An assessment of the motivation and ability of local authorities in the North West of England to meet the Paris Agreement in relation to terrestrial transport emissions

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Glossary of Terms

AR	Assessment report
BECCS	Bioenergy with carbon capture and storage
BEIS	Department for business, environment and industrial strategy
Bkm	Thousand million (billion) kilometres (10^9)
CBD	Central business district
CDR	Carbon dioxide removal
CIL	Community infrastructure levy
CO_2	Carbon dioxide
CO_2e	Carbon dioxide and equivalent amount of other greenhouse gases
CCC	Committee on climate change
COP	Conference of parties
Covid 19	2020/21 pandemic virus
DfT	Department for transport
DUKES	Digest of UK energy statistics
EAFO	European alternative fuel observatory
EV	Electric vehicle
E-bike	Electrically assisted bicycle
EU	European Union
GB	Great Britain (UK minus Northern Ireland)
gCO_2/km	Grammes carbon dioxide per kilometre
gCO_2/kWh	Grammes carbon dioxide per kilowatt hour
gCO_2/l	Grammes carbon dioxide emitted per litre of fuel
GDP	Gross domestic product
$GtCO_2$	Thousand million tonnes carbon dioxide (10^9)
HGV	Heavy goods vehicle
HS2	High speed rail scheme connecting Manchester, Leeds and Birmingham
IPCC	Intergovernmental panel on climate change
km	Thousand metres (kilometre) (10^3)
kWh/km	Kilowatt hours per kilometre
$ktCO_2$	Thousand tonnes carbon dioxide (10^3)
l/100km	Litres of fuel used per 100 kilometres of travel
Large cities	Local authority jurisdictions covering principal regional cities
LAU	Local administrative unit

LEP	Local enterprise partnership
LGV	Light goods vehicle
LTP	Local transport plan
NDC	Nationally determined contribution
NEDC	New emissions driving cycle (standard emissions test for cars up to 2018)
NO_x	Nitrous oxides
NTS	National travel survey
NUTS	Nomenclature of terrestrial units for statistics (Eurostat, 2018)
NUTS1	National/regional designation with population 3 to 7 million
NUTS2	Regional designation with population 0.8 to 3 million
NUTS3	Regional/local designation with population 0.15 to 0.8 million
$MtCO_2$	Million tonnes carbon dioxide (10^6)
ONS	Office for national statistics
PCT	Propensity to cycle toolkit
PM	Particulate matter
RCP	Representative concentration pathway
RTFO	Renewable transport fuel obligation
Small cities	Local authority jurisdictions outside principal cities
TfN	Transport for the North
UK	United Kingdom of Great Britain and Northern Ireland
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
VED	Vehicle excise duty
WLTP	World light test procedure (standard emissions test for cars after 2018)

Abstract

In Paris 2015, the nations of the world agreed to limit the increase in global mean temperature to well below 2°C, meaning controls on greenhouse gas emissions are urgently required. In the UK, cutting transport emissions has proven challenging. Investigating the factors that constrain this potential is, therefore, critical for the UK in delivering on its climate change commitments.

Many of the UK's large cities have developed ambitious plans describing how they might reduce transport greenhouse gas emissions. These plans generally place an emphasis on large-scale interventions such as metro systems or congestion charges. However, in industrialised areas of the world, most of the population, and transport greenhouse gas emissions, are not associated with large cities, but with 'small cities'. In these communities, such large-scale interventions may not be practical or effective. In this thesis, it is argued that, outside large cities in industrialised regions of the world, particularly in lower tier regions, there are knowledge gaps relating to reducing transport greenhouse gas emissions. Specifically, in terms of meeting climate change targets in these areas, the relationship between local government policy and regional capability is poorly understood. To address these knowledge gaps, this thesis presents an investigation into reducing transport greenhouse gas emissions in small cities in a lower tier region of the industrialised world. This investigation has been undertaken in the North West of England and from the perspective of the local authorities that control local policy development and implementation.

The research involves desk-based analysis and interviews with planners who are responsible for developing and implementing transport policy in a selection of local authorities covering differing city jurisdictions. These assessments identify factors that control motivation and ability relating to emissions reduction. The findings help to define existing policy constraints and patterns of their diffusion. Data analysis, including from grey and academic literature sources, is used as the basis for a new regional model of transport emissions, to assess the impact of policies associated with small cities in meeting regional, national and global Paris Agreement targets.

The thesis concludes that local constraints, relating to development and implementation of policy, significantly restrict regional capability, in terms of meeting defined targets. In meeting these targets, the research highlights the importance of planners' perception of local population attitudes in determining their motivation, together with the importance of local and national political support. The relationship between relative and absolute city size and ability to instigate change is also described. Constraints on ability and motivation mean that, outside large cities, half of the local authorities contacted were not committed to significantly reducing transport emissions and, where commitments were given, planners considered that, in the current landscape, these commitments would not be achieved. Recommendations outline how provision of targeted personnel, power and funding, when applied to small cities in the industrialised world, could alleviate constraints.

Word Count

80,000 excluding contents, declaration, copyright statement, bibliography and appendices.

Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Copyright Statement

Dedication

I would like to thank my supervisors Carly McLachlan and Alice Larkin for their support, patience and assistance in completing this research taking into account my inexperience in the research field.

This research has only been possible within the environment provided by the Tyndall Centre for Climate Change Research at the University of Manchester. I wish to thank all members of this team for providing such a productive research framework over the course of many tea, and virtual tea, discussions.

I would also like to thank my colleagues at Jacobs who have supported the development of this thesis through letting me work part time and take a year off to complete the project, especially my work supervisor Jon Ashton.

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CHAPTER ONE – INTRODUCTION

1.1 Rationale

In Paris 2015, the governments of the world committed to restricting global mean temperature rises, associated with climate change, to 'well below 2^{o}C' (UNFCCC, 2015). To accomplish this, nations agreed to prepare pledges to limit cumulative greenhouse gas emissions (Bates, 2015). The UK Government has subsequently responded to this agreement by committing to reach 'net zero' greenhouse gas emissions by 2050 (CCC, 2019b; HM Government, 2020b).

The Department for Business, Energy and Industrial Strategy recently reported that UK greenhouse gas emissions have reduced from nearly 800MtCO_2e in 1990, to about 450MtCO_2e in 2018 (BEIS, 2020b). While emissions in some sectors fell significantly, transport emissions, which since 2016 have represented the largest UK sector in terms of greenhouse gases, only recorded a 3% fall (BEIS, 2020b). The picture during the 2020/21 Covid 19 pandemic has, however, been quite different. Government data (Figure 1.1 (DfT, 2021)), indicates that 2020/21 Covid 19 lockdowns had a significant impact on UK traffic flows.

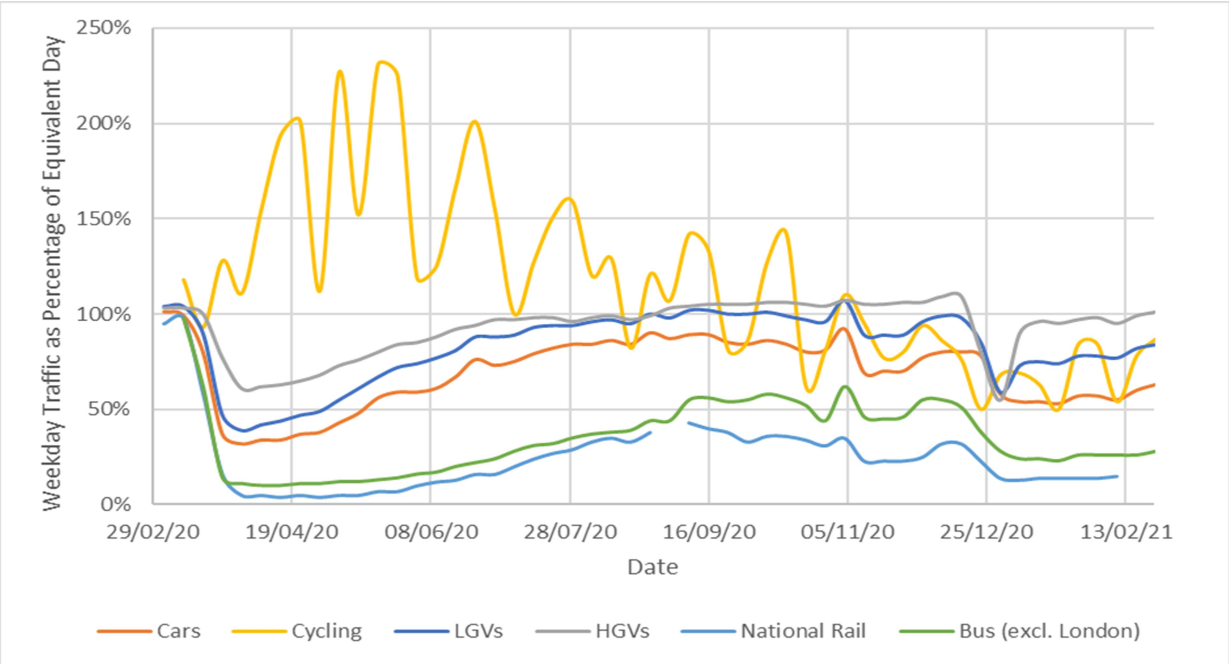

Figure 1.1 – Impact of Covid 19 on traffic flows in England (DfT, 2021)

The UK's virus lockdowns were initially associated with a 60% reduction in car traffic, but as lockdowns were lifted and reimposed, in the later part of 2020, UK car traffic was recorded to be only about 20% below pre-lockdown levels. In parallel to a reduction in the use of cars, a decrease of over 50% in use of buses and trains was recorded. This decrease in use of public transport was maintained even after lockdowns were removed. The data also shows that increases in cycling of up to 200% occurred in the summer of 2020 but dissipated over autumn and winter 2020, as colder and wetter weather occurred. While this thesis is not focused on transport impacts of Covid 19, Figure 1.1 illustrates that significant and rapid changes in transport systems are possible. Glaser & Krizek (2021) thus argue that the response to Covid 19 represents an opportunity to change transport systems, so as to bring about a reduction in greenhouse gas emissions. Taking this opportunity into consideration and the difficulties that are apparent, it is essential that mechanisms that can meaningfully and rapidly reduce transport greenhouse gas emissions, are understood and analysed in depth.

Over the last 20 years, several researchers have presented pathways relating to future low emissions UK transport (Tight et al., 2005; Brand et al., 2017; Centre for Alternative Technology, 2019; Hill et al., 2019). However, relatively few studies have been undertaken relating to why these pathways have not been achieved (Nieuwenhuijsen et al., 2019; Biresselioglu et al., 2018; Steinhilber et al., 2013). Hickman & Banister (2014, p324) argue that the UK Government does not have a coherent plan for future control of transport emissions as "sustainable transport remains a largely unresolved policy area."

To implement a transition to a low emissions mobility culture, the views and actions of local populations need to be changed (Wanzenböck & Frenken, 2020). To assess the practicalities of achieving global climate change targets, the ability of local stakeholders to achieve local targets, therefore, need to be investigated (Doukas & Nikas, 2020). In addition, Gambhir et al. (2019) argue that, to understand global targets, these should be verified against the actions of local stakeholders. Local government is best positioned to understand local actions necessary to meet local targets (Wanzenböck & Frenken, 2020). Peters et al. (2010) argue that local authorities have a pivotal role in coordinating, influencing and leading action in greenhouse gas reduction initiatives, and so engagement with local authorities is vital to success in delivery of a low carbon future. In assessment of changes in public attitudes and behaviour relating to climate change, the United Nations state that "the participation and cooperation of local authorities will be a determining factor" (United Nations, 1992, p282).

Although there is a clear case that local interventions are a necessary component of the mitigation agenda, Robinson (2006) argues that there is a deficit in knowledge relating to assessment of local actions, in terms of local authorities in smaller settlements in less wealthy and lower tier regions of industrialised countries of the world. The North West of England represents such a less wealthy, lower tier region of the UK (Petrella, 2006; Nurse, 2015) and population statistics indicate that only about one million, of the over seven million people who inhabit the region, live in large cities (ONS, 2020c).

One way to understand regional transport emissions is to consider actions taken across a city hierarchy (Knowles & Wareing, 1981, p223). In the North West of England this hierarchy consists of large cities (Manchester and Liverpool), small cities surrounding these and acting as suburbs (Oldham and St Helens), small cities in separate conurbations (Warrington and Burnley) and rural areas. The geographical scale outside large cities has arguably been neglected (Bell & Jayne, 2006; Hall & Barrett, 2018, p8) and Robinson (2006) calls small cities within less wealthy regions in industrialised nations 'ordinary cities,' since they are actually the communities where the majority of people make their homes. She states that the large cities of the world, acting as upper tier communities in upper tier regions, make the headlines and attract research but they are not representative of ordinary communities. In addition, surveys undertaken by the UK Department for Transport indicate that in small cities average travel distances are substantially greater than those occurring in large cities (DfT, 2020f). In small cities car use is also recorded to be substantially greater than that occurring in large cities (DfT, 2020f). The transport mitigation policies developed and implemented in large cities are, therefore, not necessarily those that can be applied effectively in small cities.

Investigations into local policymaking, aiming to reduce transport greenhouse gas emissions, have been undertaken by several authors (McCollum & Yang, 2009; Olsson et al., 2015; Shepherd et al., 2006; Brand et al., 2020) but these studies have not specifically considered small cities and the hierarchy in which they sit. The studies have also not investigated the viewpoints of local authorities in developing and implementing transport greenhouse gas reduction policies within these differing communities. Whilst implementing change in local greenhouse gas emissions is governed by a multilevel process covering national, regional and local scales (Geels, 2006), it has been established that local authorities have a pivotal role in this process (Peters et al., 2010). Through investigation from the perspective of local authorities the importance of this role, together with associated interactions with regional and national scales, can be assessed, for large and small regional cities.

In this thesis the development and implementation of policy relating to reducing transport emissions is, therefore, investigated in areas outside large cities that better represent the 'ordinary cities' of the industrialised world. Through this investigation, a better understanding of transport mitigation interventions is developed to fill the following gaps in the literature:

- The deficit in knowledge relating to the mitigation actions of local government in areas outside large cities, in lower tier regions of the industrialised world.
- A comparison of global greenhouse gas reduction ambitions against potential local stakeholder capabilities, particularly those associated with local government.
- Local and national barriers that have limited the reduction in transport greenhouse gas emissions.

In response to these three gaps in knowledge, the proposed research will focus on areas outside of large cities in lower tier regions of the UK and barriers that exist in terms of motivation and ability to adopt and implement low emissions policy. In this context ability relates to powers and resources available to achieve greenhouse gas reduction and motivation relates to willingness to use, or support the use of, these powers and resources (Nguyen et al., 2019).

To investigate these deficits, the characteristics of small cities in a region such as the North West of England need to be defined, together with the landscape in which they sit, in terms of transport emissions. Local motivation and ability to instigate policy to reduce transport greenhouse gases, then need to be investigated. Finally, the effect of motivation and ability on the capability of the region to reduce emissions needs to be defined and compared to global emission reduction pathways. Hence an interdisciplinary study of transport systems is required utilising qualitative analysis of local governmental regimes and quantitative analysis of how these regimes impact local emissions. The results of investigations into local authority characteristics, motivation and ability and regional capability, can then be used to draw conclusions, relating to how to improve progress towards reducing transport greenhouse gas emissions in the UK.

The research presented in this thesis thus studies local mitigation policy, from the viewpoint of the stakeholders who control this policy. The research also explores how policy may be affected by regional and local hierarchies, in areas outside large cities where the majority of populations in the industrialised world actually live. The research adds important knowledge to the study of transport greenhouse gas reduction and aids in the development of international, national and local policy.

It is noted that, as the focus of the research is on local authorities and particularly on those authorities that are smaller with less wealth and power, it will not be associated with the delivery of low emissions solutions relating to aviation and shipping. The research will, therefore, focus on terrestrial transport where these local authorities have the most influence.

1.2 Aim and objectives

The proposed research can be summarised in terms of an overall aim:

To assess the motivation and ability of local authorities in the North West of England to meet the Paris Agreement in relation to terrestrial transport emissions.

This aim will be realised through delivery of a series of objectives:

Objective 1 - Define political, geographical, economic and social characteristics of North West of England local authorities, to provide the background to study of small cities.

Objective 2 - Identify the range of potential policies that these local authorities could use to reduce terrestrial transport greenhouse gas emissions and how these relate to global and national greenhouse gas reduction targets. This will provide the background to study of transport greenhouse gas emissions and mitigation interventions.

Objective 3 - Investigate how local authority characteristics affect the motivation and ability to deliver these policies, to understand and analyse how local authorities within small cities react to issues relating to transport greenhouse gases.

Objective 4 - Evaluate North West of England regional transport greenhouse gas emissions. This will provide the background to study of local and national mitigation targets.

Objective 5 - Model potential policy pathways by which regional transport emissions may be reduced in line with Paris Agreement commitments, to understand and analyse regional capabilities associated with mitigation targets.

Objective 6 - Assess the effectiveness of these potential policy pathways, taking into account local authority motivation and ability and Paris Agreement cumulative emission budgets, to assess regional capabilities in terms of national targets.

Objective 7 - Discuss how the structure of the North West of England affects the capability of the region to reduce transport greenhouse gas emissions, in line with Paris Agreement commitments, to allow conclusions to be drawn relating to each of the knowledge gaps under investigation.

Objective 8 - Provide insights to apply to the North West of England and, as appropriate, to similar regions, relating to global reduction in transport greenhouse gas emissions compatible with the Paris Agreement, to provide recommendations relating to each of the knowledge gaps investigated.

1.3 Thesis structure

The thesis will consist of the following chapters:

Chapter 1 outlines a thesis rationale and defines thesis aim and objectives.

Chapter 2 defines a methodology used to investigate and model transport greenhouse gas reduction policies and the pathways applied to these.

Chapter 3 describes local authority characteristics and current policy framework present within the North West of England, to meet Objective 1.

Chapter 4 provides a literature review relating to Paris Agreement commitments, local authority governance and transport greenhouse gas emission reduction policies, to meet Objective 2.

Chapter 5 presents results of interviews with a selection of local authority planners responsible for transport across the region, to meet Objective 3.

Chapter 6 describes modelling of current transport greenhouse gas emissions and potential pathways through which these can be reduced, together with an assessment of these potential pathways in the context of Paris Agreement commitments, to meet Objectives 4, 5 and 6.

Chapter 7 outlines discussion of how the characteristics of the local authorities in the North West of England affect motivation and ability to reduce transport greenhouse gas emissions, in the context of Paris Agreement commitments, to meet Objective 7.

Chapter 8 provides a summary of conclusions reached over the course of the research and outlines how these conclusions can be applied in the global effort to reduce transport greenhouse gas emissions in the context of the Paris Agreement, to meet Objective 8. Recommendations relating to future work investigating transport in the ordinary cities of the industrialised world are also given.

CHAPTER TWO - METHODOLOGY

2.1 Introduction

This section of the thesis presents the methodology used in meeting thesis objectives and addressing the gaps in the literature. The research process covered by this methodology is shown in Figure 2.1 and discussed in Sections 2.1 to 2.4 of this chapter.

Figure 2.1 – Thesis research process

The chapter introduction outlines definitions that are used in future discussions. Section 2.2 then describes the methodology used in the literature review. Section 2.3 sets out the methodology used in investigating local authorities. Finally, Section 2.4 explains the research modelling methodology. Key conclusions are summarised in Section 2.5.

As noted in Chapter 1, the knowledge gaps that are addressed within the thesis relate to investigating the ability and motivation of small cities to reduce transport greenhouse gases and how this affects regional capability to reduce emissions. In addition, in order to allow an emphasis to be placed on the 'ordinary cities' highlighted by Robinson (2006), the region under consideration should represent an economically lower tier area of the industrialised world. Within the region under consideration, components need to be defined that can be related to each of the different types and sizes of settlement under review.

Keil & Ronneberger (2008) indicate that, to fully investigate how the cities within a region interact, an area of the order of 100km needs to be considered. Within this area a great variety of transport systems are present. In order to investigate these diverse systems, assessment is required based on a connected viewpoint, avoiding local fragmentation (Granger & Kosmider, 2016). Although less than 20% of travel in the UK involves trips over

10 miles (16km) (Table NTS0307 (DfT, 2020f)), these longer trips, by their nature, make up a significant proportion of distance covered by the local population and it is distance covered that is one of the key drivers of impact with relation to greenhouse gas emissions (Stead, 1999). There is, also, a significant contrast in distance covered between different populations, with residents in rural areas travelling nearly twice as far as those in central urban areas (DfT, 2020f). To investigate regional transport systems, assessment, therefore, needs to go beyond the local commuting sphere of a single city, to:

- Enable an integrated connected investigation of regional transport systems.
- Investigate all trip types and lengths within the region.
- Compare different trip regimes associated with varied populations.

Based on EU area designations, the NUTS 1 regional scale best fits this aim, encompassing population distributions of 3 to 7 million over multiple cities of varying types and sizes (Eurostat, 2018). An area of interest for the thesis has, therefore, been defined that relates to the NUTS 1 region of the North West of England. This particular region has been chosen as it provides an example of a lower tier area (Petrella, 2006), has a history of development needs (Nurse, 2015), has a wide variety of authorities ranging from the large city of Manchester to predominantly rural areas such as Eden Local Authority, is readily accessible for study from a base in the city of Manchester and is familiar in terms of local geography and structure.

Within the region, components need to be defined that can be related to a variety of settlement types. Within the North West of England 39 local authorities exist. Local authority boundaries are those used across the EU, as ‘local administrative units’ (LAUs), in defining local statistical data sets (Eurostat, 2018). LAU boundaries also define different communities and the extent of different local government jurisdictions (HM Government, 2019). Local authorities in the North West of England relate to large cities, small cities acting as suburbs to these, small cities within separate conurbations and rural areas (ONS, 2017). Through concentrating on local authorities, a variety of settlement types can be investigated in conjunction with associated statistical data sets compiled by UK Government departments. On this basis the region considered, within research described in this thesis, will be the North West of England and the components assessed will be the 39 local authorities (LAUs) that are present in the region. The LAUs within the North West of England are shown in Figure 2.2.

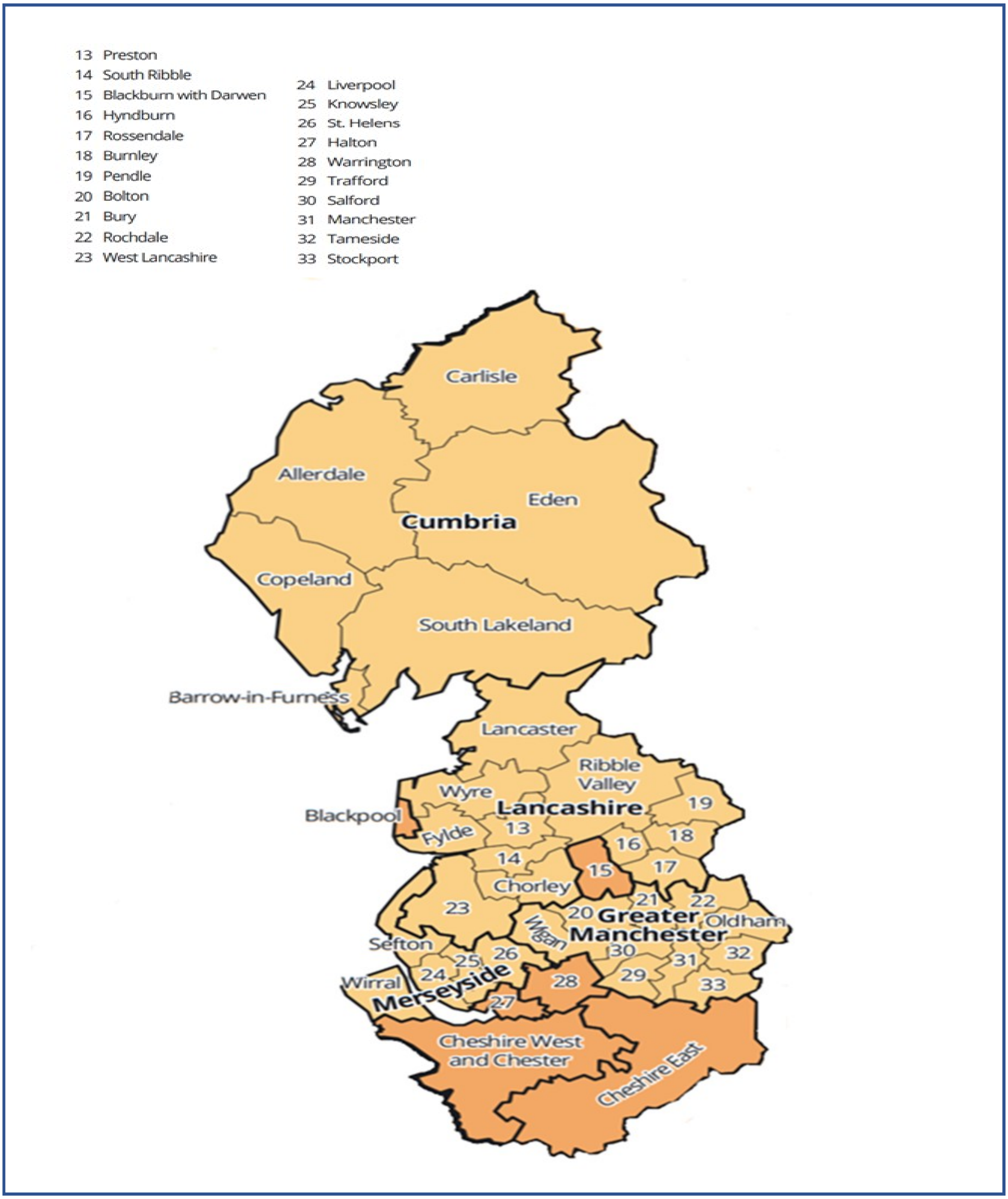

Figure 2.2 – Local authorities in the North West of England
(Copyright Office for National Statistics under Open Government Licence)

Figure 2.2 shows local authorities, together with the NUTS2 county regions of Cumbria, Lancashire, Merseyside and Greater Manchester, in which they sit. The six regional unitary authorities that act as self-governing LAUs outside the county hierarchies are shaded darker in the figure. Government structures relating to the region are described in Chapter 3.

In the remainder of this thesis the term large city will be used to designate local authorities such as Manchester and Liverpool that form the principal urban areas of the region. The term small city will be used to designate other smaller local authority jurisdictions that cover suburbs and separate conurbations. In addition, where local authorities cover multiple small settlements in more rural areas these will also be referred to as small cities. The term small city hence relates to all communities outside the large cities of the region. This is in keeping with a definition of a city as “a municipality whose boundaries and powers of self-government are defined” (Webster, 2010) and allows a clear distinction to be made between principal cities and ordinary cities, as highlighted by Robinson (2006). The characteristics of these local authorities are described in detail in Chapter 3.

2.2 Literature review

To provide a useful dataset, a synthesis of information is required. The process starts with a search of academic and non-academic literature and data in order to provide a baseline, connected to and from the viewpoint of investigating the main knowledge gaps associated with the thesis (Potter, 2006).

For the thesis, a three-stage approach to data collection has been undertaken. The first stage involved a general sift of academic literature, to fully identify knowledge gaps and, thereby, define the aim and objectives of the research. Once a preliminary setting of these had been achieved, a second phase of data collection was undertaken to fully define research boundaries and parameters. Finally, a third stage of critical review was undertaken from the viewpoint of specific academic queries. There was considerable overlap between these three stages as the aim, objectives and the nature of academic queries developed over the course of the research. Initial searches related specifically to the three knowledge deficits noted in Chapter 1. Several hundred academic searches were ultimately necessary over the course of the literature review to fully investigate the thesis objectives.

The first stage of data collection was primarily undertaken over the period from 2016 to 2018 and consisted of a critical review of academic and grey literature relating to the three primary fields of the research: carbon budgets, small city governance and transport regime interventions. Searches of literature were initially undertaken using academic databases, starting with wide search parameters based on searchers relating to these three fields, but were then, as necessary, systematically narrowed to obtain a usable dataset in terms of size, context and relevance. Data searches included review of authors and citations to identify the primary academic actors, in the various fields investigated and the critical academic sources used. Where relevant to the thesis, critical authors and citations were then added to data searches. Searches were continued until no new relevant information was being uncovered. In parallel, where grey governmental and non-governmental reports and literature were referenced, these were investigated and the main actors in terms of producing non-academic data identified and reviewed. Review results were entered into a spreadsheet, listing their core contribution to the study and added to the potential basket of citations for the study using Mendeley reference management software.

In addition to the sources relating to academic papers and non-academic reports, books on the various subjects relating to the thesis have been referenced. Books were particularly reviewed where they were used within academic citations or where they provided a generalised subject overview of an aspect of the research.

The second phase of data collection primarily occurred over the period 2019 to 2020. The aim of this stage was to narrow and update references. Due to the long time period involved in the research, given the PhD has been conducted on a part-time basis, and the large number of academic studies being generated, it was necessary to go back to some data searches to ensure up to date sources. Again, searches were continued until no new relevant information was being uncovered and papers were entered into the search spreadsheet and referencing software.

In addition to the academic literature, there is a large amount of grey literature and data relating to these fields. Grey literature was also reviewed and updated at this stage, in particular the three main grey datasets used in the research; BEIS annual climate change impact reports, ONS annual lifestyle surveys and data derived from the 2001 and 2011 censuses and DfT vehicle statistics.

Where new datasets have been issued, in the second half of 2020, research has continued to be updated to ensure that the thesis provides conclusions that are as relevant, as practical, to current conditions. A cut off has been set at the end of 2020, in review of updating of grey literature, to allow finalisation of the thesis to be completed, although where new information of particular relevance emerged after this cut off, it has been incorporated into the thesis. Given Covid 19 disruptions, many of the statistics released in the early part of 2021 have, however, not been representative of general trends in UK transport and in terms of undertaking significant updates, it has not been appropriate to use this data.

The final phase of data collection was undertaken in 2020 and 2021 and involved collection and review of data relating to specific queries identified in development of research objectives, particularly with relevance to review of different interventions. The result of these data searches was a set of three academic datasets, with accompanying spreadsheet analysis, giving core conclusions of each study, together with grey literature and book references. In order to develop the thesis literature review, the datasets have been analysed, interpreted and critically reviewed in order to provide a knowledge map of research topics in terms of scope, development over time, theories, methodologies and context, with particular emphasis on knowledge gaps that are to be addressed in research being undertaken (Hart, 2018). The data maps were then used to develop the literature review presented in Chapter 4. The literature review was written taking into account the research objectives and, in particular, the overall aim of the research.

There are three specific issues that have created challenges within the thesis literature review process. These are:

- The long period over which the research has been undertaken.
- The rapidly changing academic landscape associated with climate change and transport system research.
- The impact of the Covid 19 pandemic on transport systems.

As the thesis has been undertaken on a part time basis, it has been expanded to cover a six year period, rather than the three to four year period over which thesis research is usually carried out. This long time period of research, in rapidly changing academic fields, runs the risk that conclusions will be out of date before they are published. This risk has been mitigated by undertaking data searches in three phases and in each phase returning to the main research queries to check whether new research has emerged. Where new research has emerged, it has been included in the thesis, at least until the defined cut off at the end of 2020.

This changing landscape is illustrated by the impact of Covid 19, on transport systems and on economic and social life in the UK and in many parts of the developing and developed world (Loske, 2020; Teixeira & Lopes, 2020). Interviews with local planners, responsible for transport planning in the North West of England, were undertaken before the impact of the pandemic was felt. The full impact of Covid 19 will not be clear for a considerable time and the focus of the thesis will continue to be on the viewpoints of local authorities in meeting Paris Agreement transport greenhouse budget targets with or without the impact of the pandemic. Some discussion about the potential impact of Covid 19 will be presented in the closing sections of the thesis but, given the timetable over which interviews and interpretation of these has been undertaken, the impact of the pandemic will not be a central component of discussions and conclusions. The full impact of Covid 19 is, at present, unknown but it may provide a catalyst for the significant levels of change required to address climate change issues (Smeds & Cavoli, 2021).

2.3 Local authority interviews

Objective 3 of the thesis requires an assessment to be undertaken of how local authority characteristics affect their implementation of interventions to reduce transport greenhouse gas emissions. Within the field of social science, assessment techniques have been developed around a core tool of use of semi structured interviews (Yates, 1998; Hammersley & Atkinson, 2007). By conducting interviews using a set template based around open questions, insights into participants viewpoints and that of the organisation they represent, can be obtained (King, 2004; Smith, 2006). In order to establish a framework for social science investigation, Smith (2006, p5) suggests a ten point checklist to establish study boundaries, that is shown on Table 2.1 and is used in subsequent discussions outlined in this section.

Table 2.1 – Social science investigation framework (Smith, 2006)

Checklist categories	
1. Personal interest	2. Experimental framework
3. Problem definition	4. Methods used
5. Data collected	6. Knowledge obtained
7. Context of study	8. Study sequence
9. Data interaction	10. Purpose of study

Personal interest

The first part of the defined framework relates to acknowledgement of personal interest in the field of study. In any social investigation, a self-examination of the position of a researcher within current political and cultural paradigms, together with society's ethical landscape, is required (Smith, 1998). As a chartered engineer, with many years' experience of design and construction of transport infrastructure, I have some existing insights into local planning processes. As an individual with political and social concerns relating to climate change, I have some existing insights into issues relating to greenhouse gas emissions. These existing insights provide a regime of useful background knowledge in terms of the research objectives, but also constitute a paradigm lens through which assessments and conclusions might be distorted (Hammersley & Atkinson, 2007).

In order to avoid distorting assessments and conclusions Hampton (2018) suggests that research should be developed on the basis of five guiding principles:

- Recognise that researcher history and position does provide some useful insights.
- Recognise that other stakeholders do not share history and insights of the researcher.
- As necessary record own insights in addition, but separately, from stakeholder insights.
- Ensure that stakeholder insights are sufficient to provide a picture beyond and above personal viewpoints.
- Follow established theory and practice in collection and assessment of data.

These principles can be summarised in terms of positioning the researcher as a detached observer of stakeholder actions (Smith, 1998). It is also necessary to recognise that social and political positions held by individuals, including both the researcher and the stakeholders, are shaped by societal and cultural environments in which they have grown up and are currently working and that these social and political positions vary with time and place (Anderson, 2006).

Experimental framework

Interviews have been undertaken for the purpose of investigating the constraints that local authorities face in implementing policy relating to reducing transport greenhouse gas emissions. Exploration and assessment is undertaken through a social science theory grounded on the systematic evaluation of interview text, in order to derive, define and map relationships (Yates, 1998; Hammersley & Atkinson, 2007).

Systematic analysis of text can be used to explore local authority viewpoints. By understanding organisational viewpoints, an attempt can be made to establish organisation rationales, associated with establishment of goals and enactment of these goals through policy and practice. Research relating to understanding of a viewpoint is covered by the field of ethnography which “seeks to explore and to represent how people create, experience and understand their everyday worlds” (Kavanagh & Till, 2020, p321). In particular the field of institutional ethnography can be referenced, which seeks to investigate people’s experience within an organisation in order to determine how the organisation works (Smith, 2006, p8). Campbell & Gregor (2008, p29) describe this framework as a methodology concerned with how social structures affect decision making systems. Teghtsoonian (2016) argues that, through understanding the social viewpoint of a stakeholder within an organisation and of the organisation itself, an insight can be obtained, into constraints on ability to exercise the power necessary to implement policy. Dudley et al. (2011) note that views expressed by individual officers, within an organisation, may not represent the views of the organisation itself, but that this potential disjoint between individual and organisational views can be reduced through assessment of detailed discussion with individuals and analyses of associated actions taken by organisations. Hence although investigation of one person or a small group of persons may not fully define the viewpoint of an organisation, the investigation may form part of an assessment framework that can be used to explore organisational viewpoints.

The institutional ethnography framework has been applied in educational, employment, planning, activist and home settings (Smith, 2006, p15). In assessment of teacher insights made within an educational environment, Talbot (2020) suggests that a framework with emphasis on viewpoint, allows understanding of how local decisions are constructed. Grace et al. (2014) used an institutional ethnography framework to investigate local authority implementation of alcohol licensing laws and, in particular, state that the framework is useful as a tool in understanding of decision making across multilevel systems. It can also be noted that viewpoints of local authority actors may also be aligned with viewpoints of local populations (Van et al., 2007) and hence represent part of the landscape in which local authority organisations operate. The methodological principle adopted, therefore, provides a means by which assessment can be undertaken of how and why decisions are made, or not made, at a local level, with reference to national and international issues.

Problem definition

As a lower tier region of the industrialised world, the North West of England NUTS1 designation, consisting of 39 small, medium and large local authorities, has been chosen as a region for study. For these authorities transport greenhouse gas reduction potential can be determined from several different perspectives. Constraints on motivation to reduce transport greenhouse gas emissions can be assessed in terms of attitude and constraints on ability can be assessed in terms of physical pathway restrictions (Biresselioglu et al., 2018). From an institutional ethnography perspective, a map of the perceived landscape of internal viewpoint and external barriers can be used to investigate motivation. In terms of transport planning, a map of pathway, chosen by each hierarchy, can be used to investigate constraints relating to particular transport modes. Ability to deliver policy can also be assessed directly, in terms of governmental structure. In the research undertaken it is proposed to use each of these mappings to assess hierarchical relationships with transport mitigation policy. Through investigating the inhibiters that occur at each hierarchical tier, within this lower tier region, maps of landscape, pathway and ability, applicable to transport mitigation policy, can be constructed. These maps can then be used to establish the nature of the relationship between hierarchical tiers and policy implementation.

Methods used and data collected

In order to understand how governmental policy has been developed and implemented, across a hierarchy of cities in the North West of England, it is necessary to interrogate planners responsible for local delivery of policy. To review all hierarchies within the region it is necessary to select a number of governmental institutions from the region. This selection is limited to the 39 local authorities, present within the North West of England, together with the two overarching rural county councils and the two overarching urban metropolitan metro mayoral councils. The number of interviews undertaken is limited by time and effort available to plan, arrange, implement and analyse investigations. Local authorities have been selected based on providing coverage of each tier of government within the region. In selecting local authorities absolute size and relative size, defined in terms of commuting hierarchy, measured in terms of net balance of inward and outward commuting (see Section 4.2 (Fuguitt, 1991)), have been considered. At least two interviews have been undertaken from each tier of government. In choosing local authorities to interview emphasis has been put on councils that are smaller in terms of absolute size and councils that are lower tier in terms of commuting hierarchies.

