing nations, where the largest safety gains can be attained with minimum expenditure. In developing countries the safety gains in non-monetised terms may yield larger potential benefits from modal diversion than in Great Britain. The issue here may be monetised values for life in such countries, if these are related to real incomes and thus relatively low. Further research, using a larger sample of journey net benefit calculations, is thus required to validate the case robustly for CMS. This would identify beneficial opportunities for modal switching and specify certain routes and target modes.

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