Based on these criteria an interview plan has been developed that targeted twelve authorities. This plan consisted of interviewing two mayoral authorities located within the large cities of the region and covering these and surrounding suburbs. It was, also, planned to interview two municipal authorities that acted within the umbrella of mayoral policy and are lower tier in terms of commuting hierarchy, together with two county councils and four of the district councils which act within the county policy umbrella. Finally, the plan called for interviews to be undertaken with two unitary authorities that are independent of mayoral or county controls.

As discussed in Section 4.2, large city interviews represent the highest regional hierarchical layer, with net positive commuting flows greater than 10%. The two suburban municipal authorities represent the lowest tier of commuting flows with net negative flows of greater than 10%. The unitary authorities represent upper intermediate hierarchies with commuting flows generally positive, but less than those represented by the large city mayoral authorities. Of the two unitary authorities chosen, one has net positive commuting flows of greater than 10%, whilst the second has positive commuting flows between 0% and 10%.

The two county councils provide transport planning for 18 district councils, each associated with net commuting flows that vary from 10% positive to over 10% negative. The four small district councils, chosen for interview, cover this whole range of commuting flows. The councils chosen for interview are summarised in Table 2.2.

Table 2.2 – North West of England interview selection

Local governmental hierarchy	Total	Total selected for interview
Large city/metro mayor authority	2	2
Suburban municipal authority	13	2
Unitary authority	6	2
County council	2	2
District council	18	4

To allow interviews to be undertaken an investigation plan was developed and subjected to ethical review. Each of the councils was contacted and the study aim explained to them. They were then asked to allow personnel responsible for transport planning to participate in interviews. All authorities, except one, agreed to allow an interview to be undertaken. The exception was one of the four district councils approached who only provided a short written response to the queries put to them. Only three interviews with district councils were, therefore, undertaken. The district council that did not participate, however, represented an intermediate hierarchy and hence interviews with the remaining district councils still provided a hierarchical range that provided an overall picture of the region. For the remaining councils, local planning personnel, as single officers, or groups of up to three officers, were interviewed after having been presented with a summary of topics to be covered and having given permission for discussions to be recorded for subsequent analysis and for derived non-attributed quotes to be used in subsequent reporting of data.

The eleven interviews undertaken represent at least two investigations from each regional governance tier and about a quarter of all authorities present within the region. From a statistical point of view, the small number of interviews undertaken does not provide sufficient coverage to allow detailed quantitative analysis of results. From a social science perspective, the interviews do, however, provide information on indicative typologies of regional structure as it relates to each local authority.

In order to plan for the investigation, a set of interview questions has been developed, each with an open structure allowing topic discussions to be initiated covering thesis areas of interest (King, 2004a). These areas of interest relate to ability, pathway and landscape, associated with setting of goals, defining policy and implementing actions, within a framework, as described by Geels (2012), consisting of authority internal structure and external financial, political, cultural and social landscape.

A 17-point interview question structure has, therefore, been developed that covered all these aspects of investigation. Questions were defined to investigate goals, policy and implementation, relating to each local authority's motivation and ability in reducing transport greenhouse gas emissions. Interview Questions 1 to 3 relate to the goals defined by each local authority and, also, provide an opportunity to set out an overall baseline for subsequent discussion. Questions 4 to 10 relate to policy development within the local authority and, in particular, to the internal and external barriers and opportunities inherent at a local level. Questions 11 to 17 relate to the actions taken to implement policy by the local authority, encompassing discussion of monitoring, targeting and effectiveness of policy. Interviews were undertaken between November 2018 and November 2019. Each interview was based around the defined questions and lasted about one hour, consisting of informal discussion with local authority planners responsible for local transport systems. A list of the question structure used in interviews is contained in Appendix A.

Once interviews were complete an exercise was undertaken to provide a map, in terms of policy themes relating to ability, pathway and landscape. Firstly, transcripts were produced from interview recordings. Within each theme, categories were chosen to provide an assessment of different aspects, relating to local authority development of goals, policy and actions, and of the environment in which this development occurred. A systematic analysis of text was then undertaken to derive quotes relevant to each designated category (King, 2004b). As necessary, where mapping of text revealed particular areas of interest, subcategories were subsequently developed to enable more detailed characterisations to be undertaken.

Ability theme categories were closely mapped to interview questions, in terms of discussion of goals, policy and actions. Pathway and landscape category assessments were taken from across the whole interview text. Assessment of comments relating to ability, was aimed at deriving an overall picture of development and implementation of local authority policy. Assessment of comments relating to pathways, was aimed at illustrating the relative importance that planners assigned to different aspects of their transport, to investigate the possible routes that could be applicable in terms of transport greenhouse gas reduction. Assessment of comments relating to landscape was aimed at illustrating how local planners viewed current systems, beyond answers to specific questions, in order to understand motivations (Campbell & Gregor, 2008, p43). Descriptions of the development of interview categorisations and their analysis are set out in Chapter 5.

Context, sequence, interactions and purpose

Context, sequence, interactions and purpose are outlined in the thesis introduction, in Chapter 1. It is proposed that knowledge derived from interviews will be used to investigate ability, pathway and landscape themes, relating to local authority reduction of transport greenhouse gas emissions. These themes will be used, in parallel to modelling, described in Section 2.4, to illustrate motivation and ability, of a small city in the industrialised world, in achieving emissions reduction compatible with the Paris Agreement. In particular, themes will be used to meet Objective 3, to explore how local authority characteristics affect implementation of policy.

2.4 Pathway modelling

The aim of the thesis is to investigate the motivation and ability of local authorities, in the context of Paris Agreement greenhouse gas emission limitations. To allow this assessment to be undertaken some modelling of current and future transport interventions is required. For the thesis, a modelling methodology has been chosen based on availability of resources, and a requirement that models are clear enough to fully illustrate impacts but accurate enough to sufficiently define these (Gately et al., 2013). In addition, as the interventions under investigation relate to small cities, any investigative methodology should be flexible enough to allow small initiatives to be assessed.

Investigating changes in transport emissions requires an assessment to be made of likely future states. A methodology that has been widely used, over the last fifty years, to assess future states is scenario analysis (Hickman et al., 2012). Scenario analysis is based on asking the questions “what can we do?” and “how can we do it?” (Godet, 2000). These questions are answered through extrapolation from current states, to allow construction of possible plausible future states, based on logical causality, incorporating consideration of probability and uncertainty (van der Heijden, 2005). Logical causality can be modelled in a number of ways, but all must provide a story through which data can be connected (van der Heijden, 2005). McCollum & Yang (2009) state that, due to the inherent risk of divergence of modelled pathways, scenario results should not be thought of as a detailed prediction of emissions but as a tool to allow different futures to be compared. Meadows et al. (2004) caution against using models as direct predictions of actual change. They state that models are instead to be used as illustrations of possibilities.

Studies that investigate transport futures vary in scale; from the global in Turton (2006), continental in Haasz et al. (2018), national in Brand et al. (2017), regional in Namdeo et al. (2019) and city specific in Olsson et al. (2015). Edelenbosch et al. (2020) note that, as scale increases, complexity, associated with interdependence assumptions, decreases but results become less transparent. In particular, they point out that, in large scale models, opportunity to relate results to local mitigation decrease.

Models also vary in terms of their underlying methodology. Large scale economic models, such as the TIMES model used by Haasz et al. (2018), in evaluating the EU, are associated with integrated optimisation of relationships between transport and social/economic variables, including technological innovation, GDP and population. Gambhir et al. (2019) argue that the scale of such models makes them prone to input and output inaccuracies and, in particular, that they do not allow assessment of local impacts and interventions. In developing scenarios in the UK, the Department of Transport (DfT) have noted that there has been a breakdown in some of, previously established, transport economic relationships over the last few years (DfT, 2018a, p36). Models based on economic variables may hence lose their ability to characterise future transport states.

In contrast, researchers such as Hickman et al. (2012) have modelled future emissions through use of expert panels. Distefano & Krubiner (2020), however, argue that, in complex systems, use of expert panels to develop quantitative scenarios lacks transparency, due to the weightings that it is necessary to apply in assessment of multiple variables, and may lack accuracy due to inherent biases that experts bring to the table. Expert panel models are, therefore, also less suited to the requirements of open and transparent modelling in the current study.

An alternative to economic modelling and to expert panel assessment, is to model transport in terms of the specific changes in emissions brought about by interventions, without direct reference to relationships with exterior variables. In a study of possible transport futures in the USA, McCollum & Yang (2009) characterise emissions in terms of local mode, activity and efficiency. This modelling methodology can be used to directly relate specific interventions to changes in transport emissions. It hence represents a methodology that can be adopted in the context of investigating local interventions in a straightforward and clear manner. Details of the methodology based around assessment of mode, activity and efficiency are outlined in Chapter 4.

Through analyses of scenarios, the relationship between application of policy and possible end states can be investigated. Forecasting can be used to investigate end states resulting from application of potential current policy. Potential current policy is described in the literature review set out in Sections 4.4 and 4.5. Forecasted end states can be compared with defined desirable end states. The difference between forecasted and defined desirable end states represents necessary additional policy that is required in order to achieve required end points (Hickman & Banister, 2014, p79). This policy modelling approach can be compared to an approach starting from defined desirable end states and backcasting to bridge the gap between these and existing policy application (Mander et al., 2008). Through combining forecasting and gap analyses a more complete picture can be investigated, of necessary changes in policy, than that which would be described in a backcasting only modelling assessment.

In Chapter 6, policy assumptions are described, relating to potential future pathways, to construct small scale forecasted scenarios illustrating possible future regional transport. The policy assumptions are related back to Paris Agreement emissions limitations, described in Chapter 4 and to policy restrictions revealed by interviews with local authority planners, described in Chapter 5. Intervention pathways can be split into two distinct approaches that Hickman & Banister (2014, p325) characterise in terms of technological and stewardship routes. The technology route relates to a pathway in which a shift occurs from conventional vehicles to vehicles with alternative low or zero emission drive systems, without change in the overall trajectories of use of private vehicles. The stewardship route relates to a pathway associated with alteration in local activity and growth in use of public and active transport. In this pathway mode shift occurs, away from use of private cars and opportunities exist for overall reduction in distance travelled.

The technology route represents pathways governed primarily by the actions of national government whilst stewardship interventions relate to local implementation of policy (Browne et al., 2012) which is the focus of this thesis. However, to investigate the impact of stewardship interventions, background pathways associated with technological change, need to be defined.

Technological scenarios involve investigating conversion of over 30 million cars, currently present in the UK, to alternative drive systems. These alternative drive systems can be characterised in terms of changes in transport efficiency. At present it is assumed that the alternative drive systems adopted, in this pathway, relate to electric vehicles (EV), given that these alternatives have already demonstrated some penetration of the UK market and in some countries around the world, such as Norway, adoption is well established (Rietmann & Lieven, 2019). Technological penetration by other drive systems, such as fuel cell hydrogen, may, however, in the future also be important. At present technological development of these alternative drive system has not achieved a significant market foothold and hence extrapolating possible future penetration is difficult. However, where fuel cell hydrogen or other technology might be relevant, it will also be referenced. This is of particular importance in transport greenhouse gas emissions relating to road movements associated with long distance freight, where, given current range and capacity limitations, a technological solution involving hydrogen may be more appropriate than an EV technological solution (Smallbone et al., 2020).

Many researchers have investigated how societal relationships affect adoption of EVs. In recent systematic literature reviews by Austmann (2020) and Kumar & Alok (2020), initial screening of papers, relating to EV adoption and sales, resulted in about a thousand potential studies. After filtering, in both reviews, assessment was undertaken of over a hundred papers. In his review Austmann (2020) splits models between those that use stated preference methodologies, based on willingness to pay, and those that use revealed preference, based on actual purchases. He, however, notes that stated preference assessments may not accurately predict intentions, as a gap exists between attitude and actions. He also notes that revealed preference studies, employing regression analysis to assign adoptive actions to different societal characteristics, are hampered by the small selective data pool provided by low current global uptake of EVs. This small data pool may also not be representative of the majority of the population as it consists of innovators who have a greater disposition for take up of new technology (Rogers, 2003, p281). In addition, Janssen (2020, p27) notes that both stated preference and revealed preference change over time, as progress in adopting innovation alters societal norms and practices.

The technology strand of modelling involves the purchase choices of millions of actors within a fiscal and legislative framework, generally set by national government. This governmental fiscal and legislative framework also influences the policy of car manufacturers in terms of development of new technological brands. The decisions of millions of actors are best modelled using a statistical methodology. Rogers (2003) provides a statistical framework that can be used to model diffusion of EV purchases in society (Pettifor, Wilson, McCollum, et al., 2017). The important aspect of this model is that attitudes change over time, as technology becomes embedded into society (Rogers, 2003). Stated preference and willingness to pay assessments, of desire to purchase a vehicle with an alternative drive system are, hence, only relevant to the particular geographic and temporal framing in which they are determined. Rogers' diffusion model allows these geographically and temporally limited framings to be extrapolated to future situations to model societal transition from one technological regime to a different regime.

The second modelling strand relates to the stewardship aspects of policy. This involves policy implementation decisions made by local governmental organisations that will have a direct impact on choices made by local populations. The direct impact on local populations will involve their reduction in use of cars, through shift to other transport modes and through absolute reduction in travel. Unlike the technology strand this model does not involve the decisions of many actors. It is based on the decisions of a small number of planners and local government executives. Once a new policy is implemented, a step change in local population behaviours can be determined from assessment of data on similar policy initiatives, in similar circumstances, as outlined in the literature review presented in Chapter 4. The stewardship modelling strand is, therefore, governed by analysis of discrete events rather than the statistical continuum, applied to technological diffusion. In stewardship modelling, outlined in Chapter 6, discrete events are, therefore, measured in terms of change in activity and mode brought about by local intervention.

Technological modelling described is similar to analysis undertaken by Pettifor, Wilson, McCollum, et al. (2017) and stewardship modelling is similar to analysis undertaken by Anable et al. (2012). However, applying these models, as described in Chapter 6, to assess combined regional emissions, in the context of Paris Agreement budgets and smaller local authority motivation and ability, represents new knowledge.

2.5 Chapter summary

This chapter outlines the methodology used in developing the research covered in the thesis. In Section 2.1 definitions are provided. In Section 2.2 the methodology used in systematic evaluation of literature to compile reviews presented in Chapters 3 and 4, is outlined. In Section 2.3 the methodology employed in development of interviews with eleven local authority planners is presented, together with the ability, pathway and landscape themes used in Chapter 5 in analysis of text from these interviews. In Section 2.4 the methodology described in Chapter 6 in statistical modelling of transport technological change and in discrete modelling of stewardship change, is introduced. The next chapter provides the background characteristics of local authorities to enable a research landscape to be defined.

CHAPTER THREE – LOCAL AUTHORITY CHARACTERISTICS

3.1 Introduction

This chapter provides a summary of the characteristics of the local authorities in the North West of England. Section 3.2 sets out the legislation that controls the actions of local authorities in the UK. Section 3.3 then describes the transport regulatory framework. Section 3.4 outlines transport emissions currently associated with each local authority. Finally, Section 3.5 provides a summary of the contents of the chapter. This chapter provides background to the literature review in Chapter 4, the interview investigations of Chapter 5 and the modelling of Chapter 6.

3.2 Legislative framework

Leach et al. (2018, p11-14) state that a system of local government with local powers is present in all Western democracies and that local government is required to deal with local diversity, respond to local needs, locally prioritise these needs, provide local accountability and remove the burden from national government. In the UK both single tier and two tier local authority structures are present (HM Government, 2019). Single tier local government consists of metropolitan boroughs or unitary authorities, corresponding to an EU 'local administrative unit' (LAU) (ONS, 2018a). Two tier local structures consist of county councils, corresponding to EU NUTS2 areas, each containing a number of smaller district councils that correspond to LAUs (ONS, 2018a). Upper tiers of local government are responsible for delivery of strategic plans and overarching policy in areas such as waste management, education and transport, whilst lower tiers deal with local planning and licensing (Institute for Government, 2020). Where a single tier of local government is present, they are responsible for all these functions (Institute for Government, 2020).

The 39 local authorities present in the North West of England are shown in Figure 2.2 and Table 3.1 together with a selection of characteristics.

Table 3.1 – North West of England local authority characteristics (Government Statistical Service, 2017; ONS, 2020c)

Authority	Designation	Populations 2018	Density persons/hectare	Urban category
Bolton	Metropolitan District	285,372	20.41	1
Bury	Metropolitan District	190,108	19.11	1
Knowsley	Metropolitan District	149,571	17.29	1
Liverpool	Metropolitan District	494,814	37.06	1
Manchester	Metropolitan District	547,627	47.35	1
Oldham	Metropolitan District	235,623	16.55	1
Rochdale	Metropolitan District	220,001	13.91	1
Salford	Metropolitan District	254,408	26.17	1
Sefton	Metropolitan District	275,396	13.45	1
St. Helens	Metropolitan District	180,049	13.20	1
Stockport	Metropolitan District	291,775	23.15	1
Tameside	Metropolitan District	225,197	21.83	1
Trafford	Metropolitan District	236,370	22.29	1
Wigan	Metropolitan District	326,088	17.33	1
Wirral	Metropolitan District	323,235	12.61	2
Allerdale	Non-metropolitan District	97,527	0.74	6
Barrow-in-Furness	Non-metropolitan District	67,137	5.08	3
Burnley	Non-metropolitan District	88,527	8.00	3
Carlisle	Non-metropolitan District	108,387	1.03	4
Chorley	Non-metropolitan District	116,821	5.76	4
Copeland	Non-metropolitan District	68,424	0.88	6
Eden	Non-metropolitan District	52,881	0.25	6
Fylde	Non-metropolitan District	79,770	4.37	4
Hyndburn	Non-metropolitan District	80,815	11.07	3
Lancaster	Non-metropolitan District	144,246	2.20	4
Pendle	Non-metropolitan District	91,405	5.40	3
Preston	Non-metropolitan District	141,818	9.92	2
Ribble Valley	Non-metropolitan District	60,057	1.03	6
Rossendale	Non-metropolitan District	70,895	5.14	3
South Lakeland	Non-metropolitan District	104,532	0.60	6
South Ribble	Non-metropolitan District	110,527	9.64	2
West Lancashire	Non-metropolitan District	113,949	2.99	5
Wyre	Non-metropolitan District	111,223	3.38	4
Blackburn with Darwen	Unitary Authority	148,942	10.87	3
Blackpool	Unitary Authority	139,305	32.28	2
Cheshire East	Unitary Authority	380,790	3.26	5
Cheshire West and Chester	Unitary Authority	340,502	3.62	4
Halton	Unitary Authority	128,432	14.22	3
Warrington	Unitary Authority	209,547	11.49	3

Local authority populations are taken from mid-2018 estimates within LAU boundaries. The metropolitan districts and unitary authorities have populations that range in size from 130,000 persons to 540,000, with the two large city LAUs of Manchester and Liverpool having significantly greater population and population densities, than other authorities. Populations of the non-metropolitan districts range from 50,000 persons in largely rural authorities to 140,000 in the small cities of Preston and Lancaster.

The ONS categorises each local authority in terms of population split between urban and rural areas (Government Statistical Service, 2017) using a six point scale consisting of:

1. Urban with major conurbation,
2. Urban with minor conurbation,
3. Urban with city and town,
4. Urban with significant rural,
5. Largely rural,
6. Mainly rural.

This categorisation indicates that, across the belt between Greater Manchester and Merseyside, all authorities are classed as being part of a major conurbation. Outside Cheshire, unitary authorities are classed as largely urban but are not associated with major conurbations, whilst the two Cheshire unitary authorities are classed as urban with significant rural and largely rural. The non-metropolitan authorities cover a large range of rural and urban settings, from urban with minor conurbation areas, such as Preston and South Ribble, to the mainly rural areas of Allerdale, Eden, Copeland, Ribble Valley and South Lakeland.

Primary control of local government is defined in the Local Government Act (2000) (HM Government, 2000). Relative to other developed countries, the UK Government provides local government with fewer resources and less ability to act independently (Eckersley, 2018). The relationship between local and national government in the UK has been deteriorating over the last thirty years (Leach et al., 2018, p34). This deterioration started with the Conservative Government’s decision to split up large metropolitan authorities as part of the reorganisation of council boundaries in the 1980s and continued with their centralisation policies in the 1990s and was not reversed by subsequent Labour

Governments, before being reinforced by the Coalition Government of the 2010s (Leach et al., 2018, p58).

Historically a number of bodies have provided guidance and support, on some aspects of planning, at an intermediate level between national and local government. Metropolitan Councils, acting at the NUTS2 level, provided some regional planning up until their 1986 abolition (Leach et al., 2018, p58). Up until 2012, regional development agencies were present at the NUTS1 level of government and provided regional spatial planning to the local authorities within their area (Pugalis & Townsend, 2013). These were replaced by 'local enterprise partnerships' (LEPs), which operate within smaller NUTS2 and NUTS3 areas (Nurse, 2015). LEPs offer greater emphasis on economic development and less emphasis on strategic planning, as they act at a smaller scale and are run by a board taken from local businesses (Pugalis & Townsend, 2013).

In 2016, in response to the economic lag of regions outside the South of England, a series of regional development initiatives were again set up, to provide strategic regional planning at the NUTS1 level (HM Treasury, 2016). In the North of England, the 2016 regional development initiative was provided by the Northern Hub, with the stated aim to provide infrastructure connectivity between the regions cities in order to promote economic development (HM Treasury, 2016, p3).

In addition, the Cities and Local Government Devolution Act (2016) made provision for a local region to choose to elect a Metro Mayor, overseeing a group of local authorities and providing an opportunity to take greater control of transport, employment, housing, public services and finances, and to receive grants and financial adjustments, including provision for retaining local business rates (Sandford, 2019). The two major conurbations of Merseyside and Greater Manchester have adopted this system by referendum (Sandford, 2019).

Local government powers are based around the principles of supporting the economic, social and environmental well-being of a local population (Leach et al., 2018, p78). Section 2(1) of the Local Government Act 2000 states that "every local authority are to have power to do anything which they consider is likely to achieve" these aims (HM Government, 2000).

However, the power to do “anything” is limited by many complex planning, funding and regulatory restrictions. Some of these restrictions are described in the following paragraphs.

Planning restrictions

The Local Government Act requires all decisions taken by local authorities to relate back to a local plan (Sheppard et al., 2017, p26). The requirements of the primary plan, produced by each local authority in the UK, are set out in the National Planning Policy Framework (Ministry of Housing, Communities and Local Government, 2019). Clause 2 of the framework states that “planning law requires that applications for planning permission be determined in accordance with the development plan, unless material considerations indicate otherwise”. The plan led approach ensures that decisions are robust and logical but introduces an extra level of complexity to decisions (Tewdwr-Jones, 2008) that may be onerous where local authorities are resource limited (Bell & Jayne, 2006).

The framework sets out the methodology for producing a local plan, covering thirteen different aspects of local authority engagement (Ministry of Housing Communities and Local Government, 2019). The framework states that planning should be governed by the principles of sustainable development. Chapter 6 of the framework, relating to achieving a strong competitive economy, states that “significant weight should be placed on the need to support economic growth and productivity” whilst Chapter 14, relating to the challenge of climate change, states that “the planning system should support the transition to a low carbon future.” However, the framework does not reference potential conflicts between continued growth and reduction in emissions, as highlighted by Daly (1996), or more lately by Raworth (2017).

Funding restrictions

Local plans, developed by local government, provide a framework of policies each local authority wish to pursue. However, policy is also bound by financial feasibility. Clause 16 of the National Planning Policy Framework states that plans should be “aspirational but deliverable” (Ministry of Housing, Communities and Local Government, 2019). Hence plans are only relevant if funding is available which can be utilised to deliver specific policy.

Funding can come directly from local government or from independent developers. For policy which carries the prospect of profitable interactions, such as housing or mineral development, provision of funding from an independent developer is practical, however, for infrastructure development where profitable interactions are limited the burden of provision of financial resources will primarily fall on the local authority (Moles & Williams, 1995).

Local authorities obtain their funding partly through national government and partly through local levies (rates) (Citizens Assembly, 2019). The balance of these contributions have, however, been changing over the last ten years, with core government grants cut by over £16 billion between 2010 and 2020, representing a reduction of over 60% in direct national government contributions to local government (Local Government Association, 2018, p3). At the same time, rate increases have been capped, further restricting financial resources (Leach et al., 2018, p48).

Some mitigation of this financial squeeze is provided by the proposals for local authorities to retain a greater proportion of business rates, rising from 50% to 75% between 2020 and 2025 (Local Government Association, 2018, p6). However, the Local Government Association (2018, p7) state that this increased income from business rates will not adequately cover local authority increased spending. In addition, a switch to more reliance on business rates, will have a greater impact on funding of poorer authorities, where lower business activity already occurs (Leach et al., 2018, p98). Local authorities also have little control over rates which businesses are charged and have less control than national government over ensuring collection of local rates (Local Government Association, 2018, p9).

Local authorities do have the opportunity to charge developers to fund local infrastructure in the form of 106 Notices and 'Community Infrastructure Levies' (CIL) (Ministry of Housing, Communities and Local Government, 2019). However, 106 Notice funding can only be collected for infrastructure costs specific to a development and cannot be used to support construction of strategic infrastructure (Sheppard et al., 2017, p134). The CIL can be used to fund strategic infrastructure, however, poorer authorities, with greater development needs, are reluctant to set a CIL as they are wary of putting off developers (Dobson, 2012).

LEPs provide another local financial stream. These bodies are led by a board drawn from local businesses and allocate national governmental funding to local authorities and, hence, take power away from local authorities and give this power to local businesses (Pugalis & Townsend, 2013). LEPs formularise a degree of competition between cities to gain funding and have been criticised for providing too little financial reward relative to required administrative effort (Ward, 2019). In addition it should be noted that, prior to Brexit, LEPs obtained a significant part of their funding from the EU (Ward, 2019).

Regulation restrictions

The third control on local authority activity relates to specific regulations. The Local Authority Act states that local authorities can do anything that adds to local economic, social and environmental wellbeing. Other Acts, however, restrict what a local authority can do. The 2017 Bus Services Act expands the ability of local authorities to enter partnerships with bus companies and set up franchises, but includes a restriction on local authorities setting up their own bus company (Butcher & Dempsey, 2018). Local authorities are subject to compulsory competitive tendering, meaning that they cannot, in most cases, construct infrastructure themselves but must allow developers to bid for this service (Leach et al., 2018, p34). These additional regulations hence provide caps on the ability of local authorities to operate independently and increase the influence of local developers and national government.

3.3 Transport framework

Local authority transport policy is described by a 'local transport plan' (LTP), development of which is defined in the DfT guidance note 'Guidance on Local Transport Plans' (DfT, 2009). The guidance note specifies that each UK local authority is required to produce an LTP, to define future policy for transport systems and set out their plan to implement this policy. The guidance states that a statutory requirement for producing an LTP, every five years, was set out in the Transport Act (2000) and local authorities had prior to 2009, produced two sets of transport plans: LTP1 in 2001 and LTP2 in 2006.

In 2008 the Local Transport Act (2008) amended the requirement for producing LTPs, after consultation relating to the first two sets of documentation (McTigue, Rye, et al., 2018). In particular the act removed the requirement that a new plan be produced every five years, stating that local authorities "may replace their plan as they see fit" (HM Government, 2008, p11). LTP3 was produced in 2011 and Elvy (2014) notes that, as a consequence of the provisions of the 2008 Act, the plans produced, as LTP3, covered longer periods than the previous two rounds of plans and that DfT guidance no longer requires formal assessment and review of LTPs, thus shifting responsibility, in terms of local transport strategy, from national to local government.

Where two tier authorities are present, the upper tier is responsible for strategic transport planning and hence takes responsibility for producing an LTP (Institute for Government, 2020). In addition LTP guidance allows LTPs to be produced through local area agreements (DfT, 2009, p19) and, for the two major conurbations of the North West of England, where regional transport executives are present and metro mayors have been introduced (Merseyside and Greater Manchester), this combined approach has been adopted.

The LTP is required to provide policy and plans in relation to five national transport goals (DfT, 2009, p12).

- Support economic growth.
- Reduce carbon emissions.
- Promote equality of opportunity.
- Contribute to better safety, security and health.
- Improve quality of life and a healthy natural environment.

In reviewing LTP3 two issues need to be borne in mind. LTP3 covers a critical period in relation to climate change mitigation policy, with plans developed following the adoption of the Climate Change Act (2008) and required to address the goal of "reducing carbon emissions" in a manner that is "consistent with the Climate Change Bill and EU Targets" (DfT, 2009, p13). The plans were also produced at the point where the UK was emerging from a recession and austerity policies meant significantly reduced council budgets (Local Government Association, 2018). The Merseyside LTP3 report states that funding was reduced by about two thirds, relative to LTP2, and that ability to implement plans was severely affected (Merseyside Transport Partnership, 2011, p10).

Table 3.2 provides an overview of the recent LTPs for the two metro mayoral authorities, two county councils and the six unitary authorities in the North West of England.

Table 3.2 – Overview of North West of England local transport plans

Local authority	LTP3 coverage	LTP4 and other documents
Greater Manchester	2011 to 2016 – 5 years	Replaced by Transport Strategy 2040. Reviewed annually and updated every 5 years.
Merseyside	2011 to 2024 – 13 years	Transport Plan for Growth produced 2015.
Cumbria	2011 to 2026 – 15 years	
Lancashire	2011 to 2021 – 10 years	5 regional spatial masterplans produced.
Blackpool	2011 to 2016 – 5 years	Readopted without amendment in 2017. New 3 year Implementation Plan in 2018.
Blackburn and Darwen	2011 to 2021 – 10 years	
Halton	2011 to 2025 – 14 years 4 year review.	Part of Merseyside document Transport Plan for Growth.
Warrington	2011 to 2030 – 19 years 4 year review.	LTP4 issued in 2019 with plan to 2041.
Cheshire East	2011 to 2016 – 5 years	LTP4, covering 2019 to 2024, issued in 2019.
Cheshire West and Chester	2011 to 2026 – 15 years	

The overview, shown in Table 3.2, indicates that over half of authorities are still working to LTP3. The two metropolitan combined authorities of Merseyside and Greater Manchester have updated their plans. Three of the six unitary authorities present in the region have also updated plans but the county councils, representing the smaller district councils, are still working to plans dating back to 2011.

In terms of funding, whilst core funding for local authorities has fallen, a number of government grants have been made available over the last ten years to enable councils to spend money on their own local transport policies. A Sustainable Transport Grant, specifically related to encouraging sustainable transport, was introduced between 2011 and 2015 and the feedback report relating to the grant stated that, where implemented, it was successful in reducing car journeys and increasing other sustainable transport options (DfT, 2017a). Earlier, funding for the Cycling Demonstration Towns and the Cycling City and Towns programmes, produced positive increases in cycling in 18 UK cities (Sloman et al., 2017). The 2017 Transforming Cities Fund provided £1.7 billion to local authorities over a four year time period in order to reduce congestion and journey times and improve air quality (DfT, 2018c). The fund proposal states that it relates to a small number of large schemes, rather than many small schemes and although improvement in cycling rates and public transport use is mentioned, reducing greenhouse gas transport emissions is not stated as a specific funding goal (DfT, 2018c, p6).

The Urban Transport Group (2020) reports that, since 2010, 82% of new short term funds were only available through competitive bids and that some authorities have spent in excess of £100,000 of their money on bids and not been successful. The Urban Transport Group report goes on to state that the consequences of this bidding process have been:

- Increased unpredictability in funding streams.
- Increased requirements to only deal with short term goals.
- Greater pressure on resources and funding.
- Greater reliance on outside consultancy.
- Less ability to support, develop and maintain in-house staff.

The introduction of the Northern Hub initiative has provided some long term strategic guidance for transport systems in the North of England, in the form of the related Transport for the North (TfN) strategy, setting out a vision of improved transport systems to promote city connectivity (TfN, 2019). The Transport for the North strategy outlines objectives of:

- Transforming economic performance.
- Increasing efficiency, reliability, integration and resilience in the transport system.
- Improving inclusivity, health and access to opportunities for all.
- Promoting and enhancing the built, historic and natural environment.

Reducing transport related greenhouse gases is not a specific objective of the strategy, however, compliance with the Climate Change Act (2008) is stated to be a "key consideration" (TfN, 2019, p80).

The TfN strategy bases a significant part of delivery of new economic prosperity on improved rail connections, including; HS2, new railway lines between Manchester and Liverpool and between Manchester and Leeds (TfN, 2019). The strategy, however, also calls for substantial investment in major new road schemes including; new connections on a

Northern Trans-Pennine route, around Manchester North West Quadrant and to Sheffield via a Trans-Pennine Tunnel. The strategy calls for spending of £60 to £70 billion on intercity infrastructure between 2020 and 2050, relating to approximately doubling of annual funding, relative to 2017, on both road and rail major schemes (TfN, 2019, p72). Hatherley (2017), however, questions whether this strategy will do anything for the small cities of the North of England, that will be by-passed by the new railways and roads.

3.4 Transport emissions

Saide et al. (2009) state that, to allow local environmental managers to take action, relating to transport emissions, a methodology is required that allows spatial distribution of these emissions to be assessed and that inaccurate assessment can mean overestimating or underestimating local effects. On a national scale, greenhouse gas inventories are collected and reported in terms of a methodology described in IPCC 2006 guidelines (Vieweg, 2017). The guidelines state that inventories should be transparent, complete, consistent, comparable and accurate (IPCC, 2006, p7). The IPCC guidelines state that accuracy should be assessed in terms of a tier system, with Tier 1 being a simpler methodology, Tier 2 an intermediate methodology and Tier 3 a complex methodology and that for critical sectors higher assessment tiers should be used to ensure accuracy. The IPCC 2006 guidelines relate to compiling national inventories of greenhouse gas emissions. Where inventories relate to smaller local boundaries, complexity increases, as boundary effects and the potential for survey overlaps, need to be assessed, in order to avoid double counting of emissions (Vieweg, 2017; Hillman et al., 2011). Wood et al. (2010) also indicate that an inventory should be based on the concept of 'polluter pays,' such that allocation should be based on those responsible for generating emissions.

Greenhouse gas inventories relating to transport systems can be compiled using either top down or bottom up methodologies (Vieweg, 2017). Top down methodologies take an overall measure of national or regional greenhouse gas emissions, such as fuel sales, and disaggregate this measure to smaller geographic areas based on local proxies, such as population (Gómez et al., 2018). These methodologies represent simpler calculation tiers and are hence potentially limited in their accuracy (Sartini et al., 2020). Bottom up methodologies model individual components of a system, within a geographic area, to build up an overall picture of emissions (Gurney et al., 2012). Bottom up methodologies represent higher accuracy tiers (Vieweg, 2017) but can be constrained by data limitations (Gately et al., 2013).

In order to compile a transport inventory, a balance needs to be sought between simplicity and accuracy, with data collection being simple enough to be transparent, practical and repeatable but complex enough to be accurate (Grote et al., 2016). Arioli et al. (2020) review 40 different greenhouse gas inventories derived for city specific locations and state that a wide variety of methodologies are used and that, to provide consistency, a single worldwide city specific methodology needs to be adopted. Gately et al. (2013) state that, in terms of a particular city, transport greenhouse gas emissions can be derived based on traffic present on local roads, but that it is not possible to assess whether vehicle occupants are local or visitors. The inability to distinguish between locals and visitors, particularly for pass through traffic in low density areas, compromises the ability of a local greenhouse inventory to allocate emissions, on a regional basis, to those actually responsible and hence may not meet polluter pays inventory requirements (Gately et al., 2013).

Ricardo Energy and Environment (2020, p21) describe the methodology used in compiling UK local transport emissions data. Their technical report states that emissions are calculated as the product of local traffic flows and fleet emissions factors for six categories (passenger cars, LGVs, rigid HGVs, articulated HGVs, buses/coaches and mopeds/motorcycles), each further subdivided into petrol and diesel vehicles. The report states that local traffic flows are taken where possible from direct measurement and, where this is not possible, particularly on local roads, from regional average traffic flows. To calculate local emissions, average emissions factors, for each vehicle category, are then applied. The report states that local emissions factors have been normalised against overall UK fuel sales to ensure their accuracy. In the UK overall fuel sales are recorded as part of the top down data assessment collected in the Digest of UK Energy Statistics (DUKES) (BEIS, 2020c). Correlation between bottom up and top down data indicates that the two methodologies provide overall measures of UK transport energy within 5% of each other (DECC, 2014, p14).

The World Resources Institute (2014, p11) protocol distinguishes three different transport system scopes relating to greenhouse gas emissions:

1. Direct emissions.

2. Electricity generation emissions.
3. Indirect emissions.

The Department for Business, Energy and Industrial Strategy (BEIS) provides national and regional data relating to direct use of fuel (Scope 1) (BEIS, 2020d, p36). Inclusion of Scope 2 and Scope 3 emissions can increase attribution of urban emissions to a city by over 40% and may represent a more complete assessment of responsibility for emissions in terms of an overall carbon footprint (Larsen & Hertwich, 2009). Although assessment of an overall carbon footprint provides a more complete measure of system emissions, it is difficult to apply at a regional level, due to the complexity of allocating external and indirect emissions (Wood et al., 2010).

In UK inventories, greenhouse gas emissions relating to electricity generation (Scope 2) are captured separately and labelled within the power generation sector (BEIS, 2020b). However, in their annual measure of energy consumption in the UK transport sector, the DfT provide a national assessment of energy relating to electric road and rail vehicles (DfT, 2020c, Table ENV0202). Scope 3 emissions are captured in a wide variety of separate national and international transport and manufacturing sector inventories, from which it would be difficult to extract local information in a transparent and consistent manner (Arioli et al., 2020; Kennedy et al., 2010).

UNFCCC guidelines, used in national Paris Agreement inventories, do not require Scope 3 inventories to be compiled (BEIS, 2020b, p3). Although an inventory based on UNFCCC guidelines does not fully describe emissions, it does provide a national picture of greenhouse gas emissions without local double counting due to overlapping system boundaries. Transport related greenhouse gas emissions from road and rail vehicles in the local authorities in the North West of England are shown in Table 3.3.

Table 3.3 – North West of England transport emissions 2018 (BEIS, 2020a)

Authority	Annual total transport emissions ($ktCO_2$)	Annual transport emissions (tCO_2/person)
Allerdale	184.6	1.9
Barrow-in-Furness	35.8	0.5
Blackburn with Darwen	154.4	1.0
Blackpool	108.5	0.8
Bolton	517.9	1.8
Burnley	131.6	1.5
Bury	385.4	2.0
Carlisle	290.8	2.7
Cheshire East	1,178.7	3.1
Cheshire West and Chester	950.1	2.8
Chorley	360.2	3.1
Copeland	74.8	1.1
Eden	497.0	9.4
Fylde	181.3	2.3
Halton	275.1	2.1
Hyndburn	146.9	1.8
Knowsley	361.8	2.4
Lancaster	359.4	2.5
Liverpool	531.1	1.1
Manchester	658.1	1.2
Oldham	242.8	1.0
Pendle	126.7	1.4
Preston	313.2	2.2
Ribble Valley	116.9	1.9
Rochdale	430.2	2.0
Rossendale	127.9	1.8
Salford	565.9	2.2
Sefton	276.6	1.0
South Lakeland	397.8	3.8
South Ribble	262.8	2.4
St. Helens	344.1	1.9
Stockport	432.6	1.5
Tameside	277.4	1.2
Trafford	348.0	1.5
Warrington	677.0	3.2
West Lancashire	227.2	2.0
Wigan	469.7	1.4
Wirral	406.9	1.3
Wyre	221.1	2.0
North West total	**13,648.5**	**1.9**

The data, in Table 3.3, shows that average annual transport greenhouse gas emissions per person generally range from about 1.0tCO_2 to about 3.0tCO_2. Mean emissions are around 1.9tCO_2. There is one significant outlier, relating to Eden Local Authority, where calculated transport emissions are nearly 10.0tCO_2.

Looking more closely at the reason for this significant outlier, where emissions per person are calculated to be over 400% of the mean in the region, three reasons for the reported exceptionally high local emissions can be identified. Firstly, Eden Local Authority represents a rural area (ONS Category 6 – Mainly Rural) where, based on National Travel Survey (NTS) data (DfT, 2020f), average distance travelled per person is expected to be significantly higher than the mean distance travelled. Secondly Eden Local Authority is the smallest in terms of population in the North West of England and, therefore, given the small sample size, is more likely to be associated with data anomalies.

The third potential reason for the data outlier, associated with Eden Local Authority, is the presence of a section of the M6 Motorway within the geographical boundary of the local authority (TfN, 2019). Data for Eden Local Authority allocates nearly 60% of all traffic greenhouse gas emissions to motorway flow (BEIS, 2020a). The M6 in the vicinity of Eden Local Authority represents the main North South road transport linkage between the industrial areas of the Southern and Central Pennines and the Scottish Region (TfN, 2019, p127). Assessment of other local authorities, that have high transport emissions per person, indicates that they also have high percentages of motorway traffic on strategic routes (Chorley – 67% and Warrington – 63%) and that local authorities with lower emissions per person are associated with little or no allocated motorway traffic (Liverpool – 1%) (BEIS, 2020a).

BEIS presents data in two ways to try and make allowance for this data problem. They provide data for all road traffic, but they also provide data for only minor road and A road traffic, associated with each local authority (BEIS, 2020a). This reduced data set, however, excludes regional motorway transport, equating to over 35% of all emissions. It does not, therefore, provide an overall picture of transport greenhouse gas emissions in the region. In order to provide an overall picture of emissions in the North West of England an adjustment of data is required.

BEIS notes that trips undertaken on minor roads and A roads are largely shorter in distance and it is, therefore, reasonable to allocate these directly to the local authorities in which they occur, on the basis that those undertaking the trips are mostly residents of the local authority and the residents and the trips that they undertake, are under the control of these authorities (BEIS, 2020a). Data on use of the motorway network, compiled by the DfT, indicates that, in England, 80% of the population uses the motorway system frequently or regularly and in the North West of England nearly 90% of adults use the motorway network at least once per month (DfT, 2014). The DfT data also indicates that over 85% of motorway trips are less than 100miles (160km) in length and the majority of motorway trips are less than 50miles (80km) in length. This can be compared to the size of the North West of England NUTS1 region of about 15,000km^2 (BEIS, 2020a) and hence an average regional dimension of over 100km. Given that most motorway trips are smaller than the overall dimensions of the region, it can be assumed that most trips on the motorway are intraregional rather than interregional. Hence, on average, it is reasonable to allocate motorway trips to the region in which they occur rather than to other regions. Given that most people use the motorway it is also reasonable to allocate motorway trips on a per capita basis.

Based on this discussion, a methodology can be defined which provides a fairer allocation of local authority transport emissions:

Local authority allocation =

geographical allocation (minor and A roads) +

per capita allocation (motorways)

Using this allocation methodology, transport emissions have been derived for all local authorities in the North West of England. Results are shown in Figure 3.1.

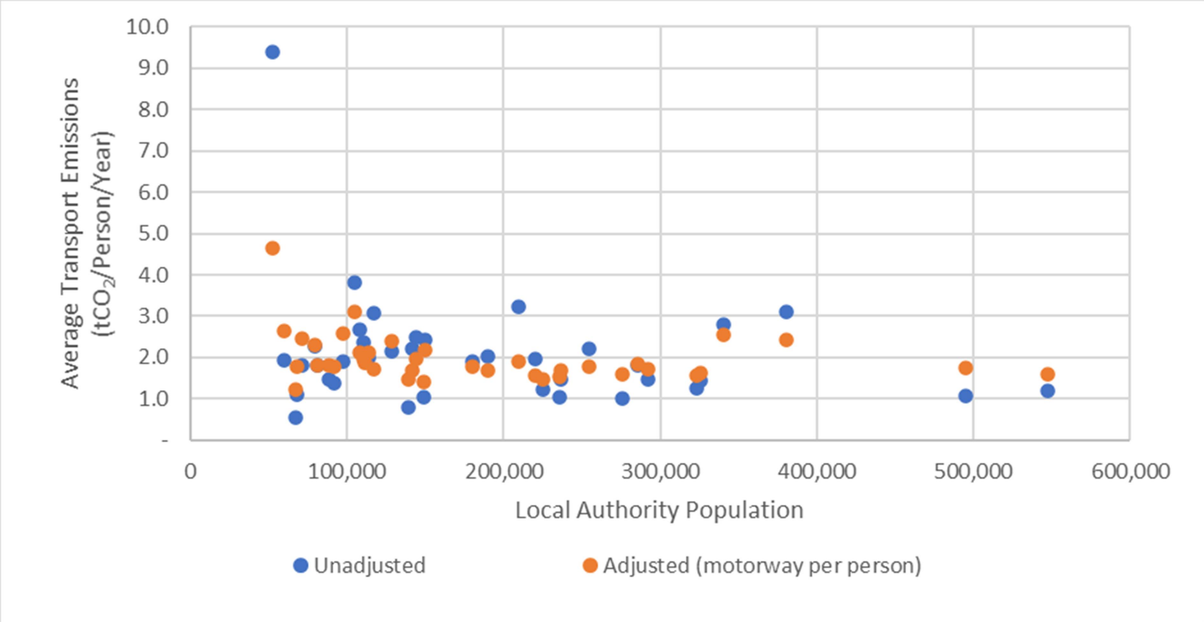

Figure 3.1 – North West of England local authority transport emissions 2018 (BEIS, 2020a)

This data in Figure 3.1 shows average transport emissions, in terms of tCO_2/person/year, stays about the same before and after adjustment but the range is reduced such that most local authorities have average annual transport emissions per person of between 1.0tCO_2 and 3.0tCO_2. The data indicates that smaller authorities may have larger emissions. A distinction can also be made between mainly rural and mainly urban local authorities. Rural authorities are indicated to have average annual transport emissions per person of about 2.5tCO_2 to 3.0tCO_2 whilst, for urban authorities, equivalent emissions are generally 1.5tCO_2 to 2.0tCO_2.

Potential exists for further refinement of these results. Data exist on car ownership within each local authority (DfT, 2020l, Table VEH0105) and this data could be used as an alternative, potentially more accurate proxy for allocation of motorway emissions. Further model refinement based on trip consumption within each geographical area might result in a more accurate allocation of emissions but a lack of trip and associated driver data makes this type of assessment difficult (Marsden & Anable, 2021). As noted by Grote et al. (2016), in derivation of local emissions, a balance needs to be established between accuracy and complexity. The unadjusted data provided by BEIS and shown in Figure 3.1 lacks accuracy. Through adjustment of this data accuracy improves but additional complexity is introduced. For local government departments with restrained resources, it can be argued that an emphasis on simplicity in terms of presentation of data should be maintained. As noted by

Marsden & Anable (2021) there is likely to be relatively little difference between allocation methods for authorities with large populations and limited through traffic. However, as illustrated by Eden Council, and shown in Figure 3.1, reallocation of emissions for authorities with small populations and substantial through traffic creates large difference in allocated emissions and hence greater assessment complexity is justified. Transport emission allocations, shown in Figure 3.1, represent a transparent and straightforward methodology, as required by Grote et al. (2016). In addition, by improving matching of transport emissions to local authority populations, data better meets the polluter pays principle outlined by Wood et al. (2010). The dataset hence represents provision of a system that can be used by local authorities to set targets, track trends and indicate the effectiveness of local policy and practice.

3.5 Chapter summary

This chapter illustrates the characteristics of the local authorities in the North West of England and the legislative framework in which these authorities implement policy, particularly that relating to transport interventions. The 39 local authorities in the North West of England have a large range of characteristics, from the large city authorities with half a million residents, to rural authorities with populations of well below 100,000. Although local authorities have the power to do 'anything' they are constrained by planning, financial and regulatory restrictions. The governance regimes relating to local authorities are further explored in Section 4.3 of Chapter 4 and related restrictions are investigated in interviews outlined in Chapter 5.

In terms of transport, the overview of LTPs, illustrated in Table 3.2, indicates a variety of documents ranging from those still in place after ten years, after having been issued in 2011, to those associated with large cities of the region, that have been recently updated. A review of transport emissions (Figure 3.1) indicates a relatively narrow range of average emissions per person, after adjustment has been made in terms of regional motorway traffic. Elevated emissions may, however, be associated with smaller authorities and with authorities in rural areas. The factors influencing emissions are further explored in Section 4.4 of Chapter 4 and used in modelling discussed in Chapter 6. In the next chapter of the thesis a literature review is described relating to each of the key areas of relevance for this study.

CHAPTER FOUR – LITERATURE REVIEW

4.1 Introduction

This chapter provides a review of literature covering the three main knowledge gaps addressed by the thesis. Section 4.2 introduces the Paris Agreement and cumulative greenhouse gas budgets. Section 4.3 explores issues relating to city form and governance. Section 4.4 presents a review of literature relating to existing transport systems and associated emissions. Section 4.5 discusses local authority interventions, aimed at reducing transport greenhouse gas emissions. Conclusions relating to the literature review, in terms of the three identified knowledge gaps, are summarised in Section 4.6.

4.2 Paris Agreement and greenhouse gas budgets

4.2.1 Background

Over the last 150 years and, in particular, over the last 50 years the natural balance of global systems has been affected by human activities (IPCC, 2014). Anthropogenic increases in concentrations of greenhouse gases have led to a rise in global mean temperature (Bennett, 2016). If current trends continue then there are likely to be severe, pervasive and irreversible changes to the climate of the planet (IPCC, 2014, p8). In 1988 the United Nations set up an Intergovernmental Panel on Climate Change (IPCC) to investigate and report on climate change issues (Blackmore & Reddish, 1996, p129). At the Rio Earth Summit in 1992 a United Nations Framework Convention on Climate Change (UNFCCC) was established, with a requirement that annual Conferences of Parties (COP) would take place to further discuss climate change issues (Blackmore & Reddish, 1996, p285). At COP21, in Paris, an agreement was reached to attempt to restrict global temperature rises to well below $2^{o}C$ (Bates, 2015). The IPCC produced their fifth climate change assessment report (AR5) in 2014 (IPCC, 2014) and, following the Paris Agreement, also produced a special report relating to restricting global temperature rises to $1.5^{o}C$ (IPCC, 2018).

4.2.2 Global climate change targets

Greenhouse gases are persistent in the atmosphere and hence it is cumulative emissions and not annual emissions, that control global temperature rises (Matthews et al., 2018). To illustrate this, Figure 4.1 shows a selection of CO_2 emission scenarios presented in the IPCC 2014 and 2018 reports.

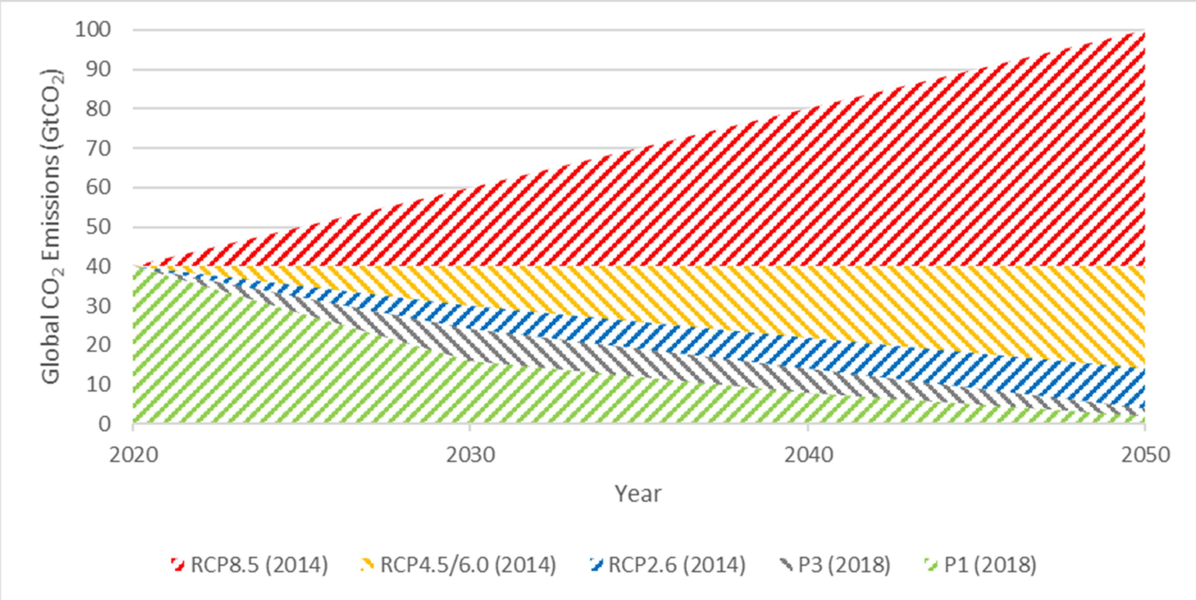

Figure 4.1 – Carbon dioxide emission pathways from Representative Concentration Pathways (RCP) using data presented in IPCC 2014 and 2018 reports (IPCC, 2014, p9; IPCC, 2018, p14)

The cumulative CO_2 emissions associated with the 2018 P1 Scenario, relating to a 1.5°C increase in global mean surface temperature, with a small amount of carbon dioxide removal (CDR), is indicated by the green hatched area of Figure 4.1. For the 2018 P3 Scenario, relating to a 1.5°C increase in global mean surface temperature, with significant CDR, the grey hatched area shows the additional emissions over and above the P1 Scenario. It is these additional emissions that need to be balanced by greater CDR for the two scenarios to achieve the same eventual outturn, in terms of increased global surface temperature. CDR relates to land use change or development of new technology to remove CO_2 from the atmosphere. It is noted that implementing technology based CDR is associated with “multiple feasibility and sustainability constraints” (IPCC, 2018, p23). Both Mander et al. (2017) and Workman et al. (2020) caution that over reliance on development of new CDR technology may mean neglect of necessary changes in the way society uses systems responsible for greenhouse gas emissions.

The blue hatched area in Figure 4.1 shows the additional emissions over and above the 1.5°C scenarios associated with the IPCC 2014 scenario (RCP2.6). Due to these additional emissions, over the period 2020 to 2050, this scenario is associated with a 2°C increase in global temperature (IPCC, 2014, p9). RCP8.5 represents a scenario where greenhouse gas emissions continue to increase whilst RCP4.5 and RCP6.0 represent scenarios where greenhouse gas emissions remain at about the level reached in 2020. These scenarios are associated with larger increases in mean global surface temperatures ranging from 2°C to greater than 5°C (IPCC, 2014, p9).

Because it is the cumulative emissions and not the annual emissions, that are important in defining global climate change effects, there are significant consequences associated with delay in reducing emissions (Anderson et al., 2008).

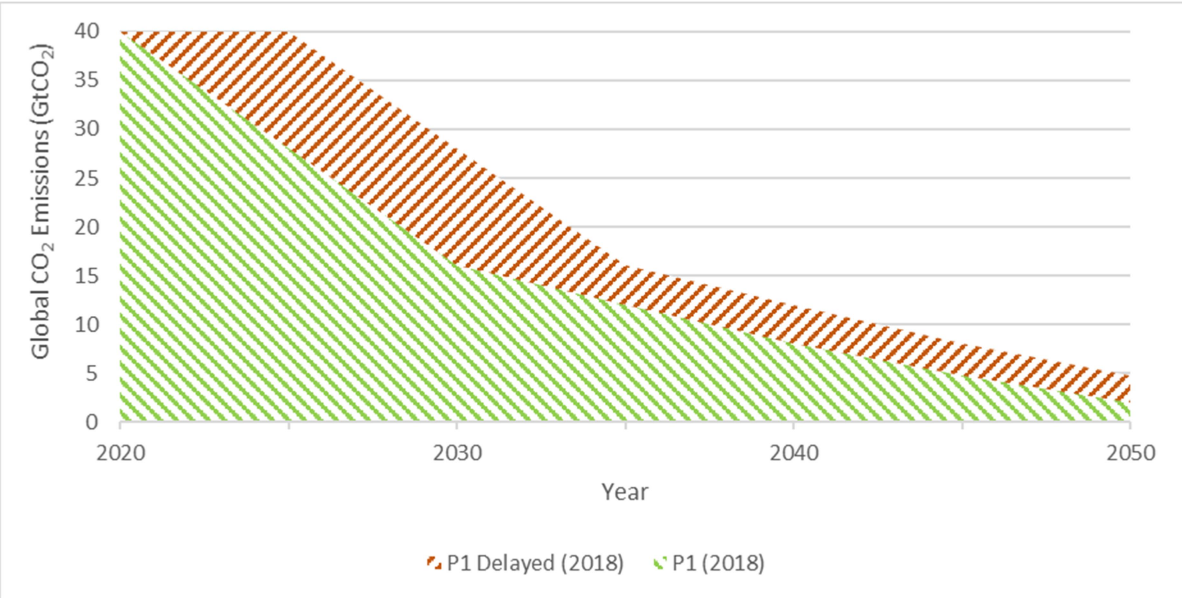

Figure 4.2 – Carbon dioxide emission pathways associated with five year delay in reducing greenhouse gases based on RCP P1 from IPCC 2018 report (IPCC, 2018, p14).

Figure 4.2 shows the emissions associated with a five-year delay in implementing the IPCC 2018 RCP P1 Scenario. Based on a starting annual rate of emissions of 40$GtCO_2$, RCP P1 represents, as shown by the green hatching, emissions of about 475$GtCO_2$, between 2020 and 2050. RCP P1 Delayed represents emissions of about 650 $GtCO_2$ and, therefore, the difference in these scenarios, represented by the orange hatching, is about 175 $GtCO_2$. This represents an increase of nearly 40% in emissions, that would need to be balanced by CDR technology if the same long-term outturn were to be achieved. In addition, as the delayed scenario has not yet reached net zero emissions, additional positive emissions would occur beyond 2050 that would require further balancing CDR.

In 2020, cumulative emissions of about 2,300GtCO_2 are estimated to have already occurred (Liu et al., 2020; IPCC, 2014, p18). The 2018 IPCC report indicates that a remaining budget, from 2018, of 840GtCO_2 is associated with a 33% probability of limiting global mean surface temperature increases to 1.5^{o}C, with 580GtCO_2 indicated for a 50% probability and 420GtCO_2 for a 66% probability (IPCC, 2018, p108). The IPCC report recommends that these budgets be further reduced by about 100GtCO_2 to allow for positive feedback systems and by another about 100GtCO_2 to allow for the effect of other greenhouse gases, but that the budgets can be increased by about 100GtCO_2 to allow for conservancy in modelling (IPCC, 2018, p108). Significant uncertainty, in excess of +/- 200GtCO_2 , is, however, associated with modelling of the impact of CO_2 emissions, with additional uncertainty, equivalent to +/- 250GtCO_2, associated with modelling the impact of other greenhouse gases. (IPCC, 2018, p108). Global CO_2 budgets relating to 1.5^{o}C temperature increases, starting in 2018, can, therefore, be calculated to be between about 300GtCO_2 and 700GtCO_2 (IPCC, 2018, p108). Equivalent budgets, from 2018, relating to a 2^{o}C temperature increase are shown, in the IPPC report, to be between about 1,000GtCO_2 and 2,000GtCO_2 (IPCC, 2018, p108).

Mean global surface temperature increases, consistent with the Paris Agreement aspiration of well below 2^{o}C, can be expressed in a number of ways (IPCC, 2018, p108; Anderson et al., 2020):

- Temperature increases with a likely chance (67%) of being below 2.0^{o}C.
- Temperature increases with an even chance (50%) of being below 1.7^{o}C.
- Temperature increases with an unlikely chance (33%) of being below 1.5^{o}C.

Based on these probability options and taking into account probable emissions in 2018 and 2019, a range of outline budgets from 2020 can be defined as shown in Table 4.1 (Anderson et al., 2020).

Table 4.1 – Derived cumulative global emissions associated with "well below 2°C" (IPCC, 2018, p108)

Temperature increase	Less than 1.5°C with 33% probability	Less than 1.7°C with 50% probability	Less than 2.0°C with 67% probability
Budget from 2020	660GtCO_2	720GtCO_2	990GtCO_2

The global budgets shown in Table 4.1 indicate a range of risk against practicality. The lower budget represents a lower risk to global environmental, social and economic systems but is associated with a greater global effort that may not be practical, given the current lack of development of CDR technology (Workman et al., 2020). The higher budgets represent greater risk to global systems but may be more practical to achieve. However, the global effort required to reach even the higher budget will still be considerable (Jiang et al., 2017). Given the high levels of uncertainty associated with these estimates and the significant consequences associated with global warming beyond the "well below 2°C" recommended by the Paris Agreement (IPCC, 2018, p11), Ekardt et al. (2018) argue that global ambition should not relate to accepting elevated risks, through adopting high budgets. Anderson et al. (2020) suggest that, in terms of the commitment of the Paris Agreement, the central figure is appropriate, and the world should be aiming at a target relating to a 50% chance of mean surface global temperature increases of 1.7°C.

4.2.3 UK climate change targets

Raupach et al. (2014) note that it is necessary to allocate greenhouse gas budgets to individual countries but that efforts to provide a central formula that all countries agree upon have not been successful. The Paris Agreement, therefore, allows different countries of the world to set their own nationally determined contribution (NDC) based on the overarching principle of provision of an equitable division of a global budget (Bates, 2015, p239). Article 4 of the Paris Agreement calls on each country to prepare and publish NDCs setting out their ambitions in reducing greenhouse gases (UNFCCC, 2015). Article 4 goes on to state that, in setting NDCs, a country should "reflect its highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances." The article further states that developed countries should take a lead in creating absolute reduction in emissions, whilst developing countries should follow, in creating absolute reduction targets, depending on their development circumstances (UNFCCC, 2015). This article hence allows for budgets to be set separately for developed and developing countries (Anderson et al., 2020).

Whilst the Paris Agreement states that NDCs should be set by each individual country in a manner that is fair and ambitious, there are no currently agreed methodologies for exactly how these principles should be utilised (Pan et al., 2017). Currently, each country has defined its greenhouse gas reduction ambitions in a different manner, with developed nations, such as the USA and those in the EU, providing specific greenhouse gas reduction percentages and developing nations, such as China and India, providing reduction pledges in terms of greenhouse gas GDP intensity (Vandyck et al., 2016). Holz et al. (2018) note that countries have, in general, poorly explained how their derived NDC budgets meet the commitments of Article 4 of the Paris Agreement; to consider different circumstances present in developing and developed countries of the world.

In deriving an acceptable methodology for setting country specific NDCs, some basic principles need to be defined. Meyer (2000) asserts that, whilst global contraction of greenhouse gas emissions is essential, it must be undertaken based on convergence to an equal per capita share. He states that contraction and convergence needs to be facilitated by transference of funds and a long term acceptance that current lifestyles may need to change. The Paris Agreement provides a mechanism for transfer of finance and technology, to aid developing countries in their commitments to meet NDC greenhouse gas reduction targets. Article 9 defines mechanisms to allow transfer of finance and Article 10 covers transfer of technology (UNFCCC, 2015). Karlsson (2016) asserts that this technology sharing is a prerequisite of achieving global sustainability and the goals of the Paris Agreement.

In preparing NDCs a process needs to be developed that takes into account the equity principles set out by Meyer and enshrined in the articles of the Paris Agreement (Holz et al., 2018). The process also needs to embrace “deep uncertainty, multiple values and diversity among contexts, stakeholders and viewpoints” (Workman et al., 2020, p83). Raupach et al. (2014) define two main methodologies for division of global greenhouse budgets; division based on distributing current emissions or division based on populations to give equal per capita budgets to all the world’s people. They note that division based on distributing current emissions would significantly restrict development opportunities for currently underdeveloped countries. Caney (2009, p128) states that division based on current emissions is, therefore "profoundly unfair." Raupach et al. (2014), however, also note that division based on equal per capita budgets would lead to requirements for very challenging mitigation pathways for developed nations and that a compromise between these two extremes may be required.

Pan et al. (2017) review thirteen different methods of assigning budgets to different countries covering six different methodologies. In addition to the current emissions and population assignment methodologies, discussed by Raupach et al. (2014), options include ability to pay for innovation, responsibility for historical emissions and numbers of wealthy individuals who are relatively responsible for greater proportions of emissions. Robiou Du Pont et al. (2017) discuss five methods of assigning budgets to different countries. These include division based on current emissions, populations, historical emissions, resources and capabilities. In reflecting different responsibilities and capabilities these alternatives all take their lead from the stipulations of Article 4 of the Paris Agreement but create additional complexity in terms of budget assignment.

The results of budget assessments, undertaken by Robiou Du Pont et al. (2017), indicate that inclusion of capability and/or historical responsibility, creates significantly greater pathway restrictions for the UK and smaller restrictions for a typical developing country. Assessments indicate that an equitable division budget creates smaller restrictions for the UK and greater restrictions on developing countries. A budget based on current emissions has the smallest restrictions on the UK and the largest on developing countries. It is also noted that analyses indicate that all budgets, except those based on current emissions, require peak UK emissions to be immediate. As shown in Figure 4.2, consequences of delaying peak emissions are significant. However, for developing countries, emission reduction pathways, indicated by Robiou Du Pont et al. (2017), generally show that peak emissions can be delayed until about 2040. In this case the assessment shown in Figure 4.2 is reversed and, if peak emissions can be achieved before 2040, significant savings would be achieved. Support to enable developing countries to save against their budgets through finance and technology transfers is, therefore, beneficial (CCC, 2016, p32).

In 2015, as part of the EU, the UK signed up to a 40% reduction in emissions by 2030, relative to the levels of 1990 (Council of the European Union, 2015). However, previously the UK had already legislated, in the 2008 Climate Change Act, to an 80% reduction in emissions, relative to 1990, by 2050 (HM Treasury, 2008). The Climate Change Act (2008) also provided for the setting up of a UK Committee on Climate Change (CCC), to advise and monitor implementing this target and provide interim carbon budgets. As a response to the Paris Agreement the CCC produced a report in 2016 which stated that, at that time, the UK's 80% reduction target should remain, but that setting a more ambitious target should be kept under review (CCC, 2016, p51). The CCC report indicated, that to keep global temperatures below 2^{o}C, net zero CO_2 would need to be reached by between 2050 and 2070, with other greenhouse gases reaching net zero before the end of the century. The report commits the UK to matching this pathway. CCC reports on progress against this pathway indicate that, until now, the UK has been able to keep within this budget, mainly through reduction in use of coal and oil in energy generation (CCC, 2020c).

In 2019 the CCC updated their response by producing a net zero report (CCC, 2019b). This report proposed that the UK commit to a goal of almost 100% reduction in CO_2 emissions, to reach net zero emissions in 2050 and a balance between UK CO_2 sinks and sources. The report also noted that the UK contribution to international aviation and shipping should be included in any net zero assessment. The CCC state (CCC, 2019b, p83) that the UK should go beyond an equal per capita share of emissions, which had been previously used to justify the UK's 80% reduction pathway, for three reasons:

1. The UK is a developed country with significant historical emissions and significant impact on greenhouse gas global systems through consumer imports. The UK developed status also means that it has more capacity to act in reducing emissions.
2. The UK's status as a developed country means that the country should act as a global climate leader through example and diplomacy in encouraging emissions reduction in the rest of the world.
3. The UK's status as a developed country means that the country has the physical and economic infrastructure that will make significant change achievable.

However, it is noted that, based on the fact that the UK population over the next thirty years is predicted to be about 0.8% of the global population (World Statistics, 2021), a CCC budget associated with a broadly linear reduction in UK greenhouse gas emissions between 2020 and 2050 (CCC, 2020b, p14) is not substantially smaller than a per capita allocation budget. UK academic responses to the CCC report were generally positive, although some commenters considered that the recommendations, even with a 2050 net zero target, did not go far enough (Science Media Centre, 2019). The UK Government accepted the recommendations of the CCC report and legislated to adopt a 2050 net zero pathway, in 2019 (CCC, 2019c, p13).

Anderson et al. (2020) argue that budgets for the developed world should only be set once a budget allowance for the developing world has been made and estimate that developing countries should account for about 80% of the total CO_2 budget, based on emissions peaks in 2020 in developed countries and 2030 in developing countries. They go on to argue that, prior to setting emissions budgets for developed countries, an allowance of 60GtCO_2 should be made for global cement and deforestation emissions, on the basis that local allocation of emissions from these global sectors would unfairly penalise individual countries and restrict their development potential (Anderson et al., 2020). Based on these principles, a budget for developed countries relative to an overall global budget of 720GtCO_2, between 2020 and 2050, would be 130GtCO_2 (Anderson et al., 2020).

Based on this assumption a UK CO_2 budget of about 3,700MtCO_2 can be derived (Anderson et al., 2020). This can be compared to an equivalent CCC CO_2 only budget of about 6,000MtCO_2, assuming a broadly linear reduction in emissions between 2020 and 2050 (CCC, 2020c) and that about 80% of UK greenhouse gas emissions relate to CO_2 (BEIS, 2020b). This thesis is concerned with terrestrial emissions of greenhouse gases in the UK. In order to investigate terrestrial emissions an allowance for international and domestic aviation and shipping should be taken off a UK overall budget. Kuriakose et al. (2021) estimate that, for the UK, an aviation and shipping allowance of 1,500MtCO_2 is appropriate, assuming that these emissions will not peak until 2030 and will not reach net zero until well after 2050.

UK terrestrial emissions, based on these assumptions, are shown on Table 4.2 below.

Table 4.2 – Derived UK terrestrial CO_2 budgets 2020 to 2050

Temperature increase	Less than 1.5^{o}C with 33% probability	Less than 1.7^{o}C with 50% probability	Less than 2.0^{o}C with 67% probability
Anderson et al., (2020)	2000MtCO_2	2200MtCO_2	3000MtCO_2
CCC (CCC, 2019b)	4100MtCO_2	4500MtCO_2	6200MtCO_2

As with the global figures, upper estimates represent increased risk of significant climate change effects but greater potential to achieve the target without significant technological change. The lower estimate will reduce risk but is likely to require rapid development of new and innovative technology, such as CDR.

4.2.4 Budgets review summary

Review of issues relating to setting of local emissions targets indicates the difficulties associated with determining and assigning budgets to each country in the world. Each budget is a compromise between differing principles. The equity principle set out in the Paris Agreement has led to the UK assigning a budget broadly based on equal global per capita emissions of greenhouse gases. Anderson et al. (2020) indicate that this equal per capita budget does not, however, wholly meet the equity principle of the Paris Agreement and a more stringent interpretation of UK budget allocation is required.

It is noted that assumed significant use of CDR may compromise pathway feasibility. In response to concerns of over reliance on speculative CDR technology, the pathways investigated in this thesis are initially modelled on the assumption that large scale CDR is not available in the next thirty years.

In this thesis, assessment of local and regional budgets will be undertaken against two different interpretations of the UK national budget. Local and regional budgets will be assessed against the budgets defined by the CCC that represent official UK Government policy and are broadly consistent with a global assignment of emissions relating to equal per capita allocations. As stated by Raupach et al. (2014) meeting this budget will be very challenging. However, assessment will also be undertaken in terms of a more onerous interpretation of global assignment of emissions, in line with the commitment to consider differing responsibility and capabilities outlined in Article 4 of the Paris Agreement. The model described by Anderson et al. (2020) is chosen as an alternative to the UK CCC model as it has been derived in the University of Manchester in collaboration with the city of Manchester, which is the largest city in the North West of England (Anthesis, 2019). It has also been used to define UK local authority budget allocations (Kuriakose et al., 2020).

As shown in Figure 4.2 there are significant consequences associated with delay in reducing greenhouse gas emissions. It is noted that 2021 will be a critical year in establishment of effectiveness in global greenhouse gas mitigation policy:

- The 1.5^{o}C and 2^{o}C illustrative scenarios, contained in the 2014 and 2018 IPCC reports, all indicate that 2020 represents the beginning of a regime of rapid reduction in greenhouse gases. Each year that this regime of rapid reduction does not start, means that meeting IPCC scenarios associated with relatively low increases in global mean surface temperature, becomes increasingly difficult. It is noted that if rapid reduction had started earlier then meeting targets would have been easier.
- After 5 years, the countries of the world will be required by the Paris Agreement to produce revised NDCs. Assessment of current NDCs indicates that they are not sufficient to meet Paris Agreement aspirations (UNEP, 2016). The total gap between the NDCs and required global allocation in 1.5^{o}C scenarios is calculated to be 20GtCO_2e, with a gap of 13GtCO_2e for 2^{o}C scenarios (Robiou Du Pont et al., 2017). If countries do not sufficiently upgrade their NDCs to take into account the shortfall in initial declarations, the feasibility of meeting the IPCC scenarios will be impacted.
- In 2021, an updated IPCC assessment report (AR6) is due to be released (IPCC, 2020). This updated report will provide more evidence on climate change effects on global environments and is likely to require scenarios to be revised (Anderson et al., 2020). The world will hence be presented with fresh, up to date information, on greenhouse gas emissions and climate change, that will increase the climate change knowledge base and reduce uncertainty.

4.3 City geography, form and governance

4.3.1 City geography

Historically the cities of the world can be viewed as a progression of connected networks and associated transport regimes (Abu-Lughod, 2006). Abu-Lughod indicates that the original city networks within the two rivers basin of modern day Iran and the subsequent Mediterranean city network of Rome, were associated with transport regimes consisting of river and small sea going vessels and that, as transport regimes developed further, the networks of cities expanded into an Asia/European trading block and a trade block associated with the Atlantic.

The Twentieth Century saw global trade develop based around a network of alpha world cities, such as London, New York, Hong Kong and Tokyo, which support worldwide communication and transport regimes (Brenner & Keil, 2006). Each of the world cities supports and is supported by an immediate peripheral area, of the order of 100km in size, to create a city region (Keil & Ronneberger, 2008). Petrella (2006) states that there are about 30 city regions which control most of world trade and commerce, including the South East of England around London. However, other city regions in the UK, such as the North West of England, are not included within this global control system (Petrella, 2006).

The nature of the city regions, in the industrialised world, has changed in the last fifty years, as manufacturing has significantly declined in city peripheries (Brenner & Keil, 2006). Manufacturing has not disappeared but has been transferred to areas of the globe where labour is cheaper, leaving a Post Fordian West of city regions with an increased service sector focus (Ravetz, 2000). In the Post Fordian West the 30 alpha city regions now provide control of transport regimes directed at moving commodities around the world from producer centre manufacturing plants, in the less developed world, to consumers in the developed world, such that about a quarter of all greenhouse gas emissions relate to international trade (Sakai & Barrett, 2016).

City regions around the world can broadly be characterised as either monocentric, containing a single primate city surrounded by much smaller settlements (London, Paris, New York) or polycentric with multiple cities of about the same size (Los Angeles or Amsterdam/Rotterdam) (Keil & Ronneberger, 2008). City regions have in the Post Fordian age tended to move towards a polycentric layout as hinterland settlements develop (Keil & Ronneberger, 2008).

Within each polycentric city region are a small number of large cities and a larger number of smaller, lower tier, cities. These small cities consist of the settlements immediately around the large cities, constituting suburbs, and settlements spread over the region, both as rural and urban communities (Knowles & Wareing, 1981, p223). In terms of the study of urban geography the emphasis has been on upper tier cities and, in particular, upper tier cities within alpha city regions (Bell & Jayne, 2006). The urban geography of small cities has been neglected (Hall & Barrett, 2018, p8). As stated in Chapter 1, the majority of people in industrialised countries, such as the UK, do not live in large cities and, hence Robinson (2006) calls small cities, in polycentric areas of the industrialised world, 'ordinary cities' as they represent typical living areas for the population. The large cities of the world, acting as upper tier communities in upper tier regions, make the headlines and attract research, but they are not representative of ordinary communities (Bell & Jayne, 2006). Hence study of small cities is important.

In order to investigate small cities in the North West of England it is necessary to look at the impact of globalisation on city networks in the context of a hierarchical system as described by Christaller (Brenner, 2006; Knowles & Wareing, 1981, p223). Hierarchy of the pre-global world was based on national boundaries and, hence, small cities in the North West of England, such as Preston and Warrington, were third tier settlements behind the primate city of London and the large regional cities of Liverpool and Manchester (Brenner & Keil, 2006). In the new world system, these communities have been relegated to small cities in a global system and Brenner (2006) now classes small cities in lower tier regions, such as Preston and Warrington, as fifth or sixth tier. Brenner (2006) describes a system where small cities have been relegated once, because of the expansion of city networks beyond national boundaries and then further relegated by being excluded from the alpha city regions which provide the main controls in a global network. Based on this assessment, the North West of England is a typical lower tier region in the Post Fordian West. It can be characterised as a polycentric region with roughly equal cities (Liverpool and Manchester) representing third and fourth tier communities with, between these, fifth and sixth tier small cities, such as Warrington and Preston, each supporting and being supported by the higher tier cities of the region (Brenner, 2006).

The North West of England has its own particular characteristics that need to be considered when reviewing local development and redevelopment. The region has an urbanisation history stretching back 250 years, to the beginning of the Industrial Revolution (Parr, 2017b). This long history of urbanisation has led to greater density of cities and greater levels of population within these cities, than in the rest of the UK (Parr, 2017b). Some generalisations can, also, be made about the city region and about the cities within the region. As a lower tier city region, the North West of England does not have a lead role in world commerce networks (Bell & Jayne, 2006). It, therefore, does not contain the relative abundance of service sector activity enjoyed by the upper tier regions, such as the South East of England. In the Post Fordian West, where manufacturing in city regions is also declining, the lower tier city regions, therefore, have an economic lag and, hence, economic prosperity within the North of England is recorded to have a deficit of £5,000 per person relative to the rest of the UK (HM Treasury, 2016, p7).

Cities come in a variety of shapes and sizes but all generally contain a central business district (CBD) in which an administration centre is located, generally associated with a central retail district (Knowles & Wareing, 1981, p233). Around the CBD a variety of industrial, commercial and residential sectors are formed, with each often distinguished by local economic status, family structures and ethnicity (Hall & Barrett, 2018, p262). Within these sectors are individual neighbourhoods consisting of a few thousand people living within about 1km of each other (Miles, 2006). The cities of the North West of England generally conform to this model.

City sectors are constantly changing as demographic, environmental, economic and socio-political factors influence where people live, shop and work, with 5% to 10% of the population moving residence every year in European cities (Hall & Barrett, 2018, p258). Roberts (2008), however, states that, in the UK, only about 1% of houses are replaced each year through demolition and new build.

Change particularly creates pressures and opportunities in and around the CBD and may leave suburbs behind (Sykes et al., 2013). Change also effects city peripheries, creating a potential to sprawl, that has, however, been largely constrained in UK cities by greenbelt policies (Bibby, 2009). Whilst greenbelt policies have meant that new development has been primarily undertaken on brownfield sites, these policies have also had the effect of increasing city densities and increasing pressure to develop dormitory communities beyond the greenbelt (Bibby, 2009).

City hierarchy and associated influence on infrastructure and services can be defined in terms of both relative and absolute size. Relative size of cities can be used to define relationships in terms of different hierarchical tiers and how individual cities act within these tiers. Assessment in terms of absolute size is, however, also necessary to fully define capabilities of cities in terms of development of facilities and infrastructure.

In terms of relative size, the central place theory hierarchical structure proposed by Christaller provides a useful guide to the ways cities interact, with each large city supported by an encircling network of small cities, that are, themselves, surrounded by towns and villages (Knowles & Wareing, 1981, p223). Central place theory, however, does not provide a complete description of today's globalised network of cities, where city to city and region to region relationships are also important and hence, in order to define the limits and opportunities associated with local services and infrastructure, the relationship of a city with its hierarchical neighbours and with the associated region and regional neighbours, needs to be understood (Derudder & Witlox, 2004).

In terms of development of local transport facilities and infrastructure, the absolute numbers of people who utilise the local transport network, also needs to be considered. Cervero (1998, p19) and Wang & Lo (2016) both state that a population of 500,000 is necessary in order to run a rail metro system, allowing reduction in city wide CO_2 emissions and that, for lesser absolute populations, the local transport system may be restricted to road use. This can be illustrated in the North West of England, where metro system hubs are only associated with the large cities of Manchester and Liverpool, where populations of about 500,000 are present.

However, depending on the hierarchical relationship between cities, populations utilising transport facilities may be increased or reduced. Where metropolitan areas have a strong connection with each other 'borrowed size' acts to increase a transport system customer base but, where a city acts as a dormitory town to a work and transport hub, 'agglomeration shadow' effects reduce populations available to utilise local transport, as facilities in upper tier cities are preferentially used (Meijers & Burger, 2017) and the dormitory town suffers an economic penalty (Knowles & Wareing, 1981, p225).

To determine the degree to which borrowed size or agglomeration shadow effects may apply to a city, an assessment of the hierarchical status of the city is required. One indicator which can be used to define hierarchical levels for cities is commuting flows (Fuguitt, 1991). Commuting data is available based on analysis of the 2011 census (ONS, 2015a). Data for the North West of England is summarised in Table 4.3. The table shows a net commuting percentage for each local authority, based on the difference between the percentage of the population that commute into the authority and the percentage of the population that commute out of the authority.

Table 4.3 – Hierarchy based on net commuting percentage (ONS, 2015a)

Net commuting percentage	Local authorities	Urban characterisation Table 3.1
>+10%	Liverpool, Manchester	Major conurbation
>+10%	Preston, Warrington	Minor conurbation and mainly urban.
0 to +10%	Blackburn with Darwin, Blackpool, Carlisle, Halton, Lancaster,	Minor conurbation and mainly urban.
0 to +10%	Allerdale, Cheshire East, Copeland, Eden, Ribble Valley, West Lancashire	Largely and mainly rural.
-10% to 0	Barrow-in-Furness, Bolton, Burnley, Cheshire West, Hynburn, Oldham, Pendle, Rochdale, Rossendale, Stockport, Trafford, Wirral	Major and minor conurbation and mainly urban.
-10% to 0	South Lakeland	Largely and mainly rural
<-10%	Bury, Chorley, Fylde, Knowsley, South Ribble, St Helens, Tameside, Wigan, Wyre	Major and minor conurbation and mainly urban.

Based on net commuting percentages, the four local authorities of Manchester, Liverpool, Preston and Warrington can be defined in terms of the upper hierarchies of the region. However, further distinction in terms of travel regimes needs to be made relating to absolute city and local authority size. As indicated by Wang & Lo (2016), the local authorities of Manchester and Liverpool contain sufficient populations for large scale transport infrastructure. However, as shown in Table 3.1, other upper hierarchical local authorities, such as Warrington and Preston, do not have large enough local populations for such large scale infrastructure to be viable.

The net commuting percentages shown in Table 4.3 can be used to further breakdown city and local authority hierarchy. The local authorities where there is a positive net inflow are those which have some of their own net employment which attracts commuters. The local authorities where net commuting is negative and very negative (<-10%) are those where local employment is relatively small and local populations travel to adjacent upper hierarchy authorities to work. These authorities are characterised by a financial lag behind other parts of the region, in terms of wages, meaning that local authorities have less money to spend on local infrastructure (Knowles & Wareing, 1981, p225). For the same reason the local authorities which are lower tier in terms of commuting to work are also likely to be lower tier in terms of other transport vectors, as local economies and population numbers cannot support specialist shopping and leisure activities and these are sourced by trips to larger centres (Meijers & Burger, 2017).

Bell & Jayne (2006) note that small cities have the potential to be small in outlook and ambition, with more emphasis on parochial affairs and less interest on wider world issues. Smallness can emphasise a sense of place or it can add to a belief that "small is lacking" and lead to youth alienation and desire to leave for large cities (Waitt et al., 2006).

Bell & Jayne (2006, p8) describe eight characteristics which may be indicative of a small city:

- More human scale, less busy, more walkable.
- Less congestion and crime and other big city problems.
- May not be dominated by a corporate presence.
- Lack large scale flagship or signature projects.
- Have retailing with greater independents sector.
- Less subdivision into monofunctional districts.
- Closer links to residential neighbourhoods.
- Higher numbers of historical buildings.

These characteristics can be used to either distinguish the small city as inferior to its larger neighbour or as positives of a smaller scale living environment with fewer neighbourhoods and closer proximity to CBDs (Knox & Mayer, 2013, p11; Fleming et al., 2006).

Development of the region as a whole, in the global system, depends on creating an attractive environment for businesses, supplied with an educated workforce and infrastructure, that allows the workforce and customers to commute to the business centre and commodities to be imported and dispersed within the region (Evans & Foord, 2006). Even though the region will improve if small cities improve, the small cities have inbuilt disadvantages over their larger neighbours. Small cities have fewer resources with which to undertake competitive exercises and have less starting infrastructure with which they can demonstrate advantage over the neighbours (Leibovitz, 2006).

In addition a city region, such as the North West of England, is made up of many different political and geographical administrations that hamper the ability of the region to work together and promotes inter administration competition to produce system winners and losers (Leibovitz, 2006). Each small city is in competition to be a centre of development for which it needs to demonstrate that it is better than its neighbours and a small city lagging behind and representing an area of underdevelopment, can drag the whole region down (Evans & Foord, 2006).

In the North West of England the higher tier cities of Manchester and Liverpool, therefore, have greater potential for innovation and for constructing services and infrastructure, that can be used in transition of existing systems, such as transport. The surrounding small cities are constrained by their smallness and by their lower tier positions within the regional hierarchy, particularly where they act as dormitory cities. The small cities need to find an identity within this regional hierarchy and deliver this identity within a challenging economic, social and political landscape (Evans & Foord, 2006). Based on these principles, the impacts of geographical restrictions on the ability and motivation of small cities to change and innovate, to reduce transport related greenhouse gas emissions, are investigated in this thesis.

4.3.2 City form and transport

The focus of the research is the ability of cities, across a variety of hierarchies, to affect transport vectors and in turn CO_2 emissions, within their borders. Local authorities have the power to alter city form and relationships have been observed between city form and transport. Cervero & Kockelman (1997) characterise the relationships between city form and transport in terms of the three D's – density, design and diversity. The ability of local authorities to alter each of these aspects of a city structure can be used to investigate their ability to alter transport patterns. However, this investigation should take into account that annual housing renewal rates in the UK are of the order of 1 to 2% and more than 70% of the houses present in 2050 have already been built (Roberts, 2008). In cities with a historical layout, densities, therefore, tend to be locked in. Given low development turnovers, ability to affect city form may, therefore, be limited.

Correlations between transport and density have been made by several researches with Newman & Kenworthy (1999, p101) indicating that cities with high densities (over 10,000 persons/km^2) have low transport energy. In applying this assessment to the UK, there are, however, several problems. Firstly, the cities that are indicated to have very high densities, of above 10,000 persons/km^2 (e.g. Cairo, Manila, Jakarta), which do have low transport energy, are often associated with the developing world, where car dependency is not as advanced as it is in fully industrialised countries. Secondly cities in industrialised parts of the world do not have such high densities and there is little potential for rapid change (Roberts, 2008). In the UK only about 35% of local authorities have a population density above 1,000 persons/km^2 and only 2%, all London boroughs, have population densities over 10,000 persons/km^2 (ONS, 2015b).

City design is seen as a more important factor, than density, in a correlation with transport energy (Naess, 2012). In particular, distance is seen as the critical control in transport energy with distance to work, distance to shops, distance to transit stops and distance to city centre, identified as the most critical factors in travel, use of car and adopting non-motorised alternatives (Stocker et al., 2015). Both Stead (1999) and Brand et al. (2013) also identify distance as a reasonable proxy for transport energy. In an urban environment, control of distance by a local authority is, therefore, identified as a mechanism which could have a significant impact on transport use.

One other issue also needs to be borne in mind when assessing distance in relation to travel. Naess (2015) indicates that, for small cities, distance travelled is partly correlated to distance to the local CBD and partly correlated to distance to CBDs in adjacent large cities. He states that this is because, for small cities, adjacent upper hierarchical cities are used for a relatively large proportion of work related, educational and shopping trips.

The final feature of urban form, that influences transport, is diversity. Diversity relates to the mix of residential and commercial properties within an area, but can also be applied to the type of housing and associated wealth gradient between low income terraced housing and higher income detached and semi-detached housing (Stocker et al., 2015). Minx et al.

(2013) indicate that wealthier householders have greater carbon footprints. Gill & Moeller (2018) note that income may be associated with greater transport related greenhouse gas emissions since, in densely populated industrialised countries, those with greater income may choose to live in suburban areas and have increased requirements for commuting.

Assessment of city form indicates that density may be of lesser importance in defining transport emissions, particularly where city layouts are locked in by historical structures. Cervero & Kockelman (1997) conclude that density, design, and diversity can each have a significant impact on transport, but that community design, to create compact neighbourhoods, is the most important of these factors. The concept of compact communities is captured in the design principles set out in the 2021 report produced by the Town and Country Planning Association (Emery & Thrift, 2021). Local authorities may hence have some control of distance travelled, particularly through provision of public and active travel alternatives and local facilities and services, in areas outside denser city centres. It is these areas where location and lifestyle may currently be associated with higher terrestrial transport emissions. Policies that relate city form to changes in transport emissions are explored further in Sections 4.4 and 4.5.

4.3.3 City governance

A transition to a local transport system, associated with net zero greenhouse gas emissions, requires a fundamental transition of the ways that local government sets its values, organises its systems and operates its policy (Hölscher et al., 2019). This transition, from one social technical system to another, consists of a complex, non-linear process, characterised as a wicked problem (Eckersley, 2018; Geels, 2006). Hölscher et al. (2019) argue that, to initiate change, power is needed over systems and over the actors within these systems and assessment of governance involves investigating the dynamics of obtaining and wielding this power.

To understand this process, the external and internal framework in which it occurs, needs to be defined. The internal framework consists of the decision process that operates within an organisation whilst the external framework consists of the landscape within which the organisation sits and the influences that this landscape exerts on the organisation (Geels, 2006). The system in which city governance operates consists of a vertical and horizontal framework of stakeholders (Williams et al., 2019). The range of stakeholders that a local authority deals with is indicated in Table 4.4.

Table 4.4 – Local authority governance stakeholders (Williams et al., 2019; Mauelshagen et al., 2014)

Vertical stakeholders	Horizontal stakeholders	
National government	Parallel government	Expert consultants
Civil service	Local developers	NGOs
Local councillors	Local media	Local pressure groups
Council planners		
Local electorate/facility users		

The vertical axis of external governance involves the definition of central policy by government, the interpretation of this policy into laws and regulations by civil service and the delivery of policy against laws and regulations by local planners and councillors (Williams et al., 2019). In the UK, this vertical axis is stronger than in other developed countries. Policy is set centrally and implemented through local authorities, who have, compared to federalist systems such as the US and Germany, less ability to define local agendas (Ehnert et al., 2018).

The horizontal axis of external governance involves the engagement of stakeholders in order to gather knowledge and gain policy acceptance (White et al., 2018). Gathering of knowledge from stakeholders is critical in enabling local planners to understand the basis of delivery of new and innovative local systems (Hölscher et al., 2019) and policy clarity is indicated to be a significant constraint on delivery of new transport systems (McTigue, Rye, et al., 2018). Requirements for knowledge are determined by the necessity to comply with government policy but also by local cultural outlook, in terms of acceptance of new ideas, and associated attitude to the risks represented by commitment of significant resources to gathering knowledge to allow implementation of these new ideas (Marsden et al., 2011). Without clarity, through knowledge acquisition, local planners may not have sufficient power to enable significant change to be enacted (Carmichael et al., 2013). The scale of knowledge engagement is also associated with the scale of the local authority organisation, with large cities being able to engage widely through international organisations, such as the Covenant of Mayors, whilst smaller authorities are limited, by resource and contact opportunities, in their outreach (Bulkeley, 2010).

In parallel with gathering of knowledge, in the horizontal stakeholder axis, it is also necessary to engage local electorate and local system users, both as stakeholders within a horizontal system and as final recipients of services within a vertical system (Williams et al., 2019). Engagement with these actors is necessary to gain acceptance of new and innovative systems (White et al., 2018).

In contrast to vertical, top down, implementation of government policy, climate change issues are also influenced by bottom up actions, coming from local government itself and from local climate change champions, who are motivated by the lack of government initiative (Bulkeley, 2010). The success of bottom up policy implementation, however, depends on successful engagement with stakeholders in developing and implementing new schemes (White et al., 2018) and may be constrained by lack of knowledge and resources (Bulkeley, 2010). However, where it is possible to implement actions at a local scale, bottom up initiatives may be successful in delivery of policy (Fox-Kämper et al., 2018).

In addition to the external policy governance systems, policy is also controlled by an internal governance system, acting within local authorities themselves. One way to envisage this internal system is in terms of a governance model based on creating an 'image,' developing 'instruments,' and implementing 'actions' (Williams et al., 2019). In the context of internal structure of development of a local authority project, Perrin et al. (2018) interpret this model as:

- Setting of goals based on government policy and local needs to define an image.
- Development of policy based on goals to act as instruments.
- Implementing policy instruments as actions relating to defined image goals.

The ability of external and internal structures, to implement policy, is subject to a number of significant constraints. Carmichael et al. (2013) list four factors, within the internal structures of a planning authority that may prevent successful development and implementation of local policy:

- Internal communication limitations.
- Knowledge limitations.
- Resource limitations.
- Viewpoint horizon limitations.

Bulkeley (2010) indicates that internal communication limitations, or the presence of policy silos, tend to confine climate change issues to environmental departments and that climate change initiatives are unlikely to be implemented in a fragmented planning system. She also states that part privatisation of local systems decreases ability to prepare coherent policy. In a study of transport planning systems of three UK local authorities, McTigue, Rye, et al. (2018) identify organisational structure as a moderate constraint, although, communication limitations between departments are not indicated to be a significant constraint on ability to enact policy.

McTigue, Rye, et al. (2018) identify knowledge and resource limitations as being important for all authorities but notes that these limitations are particularly experinced in smaller authorities. Tønnesen (2015) also identifies knowledge and resource deficits in smaller authorities as key factors in ability to effectively implement policy. Marsden & Groer (2016) argue that availability of resources is more important than governance structure in delivering policy.

In terms of viewpoint, Carmichael et al. (2013) state that, in order to successfully deliver policy, a long term goal needs to be in place and that government guidelines are required in order to avoid policy that is reactive rather than proactive. Ehnert et al. (2018) argue that the UK system of centralist government means that local authorities will only enact policy if given a strong central lead. Mauelshagen et al. (2014) state that, in the UK, local authority ability to exercise power is limited by emphasis on centralised decision making. An emphasis on short term policy goals, means that issues with long term impacts, such as climate change, may receive less priority (McClure & Baker, 2018).

Bache et al. (2015) state that setting a national climate change goal does not necessarily translate to local action and that local economic interests are, at present, overriding a weakly articulated national climate change mitigation goal. Review of UK governance indicates that current structures limit ability of local authorities to implement local policy but that these limitations are particularly experienced in smaller authorities. The importance of engagement with bottom-up initiatives is also highlighted. This thesis will explore how these limitations are experienced by local planners in the North West of England and how they affect motivation and ability to develop and implement policy relating to reduction in transport greenhouse gas emissions.

4.3.4 City geography summary

The literature review contained in this section provides a summary of city geography and governance as it relates to the industrialised world. The importance of absolute and relative size in determining city hierarchy is emphasised. The effects of this hierarchy on the vertical and horizontal governance regimes that control ability and motivation to develop and implement local policy are then described. This understanding of city hierarchy provides a basis for assessment of interviews set out in Chapter 5 and of modelling contained in Chapter 6.

4.4 Transport background

4.4.1 Introduction

In this section discussion of greenhouse gas emissions associated with terrestrial transport in the UK is presented, together with changes that are likely to occur in these systems without interventions by local authorities. Section 4.4.2 covers transport systems. Section 4.4.3 then covers greenhouse gas emissions associated with these systems. In terms of the intervention pathways defined by Hickman & Banister (2014, Figure 8.3), as noted in Section 2.4, the changes outlined in this section primarily relate to technological interventions that are within the control of national government. Against this background the interventions discussed in the following section (Section 4.5) then relate to stewardship changes associated with the actions of local authorities.

4.4.2 Transport systems

In 2018 transport was responsible for over a quarter of all UK greenhouse gas emissions and this percentage is rising, as emissions in other major sectors have significantly reduced, whilst transport emissions have generally remained the same (BEIS, 2020b). Whitelegg (2016, p15) notes that, although time spent travelling has remained more or less the same, over the last 200 years, vehicle speeds have increased. Increased speeds have meant that distances travelled per person have increased. Both Stead (1999) and Brand et al. (2013) note that vehicle distance travelled can be equated to transport greenhouse gas emissions. DfT Table ENV0202 (TSGB0307) indicates that in 2018 UK terrestrial transport was responsible for 126.4MtCO_2, of which over 95% was associated with travel on roads (DfT, 2020c).

In terms of understanding travel patterns, the UK National Travel Survey (NTS) can be consulted. This travel survey has been undertaken annually since 2002 and provides data that goes back to the 1960s (DfT, 2020f). Banister (2018) calls this dataset invaluable. The NTS provides a split of national and regional travel by purpose and by mode, as summarised in Table 4.5. This data indicates that the average person in the UK travels about 10,400km per year, with about 70% by car, as driver or passenger, over 25% for the purpose of commuting or business and over 40% for leisure, including holidays.

Table 4.5 – UK transport average annual mode and purpose per person derived from National Travel Survey 2018/2019 (DfT, 2020f)

Mode	Average km/person/year	Purpose	Average km/person/year
Walk	331	Commuting	2041
Bicycle	90	Business	888
Car/van driver	5160	Education/escort education	544
Car/van passenger	2176	Shopping	1119
Motorcycle	34	Other escort	701
Local bus	265	Personal business	708
Non-local bus	62	Leisure (including holidays)	4305
Rail	993		
Taxi	97		
Other transport (including flying)	237	Other (including just walk)	93

In addition to private travel, a significant proportion of transport greenhouse gas emissions in the UK is associated with freight movement. UK transport emissions data indicates that 35% of road greenhouse gas emissions relate to distance travelled by ‘heavy goods vehicles’ (HGVs) and ‘light goods vehicles’ (LGVs) and that this percentage is increasing and was less than 30% 20 years ago (BEIS, 2020b).

In addition to the data collected within the NTS, the DfT undertake continued surveys of traffic flows (DfT, 2018b). This data can be used to provide an indication of historical changes in vehicle distance travelled in the UK. Distance travelled per person on British roads, between 1950 and 2019, is shown in Figure 4.3. Vehicle kilometres are taken from

DfT Table TRA0201 (DfT, 2020n) and populations are taken from ONS estimates (ONS, 2020c).

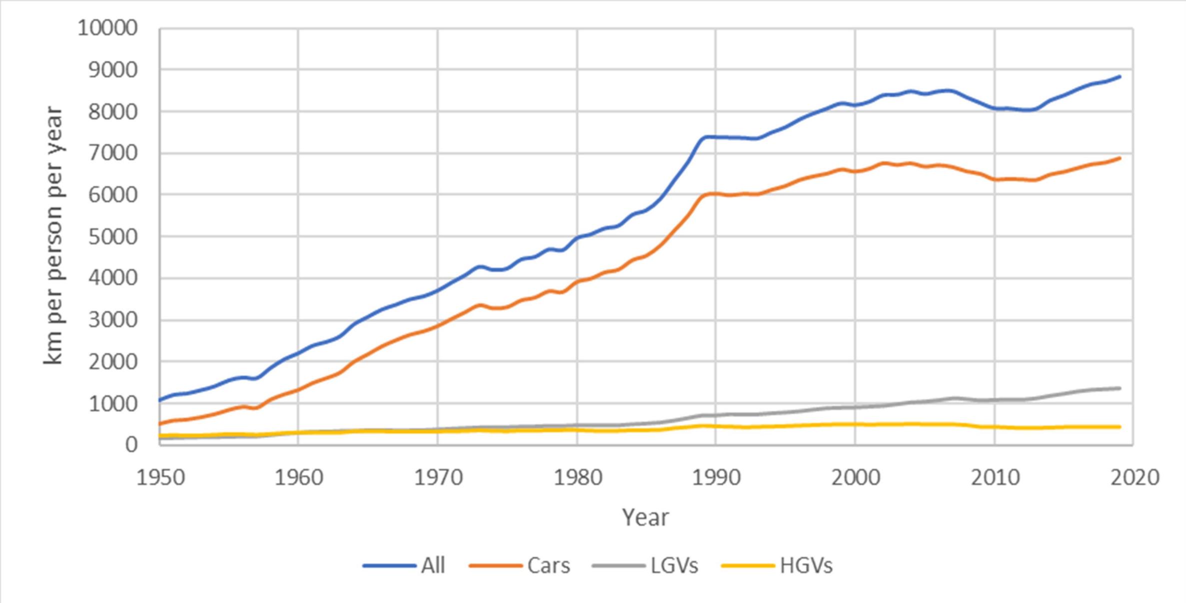

Figure 4.3 – Great Britain vehicle kilometres per person per year between 1950 and 2019 (DfT, 2020m; ONS, 2020c)

Figure 4.3 shows a general increase in kilometres driven between 1950 and 2019, with an indication that prior to 1990 traffic was increasing at about 1500 kilometres per person per decade and after 1990 this increase reduced to about 500 kilometres per person per decade. It should be noted that after 1990 there appears to be an increase in the proportion of LGV kilometres, relative to ordinary car kilometres. Browne et al. (2014) records that, whilst most LGV kilometres relate to movement of goods and business operations, about a third of all LGV use relates to commuting. This and data shown in Figure 4.3, hence, indicates that, after 1990, a proportion of commuting activity has been transferred from private cars to LGVs. This is associated with an increase in LGV ownership of 30% between 2007 and 2019, as opposed to an increase in private car ownership of less than 15% (DfT, 2020m). Growth in use of LGVs may be associated with a fivefold rise in the proportion of online sales over this period (ONS, 2021) and hence an increase in the proportion of goods that are locally delivered (Morganti et al., 2014). At the same time HGV distance travelled per person is indicated to have remained broadly constant since 1990.

Extrapolating the rate of increase of vehicle distance travelled (500km/person/decade), indicates that 10,400km per person could be reached in 2050. Given a 10% predicted increase in population of the UK (ONS, 2020b), this relates to a 30% increase in overall vehicle kilometres between 2020 and 2050.

Debate relating to changes in vehicle distance travelled, in the UK and other industrialised countries, has focussed on whether consumer choice has led to a peak in car use (Wadud & Baierl, 2017) or whether economic variables, such as fuel price, can still explain changes in traffic levels (Bastian et al., 2016). Kamruzzaman et al. (2020) indicate that changes in use of car are influenced by both global financial factors and by local policy and demographic factors. Focas & Christidis (2017) note that it may be too early to make a determination of whether peak car is occurring but that some conclusions can be drawn, such as the fact that young people in urban locations are, at least, delaying purchase of a car, leading to some flattening of car use. Givord et al. (2018) note that elasticity, linking use of cars to fuel price, is low. However, Gillingham & Munk-Nielsen (2019) report that elasticities can be significantly increased if an alternative travel mode, such as public transport, is readily available. Traffic in large cities, with significant public transport systems, where congestion charges have been introduced, has fallen by about 20% (Börjesson et al., 2014). Mattioli et al. (2018), however, state that elasticity, between fuel cost and distance travelled, is particularly small for rural poor, who use a car and have little choice in terms of travel mode, and traffic in these areas is, hence, more likely to continue to increase.

Predictions of growth in vehicle kilometres in the UK are presented in DfT forecasts, prepared in 2018 (DfT, 2018a). These forecasts provide seven scenarios of future traffic growth as shown in Table 4.6.

Table 4.6 – UK DfT traffic growth forecasts (DfT, 2018a, p52)

DfT Scenario	**Assumptions**	**Growth in overall traffic distance (billion vehicle kilometres) 2015 to 2050**
1	Central fuel and population	35%
2	High GDP low fuel	43%
3	Low GDP high fuel	26%
4	High migration	39%
5	Low migration	31%
6	Extrapolated trip rates	17%
7	Shift to zero emission vehicles	51%

The DfT indicate that the first five scenarios illustrate conventional coupling of growth in traffic distance with GDP, population and fuel price (DfT, 2018a, p29). They base the sixth scenario only on extrapolating current trends in traffic and indicate a significantly lower growth rate. They state that the last scenario is based on a sustained shift to low emission vehicles, with an associated significant reduction in fuel price per kilometre, leading to a 51% increase in traffic. They indicate that Scenario 7 is the only forecast that achieves greenhouse gas emissions reductions compatible with the UK legislative framework at the time (80% reduction by 2050) whilst other scenarios only indicate a 15% to 30% reduction in greenhouse gas emissions. This is despite the increased growth in traffic associated with Scenario 7.

The scenarios are associated with a large amount of uncertainty, as illustrated by the 300% difference between the lowest and highest forecasts. The DfT state that they have had to completely decouple the link between GDP and traffic growth in London for their scenarios to be realistic and that the link between income and traffic forecasts may be changing in the rest of the country (DfT, 2018a, p7). They hence indicate that traditional coupling of economic indicators with traffic distances may be becoming less relevant, particularly in large urban areas.

As the scenarios are based on 2015 traffic distance, data up to the end of 2020 can be used to get an idea of the progress against the forecasts. Up to the end of 2019 an 8% increase in traffic had been recorded in the UK, relative to 2015 (DfT, 2020n), which can be compared to a DfT Scenario 1 prediction of a 7% increase in traffic and a Scenario 6 prediction of a 4.5% increase (DfT, 2018a, p52). Traffic figures were, therefore, at the end of 2019, exceeding the lower and central DfT scenarios. Extrapolating data shown in Figure 4.3 is compatible with upper DfT forecasts. Extrapolating trends occurring between 2015 and 2019 would give even higher growth but it is too soon to assess whether increased changes in vehicle kilometres per person, in this period, represent long term trends or short-term fluctuations.

The exact reason for a reduced rate, of increase in vehicle kilometres, after 1990 is not clear, but, as shown in Figure 4.3, the trend in increased distance has been broadly consistent since around 1990 and, as discussed, DfT forecasts are generally consistent with this trend. Data indicates that peak traffic may be occurring in large cities, particularly where young populations are present, where there is significant public transport infrastructure and where traffic restrictions are imposed. Continued growth in traffic is, however, likely to be associated with other areas.

4.4.3 Transport emissions

Virtually all the greenhouse gas emissions associated with cars, vans and lorries relate to creation of CO_2 (BEIS, 2020b) and, therefore, in assessment of terrestrial transport systems, it is possible to concentrate on CO_2 alone. CO_2 emissions can be equated to individual transport vectors. Emissions relating to a particular transport mode can be calculated on the basis of Equation 4.1 (Schmitz Gonçalves et al., 2019):

$$\mathbf{CO_2\ Emissions = A \times S \times I \times F}\ \text{- (Equation 4.1)}$$

Where:

A = Activity in kms.

S = Split in mode by %.

I = Energy intensity in energy per km.

F = Emissions factor in tCO_2 per unit energy.

Where a vehicle runs on petrol or diesel it burns fuel and produces greenhouse gases. DfT Table ENV0103 indicates that in 2018, in laboratory conditions, the average UK petrol car burned about 5.6 litres of fuel per 100km of travel, with diesel cars doing slightly better at 4.9 litres per 100km and diesel vans doing worse at 6.4 litres of fuel per 100km (DfT, 2020c). The DfT data indicates that, for both petrol and diesel cars, consumption efficiency has improved by just above 30% since 1997. On road efficiencies are estimated to be about 14% worse than laboratory efficiencies (Tietge et al., 2018). The gap, between efficiency measured in the laboratory and efficiency measured on the road, has halved in the last three years, with the introduction of a standardised test known as the 'world-wide harmonized light duty test procedure' (WLTP) (Pavlovic et al., 2018). Burning an average litre of petrol (l), in the UK, produces about 2200g of CO_2 and an average litre of diesel (l) produces about 2600g of CO_2 (BEIS, 2019). Based on Equation 4.1, greenhouse gas emissions per kilometre activity, for diesel and petrol car modes, can be calculated as:

Emissions per km (gCO_2/km) = I x F x Laboratory Efficiency/100

I = Average energy intensity – litres of fuel per hundred kilometres (l/100km)

F = Average emissions factor – grammes of carbon dioxide per litre of fuel (gCO_2/l)

Based on this expression average conventional car emissions in 2018 in the UK are shown in Table 4.7.

Table 4.7 – Derived UK average diesel and petrol car emissions per kilometre 2018 (DfT, 2020c; BEIS, 2019; Tietge et al., 2018)

Car Type	Driving efficiency (l/100km)	Calorific efficiency (gCO_2/l)	Laboratory efficiency	On road emissions (gCO_2/km)
Petrol	5.6	2200	1.14	140
Diesel	4.9	2600	1.14	145
Diesel LGV	6.4	2600	1.14	190

EU standards require average new cars to achieve laboratory emissions of 130gCO_2/km in 2015 and 95gCO_2/km in 2021 (Hu & Chen, 2016). EU standards for LGVs require laboratory emissions of 147gCO_2/km in 2021 (European Union, 2019b). All efficiencies are required to improve by a further 15% by 2025 (European Union, 2019b). For HGVs EU standards require reduction in emissions, relative to 2020, by 15% in 2025 and by 30% in 2030 (European Union, 2019a).

Significant improvements in conventional engine technology have occurred over the last 20 years, but only in the last 10 years has this been translated into better mileage efficiency, as previous technological improvements have been used only to increase performance in larger cars (Hu & Chen, 2016). Whether car manufacturers have improved their engine energy efficiencies due to regulation or due to consumer preference is not easy to assess, as, for example, interviews undertaken by Hafner et al. (2017) suggest that environmental performance is not significant in vehicle purchase choice. Fritz et al. (2019) suggest that regulations relating to engine efficiencies should be further tightened, to continue improvement in mileage efficiency and Crippa et al. (2016) state that, due to the global trade in cars, EU regulations have already led to significantly better efficiencies around the world.

Increased efficiency of conventional cars may also be associated with a switch to smaller vehicles. This potential is illustrated in Figure 4.4. Purchases of vehicles with tax codes relating to emissions less than 100gCO_2/km and tax codes with emissions of between 100 and 150gCO_2/km, have significantly risen since 2005, whilst those representing cars with less efficient engines have reduced by over 50% (DfT, 2020m). This is partly due to a general increase in efficiency of engines and partly due to purchasing of smaller cars. It is, however, difficult to assess whether changes are due to increases in engine efficiencies or due to increased purchase of smaller cars. In a study of similar efficiency improvements in the Netherlands, Kok (2013) ascribes 75% of change to technology improvements and only 25% to consumer choice between 2008 and 2011.

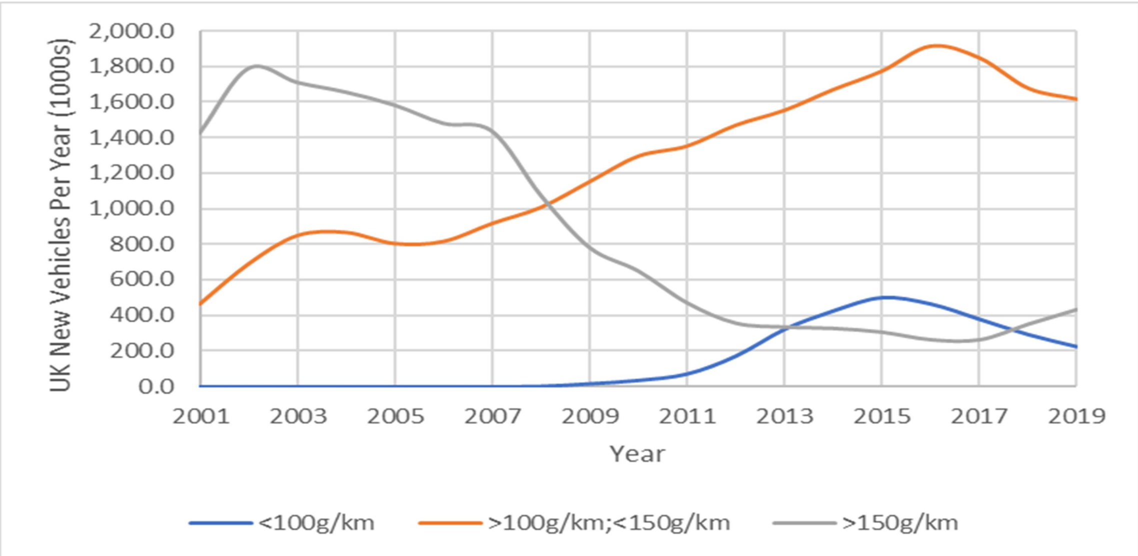

Figure 4.4 – UK new vehicle tax band registrations 2001 to 2019 (Table DfT VEH0256 (DfT, 2020m))

From 2017, UK tax band variable rates, relative to engine efficiency, were abolished, except for a first year surcharge and a continued zero rate for low emission vehicles (less than 50gCO_2/km) (Auto Express, 2021). It is noted that the data shown in Figure 4.4 indicates that, since the 2017 relaxation of tax band rates, improvements in car class purchases have been partly reversed, although the numbers of very low emissions vehicles has continued to increase (Table VEH0150 (DfT, 2020m)). The adoption of the new WLTP test, between 2018 and 2020, will have an impact on these figures, as the new test approximately halved the difference between real world and laboratory measurements (Pavlovic et al., 2018). This will mean that vehicles, originally classified on the upper edge of one class, will move to a higher tax class. Despite these recent partial reversals, the average greenhouse gas emissions of new cars in the UK was, in 2019, nearly 30% lower than it was in 2001 (DfT, 2020m).

Improvement in emissions can also be associated with altering fuel used by conventional engines. In terms of fuel systems, EU regulations require the renewable component of transport hydrocarbon fuels to increase from 4.75% in 2018, to 9.75% in 2020 and 12.4% in 2032 (van Niekerk & Kay, 2020). In addition, regulations require the lifecycle assessment of EU fuels to be reduced by 6% in 2020, relative to 2010 (DfT, 2020j). In the UK, transport system hydrocarbon renewable components are controlled through use of a 'renewable transport fuel obligation' (RTFO) (Chalmers & Archer, 2011). Regulations require UK suppliers of hydrocarbon fuel, over 450,000 litres per year, to produce, trade or purchase sufficient RTFOs to cover annual production volumes, or face fines (DfT, 2020i). Provisional figures indicate that 2,680 million litres of RTFOs were produced in 2019, representing 5.1% of UK transport hydrocarbon fuels (DfT, 2020h). The figures show that less than 20% of RTFOs were from food waste with about 50% related to used cooking oil, mostly from China. Acquaye et al. (2012) undertook a lifecycle assessment of hypothetical RTFO schemes and concluded that a 20% penetration of renewable transport fuel components would lead to a 6% reduction in greenhouse gas emissions. Based on this figure and allowing for double counting, the current scheme may have reduced UK transport greenhouse gas emissions by about 1%. Statistics will be produced in 2021 to show whether lifecycle reduction in fuel system greenhouse gases, relative to 2010, have met the 6% criteria specified by the EU.

In assessment of driving restrictions, that can affect potential greenhouse gas emissions of conventional vehicles, Zeng et al. (2016) conclude that speed is an important component. They report that a speed of 50 miles/hr (80km/hr) provides optimum driving efficiency but that local speed restrictions, in changing speeds from 30 miles/hr to 20 miles/hr (50km/hr to 30km/hr), do not significantly affect efficiency in terms of greenhouse gas emissions. Hence national speed restrictions, that are within the control of national government can have a significant effect on emission efficiency, but local speed restrictions that are within the control of local government have a lower impact potential.

As an alternative to conventional diesel and petrol vehicles a wide selection of 'electric vehicles' (EV) are also being developed around the world. EVs have been available for over a hundred years but only in the last twenty years, as a response to issues associated with climate change, have EVs been seen as a real alternative to conventional vehicles (Dijk et al., 2013). EVs are available as cars and vans which run wholly on electric systems or as hybrids that run partly on electricity and partly on diesel and petrol (Dijk et al., 2013). For an EV that runs only on an electric motor, emissions associated with travel depend on the efficiency of national and regional electricity generation (Kamiya et al., 2019). For hybrid systems, emissions rates, in gCO_2/km, will be somewhere in between pure EV and conventional efficiencies, depending on technological specification and driving regime (Kamiya et al., 2019).

To derive EV efficiencies, it is necessary to know driving energy rate, in kWh/km and electricity generation efficiency in gCO_2/kWh. The product of these two factors relates to driving emissions, in gCO_2/km (Ambrose et al., 2020). Table 4.8 shows efficiency and emissions for a selection of average EVs, in the UK, currently and in a possible future where electricity generation is undertaken with less use of fossil fuels. Future electricity generation efficiencies are taken from the most optimistic of the National Grid's scenarios for 2050, assuming a 95% reduction in generation emissions but with no allowance for large scale carbon dioxide removal (CDR) (National Grid, 2020). It should be noted that the National Grid state that, if CDR can be fully developed over the next 30 years, they can deliver electricity with significant net negative emissions.

Table 4.8 – Derived UK average EV car emissions per kilometre 2019 and 2050 (Santucci et al., 2016; Ambrose et al., 2020; Figenbaum, 2018; National Grid, 2020, p147)

Vehicle type	Driving efficiency (kWh/km)	2019 generation efficiency (gCO_2/kWh)	Current on road emissions (gCO_2/km)	2050 generation efficiency (gCO_2/kWh)	Future on road emissions (gCO_2/km)
EV Motorbike	0.05	167	8	8	0.4
Small EV	0.15		24		1.2
Medium EV	0.20		33		1.6
Large EV/LGV	0.25		42		2.0

Table 4.8 shows that on road efficiencies for EVs are currently about 75% better than conventional cars, and have the potential, through decarbonising the grid, to be over 95% better.

For any vehicle, emissions of CO_2, in addition to those generated on road, are, however, also associated with manufacture and maintenance (Yang et al., 2020). These manufacturing and maintenance emissions will occur for both conventional vehicles and EVs. EVs have greater manufacturing emissions but have simpler engines and may have the potential to run for longer periods with less maintenance (Sharma et al., 2013). Hill et al. (2019) state that manufacture of a typical EV uses about 8.8tCO_2 whilst manufacturer of a conventional vehicle uses about 5.6tCO_2. However, they note that about half the manufacturer CO_2 is associated with electricity generation. Hence this differential will reduce as generation efficiency is improved. In the long term, where zero emission generation is envisaged, the manufacturing differential between conventional vehicles and EVs may, therefore, only be about 1.5tCO_2. Based on emissions of 100gCO_2/km an extra 15,000km of EV mileage, associated with a simpler and lower maintenance drive system, would, therefore, be required to remove this differential. In CO_2 emissions scenarios, described in Chapter 6 of this thesis, manufacturing CO_2 emissions are not included in budgets, on the basis that these emissions and associated budget allowances, will be included in an industrial manufacturing inventory that, in parallel with the transport sector, will be required to follow a greenhouse gas emissions reduction pathway.

4.4.4 Transport review summary

The literature review contained in this section provides a summary of greenhouse gas emissions associated with conventional petrol and diesel cars and with electric vehicles. These emissions are used as a baseline for discussion of local authority interventions contained in Section 4.5 and for modelling contained in Chapter 6.

4.5 Local authority interventions

4.5.1 Introduction

Ieromonachou et al. (2004) state that radical changes in urban systems will be required to achieve the goal of reduction in transport greenhouse gas emissions. In 2004 only a small number of local authorities were reported to have made any significant progress in mapping a way forward for greenhouse gas reduction (Allman et al., 2004). In their study of local authorities in 2016, twelve years later, Webb, et al. (2016) state that 70% of councils were still yet to significantly engage with the problems associated with reducing greenhouse gas emissions. This data, therefore, indicates that there is a significant potential for increased engagement of local authorities in terms of reducing transport emissions. The strategies that local authorities can use to intervene in transport emissions are discussed in this section. In Section 4.5.2 intervention principles are characterised. In Section 4.5.3 these principles are applied to mode interventions and in Section 4.5.4 purpose interventions are discussed.

4.5.2 Intervention principles

Williams et al. (2019) classify interventions by local authorities into six categories:

- Do nothing and trust that the public will make their own choice.
- Inform the public and trust they will make informed choices.
- Enable change through making facilities available to allow choices to be made.
- Guide change through incentives or disincentives to signal preferred choices.
- Restrict to prevent some negative choices.
- Eliminate to prevent all negative choices.

The policy scales, indicated by Williams et al. (2019), can broadly be split into two categories. Barr & Prillwitz (2014) state that actions where local populations are provided with examples, informed, enabled, guided or encouraged, relate to the case where individuals are expected to make their own choice and that, where a governing body restricts, eliminates or enforces change, responsibility is taken out of the hands of the individual and assumed by the governing body. In many parts of the industrialised world, a neoliberal agenda means that government is reluctant to impose choices on individuals and hence change involving restricting, eliminating or enforcing, is avoided (Magnusson, 2015; Cass & Faulconbridge, 2016). Reluctance to impose choice on individuals has also meant that national government has tended to pass responsibility for delivery of policy, relating to individual lifestyle, down to local government (Bloyce & White, 2018).

Lehner et al. (2016) discuss individual choices in terms of a distinction between reasoned logical decisions and intuitive habitual decisions. They report that about half of all decisions, made by individuals, are intuitive and habitual and not necessarily reasoned and logical and that decisions involving complex information are often made intuitively. Policy aimed at changes in individual lifestyle choices may hence need to be addressed with greater emphasis on intuitive decisions, rather than on logical decisions (Cass & Faulconbridge, 2016). Logical choice frameworks involve providing information and facilities in order to rationally demonstrate change, whilst intuitive frameworks involve altering the environment of societal norms surrounding the individual, in order to guide or encourage change (Lehner et al., 2016). Delineation between rational and intuitive lifestyle choice frameworks does not, however, provide a full picture, as change mechanisms depend on a variety of interactions with local, environmental, political, sociological and technological factors (Zhang & Watson, 2020). Although habit may be dominant, factors are accessed both rationally and intuitively and, in assessment of individual motivation, it is difficult to demonstrate a distinction (Janssen, 2020, p135; Lattarulo et al., 2019).

Lehner et al. (2016) note that, where populations are influenced without imposing specific restrictions, actions can be classified in terms of a hierarchy of nudging, ranging from policies that aim only to change behaviour to policies that aim to change mindset. They note that nudging policies overlap and are most effective as part of broad policy packages and that small changes in information or environment are unlikely to bring about significant change without parallel changes in the social norms governing how a population views the world. Avineri (2012) states that policy aimed only at changing behaviour, should be in addition to policy aimed at changing mindset and not a replacement, because overall changes in society can only occur once mindsets are altered. Barr & Prillwitz (2014) argue that a narrow focus on nudging policy may mean that the larger societal changes, necessary to tackle significant problems, such as climate change, are not applied.

In terms of transport, in order for behaviour changes to be effective the physical constraints on travel that make populations, particularly in rural and suburban areas, dependent on cars for travel, need to be addressed (Schwanen et al., 2012). In order for changes in behaviour to occur, knowledge is important, but appropriate facilities and opportunity are also required (Tonglet et al., 2004). In addition, habitual dependence on use of cars, as opposed to use of public transport or active travel forms, needs to be considered. Lattarulo et al. (2019) note that, where a person has a strong preference for a mobility choice, they are less likely to apply logical criteria, in assessment of potential to change their behaviour and may actually assess their choices irrationally in order to justify habitual mobility patterns. In research relating to adopting EVs, Hafner et al. (2017) indicate that image is the most important psychological factor controlling purchase decisions. Buehler (2011) indicates that social pressures influence image and are important in determining whether a person is willing to change habits.

Verplanken & Wood (2006) indicate that applying significant levers, such as interventions involving financial or legislative policy, are necessary to break strong mobility habits and that even when habits are changed a regime of environmental support is required in order to prevent reversion to previous behaviours. Rogers (2003, p282) indicates that a small proportion of the population (innovators) are already psychologically inclined to change their behaviour whilst most of the population (early and late majority) will only change behaviour once innovations are embedded in society. If local authorities can identify and encourage innovators they can speed up the mechanisms of change (Pettifor, Wilson, Axsen, et al., 2017).

Research, therefore, indicates that interventions need to be substantial enough that societal norms are changed, through removing practical and psychological constraints on new mobility patterns. Isolated initiatives, that aim only at changing local knowledge or behaviours, are unlikely to bring about substantial change in mobility. Interventions involving enforcement are also likely to be required if significant change is necessary. The impact of interventions can also be increased where it is targeted at those who are already predisposed to adopt new mobility patterns and supported by provision of infrastructure encouraging transport alternatives.

A variety of demographic factors have been found to correlate with potential for adopting new environmental initiatives. Increased income and education are generally indicators of those who are likely to engage in positive environmental actions, with women and those with families also being identified as indicators in some studies (Tomaselli et al., 2019; Katt & Meixner, 2020; Simsekoglu & Nayum, 2019; Liu & Mu, 2016; Ding et al., 2018; Liu et al., 2014; Sovacool et al., 2018). Those who are wealthy are, however, also likely to be initially associated with greater per capita greenhouse gas emissions (Baiocchi et al., 2015). One study that indicated a different perspective relates to purchasing of photovoltaic systems in Tehran, where costs of panels were low enough, due to government subsidies, that everyone could afford installation and in this case poorer families were more likely to purchase the system (Bashiri & Alizadeh, 2018). This study indicates that cost may represent a barrier in adopting an improved environmental lifestyle. To allow the whole population to engage in positive environmental actions it is, hence, necessary to remove financial constraints.

Actions taken by local authorities can be split between those that are reactive and those that are proactive. Reactive actions relate to short term policy that is applied as development proposals are presented and funding is realised, through CIL and 106 Notices. Proactive actions are those instigated and, as practical, funded by the local authority themselves, in line with long term goals. Based on a necessity for radical urban system changes, reliance on a reactive framework represents a barrier to effective action (Carmichael et al., 2013). In addition, for smaller councils with less funding and resources it is difficult to instigate large scale changes (Bell & Jayne, 2006). Paterson et al. (2017) state that scale is more important than political and social structure, in ability to implement urban changes associated with sustainability. Tønnesen (2015) states that larger authorities are better placed, both financially and institutionally to bring about change. Local authorities, therefore, need to be prepared to work together with each other to optimise their resources, as working in isolation is likely to restrict authorities from taking necessary radical actions (Lazzarini, 2018; Pfeiffer et al., 2015).

4.5.3 Mode interventions

Taking into account the principles outlined in Section 4.5.2, local authority interventions relating to changing transport modes are discussed in the following section. The mode changes discussed relate to reducing overall travel, adopting EVs and adopting active, public and para transport systems. Interventions relating to the purpose of travel are then discussed in Section 4.5.4.

Reduced travel

The DfT commissioned a report in 2015, to investigate the factors that contribute to growth in traffic (DfT, 2015, p6) that concluded:

- There continues to be a good correlation between national distance travelled and GDP.
- Increased income leads to increased personal car distance travelled.
- Percentage car ownership generally increased between 1995 and 2013 in most of the country, but in London it has reduced.
- Although relative costs of cars themselves have fallen, motoring costs in general have risen, particularly for the young, as fuel and insurance costs have risen at a greater rate.

- Tax increases levied at company cars have made a significant contribution to reduced business mileage.
- Growth in population in urban areas has been offset by reduced urban car use, particularly for the young, but there is still a net upward trend.
- Increased telecommuting may have contributed, to a small degree, to decreased car use per person in urban areas.
- Demographic changes of the populations are not likely to have a significant effect on car usage.
- Cars continue to be seen in a positive light and negative environmental views are not significantly affecting car use.
- Congestion is not affecting overall car mileage.
- Land use changes are not significantly affecting car mileage.
- There is likely to be continued growth in car ownership and car mileage for the foreseeable future.

In the light of these trends and insights, the DfT 2018 forecast continues to indicate increased levels of traffic (DfT, 2018a). If local authorities wish to reduce vehicle distance travelled, then they are hence likely to be attempting this in an environment of increasing car use. However, success in reducing traffic levels in London and the effect that this has had on car ownership, compared to the rest of the country (DfT, 2015), indicates that there may be ways of reducing overall car trips. It is, however, noted that UK car travel is already lower than that occurring in many other Western European countries (Pasaoglu et al., 2014).

Cools et al. (2012) categorise options for local curbs on vehicle distance travelled in terms of infrastructure, financial controls, regulatory changes and marketing campaigns. Infrastructure alteration includes provision of extra vehicle systems, such as park and ride regimes. Vehicle financial restrictions, such as road and parking pricing schemes, do not prohibit vehicle movements but put a monetary cost on entry into a specific area, whereas regulatory changes prevent or restrict particular vehicle movements within an area. Pricing schemes hence relate to individual choice, taking into account financial status, whilst, where regulations are used, individual choice is removed (Barr & Prillwitz, 2014). Marketing campaigns present awareness of car use and alternatives and rely on individuals to react to this information.

Cities such as Cambridge, York and Winchester have introduced park and ride schemes, over the last twenty years, to allow parking at urban perimeters so that connected buses can take drivers into city centres and have been successful in reducing traffic in historical urban areas where it is difficult to alter road layouts (Hounsell et al., 2011). Assessment of park and ride scheme studies by Parkhurst (2000), however, indicates that such infrastructure schemes do not generally reduce overall vehicle traffic, as decreased city centre traffic is balanced by increased suburban traffic. Transport greenhouse gas emissions are, therefore, not reduced.

Glaister & Graham (2006) state that, if alternative traffic reduction strategies cannot be found, then road pricing is required. Rosenblum et al. (2020) and Saharan et al. (2020) both state that pricing is necessary in order to pass on environmental costs to car uses. Mingardo et al. (2015) argue that control of pricing can raise revenue for a city and, also, improve urban environments and reduce congestion. The London Congestion Charge is reported to have reduced local traffic by about 20% and, also, reduced traffic in surrounding areas by about 5% (Hensher & Li, 2013). Krabbenborg et al. (2020), however, point out that the rejection of similar schemes, in Manchester and Edinburgh, appears to demonstrate that there is little appetite, in the UK, for additional large urban road pricing schemes. They further state that the schemes were rejected because they were not seen as fair or effective and that there is a requirement to demonstrate these features to the public before new schemes are instigated. However, they state that, once a scheme is in place, local acceptance generally grows and it is, then, easier to introduce alterations and extensions. Hensher & Li (2013) suggest that acceptance of the Stockholm congestion charge scheme was partly due to incorporation of a trial period in system development, allowing demonstration, to residents, of benefits in terms of improvements in congestion and the local environment. Vonk Noordegraaf et al. (2014) point out that successful road pricing has been associated with information, communication and marketing strategies but also with local and national governmental actors who have championed schemes and positively presented them to the public. Small scale road charging is also possible, as demonstrated by the Durham scheme which operates on one road around the castle (Ieromonachou et al., 2004). However, assessment undertaken by Zhang et al. (2006) indicates that large scale congestion charges are not cost effective in small cities.

Local authorities also have the power to completely ban vehicles and allow area pedestrianisation. Soni & Soni (2016) list benefits of pedestrianisation in terms of traffic reduction, increased social interactions, better local environments, healthier local populations and increased local economic performance. Hass-Klau (1997) notes that, where implemented, pedestrianisation has generally been successful, but such schemes need to be associated with changes in local transport systems. She indicates that, for smaller urban areas, an upgrade in local bus public transport is required and, for larger urban areas, a train based transport system, incorporating the newly pedestrianized area, is required.

Regulations relating to restrictions on cars are generally more acceptable to the public when they are associated with a clear purpose (Krabbenborg et al., 2020). Legal requirements on local authorities, relating to imposing clean air zones associated with excessive levels of 'nitrous oxides' (NO_x) and 'particulate matter' (PM), therefore, provide a methodology for implementing transport restrictions (Perez et al., 2015). Such legal requirements, however, generally only apply to large cities. In the North West of England only Manchester and Liverpool have requirements to improve street level air quality (DEFRA, 2018). Greater Manchester mayoral authority plan to instigate a clean air zone, covering the areal extent of all ten local authorities within their jurisdiction, allowing them to levy fees on polluting vehicles and hence to restrict their use, as has already been accomplished in London (Clean Air Greater Manchester, 2020). Liverpool are in discussion with the UK Government over their requirements for a clean air zone, that may only be applied to a small number of arterial roads (Liverpool Echo, 2020). For other councils covering small cities there is no clear legal requirement for creating a clean air zone.

Several lesser options are available relating to financial control of local traffic in the form of parking charges and restrictions (Saharan et al., 2020). Marsden et al. (2020) state that local government has an obligation to control access to kerbs, as part of its civic duties, and parking pricing should be an integral part of this control. Lehner & Peer (2019) state that the effect of parking fees on traffic flows, are, however, highly dependent on local transport regimes. Simićević et al. (2013) record that as parking charges increase potential for use of public transport also increases, but that most people only alter the place where they park to avoid increased charges. They also state that less than 5% of people would completely cancel their journey due to impositions of increased parking charges. Hence, for increased parking charges to be effective, they need to be consistent over a large area and supported by public transport alternatives.

The review of traffic reduction potential highlights that, in an environment where growth in use of cars is increasing, particularly in small cities, radical change in society is required to achieve transport greenhouse gas reduction goals. Hence, large scale interventions, such as congestion charges and pedestrianisations, are indicated as being necessary. The review highlights that such interventions are associated with large cities and are only likely to be successful where they are coupled with provision of alternative transport modes and where their necessity and fairness are demonstrated to local populations.

EV mode

EV promotion policies, relating to vehicle design and financial features, are largely under the control of national government and international manufacturers, however, local government has some control over policy relating to city wide promotion and support of EVs and restrictions of conventional vehicles (Browne et al., 2012). Adopting radical policy, such as placing personal limits on driving conventional vehicles, is theoretically possible. However, as discussed in the introduction to this section, in the current individualist political climate of industrialised countries, is unlikely to be acceptable (Wang et al., 2015). In contrast, current policy relating to spending on large road building schemes, in order to reduce congestion, whilst being acceptable, is not likely to bring about a reduction in transport greenhouse gases and in the long term is not even likely to reduce congestion (Melia, 2019). Policy, relating to switch in vehicle mode, hence needs to be both politically acceptable and environmentally effective.

Policy also needs to be aimed at the correct people. The NTS indicates that half of those in the upper two quintile brackets, in terms of income, have two or more cars, whilst nearly half of those in the lowest quintile bracket have no car (DfT, 2020f). In Norway those with more than one car were more likely to switch one to EV, retaining conventional vehicles for some trips (Holtsmark & Skonhoft, 2014). Those in the lowest income quintile are less likely to own a car but, where they live in rural areas with few transport alternatives, are more likely to have funding further restricted, through being required to own a car that they cannot easily afford (Mattioli et al., 2018). Of the growing number of those under thirty without a driving license, half potentially intend, at some point, to get a licence (DfT, 2020f) and hence need to be included in vehicle emission reduction strategies. Less than 1% of those without a license state that environmental concern was the main consideration for not driving (DfT, 2020f). Brand et al. (2017) point out that half of all new car purchases made in the UK are not made by individuals but by vehicle fleet managers and hence those responsible for large scale vehicle purchases can be particularly targeted in a push to increase adoption of EVs. Gnann et al. (2015) suggest that tax incentives specific to fleet managers would be an efficient way of boosting growth in EVs.

In assessment of policy relating to mode switch in powered vehicles, Rietmann & Lieven (2019) discuss regulatory restrictions, financial incentives and support in constructing infrastructure. There is some disagreement on the relative importance of these factors. Although Morton et al. (2017) note that the London Congestion Charge was positive in promoting EVs, Mersky et al. (2016) conclude that regulatory incentives are the least important in encouraging mode switch. A number of researchers state that financial incentives are the most important factor in terms of mode switch (Ystmark et al., 2016; Rudolph, 2016) whilst others state that a charging network is of more importance (Sierzchula et al., 2014; Nie et al., 2016).

Regulations can be introduced to incentivise EVs over conventional vehicles through imposing parking or road lane access restrictions, such as allowing EVs to drive in bus lanes. These incentives were part of the relatively successful push to introduce EVs into Norway. There is, however, doubt about the effectiveness of such policies, with both Zhang et al. (2016) and Mersky et al. (2016) stating, after analysing sales across several municipalities, that bus lane access did not contribute to EV growth.

Financial incentives can be introduced by national government in terms of cash purchase rebates or tax exemptions and Figenbaum et al. (2015) state that successful diffusion of EVs in Norway has been the result of continued use of a rebate scheme. Early adopters are eager to take up new technology as they see it as providing a social and symbolic boost (Schuitema et al., 2013; Noppers et al., 2015). Brand et al. (2017) indicate that they are hence prepared to pay a premium for new technology, estimated as being about £3,000. Pettifor, Wilson, McCollum, et al. (2017), however, indicate that societal majorities view new technology as risky and, if given a choice, would only make a switch between conventional vehicles and EVs if they receive a financial incentive, estimated to be about £3,000, increasing to over £10,000 for those sceptical of new technology. They indicate that financial premiums, applied to new technology, by societal majorities, reduce over time and eventually reach zero, as new technology becomes embedded into society, but remain high for new technology sceptics. Risk premiums, however, can increase by thousands of pounds if vehicle range or charging times are perceived to be insufficient (Hidrue et al., 2011) but could be reduced in hybridised vehicles, where options are available to use both conventional and electric technology in the same car (Nazari et al., 2019).

Rudolph (2016) states that those who already make low emission and active transport choices are likely to see significant discounts on EVs as a reason to switch to driving, increasing the numbers of cars on the road. He further argues that applying financial incentives, to switch between conventional vehicles and EVs, is socially unjust, as it only allows those who are already wealthy to purchase more goods. Glaister & Graham (2006) state that although road pricing is primarily used to deal with congestion problems, it could also be used to deal with environmental problems. They, however, point out that road pricing, in the form of fuel duty, is already in place and it is likely that additional financial restraints would only be justifiable in a few urban centres. Santos (2017) points out that use of fuel duty, to discourage conventional vehicles, is inefficient because elasticities between distance and price are small and that blanket duties are regressive and disproportionally target the poor who have no alternative to a car. Gnann et al. (2015), however, indicate that fuel prices may have an important role in early diffusion of EVs and estimate that a 25% increase in fuel prices would double uptake of EVs in Germany between 2015 and 2020. In any taxation system a balance needs to be sought between revenue generation and revenue reduction brought about through applications of exemptions (Fazeli et al., 2017). Use of financial instruments in order to promote or restrict particular vehicle types also needs to be justifiable to electorates (Brand, Anable, et al., 2013).

Assessment by Lieven (2015), over 30 countries, indicates that charging network density provides a good correlation to EV sales and hence a policy to support constructing EV infrastructure appears to be justified. Mersky et al. (2016) state that, in the most developed EV market in the world, in Norway, the surge in purchases in 2011 coincided with the Norwegian Government's policy to build a network of charging stations. They, however, point out that it is not clear whether the presence of the charging network induced purchases of EVs or is only a result of increases in EVs sales. A study undertaken by the National Renewables Energy Laboratory, in the USA, indicates that awareness of the presence of a local charging station network is an important factor in generating a positive view of EVs (Singer, 2016, p26). In addition, assessment by Hidrue et al. (2011) indicates that increased range and reduced charging time were the most important factors in how much customers were willing to pay in purchase of EVs. However, Bjerkan et al. (2016) state that less than 5% of people rate the presence of infrastructure as the critical factor in purchasing of EVs with over 80% of people rating monetary incentives as the most critical factor. Noel et al. (2019) argue that range anxiety, due to the perceived absence of charging stations, is mainly a psychological reaction, that should be managed through communication and Weldon et al. (2016) note that once EV purchases have been made, drivers adjust routines without significant problems to fit around charging. In order for EVs to be initially considered as a purchase option, Lieven (2015), however, concludes that introducing charging networks to promote EVs is an absolute necessity and both Shi et al. (2020) and Yu et al. (2016) indicate that, to ensure continued EV diffusion, charging networks need to be subsidized so that they grow ahead of EV purchases.

The roll out of EVs in Norway indicates the critical role of national government. Review of literature, however, indicates that local authorities also have an important part to play in introducing EVs. Assessments indicate that, whilst costs and available funding are likely to be the final determinant in purchase of alternative vehicles, risk premiums increase without the presence of large-scale infrastructure. A necessity for increased incentives is, therefore, associated with the absence of conspicuous charging locations. Local authorities thus have a role in ensuring that infrastructure improvement initiatives occur.

Public and para transport mode

A study by Hayden et al. (2017) indicates that most people are aware that cars play a big part in creating climate change and that there is a requirement to reduce use of cars. A switch to alternative travel modes and a lower use of cars does not only reduce greenhouse gas emissions, it also directly reduces traffic accidents, congestion, community severance and improves air quality, energy distribution and individual health through greater mobility (Whitelegg, 2016, p28). Kenworthy (2018) suggests that, due to trip leverage, every extra alternative travel kilometre, generated through mode switch, saves 3.6 kilometres of vehicle mileage. Alternatives to cars also have the capacity to have greater occupancy rates leading to more efficient transport (Alam & Hatzopoulou, 2014). In addition consolidating passengers means that introduction of low energy transport systems is more easily accomplished (Salvucci et al., 2019). Mode shift, away from private cars, can be to a variety of alternatives encompassing public transport (trains and buses) and para transport (minibuses and taxis) (Sloman, 2010). These alternatives are owned by local or commercial enterprises, or by government organisations, and those using the system are charged a fee per trip made, as opposed to use of private car, where individuals make trips in vehicles that they personally own or control (Foxx, 2019).

In the UK the population has a poor perception of some forms of public transport, with people interviewed in Birmingham as part of a study by van Soest et al. (2019), regarding public transport as expensive, crowded, unreliable, slow and dirty. The study did, however, indicate that, in those areas of the city where more positive views of the public transport system were held, there was greater use of the system. The study, however, acknowledges that it is not clear whether a more positive view of public transport results in greater use of the system or is a consequence of greater use.

Public and para transport costs consist of vehicles, operators and fuel, together with infrastructure where dedicated system track is required and these costs need to be covered by fees charged by system users, together with available subsidies and, where commercial enterprise is running a system, also need to generate a profit (Desaulniers & Hickman, 2007). Large scale systems, such as high-speed rail, involve millions of pounds in investment and operation and generally require significant government involvement, whilst medium systems, such as bus networks, still involve hundreds of thousands of pounds in operation costs but are generally sized such that they could be run independently by a local company or a local authority (Wolmar, 2016). Small scale public transport, involving a few small vehicles, such as taxis or minibuses, can be operated on budgets involving only tens of thousands of pounds and, hence, can be run by individuals or small businesses (Brake et al., 2004). Wang et al. (2015) indicate that, in low density rural environments, a demand responsive public transport system, operating with a small number of vehicles, within a flexible pickup and routing niche, may be a practical alternative to use of private cars.

In the UK, buses and trains, outside London, are run by licensed and franchised companies with government subsidies making up a significant part of their income (Bowman, 2015; PTEG, 2013). In general bus and train operators set their own timetables and fares (Butcher & Dempsey, 2018). As set out in the 2008 Local Transport Act, in large metropolitan areas, such as Merseyside and Greater Manchester, the presence of local transport executives gives local government some greater powers over bus and train fares and timetables (HM Government, 2008). The 2017 Bus Service Act allows local authorities to enter into quality partnerships with local bus operators to plan new services, however, the final say on introducing new services remains with the bus operator and the act does not allow a local authority to set up its own bus service (Butcher & Dempsey, 2018). Taxis and other small transport systems, defined in terms of having less than 8 seats, are operated under local government license that allows some control of vehicles used (The UK Rules, 2021). In addition, regulations allow for local government or other local organisations to set up community transport systems, on the basis of non-profit operation, in order to serve particular groups who are excluded by current transport regimes (Davison et al., 2014). The Local Government Association (2017) note that regulation of taxis is a crucial aspect of local authority powers and one lax authority may allow poorly regulated vehicles to operate over a whole region.

Reduction in fares may increase passenger numbers but the elasticity relationship, between fares and passenger numbers, generally means that profits fall if fares are reduced (TRL, 2004, p15). There is a tendency for public transport operators to increase profits, by increasing fares and allowing a decrease in passenger numbers (Local Government Association, 2020b). Conversely, assessment by Zhang et al. (2006), of interventions that could be used to optimise use of public transport systems for the city of Preston, suggest that a halving of fares is required. It is, therefore, indicated that running public transport systems as commercial operations may not be compatible with a desire to increase ridership.

For small transport systems, local authorities have some scope to change licensing requirements and, as taxis are associated with high mileage and hence rapid fleet turnover, an immediate licensing change could result in rapid system change (Langbroek & Hagman, 2020; Gawron et al., 2019). The restrictions on operating buses mean that the powers of local authorities, to change medium transport regimes, are limited. For large infrastructure schemes, local authorities may promote projects but can be left waiting for their preferred schemes to be approved. Docherty (2000) records the frustration of Merseyside local authorities, waiting for their preferred rail schemes to be implemented, but notes that introducing regional mayors may provide greater capacity to engage in national policy.

Data on changes in rail transport are available within DfT public transport statistical datasets (DfT, 2020o). This data shows that, in the last ten years, rail use has grown by about 3% per year (Table TSGB0603 (RAI0103) (DfT, 2020n)). There are, however, regional variations in these increases, with the UK Office of Rail and Road regional data (Office of Rail and Road, 2020) indicating annual growth of greater than 5% in Cheshire and less than 1% in Cumbria. In addition, DfT data shows that national rail infrastructure in Manchester is reaching capacity. In the last ten years Manchester stations have, on average, recorded 2.4% peak overcapacity, as opposed to only 0.1% peak overcapacity in Liverpool (Table RAI0209 (DfT, 2020n)). However, Manchester is at the centre of a separate metro system that has seen increase in use by over 10% per year since 2010 (Table LRT0101 (DfT, 2020n)). This data indicates that, with adequate investment, it is possible to increase local patronage of both heavy rail systems (as achieved in Cheshire) and light rail systems (as achieved in Manchester) by at least 5% a year. This is equivalent to a 30% increase in capacity over 5 years and a 100% increase over 15 years. However, given long planning periods, associated with rail schemes, there is likely to be a significant delay before passenger numbers can be significantly increased in areas where capacity is currently growing slowly.

For bus travel, DfT public transport statistical data shows that bus use, outside London, has, over the last ten years, been reducing by about 2% per year (Table BUS0203 (DfT, 2020n)). Buses can be used for both short intracity trips and longer intercity trips. They are hence more flexible than rail and in their 2013 report on bus feasibility the association of Passenger Transport Executives called them the “backbone of public transport in our regional cities” (PTEG, 2013, p1). They go on to state that the bus network sees three times the use of the national rail network and that investment in buses is beneficial to local economies, as it provides transport links for those without cars. The bus hence allows those who experience mobility disadvantage to contribute to their local society, as opposed to becoming isolated and excluded. Examples of bus initiatives include the scheme described by Yajima et al. (2013), where reorganisation of routes in a small city, to better match passenger aspirations, together with introducing an on demand minibus service, resulted in an increase in bus use of over 30%.

Introducing alternatives to private cars, in the form of public and para transport, represents an important element of a policy package and may provide more equitable travel options for poorer parts of society. Where control of alternative transport systems is wholly within the control of enterprises, whose goal is to maximise profit, financial elasticities indicate that increased ridership will not be a priority. However, successful local investment in systems such as the Manchester Metro has shown that increased use of public transport can be achieved. For local authorities to improve use of public and para transport they need to have powers to improve local transport systems and the financial resources necessary to supply infrastructure.

Active travel mode

In a study by Ralph et al. (2020), 60% of people stated that they would consider walking to a destination involving a trip less than 1 mile (1.6km). In the study, reasons given for not walking related to having to carry items, such as shopping, looking after children or the elderly and lack of time. The study also identified that those choosing not to walk were also put off by their overestimated perception of distance and time, their perception of the safety of walking, their perception of excessive exertion and their habit of not walking. In a study by Swiers et al. (2017), the main barriers to cycling were noted to be weather, safety and lack of cycle friendly facilities. The NTS (DfT, 2020f) records that the average trip length in the UK, by walking, in 2019, was 0.7 miles (1.1km) and this average has remained the same over the last twenty years. The average trip length by cycling is recorded, in the NTS, to be 3.3 miles (5.3km) and is reported to have increased by 40% over the last 20 years. The NTS records that 24% of trips made in the UK are less than 1 mile (1.6km) and 68% are less than 5 miles (8km).

The NTS indicates that 42% of the population own, or have access to a bicycle and this rises to over 70% for those under 16 (DfT, 2020f). The Local Government Association (2020a) states that less than 5% of UK trip distance is by active travel, 21% of people in the UK cycle regularly and if most short trips could be made by cycling, there would be a 23% reduction in transport greenhouse gas emissions. As active travel represents zero emissions per kilometre and has additional benefits over travel by powered vehicles, in terms of increased health, a mode shift to active travel is seen as of significant benefit for the country (DfT, 2020d, p8). In terms of the percentages of trips that are made by active travel, there are large differences between countries. In the UK less than 2% of trips are made by bicycle (DfT, 2020f), whereas in Germany and Sweden 10% of trips are made by bicycle and, in Denmark and the Netherlands, this rises to 18% and 23% respectively (Pucher & Buehler, 2008). Van Goeverden et al. (2015) indicate that, to achieve high active trip levels in the Netherlands and Denmark, 20 years of campaigning and support, through infrastructure construction, were required.

Many studies of the effect of infrastructure and marketing campaigns on cycling have been undertaken in countries including Canada (Zahabi et al., 2016), New Zealand (Keall et al., 2018), Australia (Heesch et al., 2015) and Spain (Cole-Hunter et al., 2015). These studies indicate that intervention can have a significant effect on local cycling percentages. Investment in cycling infrastructure in 18 towns between 2005 and 2011, as part of the UK Cycling Cities and Towns and Cycling Demonstration Towns programmes, showed, on average, over 20% increase in cycling (Sloman et al., 2017). Sahlqvist et al. (2015), however, report that two thirds of increased cycling traffic only relate to leisure use and does not necessarily replace other transport modes. Review of several studies by Forsyth & Krizek (2010) indicate the importance of provision of new infrastructure in conjunction with marketing and visibility of initiatives. The importance of good infrastructure design, in a pleasant environment and project visibility were reiterated by Sahlqvist et al. (2015). Wardman et al (2007) indicate that marketing campaigns on their own might produce small changes in cycling but, in conjunction with well designed infrastructure, these effects are doubled or tripled. Yang et al. (2010) state that intervention without new infrastructure is of limited benefit. Félix et al. (2020) report that extending and connecting cycle infrastructure, in the city of Lisbon, increased cycling by 350% and introducing a bike sharing scheme increased ridership by another 250%. Cervero et al. (2019) hence argue that a wide range of interventions are required to promote cycling in UK cities.

Barriers identified, relating to increased cycling, include distance to destination, especially for non-leisure related cycling (Wuerzer & Mason, 2015; Heesch et al., 2015), safety (Rossetti et al., 2018), number of intersections (Buehler & Dill, 2016), existing car ownership (Wuerzer & Mason, 2015), elevation (Cole-Hunter et al., 2015), route crowding (Vedel et al., 2017) and weather (Swiers et al., 2017). Assessment of preferences by Caulfield et al. (2012) indicates that perceptions of safety means that cyclist prefer segregated cycle lanes and assessment by Wardman et al. (2007) indicates that, where segregated cycle lanes are provided, they are likely to induce 50% greater cycling activity than non-segregated lanes. Forsyth & Krizek (2010) note that segregated lanes may not, on their own, be safer than non-segregated lanes, as intersections are the most dangerous part of any cycle trip, but they further note that the evidence is poor and that segregation is likely to have a positive effect on perception of safety. Cole-Hunter et al. (2015) note that barriers to cycling, relating to elevation and distance, would be significantly reduced by the use of e-bikes and the UK Local Government Association (2020a) notes that high levels of active travel have been achieved in Scandinavia, where weather and elevations are similar to those present in the UK. However, it should be noted that those who take up cycling may be mainly drawn from public transport, hence active travel increase may only marginally reduce use of cars (Wardman et al., 2007).

The UK Government has recently launched a new cycling initiative (DfT, 2020d). The Government report that the new strategy will involve setting up a new Active Travel England organisation who will oversee the development of mini-Holland schemes in 12 local authorities, with emphasis on robust connected new infrastructure. Given that there are over 300 local authorities in the UK, 12 schemes, however, represent less than 5% of the total and a great deal of time and effort in preparing bids (Urban Transport Group, 2020). In their 2017 guidance the DfT state that, in an urban setting, local authorities should aim at a network where all individuals are within 1000m of cycle routes and ultimately that this distance be reduced to 400m (DfT, 2017b, p18). For a small city such as Warrington, covering an urban built up area of about 4,500 hectares (Nomis, 2011c), relating to a nominal city diameter of about 4.0km, this equates to about 25km of cycleway increasing to about 50km.

Another resource that has been prepared to allow local authorities to assess the potential for improvements in local cycling percentages is the ‘Propensity to Cycle Toolkit’ (PCT, 2020). The toolkit takes commuting and travel to school data, from the 2011 census and extrapolates targets for each local authority ward across the country to illustrate benefits relating to health and reduced transport greenhouse gas emissions. Potential impacts vary across the North West of England as illustrated in Table 4.9, for example urban and rural areas.

Table 4.9 – Active travel mode percentages indicated in Propensity to Cycle commuting scenarios (PCT, 2020)

Travel mode	Urban ward Warrington 011	Rural ward Wyre 006
2011 census	5%	2%
Gender equality	8%	3%
Government targets	11%	4%
Go Dutch	35%	15%
E-bike	39%	20%

Table 4.9 shows the large potential impact of e-bikes. E-bikes are bicycles that have electric assistance in pedalling and are legally treated the same way as other bicycles on the road, provided that they can still be propelled with pedals, that they are limited to 15.5mph (25km/hr) and that they have no more than 250 watts of power (HM Government, 2020a). The DfT 2020 cycling and walking strategy calls e-bikes “hugely important” in delivery of its goals (DfT, 2020d, p39). A study by Cairns et al. (2017) indicates that those loaned e-bikes in Brighton drove cars by 20% less and cycled, on average, 15 to 20 miles a week. A 250 watt electrically assisted bicycle is typically associated, for a 10km trip, with 100 watt hours of electrical energy (Electric Bikes, 2012) relating to 0.01kWh/km, as opposed, as shown in Table 4.8, to 0.05kWh/km for an electric motorbike or 0.20kWh/km for an electric car.

Assessment indicates that there is a large potential for increased active travel. The active travel regimes present in the Netherlands and Denmark indicate that such a potential can be realised. However, despite UK Government stated policies (Wardman et al., 1997), over the last twenty years little progress has been made (DfT, 2020f). Local authorities can take up the challenge associated with imposing a societal change in use of active transport, with all the associated societal advantages. They need the training and funding to deliver this change. There is significant potential for use of new technology, in the form of e-bikes, in delivery of this new transport regime. In newly constructed small centres, such as Vauban in Germany, through use of car restrictions, a travel regime that is primarily based around active travel can be achieved (Minh, 2016). The slow rates of redevelopment in the UK means that historical lock in of travel patterns around cars can, however, reduce the potential for active travel and, where development continues to lock in a preference for car mobility, negligible progress in promotion of active travel will continue (Wardman et al., 2007; Johansson et al., 2016).

In large cities, where populations are concentrated, active travel may be an option, but is restricted by design and layout in outlying suburbs (Frank et al., 2003). For small cities distances to central facilities may be less, but, where populations preferentially use facilities in neighbouring larger communities, it is again difficult to encourage active travel (Meijers & Burger, 2017). In rural areas the scope for active travel is more limited, as trips tend to be longer, however, if local facilities can be improved then short trips using active travel regimes can be encouraged (Ao et al., 2019). There is hence a role for local authorities in promoting active travel, through constructing local high quality infrastructure in conjunction with development and support of local facilities. In large high density cities and in new travel friendly developments, where local facilities are already present, a lifestyle, without a car, may be practical (Tallon & Bromley, 2004). In existing small cities there may, however, be greater challenges relating to promoting active travel (Mouratidis et al., 2019).

4.5.4 Purpose interventions

In parallel to mode switch potentials, stewardship interventions can be targeted at specific travel purpose categorisations. In this section purpose interventions relating to work, education, leisure, shopping and freight are discussed. The main tool of these interventions is the travel plan, applicable to work, educational and local holiday sites. For new construction all local authorities have the power to impose travel plans on developers. Enoch (2016, p(xii)) states that travel plans provide a mechanism for delivery of local mobility management policy for the benefit of users in a partnership between local government, operators, businesses and the users themselves.

Review of 20 work plans, by Cairns et al. (2010), indicates that plans applied to newly constructed large city sites achieved emissions reductions of greater than 60%, whilst plans applied to existing sites achieved less than 20% emissions reduction. The review showed that for new sites in suburban areas reduction potential was about 50% and between about 10% and 15% for existing sites. Rye et al. (2011), however, note that, when implemented, travel plans have tended to be forgotten as results have not been monitored. One particular work stewardship intervention tool that has been introduced in the UK, by Nottingham Council, and is under consideration by some North West of England councils, is the workplace parking levy. Dale et al. (2019) report that application of a levy, on provision of private business parking in Nottingham, is associated with a reduction in car commuting and has also financially supported development of alternative local tram and bus systems.

For educational settings, review of school travel plans by Hinckson & Faulkner (2018) indicates emissions savings of 5% to 10%. They note that plans take two to three years of continued application to achieve full results. Review, in New Zealand, by Hawley et al. (2019) indicates that establishment of well-developed local community initiatives is required in order to allow pupil active travel rates to approach and exceed 50%. This emphasis on a community wide active travel ethos is also discussed by Goodman et al. (2019), who use the 'propensity to cycle' (PCT) website to evaluate the impact of an environment in which active travel in the UK is viewed in the same positive light as it is in the Netherlands. Their assessment indicates that the PCT Go Dutch initiative could result in a tenfold increase in school active travel, from current rates of less than 5%, to new rates approaching 50%.

The NTS indicates that, for an average member of the public, 40% of all distance travelled consists of leisure activities (DfT, 2020f). These activities constitute the largest section of a local travel regime, but, as noted by Brand & Preston (2010), are the least understood and the least easy to control. However, they state that leisure activities are closely related to other activities. Kenworthy (2018) argues that reduction in car use for commuting, education and shopping, can lead to reduction for all personal activities. Hence, mode switch and purpose reduction initiatives will also have some impact on day-to-day leisure activities. In addition, if holiday destinations are required to adopt travel plans, then local initiatives, similar to those applied in educational and business settings, can be adopted (Enoch, 2016, p80).

As noted by Cairns et al. (2004) one significant set of stewardship interventions is that associated with support for home working, shopping and leisure activities. Increased home and local activities can result in a fundamental reduction in travel. The rise of internet services in industrialised areas of the world has meant that, for a large proportion of the population, physical commuting is not always necessary. The impact of Covid 19, on working from home, is illustrative of this potential. Analysis on the impact of the pandemic on home working in Australia, by Beck et al. (2020), indicates that about half the working population could work remotely for a substantial proportion of their work week. The analysis indicates that experiences of working from home were generally positive, with about half of those who worked from home, during the pandemic, indicating that they might continue to avoid commuting. If this increase in home working continued to be realised it would potentially double working from home rates, from about 15% to about 30% and be associated with a saving of over 10% in commuting trips. Increased working from home is, however, specifically associated with rebound effects, as those confined to a single location are more likely to increase distant leisure activities (Cerqueira et al., 2020). Those working from home are also more likely to live in more rural areas where longer trips are required for educational and shopping activities (Cerqueira et al., 2020). Stanek & Mokhtarian (1998) suggest that community teleworking centres could further encourage home working. These community facilities could provide a working environment away from family distractions and home office restrictions. Community teleworking centres could be provided through local stewardship interventions and Bieser et al. (2021) argue that they could also reduce rebound effects associated with a single location lifestyle.

Stewardship interventions relating to shopping are complex. To assess transport greenhouse gas emissions relating to a shopping trip, an assessment is required of how a product moves from a supplier to a consumer via a shopping enterprise. Assessment of shopping is hence integrated with optimisation of freight movements and optimisation of the freight/shopper movement matrix is difficult (Rotem-Mindali & Weltevreden, 2013). At one extreme is the supermarket who have efficient integrated supply chains but rely on many shoppers travelling to their location to pick up goods. At the other extreme is a system of online shopping, direct from a supplier to a home consumer, bypassing the shopping enterprise. This alternative system can, however, lead to many additional freight trips as each individual product is delivered to each individual household. In between these two extremes is a system of small local shops, each with their own supply chain, but associated with short consumer shopping trips. Analysis, by Rizet et al. (2010), indicates that, in current systems, the integrated delivery chain established for large supermarkets off sets savings that can be made by local shopping. However, their analysis does allow some conclusions to be made. Long supply chains involving purchasing of goods from remote locations, such as apples from New Zealand, will inevitably lead to high emissions, whatever the shopping system used. In addition, consolidation of movement of goods within the supply chain is beneficial in reducing transport emissions. Carling et al. (2015) suggest setting up of local community pick-up points, within walkable distance for all customers, to which retailers can deliver goods in bulk. They calculate that this system can reduce shopping transport emissions by over 80%. A move to local supply of goods, where this is practical, can also shorten supply chains and reduce the need for regional freight transport.

In rural areas local interventions can have a significant impact on shopping emissions. Shoppers in rural areas are associated with fewer local facilities and are hence required to make longer trips to source local goods. Support for rural community shopping initiatives, in association with local community transport initiatives, can, therefore, improve local economic activity and significantly reduce trip distances (ORCC, 2013; Plunket Foundation, 2020).

Discussion of shopping interventions leads to a consideration of freight stewardship interventions. Cossu (2016) argues that, in large urban areas, freight consolidation centres have the potential to reduce local LGV emissions by 10%. Aditjandra (2018) asserts that, in large cities, where traffic control systems are put in place, similar to those used in London, reduction in local freight movements of 50% can be achieved. Reductions in regional HGV freight movements are more difficult to achieve. HGV movements are associated with national distribution of goods. A move to local supply of goods may be associated with some reduction in HGV movements. To assess the potential for local stewardship interventions an understanding of the relative proportions of different goods carried by UK HGVs is required. Domestic road freight statistical data indicates, in terms of tonne kilometres, that only about 18% of HGV goods moved on UK roads are food products (Table RFS0105 (DfT, 2020b)). The remaining goods consist of; raw food and mineral supplies (17%), manufactured metal, wood and chemical products (27%), waste products (13%), mail and parcels (3%) and other mixed loads including unidentifiable loads (22%). The data shows that 12% of UK HGV movements are associated with the North West of England (Table RFS0121 (DfT, 2020b)) and that, of freight movements starting in the region, about one third are delivered to addresses within the region and two thirds end up in other areas of the country (Table RFS0123 (DfT, 2020b)). A reduction in food movements of 50% would, hence, only relate to a reduction in regional HGV movements of less than 10%. As over half of domestic HGV freight is associated with the bulk movements of raw materials, goods and waste products, a more substantial reduction in HGV movements would require a fundamental shift in UK economic systems. In review of emissions associated with HGV movements in Ireland, Whyte et al. (2013) conclude that these are closely associated with national economic activity and that more detailed studies of this relationship are required in order to understand how HGV emissions might be reduced.

4.5.5 Interventions review summary

This transport intervention literature review can be used to draw some conclusions relating to the necessary policy pathways that can be applied to the region. The review indicates that many different interventions are available. Application of isolated policies, particularly those that do not impose specific restrictions, are unlikely to result in significant regime changes. Significant changes will result from an imposition of multiple policies including those involving restricting inefficient transport systems and promoting alternatives. Policy is, however, being implemented against a background of continued traffic growth. Assessment indicates that in large cities there are signs that continued growth may be plateauing but outside these areas this regime appears to be continuing.

Whilst some interventions relating to rebates and tax incentives for different types of cars may be outside the control of local authorities, there are still many policies that are within local authority control. In large urban areas congestion charging or equivalent emission zone restrictions are proven policy initiatives. Local pedestrianisation is also an option. Outside large urban areas there is, however, less potential to impose such initiatives. Restrictions placed on use of cars should be balanced by improvements in use of appropriate local alternatives. Local alternatives can include metros in large cities and buses in small cities. Both these can be supplemented by active travel regimes. Local flexible transport and improvements in local facilities can also play a part in more rural communities. Significant change is associated with alteration of societal norms. Local authorities, hence, have a crucial role in explaining and championing interventions to gain support from local populations.

Interventions to reduce emissions in freight vehicles play an important role in local authority policy packages. Local freight systems in urban areas have the potential to significantly reduce LGV movements. The potential to reduce HGV movements is, however, less clear. Control of freight movements in more rural areas is also more difficult to implement. However, support of local shops and offices may be an effective policy in these areas.

In the short-term implementing local travel plans can have an impact on travel regimes. Again, this impact is more pronounced in large cities. Local travel plans can directly affect work and educational trips and can also be used, directly and indirectly, to reduce the number of leisure trips using conventional vehicles. In the long term a significant shift away from a car culture can only be brought about through a societal shift in values. Constructing infrastructure to support alternative transport regimes is, however, an important component of this value shift through persuading local populations that car alternatives are necessary and practical.

4.6 Chapter summary

In the critical review of literature covered in this chapter, the hierarchy in which cities in the North West of England exist is described, and an assessment of this hierarchy is presented. The vertical and horizontal governance framework in which local authority transitions occur is outlined and it is noted that city size and hierarchy affect how power is exercised within this framework. Community transport regimes are discussed and the importance of distance is highlighted. It is argued that, although substantial and rapid changes in city layouts are not practical, there are many potential interventions that can be implemented to alter local transport regimes. The review highlights that local authorities have an important role in altering regimes, through promoting low emissions transport and restricting conventional transport. This role is again affected by city size and hierarchy. In Chapter 5, interviews with local authority planners are reported in the context of these results. The interviews aim to further define how city size and hierarchy affects ability and motivation of different cities to develop and implement transport greenhouse gas reduction policies. This investigation is undertaken to explore the knowledge gaps defined in Chapter 1, relating to constraints on development and implementation of policy, from the viewpoint of local authorities.

The review highlights the importance of reaching global and national cumulative emissions targets to restrict rises in global temperatures and the importance of avoiding delays in implementation of policy to reach these targets. The review describes the balancing of risk, equity and practicality that is associated with defining cumulative emissions budgets with principles behind the UK Government's interpretation of Paris Agreement commitments outlined. It is argued that the Government target broadly relates to a per capita apportioning of global emissions. The review has, however, also described alternative interpretations of the Paris Agreement, defined on the basis of greater emphasis on equity principles. Different cumulative emissions budgets, associated with alternative interpretations of the Paris Agreement are thus presented. In Chapter 6 local authority capabilities, to reduce greenhouse gases, are investigated. This investigation is undertaken to explore the knowledge gap relating to a matching of local actions to regional, national and global cumulative emissions targets, in the context of different interpretations of the Paris Agreement.

The next chapter describes interviews undertaken with local authorities to investigate motivation and ability, in developing and implementing intervention policies, based on the background defined in this literature review.

CHAPTER FIVE – LOCAL AUTHORITY INTERVIEWS

5.1 Introduction

In this chapter, systematic analysis of interviews undertaken with local authority planners responsible for transport, is described. The interview topics, introduced in Chapter 2, have been assessed in terms of three main themes: **ability**, **pathway** and **landscape**. Themes have been chosen to explore how each local authority characterises their motivation and ability to reduce transport greenhouse gas emissions, in the context of Objective 3 of the research; to investigate the relationship between local authority characteristics and ability and motivation to deliver transport greenhouse gas reduction policies. As noted in Chapter 1, this objective is, in particular, associated with investigating small cities. As noted in Chapter 4, ability and motivation of small cities are best understood in terms of their position in a regional hierarchy. In assessments, outlined in this chapter, local authority characteristics are, therefore, investigated with reference to their location within the hierarchy of the region.

The relationship between themes, categories and subcategories is shown in Figure 5.1.

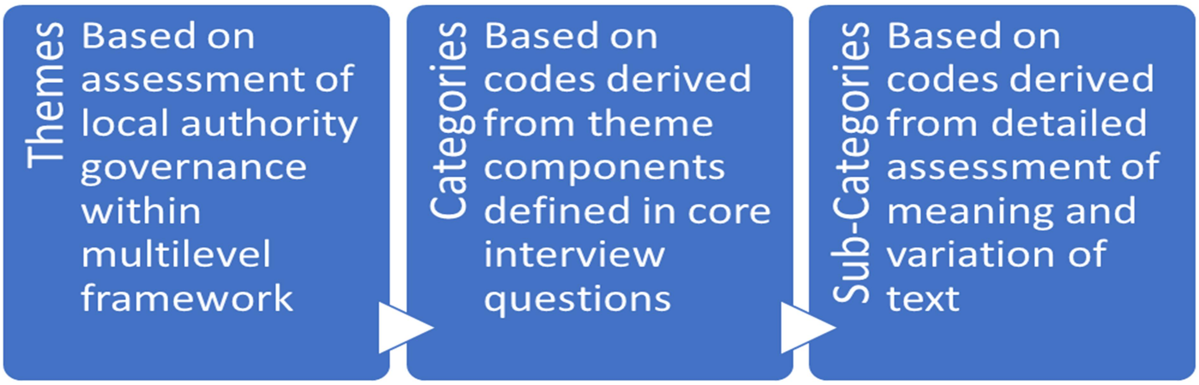

Figure 5.1 – Relationship between themes, categories and subcategories used in analyses of interview text

As shown in Figure 5.1, and discussed in the methodology outlined in Chapter 2, themes focus on the policy development niche represented by local authority internal governance systems and, as described by Geels (2006), the exterior landscape in which these operate. In defining themes there is less focus on the wider societal social technical trends described in the transition model developed by Geels (2006). Category codes have been developed based on specific investigation components illustrated by the question structure used in interviews with local authority planners (Yates, 1998, p197). Where appropriate, grounded analyses of text, within categories, has been used to further define the main groupings of topics to allow subcategories to be defined (Yates, 1998, p201).

Themes and related categories are described in Section 5.2. The results of data collection and analysis are shown in Section 5.3. These results are then discussed in Section 5.4 and conclusions are developed. Key conclusions are summarised in Section 5.5. The analysis provides a mapping of ability, pathway and landscape, against governmental hierarchies, across the whole of the NUTS1 region of the North West of England, to enable an assessment to be undertaken of the effectiveness of policy in both large cities and small 'ordinary' cities. These mappings are used in Chapter 6 to assist and inform, the generation of transport greenhouse gas emissions reduction pathways.

5.2 Theme and category descriptions

The ability theme relates to direct answers to interview questions, to explore local authority planner's perceived ability to instigate reducing transport related greenhouse gas emissions. The pathway theme relates to the methodologies that each local authority planner envisages in reducing transport greenhouse gases. These themes relate to alternative lenses of policy investigation described by Marsden & Reardon (2017), based on assessment of policy either as a process (setting goals, followed by policy formulation, deliberation, implementation and evaluation) or as a set of individual components (goals, instruments, tools and mechanisms). The landscape theme investigated, relates to the language used by local authority planners throughout interviews to describe the internal and external landscape in which they perceived they are working, as described by Geels (2011).

Themes and categories are shown in Table 5.1. Derivation of categories is summarised in the remainder of this section.

Table 5.1 - Interview themes and categories

Theme 1 – Ability	Theme 2 – Pathway	Theme 3 - Landscape
GOALS	PRIVATE	BARRIERS
CHALLENGES	TAXIS	VIEWPOINT
PRIORITIES	BUSES	
RESOURCES	RAIL & TRAMS	
RESPONSIBILITY	WALKING & CYCLING	
CONSTRAINTS		
OPPORTUNITIES		
EFFECTIVENESS		
MONITORING		

Categories relating to **ability** consist of:

- GOALS – Category derived mainly from Questions 1 and 2, providing a baseline description of authority stance and background relating to transport greenhouse gas mitigation.
- CHALLENGES – Category derived from Questions 1 and 2, providing an interpretation of how the authority views the mitigation stance that they have adopted.
- PRIORITIES – Third category derived from Questions 1 and 2, together with Question 9, providing an indication of importance that the authority places on transport greenhouse gas reduction, relative to other authority goals.
- RESOURCES – Category derived from Question 3, together with Questions 5 and 6, relating to documentation utilised and developed by each authority to define formal policy. This category provides an indication of the knowledge and resource base available to the authority.
- RESPONSIBILITY – Category derived from Question 4 relating to the view of the authority on responsibility for greenhouse gas reduction. This category provides a further indication of the viewpoint of the authority in terms of the necessity of their own actions in defining and implementing policy.
- CONSTRAINTS – Category relating to the constraints expressed by the authority based on answers to Question 7. Answers to Question 17 also provide additional information on constraints perceived by each authority.
- OPPORTUNITIES – Category, based on Question 8, relating to positives that each authority recognise in greenhouse gas mitigation policy. This category provides a

contrast to the CONSTRAINTS and allows a comparison to be made between negative and positive viewpoints.

- EFFECTIVENESS – Category based on Question 15 and 16, relating to whether each authority thinks that zero carbon goals, relating to transport, can be achieved.
- MONITORING – Category, based on Questions 11 to 14, relating to setting of targets by each authority, providing an indication of resource allocation and commitment applied to problems associated with transport greenhouse gas emissions.

Categories relating to **pathway** are mainly based around Question 10 and Question 15 of the interviews but references to specific transport policy initiatives are taken from the whole interview. These categories provide an indication of pathways envisaged, or adopted, by each local authority in reducing their transport greenhouse gas emissions and achieving a zero-carbon transport system:

- PRIVATE – Category relating to use of private vehicles.
- TAXIS – Category relating to use of para-transport systems.
- BUSES – Category relating to use of local bus systems.
- RAIL & TRAMS – Category relating to use of public transport systems, other than buses.
- WALKING & CYCLING – Category relating to use of active transport systems.

Categories relating to **landscape** were chosen to illustrate the core mappings of decisions by local authorities in terms of barriers and viewpoints. As described by Geels (2012) the setting of goals and policy, and implementing these, are affected by the financial, cultural, political and social landscape in which decisions are made. Landscape categories were:

- BARRIERS – Category relating to emission reduction difficulties as directly described by local authorities in interviews. This category relates to the CONSTRAINTS category, within the ability theme, but also covers the broader views on inherent external barriers affecting decisions expressed by interviewees, both in response to specific Questions 7 and 8 and throughout the interviews.
- VIEWPOINT – Category based on specific outlooks expressed by interviewees, to provide an additional organisation description tool, based on how internal actors experience their workplace (Campbell & Gregor, 2008). This category was derived from all text developed from the interviews.

5.3 Interview analysis

5.3.1 Introduction

A key aspect of the research is comparison between authorities at the same and differing governmental tiers. The data collected does not justify a systematic statistical analysis of responses. However, in order to provide a background to grounded qualitative analysis, a simple quantitative count of responses has been undertaken as an initial analysis stage. McTigue et al. (2020) note that a relative ranking of responses is a useful tool in presenting and discussing results of qualitative analysis.

For each category, a three-phase assessment has been undertaken to build a systematic map for each interviewee and for each hierarchical tier within the local government structure. Firstly, the numbers of references are quantified to provide a basis by which to map the relative importance that each interviewee places on each concept. Secondly each textural phase is characterised in terms of positive, negative, or neutral opinion. An optimistic phrase, in terms of mitigation, such as “we want to do something good,” is classified as positive. A pessimistic phrase, such as “I don’t think there is a funding pot,” is classified as negative. Where phrases cannot specifically be characterised as positive or negative, such as “we are working closely with the county,” they are classed as neutral. The numbers of positive, negative and neutral phases are quantified to enable an outline assessment of net overall attitudes to be made. The third stage of the analysis relates to identification of key phrases, that appear to exemplify categorisation for each interviewee and each government hierarchical tier. Key phrases are used to allow subcategories to be defined and are also used to illustrate particular conclusions.

For each assessment category, a table has been compiled as illustrated in Table 5.2. For most categories, comments are available from all eleven interviews. Occasionally no particular comments relating to a specific category are apparent, or comments have been folded into other discussion categories, so that there are some categories where not all interviews are represented. Where relevant, comments made within the written response, received from the twelfth council contacted, have also been incorporated into tables. Each categorisation is followed by a discussion of results.

Table 5.2 – Interview category assessment

<table>
<tr><th>Authority type</th><th>Total comments</th><th>Comment positivity</th><th>Key phrases</th></tr>
<tr><td>Mayoral combined authority</td><td rowspan="5">Total numbers of comments associated with category or subcategory</td><td rowspan="5">Net assessment of comments in terms of positive, negative and neutral phrases</td><td rowspan="5">Key phrases that are illustrative of each category.</td></tr>
<tr><td>Metropolitan authority</td></tr>
<tr><td>County council</td></tr>
<tr><td>Unitary authorities</td></tr>
<tr><td>District councils</td></tr>
</table>

5.3.2 Ability theme

GOALS

Authority type	**Total comments**	**Comment positivity**	**Key phrases**
Mayoral combined authority	14	+3/+5	"Clean cities are progressive cities." "Great place to grow up."
Metropolitan authority	28	-6/+6	"Not a specific focus on carbon mitigation" "Hard to sell" "Huge amount going on"
County council	47	0/-15	"Very out of date" "Easier in Manchester"
Unitary authorities	22	-2/-6	"Not quite as straightforward" "Taking from government"
District councils	47	-2/-9/+3/-1	"No specific policy" "Declared a climate emergency"

The first questions asked within the interviews related to the image/goal that each local authority ascribe to, within their transport systems. Setting of goals represents the first stage of an images, tools and action model (Perrin et al., 2018). The goals represent the images on which tools (policy) and actions (practice) are set. Marsden & Bonsal (2006) argue that a clear goal can act as a catalyst in achievement of defined environmental targets. Barr (2004), however, notes that, in the field of environmental governance, there is often a gap between setting of goals and action taken.

Planners from the mayoral combined authorities immediately presented a clear set of optimistic goals relating to their transport systems and remained positive in all discussion of their goal setting. The messages associated with other local authority tiers were, however, more mixed and more negative. The metropolitan authorities, that acted within the mayoral governmental structure, did not share the positive views expressed by the mayoral departments. Although one authority stated that lots was going on, they did not share mayoral messaging. In the second municipal authority, discussion of goals initiated negative statements relating to greenhouse gas emissions within their transport systems.

Similar negative statements, in terms of goals, were associated with county councils, with policy goals being described as out of date and limited by circumstances. A comparison to the situation in Manchester and the perceived relative ease of change within the mayoral government systems, was repeated several times in several interviews. In discussion of goals, negative views were also expressed within the unitary authorities and for most part within the district authorities. Excuses in terms of the complexity and the relative responsibility in setting goals were made. The exception was one district council who had recently declared a climate change emergency and were positive and enthusiastic about their, hot off the press, initiatives.

CHALLENGES

Authority type	**Total comments**	**Comment positivity**	**Key phrases**
Mayoral combined authority	7	-5	"Growth and decouple later." "Get people into work"
Metropolitan authority	10	-9	"Amazingly low rates of walking and cycling" "Very, very hard sell" "Two hundred years in terms of layout"
County council	27	-13/-5	"Relying on market forces" "Manchester can run a franchise" "Fragmented – so fragmented"
Unitary authorities	9	-2/-6	"Priority is growth"
District councils	4	-3	"Reliant on Stagecoach"

The negative side of goal setting, covered in the early parts of interviews, related to the challenges that were perceived by each authority. The negatives were brought up again within the discussion of policy constraints. For some of the authorities, discussion of goal challenges and policy constraints, were merged and, hence, comments relating to goal challenges are not associated with every interview.

In discussion of goals the most common challenge brought up, at all authority levels, related to reliance on market forces and a growth agenda. For mayoral authorities, the growth agenda and requirements for running efficient city economic systems, was highlighted. It was stated that growth needed to be maintained, whilst undertaking transport greenhouse gas emissions reduction. Growth and market forces were also mentioned at county and unitary authority levels. At district levels challenges relating to working with market forces were highlighted, with reference to working with commercial stakeholders, outside the direct control of authorities.

Challenges mentioned, at this stage in interview discussions, also referenced practical limitations of existing population attitudes and existing infrastructure layouts. At metropolitan and county levels, greenhouse gas reduction ambitions were described as fragmented and hard to sell to local populations. The two authorities where these specific challenges were highlighted, presented the most negative perspective in terms of discussion of goals.

PRIORITIES

Authority type	**Total comments**	**Comment positivity**	**Key phrases**
Mayoral combined authority	22	0/+3	"We have big plans" "Massive priority" "No magic bullet"
Metropolitan authority	45	-12/+7	"We need economic growth" "Locally carbon negative but nationally carbon positive" "Lead by example"
County council	35	-3/-5	"One of many important issues" "Going the other way"
Unitary authorities	40	-1/-7	"Charging for parking not popular" "Lots of support for it amongst people under the age of 35"
District councils	63	+2/-4/-1/+1	"Embryonic" "Talking 15 to 20 years"

Discussion of priorities represents one of the most mixed in terms of interview category positivity. Seven of the twelve authorities contacted presented a negative view of their priorities, relating to reducing greenhouse gas emissions in their transport systems. The remaining five authorities presented neutral or positive overall views. None of the authorities, however, categorically stated that a reduced carbon agenda was their top priority.

At mayoral level one authority presented a neutral set of priorities, reiterating a growth agenda whilst stating that big plans were being made. The other authority presented a broadly positive set of priorities, stating that reducing greenhouse gases was a massive priority. Again, at metropolitan level a mixed set of priorities was presented with one authority stating that they wanted to lead by example whilst the second authority questioned whether they really needed to reduce their emissions, or if they could locally increase emissions and rely on other authorities to achieve mitigation goals.

The mixed messages, in terms of priorities, continued at county, unitary and district authority levels. A large number of comments were made indicating small positive, or small to medium negative, stances. Where negative stances were presented, this was balanced by acknowledgement that issues were important to the council and received lots of support from some areas of local communities. The practical limitations on setting and achieving policies were again highlighted with talk of these being embryonic and taking a long time to reach any conclusion.

RESOURCES

Authority type	Total comments	Comment positivity	Key phrases
Mayoral combined authority	32	+5/+5	"Very clear on clean growth" "Own strategy team"
Metropolitan authority	14	-3/+3	"Subject to finance" "I don't know" "Significant buy in"
County council	46	-3/-11	"LTP is a bit old" "Fighting for scraps" "Very dependent on funding"
Unitary authorities	47	-12/-4	"Looks disjointed" "Cannot bid for staff" "Added to their day jobs"
District councils	55	-6/-7/+4	"Can't think of any documentation" "Small team" "Limited funding" "Not spoken about LTP for a while" "Just keep banging on their doors" "Scant is probably the word"

The second part of the interviews related to the development of policy transition tools (Perrin et al., 2018). The first aspect of policy discussed related to resources and documentation. McTigue, Rye, et al. (2018) note that resource limitations and lack of clarity in documentation, represented the largest constraints on policy implementation for local authorities across the UK, particularly for small authorities.

For mayoral authorities, resources and documentation were not presented as obstacles to development of policy. It was stated that the authorities were able to present a clear policy through use of their own strategy teams. A difference in emphasis was, however, present between the two central authorities. One authority presented an emphasis on growth. The other authority placed an emphasis on an approach that crossed boundaries within the authority with greenhouse gas reduction “baked into everybody’s role” across the organisation.

For the metropolitan authorities, sitting beneath the mayoral authorities, a mixed position emerged. One authority stated that they had significant buy in through use of an authority steering group whilst the other metropolitan authority stated that implementing policy was subject to funding and requirements for specialist analysis meant that policies could not be developed in house.

The limits of in-house capabilities were reiterated by most planners outside the mayoral authorities. Transport planners were not familiar with UK documentation, relating to reducing greenhouse gas emissions, such as CCC reports. They also complained, in the absence of internal knowledge, they had to use outside consultants to develop policy, as bidding governance rules generally restricted use of funds for supporting new internal staff. These restrictions left authorities, at all levels outside mayor’s offices, with small teams, lacking knowledge, having to double up on jobs and lacking funds. To develop policy one authority described fighting for scraps and being very dependent on funding. Another authority described their development of policy as disjointed.

In terms of existing documentation, the authorities, that had recently managed to update their LTPs, were more positive than those authorities that still had LTPs in place dating back to 2011. Where new LTPs had been developed, transport planners were very familiar with the content and happy to discuss the different aspects of their emerging policy. Those authorities that had not updated their LTPs acknowledged that they were a bit old and had not been spoken about in a while.

Outside the mayoral and metropolitan authorities, the one district council who were positive, in terms of discussion of resources, stated they felt that a difference could be made and were prepared to keep “banging on doors” to achieve this. This was the district council who had recently declared a climate emergency. They, however, noted that their resources in developing policy were scant.

RESPONSIBILITY

Authority type	Total comments	Comment positivity	Key phrases
Mayoral combined authority	29	-1/+3	"All of the above" "Shared responsibility"
Metropolitan authority	24	-2/+3	"Everybody" "Central government needs to provide"
County council	17	-1/-5	"All have a role" "Unless government comes in hard with a fiscal stick"
Unitary authorities	37	-12/-2	"We all are at a very human level" "Can save polar bears or Londoners"
District councils	28	-9/-1	"Very much shared" "Isn't going to happen without money"

Discussion of responsibility, relating to development of local policy, revealed a common stance across all authority tiers. All authority planners stated that reducing transport greenhouse gases should not wholly be the responsibility of local authorities but should also be the responsibility of national government and local populations. Those authorities that made net positive comments, relating to responsibilities, also commented that they wanted to be trailblazers and to lead by example.

Authorities with a more negative comment balance, stated that central government needed to get more heavily involved in pushing policy and that talk of responsibility was redundant if funding was not provided. It was stated that councils could only deliver on policy if they were given adequate resources. It was also implied that there was an inherent bias against authorities outside the capital in that the government framed the debate in terms of "you can save polar bears or Londoners" and that if current government policy continued polar bear futures were not good.

References to the role of local populations included the statement that it was difficult to take action when people just chose to drive, and frustration was noted that local populations did not make more environmentally sustainable transport choices. It was stated that national government needed to come in with "a big fiscal stick", to bring about change in the attitude of local populations, but that this was unlikely to happen.

CONSTRAINTS

Authority type	Total comments	Comment positivity	Key phrases
Mayoral combined authority	11	-3/-1	"It's going to come down to cost"
Metropolitan authority	31	-8/-7	"Fascination with growth" "No capacity into Manchester" "Difficult to use public transport" "Cannot afford an electric vehicle"
County council	18	-7	"Geography is a challenge" "Struggles with austerity"
Unitary authorities	21	-14/-1	"Funding is the biggest challenge" "Promotion is difficult"
District councils	37	-11/-6/-8/-1	"Perception that going to cause all this disruption" "We don't have the engineers or the experience" "Resources both human and financial"

Constraints represent responses to interview Question 7, relating to policy implementation barriers. A more wide-ranging assessment of the viewpoint of each local authority, regarding the landscape of perceived barriers to setting of goals, developing policy and implementing actions, is contained in discussion of the landscape theme.

In response to the interview question relating to policy constraints, the mayoral authorities noted that cost represented the main constraint on ability to implement actions. It was also noted that mayoral powers were still emerging and under development and further work was required to bring together relevant stakeholders and that local authorities had lots of power in delivery of a low carbon future and needed to work together to achieve this end. One of the mayoral authorities stated, however, that achieving reduced emissions was also associated with changing people's behaviour, but that young people were already travelling differently.

The metropolitan authorities listed many more constraints. For one of these authorities the constraints were primarily associated with funding and resources available at local level, to allow designs to be delivered and to upgrade old and inadequate infrastructure. It was noted that rail capacity into Manchester remained a significant constraint for improvement of intercity transport flows. For the other municipal authority, the attitude of local populations represented the main constraint on delivery of policy, with people not taking responsibility themselves and just jumping into their car. It was stated that an answer could be found in upgrading and taking control of public transport, as current systems were inadequate and outside local control. It was, however, reiterated that presenting a choice to local populations was only part of the solution and people needed to be persuaded to make their own appropriate sustainable decisions.

For the county authorities, constraints were very much associated with large rural geographies, with it being noted that there was no feasible economic alternative to reliance on personal cars. To break this reliance, the role of government was stressed. The lack of power over bus franchises was also noted as a constraint, with a contrast made with the situation in Manchester, where the mayoral authorities had more power and influence over commercial bus companies.

The relationship between rural landscapes and cars and public transport was reiterated at the district council level. The car first mentality of local populations and their antipathy to change were highlighted. It was, however, noted that when well-planned local improvement schemes were introduced, they were embraced and used. At the smaller scale district councils, constraints associated with financial and human resources were emphasised. Designs involving complex interactions with existing infrastructure needed to be undertaken by outside consultants and could not be undertaken by in house teams. It was stated that authorities should not have to go bidding for necessary design funds, but that sufficient money should be available to allow in house designs to be undertaken. One of the planners stated that they did not know what to do to achieve reduction in transport emissions.

For the unitary authorities funding was also noted to be the biggest challenge, in delivery of reduction in transport emissions. Due to reduced budgets, design staff had had to be let go. With alternatives not presented to the public the authority stated that it was difficult to promote different travel modes. Again, a contrast was made with Manchester, where 24-hour buses were available, whereas locally it was difficult to catch a bus in a normal evening and impossible at night. Work to improve transport systems was described as an uphill battle with potential that progress could be undone by poor publicity. It was also noted that reduced control of schools had impacted on ability of local authorities to change transport systems.

In terms of the overall constraints, funding, complexity, political processes, population attitude and existing infrastructure were brought up at all levels of local government. Constraints relating to size and expertise were brought up at all levels, apart from at the level of the mayoral authorities.

OPPORTUNITIES

Authority type	Total comments	Comment positivity	Key phrases
Mayoral combined authority	19	+7/+2	"Strategic level body that can make decisions" "A lot of funding" "It's a commercial market"
Metropolitan authority	12	-2/+7	"Examples where it hasn't worked" "More and more stakeholders"
County council	10	+3	"Enhance the ability to escape"
Unitary authorities	13	+3/-1	"Good legacy systems" "Got a relationship"
District councils	14	+3/+1/0	"Lot of people round the table" "Very supportive politicians"

When questioned about opportunities available, most of the authorities interviewed gave positive answers but, even in this section of the interviews, net negative responses were recorded in two discussions. Negatives brought up during discussion of opportunities included examples of initiatives that had not worked and examples of conflicts that had occurred when trying to apply policy opportunities.

The mayoral authorities noted that they had inherent opportunities associated with being part of well-funded strategic level bodies. This size allowed these authorities to operate better in a political system where the government encouraged private companies. It was noted that, in this market, it was difficult for smaller individual local authorities to make achievements.

The more positive local authorities at both metropolitan level and district level stated that they had significant support and buy in, from local politicians for greenhouse gas reduction policies. This support allowed them to define appropriate overarching policy goals. Having a sustainable outlook was also noted as a positive for another local district council.

One opportunity common to several authorities related to having and maintaining good public transport infrastructure. In an environment where it was difficult to change and enhance infrastructure systems, having a head start allowed authorities to go further in promoting use of public transport. Another opportunity mentioned by several authorities related to ability to get stakeholders around a table. Ability to get increased numbers of outside parties engaged in policy development was seen as a positive. For one of the district councils, they were able to design and install electric vehicle infrastructure when they were approached and offered support by an external commercial company. Another district council, however, stated that there were no particular opportunities appearing.

EFFECTIVENESS

Authority type	Total comments	Comment positivity	Key phrases
Mayoral combined authority	69	0/+2	"No silver bullet" "Big question" "That became the norm" "Younger generation" "Brave action" "Put our economy at risk"
Metropolitan authority	66	-9/-16	"More political will" "We are poor" "Cultural change"
County council	78	-12/-16	"The market cannot deliver" "No agreed way forward" "Will still be buying cars in 20 years"
Unitary authorities	66	-2/-18	"Not got the scale" "Very small team" "Probably unlikely"
District councils	68	-8/-7/-3	"We don't have the expertise" "Bit of a challenge" "Terrified"

Questions about the final part of a governance framework (Perrin et al., 2018), relating to actions which could be taken by local authorities in order to reduce transport greenhouse gases, resulted in the greatest amount of discussion in most of the interviews undertaken. This may have been because these questions came towards the end of the interviews and at this stage interviewees wanted to make sure that they made all relevant points. Policy effectiveness in direct response to questions asked in interviews are discussed in this section. A wider assessment of reference to potential implementation pathways, taken from across all the interview, is covered in the pathway theme.

As with several other interview categories the mayoral authorities were the only planners who registered net positive comments regarding implementing policy. For all other authorities, the negatives outweighed the positives in relation to ability to change existing transport systems.

At the mayoral level it was acknowledged that there was no single straightforward means of changing existing transport systems. Solutions were seen as involving changing transport norms, taking a lead from the choices made by younger generations. New norms involved getting people out of cars. The mayoral authorities stated that they were prepared to be innovative to develop systems that allowed growth but delivered a low carbon future. It was noted that the ability to prepare strategic level regional plans had been lost when regional assemblies were disbanded in 2012. The newfound ability, for the combined authorities and Transport for the North (TfN), to prepare strategic plans, was, therefore, seen as a potential mechanism for bringing about significant change. It was, however, stated that policies would not be enacted that put local economies at risk and policies could not be enacted which directly contravened the wishes of local and national politicians. After the recent loss of a local congestion charging referendum, direct road charging was not seen as a solution, although indirect charging through introducing clean air controls was being considered.

Metropolitan authorities described lots of problems in implementing policy. One authority stated plainly that “we are poor.” This lack of funds, together with a lack of political will, were seen as fundamental constraints on implementing policy. It was stated that local developers had more power than local authorities. This was especially a problem in terms of public transport, described as being awful, and the importance of improvement in these systems was emphasised. Public transport needed to be fit for purpose, to provide an alternative option for local populations. However, it was stated that the opposite was occurring with more routes being axed.

For county councils a large number of negative statements were again made. The lack of government leadership to provide a landscape through which local policies could be implemented was highlighted. The strategic role offered by TfN was mentioned but it was noted that this role did not necessarily impact on short local trips. There was less mention of public transport and an acceptance that cars were part of the long-term solution. It was noted that the public transport network was not extensive enough to replace most car journeys. Problems relating to lack of investment were again highlighted, but, even where money was available, it was stated that there was no agreed way forward.

The unitary authorities again highlighted funding together with political support and will. It was also noted, in these smaller authorities, that economies of scale became important in terms of infrastructure and in terms of authority design teams. The difficulties in persuading local populations to change their travel behaviours were highlighted. This behaviour change was characterised in terms of transforming "hearts and minds" and noted to be a hard sell. The mindsets which may be present in younger generations was seen as a positive but an overall shift in public mindsets was stated to be the biggest problem facing an authority wanting to reduce transport greenhouse gas emissions. It was admitted that, within the current political, social, cultural and financial landscape in which these local authorities were operating, it was probably unlikely that decarbonising local transport systems could be achieved.

At the even smaller district councils more negative statements were made relating to the effectiveness of implementing policy. Worry was expressed that pushing developers to change their schemes to support alternative transport systems, would reduce viability and drive away investment. Existing public transport systems were described as "pretty shoddy." It was stated that planners were aware of issues associated with transport greenhouse gas emissions but did not have the expertise or the support to carry through plans that would significantly affect these emissions. The conclusion was again that decarbonising transport systems would probably not be achieved and that the prospect of having to alter systems radically, to bring about significant emissions reduction, was scary.

MONITORING

Authority type	Total comments	Comment positivity	Key phrases
Mayoral combined authority	18	+3/+1	"There are data sets that we look at" "Taking note of the proxies"
Metropolitan authority	13	-4/-1	"Have to google it" "Wouldn't know" "Outside our remit"
County council	31	-6/-12	"Messages which tick boxes" "Air quality more important"
Unitary authorities	4	-3/-1	"Only time would be funding"
District councils	18	-4/-3/-1	"Expect county to monitor" "Need some guidance" "Don't know"

The monitoring regime present relating to transport greenhouse gas emissions was the subject of three questions in the interviews but resulted in only a small amount of discussion. This is related to the fact that none of the current LTPs covering the region require authorities to specifically keep track of transport greenhouse gas emissions, although this data is available from BEIS (BEIS, 2020a). One mayoral authority conceded that they did look at some data sets and this was consistent with their stated overall policy to achieve a zero-carbon transport system. The other mayoral authority has also issued a commitment to reach zero carbon in the next twenty years but only stated, in terms of monitoring this transition, that they looked at a range of proxies.

For other authority tiers, there was little to say about monitoring of transport emissions. It was stated that monitoring would only be done if required for a specific proposal or it was assumed to be done by others within different parts of the authority. The most common answer to questions about monitoring was that it was not known what data was available and where to access this data. There was little awareness of what targets were. It was noted at the county council level that data was, in any case, skewed by motorway traffic and non-local vehicles, making it difficult to apply data to specific local authorities. It was, however, noted that extensive air quality monitoring was being undertaken by local authorities due to legal obligations associated with NO_x and PM levels.

Ability theme summary

Assessment of responses to interview questions indicates a substantial difference, in terms of ability to reduce transport greenhouse gases, between mayoral authorities and other authorities. For authorities outside of mayoral control, negative comments generally outweighed positive comments. Even for municipal authorities, where a direct relationship with mayoral authorities exists, more negative comments were noted.

For smaller unitary and district authorities, problems were highlighted relating to size and funding. For the larger county councils, problems relating to internal size were not as prevalent. However, it was noted that they controlled largely rural areas and, in this environment, it would be difficult to provide alternatives to use of private cars. For municipal authorities, the state of existing infrastructure and the cost of upgrading this system was highlighted. Outside large cities, reference was made, by several planners, to the fact that cities such as Manchester had big advantages, in terms of infrastructure and local public transport systems. It was also noted several times that the remoteness of national government and national politicians meant that insufficient appreciation of, and support for, local policies was present.

Overall, the authorities appreciated that reducing greenhouse gas emissions in transport systems was required and recognised that this represented a significant challenge. For the mayoral authorities, an overall strategy had been defined and was ready to be implemented, subject to financial support. For other authorities, the lack of funding and of overall political and public support, meant that policy had in general not been developed and implemented. Where local politicians provided local political support, more positive comments were noted but overall prospects for significant reduction in transport greenhouse gases were still reported to be low.

5.3.3 Pathway theme

The following section looks specifically at the mode shifts that are envisaged by each local authority to change their transport systems. Mode shifts are taken from assessment across the whole interview structure but are especially applicable to discussion around answers to Question 10. Total comments and positivity are tabulated, with positivity being taken from analysis of the net balance between positive, negative and neutral statements. Assessment is undertaken across all text associated with each authority type and, therefore, only one indication of positivity is given for each authority type. As this section covers more technical details of pathways considered by each authority, the numbers of neutral statements are relatively large and, therefore, positivity numbers are relatively small.

PRIVATE

Authority type	Total comments	Comment positivity	Key phrases
Mayoral combined authority	38	+4	"Switching everyone to EV is not the answer" "Clean congestion not an ideal" "Decouple prosperity from the car"
Metropolitan authority	51	-11	"Comes down to air quality" "Anti-idling campaign" "People make the choices"
County council	45	-11	"Car free future not achievable" "If people choose to drive" "Legacy of road builders"
Unitary authorities	63	-12	"Alternatives not there" "If you are in a city you get a train" "Flats wouldn't have their own space" "May be that EV is the solution"
District councils	41	+2	"People still using their car" "Enabling people to have an EV" "Juggle restricted parking"

Comments relating to private cars were more numerous than comments relating to other pathway alternatives. Comments related to discussion of getting people out of their cars and of a technological shift in current car fleets, to bring about widespread adoption of EVs. Assessment of net balance of positive and negative statements indicated that, the mayoral authority had a positive outlook in terms of a private car future whilst most other authorities, apart from one district council, had a neutral or negative outlook. The one district authority with a positive outlook was enthusiastic about new policies that they had recently initiated.

The main difference between mayoral authorities and metropolitan, county and unitary authorities, related to discussion of the prospects of reduction in use of cars. At the mayoral level it was stated that switching everyone to EV was not a full solution to problems associated with transport greenhouse gas emissions. It was noted that getting people out of cars was not straightforward because "people aren't logical" but a pathway for significant reduction in car ownership within large cities could be envisaged at this level, as younger generations embraced a car free life and prosperity became decoupled from car ownership. Mechanisms could be put in place, at this level, to reduce car ownership, through improved public transport and some car restrictions, in terms of parking controls and clean air zones. Use of an active congestion charge was, however, noted to have been currently ruled out in North West of England large cities. For authorities outside large cities, a future where stewardship could significantly reduce use of cars was much less clear. It was stated that alternatives to cars were not present and the question was asked “what about the rural areas?”

At the metropolitan level it was acknowledged that building new roads produced negative outcomes, in terms of increased traffic and increased congestion in other parts of the road network. However, it was stated that fears relating to the economic viability of local city centres meant that they were reluctant to impose any car restrictions and were sensitive to complaints relating to parking charges. It was acknowledged that there was potential for a stewardship approach as most trips undertaken by car were short. Some small initiatives were in place, in terms of anti-idling campaigns and home work encouragements, but no large scale initiatives to reduce use of cars were brought up.

For the county level authorities, there was even more emphasis on use of cars, as the areas these authorities covered were associated with longer trip lengths, than those in small district and unitary authorities, and they also dealt with more rural areas than the municipal and mayoral authorities. A legacy of road building was noted to have led to regional car dependency, that meant that the instinct of local populations was to drive. Without alternatives it was seen as difficult to address this car dependency. It was also noted that, in terms of national emissions figures, county councils were assigned a lot of motorway traffic, that they did not control. Again, some small schemes were mentioned including a promotion relating to taking car free holidays within regional national parks.

The unitary level authorities stated that alternatives to cars were not currently present. It was stated that people did not live close to their desired destinations and limited choices were available. A comparison was made with large cities where train system hubs were present. Against this, the car free alternative of a train system was not available in a small city. It was, however, recognised that congestion and city centre parking were problems for the local economy. At one of the unitary authorities interviewed, significant new plans were in place. They were in the process of updating their LTP and had plans to extensively improve bus route infrastructure. They had also undertaken local consultations relating to the introduction of a workplace parking levy. Consultation had not generated overwhelming support but had also generated relatively little negative comment. Younger portions of the population were more in favour of this proposal. A workplace parking levy involves charging employers within a city centre for each parking spot that they control. Dale et al. (2019) describe applying this concept in Nottingham in 2012 as being successful in terms of revenue generation and increased ability to invest in local transport infrastructure. They state that the scheme has improved the financial viability of Nottingham city centre and may have had a small impact on increased ridership of local public transport systems. They, however, note that in the UK, as of 2019, only Nottingham has introduced such a levy.

District councils similarly reiterated that cars represented the only transport option available for local populations, even though streets were getting choked. The impact of parking charges was discussed, but in general it was noted that parking fees were low and it was difficult to juggle desire to increase charges and fear of discouraging access to city centres. It was stated that the future did not involve discouraging cars.

Technology solutions to reduce greenhouse gases were discussed at all levels of authority interviewed. For mayoral and metropolitan authorities, representing large urban areas, a link was made between reducing greenhouse gas emissions and reducing NO_x and PM emissions. For the mayoral authorities, the possibility of taxing the dirtiest fuels was discussed. It was, however, noted that, where cars still existed, carbon emissions from brakes and clutches might always be a problem. For the metropolitan authorities it was only acknowledged that switching to EVs would also improve air pollution and that a national policy to reduce NO_x and PM would also influence adoption of alternative vehicle technologies.

The key aspect of a technological shift, highlighted in interviews with mayoral authorities, was the development of alternatives with a range that satisfied consumers. Responsibility for ensuring range improvements was stated to be outside the control of local government and within the control of national government and car manufacturers. It was, however, acknowledged that range anxiety dissipates once owners of EVs start using their car on a regular basis.

In metropolitan authorities, several doubts about a technological solution to transport greenhouse gas emissions, were expressed. The cost of upgrading electricity grids was seen as a significant constraint on adopting EVs. In addition, the limitations of home charging in terraced houses and flats were brought up. It was stated that charging from lamp posts was being considered but no effective system had yet been developed. In addition, the large cost of EVs was seen as a deterrent to local populations, who could not afford such a luxury. It was stated that local populations had to make a choice and local councils could help by making it mandatory that new developments had capacity to provide plug in points. The opinion was, however, expressed that, as local populations sat inside their cars, they did not have enough awareness of air quality problems and would only take notice if “cars had exhausts inside.”

In county areas the roll out of EVs was seen as important in greenhouse gas mitigation strategies. A solution was envisaged where all cars ran on electricity and the electricity was generated in association with zero emissions. Opportunities to introduce EV charging points, across the areas under the county council’s control, were being encouraged to alleviate local population worries about being stranded. It was stated that a lot was expected of EVs.

In the unitary authorities the question was asked as to whether EVs were the solution, in terms of transport greenhouse gas emissions. Worry was expressed about where charging could occur, particularly where flats were built that did not have their own designated parking space. The councils were investigating charging in car parks, that they controlled, in conjunction with necessities to upgrade electricity grids. Recent negative press associated with hybrids was mentioned as a deterrent in the purchase of EVs. This negative press related to recent claims in newspapers that hybrids had been purchased using tax breaks, but that electric modes had never been turned on, meaning that they were run exclusively as diesel and petrol vehicles, achieving no emissions savings.

The view of EVs at district council level was more positive. Local planners were generally placing a mandatory requirement on developers to install charging in new housing. The problems of charging, in association with terraced housing, were brought up, as an area where future consideration was required. The interviewees were positive, however, about their plans to introduce charging points in local car parks for use by the public. One council was particularly pleased, to be able to lead by example, by switching their mayoral vehicle to an EV.

In general, assessment of private vehicle pathways, indicates that for large cities, controlled by mayoral authorities, a greater emphasis was placed on stewardship. Discussion in metropolitan areas was more balanced, between stewardship and technology, but there were doubts about both mitigation routes. In the small cities, controlled by county councils, unitary authorities and district councils, there was more emphasis on technological mitigation. For all mitigation pathways, however, significant doubts were expressed in terms of feasibility.

TAXIS

Authority type	**Total comments**	**Comment positivity**	**Key phrases**
Mayoral combined authority	2	-	"Clean air zone for taxis"
Metropolitan authority	1	-	"Looking at taxi fleet"
County council	0	-	
Unitary authorities	3	+1	"Big opportunity for taxis"
District councils	2	+1	"Very strict taxi policy"

Relatively little discussion was recorded relating to para-vehicle alternatives to private cars, associated with use of taxis or demand responsive travel systems. At the mayoral level it was acknowledged that taxis would be affected by clean air zones and, at the metropolitan level, a review of taxi fleets was reported to be underway. At the county level taxis were not mentioned, although no questions, specifically relating to taxis, were asked. Only at the smaller scales, covered by the unitary and district councils, were significant references to taxis made, although local demand responsive systems were not bought up in interviews.

One unitary authority stated that they were in consultation with taxi drivers and saw big opportunities for local delivery of emissions savings, through conversion of the local fleet to EVs. A district council also reported that they had recently updated and tightened their taxi licensing policies, after it was pointed out that previous licensing rules had been unduly lax. Both councils were associated with initiatives in several other transport spheres and both were recorded as having relatively higher positivity.

BUSES

Authority type	Total comments	Comment positivity	Key phrases
Mayoral combined authority	11	+2	"Logically should be the bus" "Want to see reformed"
Metropolitan authority	17	-4	"Prioritize buses" "Taking more control" "More routes get axed"
County council	18	-3	"Tell us where to go" "City can run a franchise" "We cannot run buses"
Unitary authorities	28	-11	"Manchester see more buses in 10 minutes" "Limited influence" "There is a keenness for EVs"
District councils	18	+1	"Not very frequent" "Investing heavily"

Regional bus services were a significant theme of discussion in all interviews. It was stated, at all levels, that buses were an important part of local transport systems. Frustration was, however, expressed, again at all levels, that local authorities did not have adequate control of local bus systems. The 2017 Bus Services Act specifically prohibits local government from running bus companies, but allows authorities with mayors to set up tightly controlled franchising operations, rather than leaving service provisions within the control of independent bus companies (Butcher & Dempsey, 2018).

The mayoral local authorities wanted to see more use of buses but also wanted to see bus systems reformed. They were prepared to use the new powers that they had acquired, under the Bus Services Act, to adjust local systems, to try to boost numbers of the public using local buses. The most negative comments on local bus systems came at metropolitan, county and unitary authority levels. At metropolitan level, an investment in new busways was perceived to have been a success, but this was balanced by views that important bus routes were being axed and that there was no ability to run bus services on routes that served important parts of the city but had few passengers. At county level it was stated that bus companies had the power to "tell us where to go" when requests were made to upgrade routes. A contrast was made with the situation in large cities where buses were much more frequent and local authorities had more control. Despite reports of good relationships with bus companies, planners at unitary authorities also contrasted their small city bus services with those provided in large cities controlled by mayors. It was stated that in large cities buses came regularly, but in small cities fewer buses ran and evening and night-time buses were not run at all. Local populations were also reported to find it difficult to understand why their local authority had little control in terms of bus pricing and route selection. There was also a perception that buses were not safe. At district level a more positive view of buses was expressed. It was stated that significant investment in bus infrastructure had been made and good relationships with bus companies had been maintained, such that local urban bus coverage was reasonable. However, even at this level it was noted that new bus routes were required, particularly in rural areas and district councils were reliant on their local bus companies to supply services.

Across the interviews there was limited discussion around technological fixes associated with electrifying buses. Authorities were interested in the principle and keen to embrace an electric bus system but did not have controls that would enable changes to be made and, if they had controls, would not have the necessary funding. Only at mayoral level was progress reported, in terms of bus electrification. At this level government funding had been obtained and part of the local bus fleet was being converted. Some interest was expressed in the UK Government's proposed initiative for an all-electric bus town (DfT, 2020a), but as this only related to one town in the whole of the UK and would involve a competitive bid against over 300 other authorities, this interest was not large.

RAIL & TRAMS

Authority type	Total comments	Comment positivity	Key phrases
Mayoral combined authority	18	+3	"Effective mass transit" "Investing heavily" "Electrification is very sustainable"
Metropolitan authority	26	-9	"Looked into 12 years ago" "HS2 only deals with very few" "How awful the rail is" "I don't catch the train"
County council	29	-3	"No high capacity in rural areas" "Need electric trains" "Some good assets" "Trains which were a bit quicker and more reliable" "Virtually no control"
Unitary authorities	21	-5	"Not that economy of scale" "Rail is a nightmare" "We want those services" "More support amongst younger"
District councils	19	-7	"Need to bring new services" "Can't build a metro" "Public transport is pretty shoddy" "We need a train system"

Discussion of public transport, other than buses, revealed a consistent pattern outside the mayoral authorities. All authorities, outside the mayoral level, expressed negative views in terms of rail and tram systems, including the district councils who had been positive in terms of private cars and buses. At all authority levels three points were made. Firstly, the existing rail systems were described as poor. Secondly, a desire was expressed that rail upgrades be made to better connect their cities. Finally, it was acknowledged that authorities had little control of ability to bring about change in existing rail or metro systems.

Very negative wording was used to describe existing rail systems at metropolitan, county, unitary and district council levels, with phrasing including shoddy, nightmare, at the bottom and awful. These views were expressed because peak rail systems were observed to be overcrowded and off-peak rail services were noted to be infrequent or missing. Whilst some existing assets were described as good, it was noted that rail links, deemed to be necessary to make local connections, were absent. The consequence of this view was expressed by one interviewee who stated that although they could take the train into work, they had generally chosen to use a private car.

At all authority levels, outside the mayoral authorities, a desire to gain more rail connections was expressed. It was stated that more service and more rail connections were wanted, particularly with reference to rural areas. The legacy of previous cuts in rail services was referred to, together with historical emphases on building of roads, rather than railways, leaving car dependent areas of the region. A desire was expressed at all levels, including the mayoral authority, that electrification of rail systems be extended, as this was seen to reduce transport greenhouse gas emissions. It was, however, noted that spending large sums on intercity schemes such as HS2 would only benefit a few cities.

In discussion of their ability to bring about changes in rail systems, the smaller authorities again expressed negative views. It was stated that, for small cities, a lack of scale meant that it was not possible to build a local metro system. In persuading national government to provide new rail connections, or better infrastructure, it was noted that authorities had virtually no control. One authority provided an example of a local rail scheme, that they had been lobbying to be built for over ten years, that had been turned down several times.

The mayoral level was the only authority where positive views relating to rail systems were expressed. It was stated that heavy investment was ongoing in new train fleets to bring about greater capacity and better quality. One mayoral authority expressed the view that they had big ambitions for rail. It was, however, noted that capacity in some areas had been reached and it was difficult to bring about improvements. The new rail schemes proposed by the Northern Powerhouse (TfN, 2019), involving new connections around Manchester, were welcomed by mayoral and municipal authorities. It was, however, noted, at the municipal level, that these large schemes needed to consider potential local extensions that might improve local connectivity.

WALKING & CYCLING

Authority type	Total comments	Comment positivity	Key phrases
Mayoral combined authority	13	+4	“Investing money to support” “Really heavily involved in”
Metropolitan authority	28	+3	“Amazingly low rates” “Very hard sell” “Look at how the Dutch travel” “Just had the first Bee Line” “Children as ambassadors”
County council	22	+9	“Plan a bit old” “Large capital program” “Successful program” “Feel safe to cycle” “Centre for people not tin boxes”
Unitary authorities	21	-4	“Undone by one accident” “Go Dutch” “Schools no longer under control” “Get knocked down and wet”
District councils	20	+2	“Might attach walking and cycling” “Quite a high priority” “Accept some costing” “Biggest cycle way”

Discussion relating to walking and cycling generated the most positive statements, relative to any other transport systems. Local transport planners were knowledgeable and enthusiastic about walking and cycling potential. Only one unitary authority had a significant negative balance in their statements, although they did note that they had done a lot to develop local walking and cycling.

Walking and cycling were noted to be a high priority at most authorities and successful programs were recorded at all authority levels. It was stated that planners felt that they could ask developers to add some walking and cycling infrastructure to their schemes. It was also stated that successful walking and cycling schemes could make significant improvements to the lives of local people and allow city centres to act as places “for people not tin boxes.” The Propensity to Cycle website (Lovelace et al., 2017) and their local comparisons to Dutch levels of cycling, was mentioned several times, with an aspiration that local schemes could achieve equivalent cycling levels. It was stated, at district and unitary authority levels, that areas under their control were small and quite flat and hence ideal in terms of utilising active travel. The role of children was also noted, as those who were enthusiastic about walking and cycling and as those who could, as ambassadors, promote greater local participation.

Negative aspects of implementing walking and cycling schemes were also, however, mentioned by most authorities. Only the mayoral authorities did not mention any negatives, calling such schemes absolutely critical. At metropolitan level it was noted that existing walking and cycling rates were amazingly low and that implementing schemes, to improve these rates, was politically challenging and a very hard sell. At county level large capital programs were described but it was acknowledged that policy documents were a bit old. It was also noted that implementation was not always straightforward and battles with cycling groups had previously occurred. One interviewee acknowledged that they used to be a keen cyclist but had been put off by having several accidents. Perceptions that cycling might not be safe were also brought up within unitary and district council interviews and it was stated that even when progress was being made it could be undone by one accident. At district council level the difficulties of implementing an improved walking scheme were illustrated through description of a project that had attracted considerable kick back, but once installed, had been appreciated. The role of e-bikes in the future of transport systems was mentioned by several interviewees. One council had invested in several bikes to be used by staff. However, planners did not know how this initiative was progressing. In terms of the role children had in promoting cycling it was noted that historical successful school cycling schemes were no longer in place. This was because academy schools had been taken out of local authority control and were no longer interested in participation in local initiatives and local authorities had no power to impose such training.

Overall councils stated that they were really proud of, and enthusiastic for, walking and cycling policy and wanted to create schemes that allowed their local populations to “go whizz into the town centre.” They, however, noted that problems associated with interfaces with pedestrians on the pavements, and cars on the road, needed to be addressed.

Pathway theme summary

Pathway assessment indicates that large mayoral authorities were generally positive, particularly in relation to stewardship solutions. Their size meant that they could envisage a transport system that revolved around large scale public transport. They were also more prone to air pollution problems, associated with a dense network of roads. The legislative powers available to councils to control NO_x and PM emissions, hence, provided these authorities with further abilities to control local traffic. Smaller councils could not, however, due to their size (Wang & Lo, 2016), provide equivalent large scale transport systems. They hence acknowledged that, in general, local populations were car dependent.

Constraints hindering the development of changes to local transport systems were brought up by all smaller councils. The fact that councils did not have the power to control fares and routes of bus and train systems was emphasised in most interviews. Low quality of existing bus and train systems was, at the same time, bemoaned. There was also little discussion of technical changes to bus and train systems, in terms of electrification, as councils had no control over these aspects of transport systems. Within small cities, with long histories of industrialisation, it was also noted that, in areas with high percentages of terraced houses, limitations on the ability of residents to install personal charging systems represented a significant barrier to technical development associated with a roll out of EVs.

Where councils felt that they had control over local systems they were enthusiastic about making some changes. Hence, they were willing to talk about local encouragement of walking and cycling schemes in small cities, where an active transport regime was a logical alternative to a regime of short private car trips. However, even within this transport niche, a loss of control of school-based transport, through the academisation of local education systems, was seen as a significant loss of power. The school transport regime was viewed as critical in motivating a younger generation to use alternative transport systems and hence loss of power in this transport niche was viewed as a significant deficit in local authority control.

Smaller councils were prepared to implement some reactive policy, in terms of requiring local developers to, at least, provide potential to install charging infrastructure in local developments. The impact of ability to control local developers was, however, tempered by two factors. Firstly this reactive policy only related to new development and taking into account the slow pace of housing redevelopment in most small cities (Roberts, 2008), would, hence, in the immediate future, only affect a small percentage of future housing stock. Secondly the power of the small local authorities to enforce significant transport system requirements on local developers was reported to be limited by a fear of economic damage, that might be brought about by discouraging development.

5.3.4 Landscape theme

The final set of categories, derived and assessed from interview transcripts, relates to the landscape that the authorities operate within, as described by Geels (2012). This landscape is described partly by the external emission reduction barriers, as perceived by each local authority and partly by the overall internal viewpoint expressed by each interviewee. Based on assessment of comments, within these two categories, a series of subcategories have also been defined. Each of these barrier and viewpoint subcategories is discussed in the following sections. Barrier and viewpoint subcategories have initially been classified in terms of the ten-point landscape framework developed by McTigue, Monios, et al. (2018), as shown in Table 5.3. In subsequent discussion, of these subcategories, classifications have been split or merged to provide clearer descriptions of differences between authority tiers.

Table 5.3 - Barrier and viewpoint subcategories (McTigue, Monios, et al., 2018)

Framework number	Ten-point landscape framework.	BARRIERS and VIEWPOINT categorisation.
1	Policy documentation.	Mapped in RESOURCES under ability theme and also covered in Table 3.2.
2	Resource availability.	Mapped within BARRIERS categorisation in terms of resources, expertise and structure.
3	Internal structure expertise.	Mapped within BARRIERS categorisation in terms of resources, expertise and structure.
4	Organisation structure.	Mapped within BARRIERS categorisation in terms of resources, expertise and structure.
5	Economic, political and social environment.	Mapped within BARRIERS categorisation in terms of economic, political and social structure.
6	Policy champions.	Mapped within VIEWPOINTS categorisation in terms of commitment support.
7	External interactions.	Mapped within BARRIERS categorisation in terms of public, media and stakeholder interactions.
8	Internal interactions.	Mapped within VIEWPOINTS categorisation in terms of commitment approach.
9	Agenda interactions.	Mapped within BARRIERS categorisation in terms of agenda interactions.
10	External conflicts.	Mapped within BARRIERS categorisation in terms of public, media and stakeholder interactions.

In addition to the framework classifications, shown in Table 5.3, review of interview text revealed two further barrier subcategories. These are barriers relating to perceived inherent transport system complexity and associated with existing infrastructure.

BARRIERS

In assessment of barriers, as in previous sections of this chapter, total comments and comment positivity are initially tabulated, with positivity being taken from analysis of the net balance between optimistic, pessimistic and neutral statements. Assessment is undertaken across all text associated with each authority type and, therefore, only one positivity figure is given at each authority level.

BARRIERS

Authority type	**Total comments**	**Comment positivity**	**Key phrases**
Mayoral combined authority	33	-16	"Strong team" "Inherent complexity" "Risk that out of kilter with growth" "Rail network is full" "No silver bullet" "People complaining" "Successful in getting the funding"
Metropolitan authority	71	-68	"Hard to sell" "Very politically challenging" "200-year-old layout" "Definite lack of skills" "Not our area" "Can't keep that in house" "Forced to adopt cheapest standards" "That negative press" "Massively complex"
County council	84	-80	"Reality of aging population" "Funding has gone" "Huge geography" "Multitude of operators" "Fragmented" "Car free future is not achievable" "Over all political" "Public transport at the bottom" "Not going to build a metro" "Worried about getting stranded"
Unitary authorities	68	-66	"Not popular" "Random hotchpotch" "Disjointed" "Significantly less" "From requiring to encouraging" "Alternatives not there" "Difficult to sell" "Do not want to know" "Limited influence" "Just see the negatives" "Add on to their day jobs" "Difficult in terms of changing the way people behave"
District councils	69	-63	"Huge rural area" "Only way by car" "Do not have funds" "Team small" "Our hands are tied" "Hard nut to crack" "People might not want that" "Expensive to use public transport" "Talking for 15 to 20 years"

By their nature most references relating to barriers represent negative comments, though occasionally positive comments with relation to barriers were made such as "we've got the mass and we've got the budget." This was, however, only significant in mayoral authorities. In other authorities very few positive comments relating to the presence of decision barriers were made.

Resource, expertise and organisational structure

The mayoral authorities did not state that they were constrained by resources, expertise, or structure. In contrast they specifically stated that their size meant that they had a strong team with no resource or expertise limitations. Metropolitan authorities act under the umbrella of a mayoral authority system and have shared resources with the mayors, in terms of development of LTPs. However, municipal planning departments still stated that they were lacking in skills, funding and resources. The planning departments stated that they were not able to develop policy relating to reducing greenhouse gas emissions because they did not have knowledge or expertise. Without the means to even develop policy the ability to implement any mitigation schemes is restricted. They recorded that they have been cut "virtually to a core." However, despite this restriction, local planners at this level would like to see more powers available so that they have greater capacity to bring about change.

These sentiments were repeated at the county level where comments were made relating to the impacts of austerity, meaning that pots of money were not available for implementing policy. At this level, difficulties were described in association with working in a competitive environment, in which funding is only awarded once an effort is made to demonstrate a business case. Efforts were described involving cajoling of district councils to work together, under county council supervision, to bring together sufficient resources to complete a bid. Any plans that were made were limited by the need for money.

Unitary authorities do not share their resources with higher or lower tiers of government but are supposed to have integrated design teams that act across all aspects of local government. These authorities have still, however, being constrained by significant cutbacks that mean significantly less staff, having to double up on jobs and expertise. It was noted that integrated funding streams were not available, meaning that schemes were only fully developed when pots of money appeared, leading to a disjointed patchwork of policy development and implementation.

The smallest authorities, at district level, stated that they did not have experience or expertise, even if they did have funding available. They also stated that, in any case, without funding no significant actions could occur. In particular, it was difficult for technical designs to be completed. Councils had several policies in place for which they did not have an implementable design. Legal restrictions generally meant that it was not possible to bid for design staff, so project designs were left incomplete. In addition, within small teams, increased difficulties, associated with compiling bids, were noted. Within small areas and small populations, the scale of infrastructure that could be built was also limited and economies of scale could, therefore, not be realised.

In terms of resources, each of the authority tiers has particular barriers, that differ slightly in terms of scale, but all, except at the mayoral level, are constrained in some way. Austerity has led to cut back of staff and small teams mean that expertise is limited. Sharing of resources across authorities is seen as a method of bridging this barrier, but the effort necessary to manage sharing whilst trying to manage core activities, mean that limited cooperation exercises have been established. Where mayoral assistance is available for metropolitan councils, to develop documentation such as LTPs, the lower tier council do not necessarily see the benefit of this exercise and are still left feeling starved of resources.

Financial structure

At the mayoral level it was stated that entrenched deprivation of the region and the lack of integration of finance streams restricted the ability of, even the largest authority, to develop and enact policy. It was acknowledged, at the mayoral level, that lack of funding meant that individual authorities were limited in terms of the policy they could implement. It was, also, stated that mayoral authorities were not prepared to develop large scale transport greenhouse gas emissions reduction programmes that, through restriction on transport systems, could lead to regional economic risk.

The overall financial state of the region was also highlighted at the metropolitan level with a statement being made that the council was barely making ends meet. Where local greenhouse mitigation technology, such as an EV, is seen as a high cost item, it was stated that adoption by significant portions of local populations was unlikely. The low economic status of the local authority meant that developers had greater power to resist requirements for scheme specific local infrastructure upgrades and local authorities were forced to allow adoption of cheaper infrastructure options.

At the county level the disparity between different economic levels was emphasised in discussion of the differences between urban and rural areas. Rural areas were noted to be economically disadvantaged by their lower economic status. Again, it was emphasised that it was difficult to push developers, in terms of delivery of infrastructure, for fear of making projects unattractive.

The contrast between the large urban areas and smaller urban areas was emphasised at unitary level. It was noted that, in large cities poorer portions of society can live without a car, as public transport access is available to local facilities. In small cities this alternative is, however, not available and poorer residents are forced to run a car. The ability of developers to avoid imposition of restrictive planning conditions was again mentioned. This lack of financial control was also felt in terms of local public transport systems. One authority gave an example of a transport system that was technically under their direction but, due to legal operating restrictions, had to be run as a remote operation, with no control of routes and fares. As councils representing small cities, district authorities were also aware of their relative local economic status. Interviewees expressed a worry that local transport restrictions would lead to damage to this status, leading to a loss of local shopping income.

The economic picture described by interviewees was one of low financial status affecting the ability of authorities to enact policy, to make significant changes in their local transport systems. The ability to enact policy was further reduced in small and low hierarchical cities. As financial status reduced, the powers of developers and other stakeholders increased and ability to impose restrictive conditions, on these outside parties, decreased.

Governance structure

At most authority levels, assessment, in terms of numbers of comments made, indicates that governance structure represented the most significant development barrier. In particular, at mayoral levels and at county council level, where most significant governmental interactions might occur, comments made relating to political constraints outweighed other constraints. Across all levels of authority, a consistent set of comments were made relating to the political regime in which planners worked. National and local political framing was closely connected to funding and resource issues. Current framing was seen as creating restrictions on ability of local authorities to reduce greenhouse gas emissions. Authorities complained that legislative power was centralised in the UK and local governments were limited in the type and extent of interventions they were able to undertake. In addition, it was noted that, where authorities might be able to implement significant actions, they were not supported by national and local government. A clear vision of national policy was not presented by central government, making it difficult for local authorities to introduce contentious local interventions. National government was accused of abdicating their responsibilities. Support from local politicians was, equally, not always available for policy interventions that might significantly affect local transport regimes. The overall political environment was described by several interviewees as difficult, challenging and complicated.

Several interviewees also brought up a history of the political environment in which they were working. It was stated that historical decisions to break up local rail services had reinforced a national movement towards car dependency, that had not been subsequently challenged. A comment was made that, up until ten years ago, whilst regional development agencies were operating, strategic local plans were in place that included a carbon reduction agenda. However, this strategic agenda had been lost with the demise of the regional development agencies. Without a strategic regional plan, local policy directions were described as fragmented. Policies promoted within Northern Powerhouse strategies were not seen as applicable to an intracity local carbon agenda, but only related to the upgrading of transport systems between cities.

Free market policies that meant that bodies, such as schools and transport system providers, acted within the commercial sector, without local government oversight, were also noted as restrictions on ability to transition to low carbon transport systems. Without control of important sectors of their transport regimes, local authorities were not able to make system changes.

Agenda Interactions

Conflict between a carbon reduction agenda and a growth agenda were mentioned at all authority levels. This conflict was emphasised at the mayoral level with interviewees stating that a perception existed that carbon reduction strategies might be out of kilter with growth aspirations. This conflict was not implicitly stated at other authorities, but it was noted that, in all cases, local economic viability needed to be retained.

In contrast policy agendas relating to clean air were seen as complimentary to a carbon reduction agenda. Several interviewees noted that a drive to improve air quality, through reducing NO_x and PM emissions, could be used as a policy gateway to reduce transport greenhouse gas emissions. Legislative obligations meant that authorities were aware of their clean air commitments and were actively monitoring air quality and responding in terms of local schemes to divert traffic away from problem areas.

Public conflict

The attitude of the public in relation to greenhouse gas emission reduction was brought up at all authorities. At metropolitan authority level it was the most mentioned topic in relation to mitigation barriers. It was also particularly high on the agenda in discussion with unitary and district council planners. The metropolitan, unitary and district councils, hence, appeared to be more aware of local population viewpoints and more wary about cutting across these.

At mayoral level it was noted that they needed to take into consideration complaints from local populations. It was, however, pointed out that complaints were not always logical. In particular, planners indicated that they took into consideration the fact that local populations did not like paying tolls.

A perception of difficulty associated with a public viewpoint was put more forcefully at the metropolitan authority level with a statement being made that people did not accept that issues were present. Messages were not always clear and lots of misunderstanding and misconceptions had occurred relating to climate change issues. Reluctance of local populations to accept change was seen as a major hurdle, in delivery of low carbon transport systems. In the end, it was stated that to reduce transport greenhouse gas emissions, established local habits needed to change. However, public attitudes made actions that might affect local behaviours a very hard sell.

At county level the problems associated with car dependency were emphasised and it was stated that it was difficult to get people out of cars. Difficulties, associated with car dependency, were particularly apparent for rural populations. In addition, councils had little control over the actions of visitors and those passing through their region. Local population attitudes were characterised as problematic. Hence, a future, where significant reduction in use of cars occurred, was difficult to envisage.

The challenges faced by a situation where local populations found it difficult to get their heads around climate change issues, were reiterated at unitary council level. Where low carbon choices were present it was stated that these were not utilised. When presented with alternatives to cars, local populations only saw the negatives, such as dangers associated with public transport and active travel. It was stated that measures that discouraged cars created ill feeling and specific measures, such as charging for parking, were seen as unpopular. Local populations needed clear and concise messages to allow change to occur, but cutbacks meant that information campaigns were difficult to organise. It was concluded that it was “very, very difficult” to change the way people behaved.

At district level planners needed to take into consideration that some initiatives might be disliked. It was noted that local populations might be quite traditional and resistant to change. They were also described as being car dependent and, hence, presentation of options, that made it difficult to use a car, was challenging. An example was given of a local scheme that introduced restricted parking and had been ignored and had to be reversed. There was a fear that local restrictions might drive populations away from local businesses.

Several interviewees mentioned perceptions held by local populations relating to EVs. It was noted that EVs were seen as expensive items that they could not afford. Local populations also viewed EVs as lacking the range they needed. The negative press associated with diesel vehicles, after emissions scandals, relating to false reporting of performance by car manufacturers (Brand, 2016), was, also, stated to be detrimental in debates concerning climate change issues.

Assessment of comments, relating to conflicts with the public, indicates that planners have significant reluctance to implement policy that they perceive to be contrary to the wishes of local populations. Investigations of the interactions between planners and local populations, by Noland et al. (2017) and by Ryan (2006) indicate that both groups tend to hold similar attitudes. Hence, in order to initiate change in policy, attitude shifts are required at levels associated with both professional planners and local populations (Bicalho et al., 2019; Van et al., 2007).

Media conflict

Interviewees only made a small number of references to the media. At mayoral level, the press was seen as a tool through which lots of publicity could be generated. However, where press was mentioned at other authority levels, it was described as negative and as creating difficulties in passing messages on to local populations. Hence, authorities outside the mayoral level had not managed to harness local press to present their viewpoint, where it might be different from that of the local populations. They were instead reactive to the negative views of the local populations expressed through local press.

Stakeholder conflicts

At mayoral level it was noted that, even with all the extra powers possessed by a metro mayor, the authority does not control all local public transport systems. At municipal level, the need to engage with a large number of stakeholders was highlighted. In particular, difficulties in engagement with rail and bus operators were emphasised. Despite a local authority desire to improve public transport systems, local planners had little power to affect local rail and bus systems. These local systems were seen to be poor in quality and to, therefore, represent significant barriers to change in transport systems. These concerns, relating to lack of control of and lack of influence on bus and train operators, were reiterated at county, unitary and district level. Whilst authorities can construct bus infrastructure, they have little control in terms of fares and timetables. For rail systems the authorities cannot even construct infrastructure and their promotion of local rail schemes has not been perceived as being successful. Locally championed rail schemes were noted to have been turned down multiple times or put “on the furthest backburner.”

Inherent complexity

The inherent complexity of transport systems and the mechanisms that govern the changes in these systems, was brought up, as a barrier to change, at all authority levels. At mayoral level local transport systems were described as inherently complex and it was pointed out that there was no magic bullet available to enable systems to change. The fact was also brought up that, within a large region such as the North West of England, transport was the responsibility of many local authorities and other stakeholders. At municipal level problems associated with transport systems were described as massively complex and as not a simple equation. County planners again described problems as complicated and stated that there was no agreed way forward. They also pointed out that the scale of the region meant that physical geography limited actions that might be taken. At unitary authority level it was noted that change was not straightforward and at district level complaints were made about goalposts being moved. At one district council, it was, however, stated that local geography may assist in provision of sustainable transport systems. Where negative comments were made relating to the complexity of transport system mitigations, these were generally illustrated by concerns about lack of funding, resources and political and popular, acceptance. However, it was implied that, even if these other barriers were removed, the inherent complexity of the issues involved would still present a significant barrier to reducing local transport greenhouse gas emissions.

Existing Infrastructure

It was pointed out, by one local planner, that the city in which he worked had over 200 years of existing infrastructure which could not be changed quickly without significant investment. Barriers relating to infrastructure were again brought up at all authority levels, particularly in large urban areas controlled by mayoral and municipal authorities and in the smallest areas controlled by district councils.

The capacity of the existing grid was brought up at mayoral and municipal level. At county level it was noted that existing development layouts had been created at a time when cars were assumed to be the main mode of transport and hence settlement layouts tended to lock in car dependency. The fact that existing infrastructure was geared to cars was brought up again at unitary and district council levels and it was stated that, as a consequence, people did not live close to where they had to work. The problems associated with adjustment to transport systems, where terraced housing or flats were present, was brought up at both municipal and district level. The sizes of areas that had to be serviced by transport systems was brought up at county and district authority levels. Infrastructure barriers discussed by various authorities represented practical constraints associated with authority size, layout and history, each peculiar to a specific location.

Barrier category summary

Assessment of comments relating to barriers revealed a common set of issues brought up by most authorities. Financial and political structures tended to receive the greatest number of comments. After these the attitude of local populations was seen as of the most importance. These three barriers generally made up over half of all comments at all authority levels. Existing infrastructure, authority size and expertise and the inherent complexity of transport systems, received fewer comments. Conflict with other agendas and conflicts with media and other stakeholders generally received the fewest comments.

At mayoral and county levels greater emphasis was put on political and financial system barriers. However, at municipal levels, problems associated with the attitudes of local populations were emphasised. Governance systems, and to a lesser extent local population attitudes, were also at the forefront of comments made at unitary council level. At district level governance systems and local infrastructure problems were given equal weight. Although, at all other authority levels size and expertise were noted to be significant barriers, these issues were not brought up at mayoral level.

VIEWPOINT

Comments relating to viewpoint are tabulated in terms of total numbers and net positivity, for each local authority. Assessment of interview questions against ability and pathway themes and against the barrier category, tended to indicate similarities between different authorities at the same governmental level. However, assessment of viewpoints indicates substantial differences between similar mayoral, municipal, county, unitary and district authorities. In assessment of this category a viewpoint net positivity count has, hence, been included for each local authority interviewed.

VIEWPOINT

Authority type	Total comments	Comment positivity	Key phrases
Mayoral combined authority	34	+21/+11	“Successful prosperous cities” “The right thing to do” “Quite clear” “Be that trailblazer”
Metropolitan authority	40	-3/+32	“Not a specific focus” “Locally carbon negative” “We have a passion” “Very keen” “Lead by example” “Members endorse”
County council	45	+15/-11	“Doing our best but not easy” “Very important to us” “People really sceptical” “Frustrated” “High level ambition”
Unitary authorities	37	+7/-10	“Fashionable this month” “Quite frightening” “Frustrating” “Do something good” “Make this a better place” “Hoping that everybody else does” “Political buy in” “Probably unlikely”
District councils	45	+1/+3/+12	“Do our best” “Terrified” “Scary” “Have to present that as evidence” “We are aware” “Doing a lot” “Want to make a difference” “Very supportive politicians” “Probably not is the truthful answer”

Comments were categorised as viewpoint if they contained expressions of how interviewees experienced issues relating to reducing transport greenhouse gas emissions (Campbell & Gregor, 2008, p40). These experiences are characterised by use of emotive terminology, such as expressions of fear or pride. Where emotive terminology has been noted in interview transcripts it has been mapped into the viewpoint categorisation.

A first stage in assessment of viewpoint categories was to investigate whether there were any specific strands within the categorisation that could be used to further delineate interviewee experience. To allow definition of subcategories, analyses of text was used to establish each of the main viewpoint groupings expressed by planners in their discussions of this category. Grouping of text around these aspects allowed subcategories to be defined that illustrated different components of viewpoints expressed within each interview. On this basis, assessment of viewpoint comments indicates that five subcategories can be defined. These relate to:

- Commitment to the issue.
- Approach to this commitment.
- Support for this commitment.
- Language relating to this commitment.
- Consequences of this commitment.

The commitment subcategory provides an indication of individual and organisational investment in policy to reduce transport greenhouse gas emissions. The approach subcategory provides an insight into the way individuals and organisations are likely to manage this. Support provides an indication of organisational backing. Language describes how interviewees expressed their viewpoint and hence provides an indication of individual and governance entity commitment strength. Finally, through expression of the consequences, interviewees presented a viewpoint of their vision of the future, taking into account the challenges, constraints, opportunities and barriers, that had been described over the course of each interview.

Commitment

At mayoral level both authorities expressed a clear commitment to achieve a zero-carbon transport system. One authority, however, caveated their commitment by stating that they also did not want to give up on a growth paradigm.

At municipal level there were significant differences in commitment and related net positivity, in terms of greenhouse gas reduction. One authority stated that carbon mitigation was not a focus and that they might be aiming at locally increasing their emissions, on the basis that they needed to expand from an existing low level of development. The other authority, however, stated that greenhouse gas emission reduction was absolutely a priority and the council would be “doing their bit”. It is worth noting that a local increase in emissions, to allow development, is not entirely against the spirit of the Paris Agreement. The agreement does allow for differing approaches based on degree of development (Bates, 2015). This differing approach is, however, contingent on all parties to the agreement equitably achieving restrictions, in a transparent manner, such that local and global budgets are met (Bretschger et al., 2018).

The two county councils also exhibited significant differences in terms of viewpoint net positivity. Both councils presented limited statements of commitment to future zero-carbon transport. The more positive of the councils stated that they were keen to promote such policies and that their overall strategy extensively mentioned such a commitment. The more negative authority also stated that they had high level ambitions that had been integrated into overall policies.

At unitary level there were again large differences between authorities in terms of net positivity. Within interviews both authorities did, however, give some commitment to reducing greenhouse gases. The more positive authority stated that a commitment was something that they wanted to be seen to be doing and the second unitary authority stated that a commitment was clear from policies. The more positive authority did, also, tie their commitment to the wider community by implying that they were acting because of the wishes of their local population.

Of the four district level authorities contacted, three were generally neutral in terms of net positivity, whilst the fourth authority made significantly more positive comments. The district authority, that only provided a written answer to queries, stated that they did not have any policy as they did not see transport greenhouse gas reduction as their responsibility. The other neutral authorities stated that they would do their best and that emissions reduction was where they wanted to go and also acknowledged the incredible importance of such issues. These negative and weak commitments can be contrasted by the more positive authority, who declared that they were committed to a climate change emergency and were doing a lot of work with lots of initiatives.

Overall, only the mayoral authorities and one of the municipal authorities gave strongly worded commitments to reduce their transport greenhouse gas emissions. Most of the other authorities stated that they had some ambition, through policy declarations, to take some action. Of the twelve authorities contacted, only two did not provide any commitment. The more negative of the municipal authorities stated that they were more intent on other policies and the district council that only provided a written response to queries, stated that they did not see transport greenhouse gas emissions as their responsibility. The level of commitments was mostly correlated with the overall viewpoint positivity of the authorities, although the more negative unitary and county councils still made some commitment to greenhouse gas reduction.

Approach

Approach taken by each authority, in terms of their stated commitment, is the second viewpoint subcategory. For the mayoral authorities, approaches were characterised as involving big ambitions and with brave actions that were clearly mapped out. One authority specifically stated that they wanted to be a trailblazer. The position of the mayoral authority as a lead for other municipal authorities was, therefore, emphasised.

At municipal level, the more positive authority stated that a huge amount of work was going on and that they were leading by example and committed in going forward. The other municipal authority, however, only stated that reducing greenhouse gases was one of the benefits to their general policies and that they did not know specifically how policy might affect local transport systems.

The county councils were more circumspect about their approaches, in terms of viewpoint assessment. The more positive authority stated that they were aware of carbon issues and keen to foster links and to help the environment. The specifics of their commitment were, however, not spelt out beyond the fact that they thought that such a commitment might be a holiday selling point and that investment included changes to vehicles under their control. The more negative authority stated that they were trying to tip the balance and considering radical policies, but that they had to face many challenges, in an environment where many people were sceptical. Negatives expressed in both interviews, hence, reflected an appreciation of difficulties inherent in reducing transport greenhouse gas emissions.

At unitary council level, the more positive council stated that they wanted to make a better place and that there was a will to change, although there were obvious difficulties. They caveated their approach by noting that their commitment was based on a hope that everyone else was also doing their bit. The comments relating to approach in the second unitary authority were, however, more negative, with references to local populations supporting fashionable policy and comfort blankets. They did, however, state that they tried to be proactive and parts of their low carbon infrastructure were the envy of the country. Although the two authorities differed in their positivity, both emphasised the difficulties inherent in a transport decarbonisation commitment.

Finally, within interviews at district level the two more neutral authorities stated that they wanted to do their best and would take an evidence-based approach. The authority, that only provided a written answer to queries, only stated that they had no responsibility or control with relation to transport policy. The remaining authority, however, spelled out that they were aware that they had lots of work to do and were looking at everything and needed to tell lots of people and were not sticking their head in the sand. This proactive commitment approach lifted them above the other councils in terms of viewpoint positivity.

In terms of approach, there was generally a correlation between viewpoints expressed and overall authority positivity. Particularly positive authorities were those that stated that they wanted to lead by example and be proactive in their approaches. The more negative authorities stated that they would be reactive to change and emphasised some of the difficulties that their approach would face. The most positive, in these terms, were the mayoral authorities. However, the most positive district council also expressed a proactive viewpoint, in terms of approach, although without having outlined the details of a specific plan.

Support

The third aspect of the viewpoint category, investigated in this section, relates to support given for policy at a local level. As shown in Table 5.3, this subcategorization, relates specifically to the champions category set out within the framework developed by McTigue, Monios, et al. (2018). In their study of transport policy against this framework McTigue, Rye, et al. (2018) noted no significant correlation between local champions and development of policy, in the period covered by LTP1 in the early 2000s. However, in later assessment of bus policy against this framework, local champions were noted to be of high importance (McTigue et al., 2020). Review of interview transcripts indicates that there were significant differences between authorities, in reported support for greenhouse reduction policies.

At the mayoral level there were clear indications that greenhouse gas mitigation policy was supported by mayors' offices at both large city metropolitan authorities. The mayors themselves were described as having big ambitions and as writing these ambitions into manifestos. This support from the mayors translated into a commitment to a mitigation policy and a proactive attitude to this policy.

At the municipal authority level, below mayoral councils, there were, however, significant differences between reported support for policies. Despite these authorities being under the umbrella of the mayoral systems, mayoral support was not specifically mentioned. However, one authority did indicate that they were getting a great deal of support from local council members and that consultation with local populations had also revealed grassroots support for mitigation policies. The more negative authority did not indicate any local political or grass roots support for greenhouse gas reduction policies and, also, did not indicate a commitment to act nor a proactive view for action.

There was also a difference in reported level of support for policies at county council level. At the more positive county council it was stated that offices were very strong in their commitment to act. Whilst, at this authority, the difficulties of acting, in a large rural geography, were emphasised, assessment of comments still indicated a general positive viewpoint. At the second county council a high-level ambition was reported but there was no indication of specific local support for policies. Planners were acting, but review indicated that, for planners, negative comments outweighed positives. The degree of local support, therefore, appears to be important in terms of overall authority viewpoint.

There were also some differences in degree of local support at unitary authority level. The more positive of the two authorities interviewed, indicated that they were aware of public concern over issues and that there was a local keenness to act. They also specifically stated that they had political support for the development of mitigation policies. The more negative authority, however, did not specifically indicate any local political support for policies and talked about general local scepticism.

At district level there was a strong correlation between reported support for policies and viewpoint positivity. At the most positive of the councils, it was stated that very committed councillors were present within the administration. However, whilst the more neutral authority planners indicated that they were aware of issues and keen to act, they did not report that their actions were specifically backed by local populations or politicians.

The degree of support from local populations and especially from local politicians, therefore, appears at all authority levels, to be particularly correlated with positivity for all councils interviewed. Positivity is then an indication of strength of commitment to reduce transport greenhouse gas emissions and the proactiveness of the approach to this commitment.

Language

Within many of the interviews emotive words were used to describe efforts to mitigate greenhouse gas emissions within local transport systems. Where language is used that contains particular emotional phrasing this can be useful as an indicator of underlying organisational viewpoint (Smith, 2006). At mayoral level, a phrase repeated in both interviews was “the right thing.” A fundamental belief in a necessity to act was, therefore revealed. Actions taken were described as brave indicating that the authorities might be prepared to act even where it was perceived to be locally unpopular.

At the more positive metropolitan authority the local planners used emotional words such as proud, positive, happy and hope and reported actions taken as successful. The more negative authority did not, however, use any specific positive wording in their answers to queries in the interviews, indicating that they might not be invested in implementing local policy.

At county council level fewer emotive phrases were used. At both authorities, the most common word used was difficult. The more positive authority stated that they were keen to bring about an attractive future and the more negative authority described themselves as frustrated and scrapping for resources. There were, therefore, some indications of a difference in emotional engagement with the issues despite both authorities regarding implementing policies to be challenging.

At the more positive unitary authority the phrase “do the right thing” was repeated. Local planners also referred to hope and an expectation of change. Their attachment to policy was, therefore, more muted than that expressed at larger municipal authorities. The more negative authority used wording such as frightening and frustration, indicating their awareness of policy barriers.

At district level the most prominent emotional phrases used were keen and terrified. Authorities, therefore, indicated that they had some commitment to implementing policies but were very aware of the barriers present. Even the more positive authority did not use specifically positive wording in answering questions but did note that policies were agreed across the administration and supported.

Consequences

The final section, assessed in terms of authority viewpoint, relates to the consequences of commitment of policy. This particularly relates to answers to Question 16 of the interview, whether planners thought that policies could deliver a local low carbon transport system. At mayoral authority levels the general conclusion was that greenhouse gas reduction could be achieved. One planner stated that they were convinced that commitments could deliver effective policy whilst at the second interview the local planner stated that they would like to think that low carbon systems could be delivered but noted that the future was still “a big question.”

At municipal level there was less optimism relating to delivery of a low carbon future. Planners, at the more positive council, stated that they hoped that policy could deliver greenhouse gas reduction. It was stated that if failure occurred it would not be from lack of effort. Even at the more negative authority it was stated that delivery of low carbon systems could happen, but no indication was given that it might happen.

At county level the more negative authority conceded that they did not think change would happen as fast as people thought it might. They thus indicated a reluctance to commit to achievement of future goals. The more positive authority was also reluctant to commit to delivery of low carbon transport systems, only saying that it could happen if investment was forthcoming. These views, hence, replicated an emphasis on transition difficulties, as indicated in assessment of approach and language subcategories.

At unitary level planners stated that they could envisage a low carbon end point but not the transition. The more positive of the authorities conceded that it was currently probably unlikely that greenhouse gas reduction would be achieved. The more negative authority stated that change was not happening.

At district level the three authorities interviewed all stated that greenhouse gas emission reduction was probably not going to be achieved. The end point of a low carbon transport system was described as more out of reach than it had been historically. Even the more positive authority stated that, truthfully, they did not envisage that policy goals could, at present, be met.

Assessment of the consequences of greenhouse gas emissions reduction policy generally revealed negative thoughts, even from the more positive interviews. The best that could be stated was that there was a hope that a low carbon end point could be delivered but that this end point could only be delivered if current resource regimes were changed. Only the most positive of the mayoral authorities stated that they thought that commitments could be reached. All other authorities either stated that the commitments could not be reached, or that commitments could only be reached if current, political and popular support increased.

Viewpoint category summary

A summary of viewpoint subcategories revealed by the interviews is shown in Table 5.4.

Table 5.4 – Summary of subcategories within viewpoint category

Authority	Commitment	Agenda	Local support	Language	Consequence	Overall
Mayoral 1	Yes	Brave	Yes	Right thing	Yes	Positive
Mayoral 2	Yes	Trailblazer	Yes	Right thing	Maybe	Positive
Municipal 1	No	One benefit	Not recorded	None	Maybe	Negative
Municipal 2	Yes	An example	Yes	Proud	Maybe	Positive
County 1	Yes	Keen	Yes	Difficult	Maybe	Positive
County 2	Yes	Balanced	Not recorded	Difficult	No	Negative
Unitary 1	Yes	Try	Not recorded	Frightening	Maybe	Negative
Unitary 2	Yes	Hope	Yes	Keenness	No	Positive
District 1	Maybe	Do our best	Not recorded	Terrified	Maybe	Neutral
District 2	Maybe	Evidence	Not recorded	Keen	Maybe	Neutral
District 3	Yes	Supportive	Yes	Agreed	No	Positive
District 4	No	No control	Not recorded	None	No	Negative

As shown in Table 5.4, only the first of the mayoral authorities was positive across all viewpoint subcategories. The second of the mayoral authorities was mostly positive but did not decisively indicate that the consequence of their policy would be substantial reduction in transport greenhouse gases. For most of the other authorities a mix of positive and negative viewpoint subcategories were noted. The generally positive authorities presented optimistic agendas and language but could not commit to achieving a specific goal. The two smallest positive authorities specifically stated that, despite their efforts they did not envisage that commitments could be fulfilled. Only two of the authorities contacted, however, stated that they were not actively seeking a significant reduction in greenhouse gases. Even these two authorities presented some policy that could reduce emissions.

Based on viewpoint assessments, the factor that has the greatest impact, on ability to instigate positive and proactive actions, is the support shown by local politicians. The factor that has the greatest influence on commitment to reduce greenhouse gases appears to be the authority size and resources.

5.4 Theme assessment summary

Each local authority is unique in some way in terms of geographical, historical, political and economic background. The interview assessment, undertaken for eight of the 39 local authorities present in the North West of England, together with the two county councils and two mayoral authorities present in the region, has tried to provide information that can allow a characterisation framework to be developed that can be used to assess local ability, pathway and landscape, associated with reducing transport greenhouse gas emissions. To develop an overall framework, the results of analysis need to be assessed against the characteristic backgrounds that shape each local authority. Where patterns emerge between analysis and backgrounds it can be postulated that these constitute a relationship.

Background characteristics that can be compared to analysis results include:

- Governance tiers.
- Hierarchical status.
- Geographical setting.
- Economic background.

Governance tier relates to authority type. Hierarchical status can be taken from assessment of net commuting as shown in Table 4.3. Geographical status can be taken from the urban and rural characteristics of each local authority shown in Table 3.1. Minx et al. (2013) indicate that financial status can be taken from average wage, compiled annually for each local authority by ONS (ONS, 2020a). For the local authorities interviewed these characterisations are shown in Table 5.5. Each characteristic is described in terms of high, medium and low status, depending on the value of indicators relative to other authorities.

Table 5.5 – Interview authority status

Authority	Governance tier	Hierarchical status	Financial status	Geography
Mayoral 1	High	High	Low	Large city
Mayoral 2	High	High	Low	Large city
Municipal 1	Medium	Low	Low	Suburb small city
Municipal 2	Medium	Low	Low	Suburb small city
County 1	High	Mixed Low	Varies	Small cities and rural
County 2	High	Mixed Medium	Varies	Rural and small cities
Unitary 1	Medium	Medium	Low	Small city
Unitary 2	Medium	High	Medium	Small city
District 1	Low	Medium	Low	Small city
District 2	Low	Low	High	Small city
District 3	Low	Low	Low	Small city
District 4	Low	Medium	Medium	Mainly rural

Ability theme

Assessment of the nine ability categories derived directly from interview questions shows some variation in terms of governance and hierarchical status. Assessment of the categories that represent the exterior factors experienced by each authority (CHALLENGES and CONSTRAINTS) does not indicate any significant variation between councils at the same governance tier. Council's assessment of outside constraints and challenges, within interviews, only appears to depend on the governance tier of the authority. Larger authorities described a proactive regime of designing goals around a requirement for growth. The smaller authorities, however, described a regime where they had to set goals whilst reacting to restraints associated with market forces.

The other interview question responses that appeared to be only significantly affected by governance tier were MONITORING and EFFECTIVENESS. There were no differences across most authorities in relation to monitoring because none had set a specific goal to achieve reduced transport greenhouse gases and they were, hence, not particularly interested in tracking local emissions data. Fundamental differences in the ability to enact policy were, however, exposed in discussion of effectiveness. The smaller authorities all stated, in some way, that they did not have the power to change current systems. They had not been given power by national government, through legislation and funding and, in addition, local populations, local developers and other stakeholders, wielded greater power than the local authorities. The exception to this imbalance was at mayoral level, where the authorities had been given greater funding and legislative instruments to control their local transport systems. They were also large enough that they did not express a worry that local developers could dictate policy. In addition, at this level it was possible to construct large public transport systems and local populations were hence more amenable to a car free lifestyle.

For the interview questions that related to goal setting (GOALS and PRIORITIES) variations were noted between different authority types and between authorities within the same governmental tiers. The more positive councils talked of being trailblazers and leading by example. The goals and priorities of the positive councils were proactive and were associated with identifying issues and changing systems to deal with these issues. The more negative authorities only provided excuses for why their goals and priorities could not feasibly change existing transport systems to reduce greenhouse gas emissions.

Discussion relating to RESPONSIBILITY generally indicated that authorities held a neutral viewpoint. All authorities stated that national and local government, together with local populations, had shared responsibility in changing current transport systems. The more positive authorities, however, were prepared to take more responsibility through declaring themselves as trailblazers and leading by example. These more positive authorities were not particularly different from other authorities in terms of hierarchical or financial status but were the authorities where local political support was reported and a proactive attitude to change adopted.

The final two question categories relate to factors that may be outside the control of authorities (RESOURCES and OPPORTUNITIES) and hence, based on discussion of other question categories, it might be expected that assessment would only show variation between answers in relation to governance tiers. However, for these two categories there was also significant variation in answers given by authorities at the same level of government. The more positive of the authorities were more optimistic in terms of the resources they needed and the opportunities that they had, than similarly structured, but more negative authorities. For authorities that embraced proactive viewpoints, opportunities, to change existing transport systems, had been actively identified and welcomed. For other authorities, opportunities were not actively sought out and were only acted upon when they were easily accessible. The resources associated with positive optimistic councils consisted of updated documentation that they had developed in house. These councils were also associated with local champions, in the forms of active local politicians, who supported seeking out opportunities and local development of resources.

Pathway theme

Assessment of categories, relating to the practicalities of reduction in transport greenhouse gas emissions, indicated that these were mostly controlled by the governmental tier of the interviewed authorities. In large cities, stewardship solutions were emphasised. In small cities technological solutions were emphasised.

Some differences were, however, noted between local authorities in the same governmental tiers. The more positive smaller authorities envisaged proactive schemes, such as a workplace parking levy and extended role out of public EV charging systems. The more negative authorities, however, appeared to be more reluctant to use their powers in restricting existing transport regimes and encouraging new. In these councils the negatives were emphasised and the potential solutions discussed less. In particular, limitations relating to power over other stakeholders were emphasised.

Landscape theme

The categories and subcategories describing landscape revealed two differing aspects of the governance system. The perceived barriers illustrated the differences between governmental tiers. The viewpoints expressed revealed differences between local authorities, with a variety of hierarchical, financial and geographical status, within the same governance tiers.

In discussion of barriers, an emphasis was placed on restrictions of local authority power to implement policy. At mayoral and county level the main restrictions, on ability to act, were associated with the financial and legislative framework in which they worked. At lower governmental levels, in small cities, more emphasis was put on the relative lack of power wielded by local authorities, when compared to developers and external transport system stakeholders. An emphasis was also put on the power of the local populations to restrict actions made by local planners. Interviewees, in these councils, were, therefore, more reluctant to take a proactive approach in delivery of a radically different transport regime.

Analysis of viewpoints brought out the differences between the councils who were prepared to take an optimistic proactive approach to change their transport systems and those who were more reactive and pessimistic. The more optimistic authorities were more likely to commit fully to a transport system with low greenhouse gases and were more likely to view this commitment in a positive light. These authorities were those where local political leadership was apparent and local proactive policy was being developed. For the more pessimistic and reactive councils, this local political support was not apparent.

The characteristics of the more proactive and optimistic authorities can be investigated with reference to the summary of viewpoints shown in Table 5.5. The financial status of a local authority does not appear to be a good indicator of a proactive viewpoint. The authorities with elevated financial status were not more likely to adopt an optimistic viewpoint. This is especially of importance because elevated financial status is associated with a greater level of emissions (Minx et al., 2013) and, therefore, it is more critical, in the context of a regional change in transport systems, that these authorities actively engage in development of policy associated with transport greenhouse gas reduction. Geographical status only appeared to affect a local authority's viewpoint where it was associated with elevated governance tier, in large city mayoral councils. The hierarchical status appears to be a better indicator of a proactive and optimistic transport emissions reduction viewpoint. The councils with greater hierarchical control of their own population were more likely to be proactive.

However, these factors do not fully define council viewpoints. One small council (District Council 3) was low in terms of governmental, hierarchical and financial status and still managed to adopt an optimistic viewpoint. This council was associated with positive local political support. Similar positive political support was noted to be associated with other proactive authorities. Optimistic viewpoints were, also, associated with a more realistic assessment of the impact of proactive policy implementation. The more proactive authorities were more likely to recognise that current systems might not allow a low carbon transport system to be delivered. Other authorities stated that sufficient change might happen without providing evidence of how change could happen. Only the proactive authority at mayoral level could fully envisage delivery of a low carbon future.

Theme assessment conclusions

The small number of councils interviewed does not provide sufficient data to allow specific conclusions to be drawn in terms of how the status of a council affects the attitudes of local planners, in terms of issues associated with transport greenhouse gas reductions. The assessments undertaken through interviews do, however, indicate the variations in attitudes present across a substantial cross section of planners and the councils they represent. The interviews undertaken provide an indication of attitudes of planners, across the North West of England, to changes required in local transport systems, to enable reduction of transport greenhouse gases. The attitudes expressed by planners is taken to be illustrative of the positions of the local governmental organisations in which they work (Campbell & Gregor, 2008, p79). Through undertaking interviews, variation in approaches taken by different authorities, relating to transport climate change issues, across the North West of England, can be mapped. A summary of the various authority outlooks is shown on Table 5.6. Authorities are categorised in terms of their governmental tier associated with their geographical locations as large or small cities. The councils are then split again by their overall attitude between those authorities that are pessimistic and reactive and those that are optimistic and proactive.

Table 5.6 – Local authority characteristics relating to reducing transport greenhouse gas emissions derived from interview investigation

Geography and governance	*Positive authorities*	*Negative authorities*
Large city mayoral	*Local political support* *Financial resources available* *Growth agenda* *Legislative powers over external stakeholders* *Air quality issues and legislative powers with potential for city wide initiatives* *Proactive planning* *Stewardship approach based on large scale infrastructure* *Support for active travel*	*NA*
Small city suburban municipal and unitary	*Upper hierarchy* *Local political support* *Limited legislative powers over external stakeholders* *Resource and funding limited* *System change commitment but realistic about capabilities* *Proactive policies but concerns about impact on local economy* *Technology emphasis based on active support for EVs with limited potential for city wide initiatives.* *Support for active travel*	*Lower hierarchy* *Limited local political support.* *Limited legislative powers over external stakeholders* *Resource and funding limited* *No system change commitment* *Reactive market led policies* *Technological emphasis based on reactive support for EVs* *Support for active travel*
Small city county and district	*Local political support* *Limited legislative powers over external stakeholders* *Resource and funding limited* *System change commitment but realistic about capabilities* *Proactive policies but concerns about impact on local economy* *Technology emphasis based on active support for EVs with good local bus systems* *Support for active travel but limited in rural settings*	*Limited local political support* *Limited legislative powers over external stakeholders* *Resource and funding limited* *No system change commitment* *Reactive market led policies* *Technological emphasis based on reactive support for EVs with good local bus systems* *Support for active travel but limited in rural settings*

The local government assessment shown on Table 5.6 indicates five categories of outlook relating to transport planning. The large mayoral authorities represent a motivated and empowered group, that have advantages over other councils in terms of resources, funding and infrastructure size and, through the mayor's offices, additional legislative powers. These councils have ambitions; to use their resource, size and legislative powers, to achieve net zero transport greenhouse gas emissions and are prepared to envisage a transport future where use of private cars is restricted.

Where metropolitan and unitary authorities are motivated by local political support and, where applicable, by their position in a local hierarchical network of cities, they can commit to a reduction in transport greenhouse gas emissions. They are however limited by resource, size and legislative frameworks. These councils are willing to take proactive actions on a city-wide scale but are reluctant to introduce measures that will restrict use of private cars. Where similar councils are not motivated, they are not particularly interested in reducing transport greenhouse gas emissions. They are willing to accept reactive opportunities within ongoing developments but are not likely to engage in large scale initiatives, particularly where these are seen as against the wishes of local populations. For the smaller district councils, the size, resource and legislative restrictions are even more important. However, local political support can still initiate a proactive motivated response. Because of restrictions, the response is limited to small scale initiatives and, generally, it is seen as essential that local residents retain use of private vehicles. For smaller councils that are not motivated, initiatives are restricted to small scale active travel schemes and, as practical, passive provision for EVs. Reducing transport greenhouse gas emissions is seen as someone else's problem.

Assessment shows two processes at work in terms of diffusion of ideas relating to engagement in reducing transport greenhouse gases. Firstly, large city authorities, with the existing advantages that they enjoy, have embraced a commitment to climate change mitigation. This diffusion process relates to the hierarchical and governmental status of local authorities. It is likely to continue in the form of diffusion down to small cities in the regional hierarchical chain. Secondly, for small cities a process of engagement has started through local political initiatives that have allowed councils to adopt an optimistic proactive viewpoint. This process will continue as local populations, politicians and planners are educated and motivated in terms of global climate change issues. For these two processes to be continued the resource and financial limitations experienced by small cities need to be addressed. These limitations may be difficult to address due to inherent infrastructure limitations and, potentially, due to the limitations in outlook of smaller communities (Bell & Jayne, 2006).

Five years ago, Webb et al. (2016) indicated that nearly three quarters of councils in the North West of England were not fully engaged in developing sustainability policies. The interview assessment, undertaken in 2019, shows that half of the councils interviewed were actively engaged in developing and implementing policies aimed at reducing transport greenhouse gases. In this short timeframe there are, therefore, already indications that progress has been made in terms of diffusion of initiatives in the region. Interviews, however, indicate that local planners in small cities perceive that they have been left behind by the alpha city region around London, as they have not been provided with adequate legislative powers and large-scale infrastructure initiatives only benefit large cities. Local planners also complain that they have been left behind by local large cities where support, in constructing local infrastructure, means that superior transport systems are present that are unlikely to be enjoyed in the small cities of the region.

5.5 Chapter summary

The assessment undertaken in this chapter, as illustrated in Table 5.6, indicates differences in local authority categorisations, between large and small city hierarchies and between positive proactive authorities and more pessimistic reactive authorities, in terms of motivation and ability to reduce transport greenhouse gases and in terms of mitigation pathways investigated. Assessment of these different authority types indicates that government and hierarchical status influences whether authorities adopt a proactive viewpoint. It also indicates that, for small cities, the presence of local champions is important in determining whether proactive viewpoints are adopted. In the next chapter cumulative greenhouse gas emissions are quantitatively assessed in relation to this regional hierarchy. In Chapter 7 results of the qualitative assessment of small cities in a regional hierarchy, as outlined in this chapter, and the quantitative assessment of the whole region, as outlined in Chapter 6, are brought together, to develop conclusions and recommendations.

CHAPTER SIX – POLICY PATHWAYS

6.1 Introduction

In Chapter 5, interviews and reviews of desk-based literature were used to investigate local authority viewpoints related to reducing transport CO_2 in the North West of England to understand knowledge gaps, relating to actions taken by small cities and relating to barriers on implementing transport emissions policies. In this chapter, policy pathways relating to reduction in transport CO_2 are outlined, so that these can be integrated with local authority viewpoints and so that the knowledge gap relating to the comparison of global greenhouse gas reduction ambitions against local authority actions can be understood. The pathways developed represent new knowledge, in terms of regional emission schedules, investigations of regional policy impacts and assessment of these against Paris Agreement budgets. The methodology used in development of schedules and pathways is introduced in Chapter 2.

In Section 6.2, the derivation of a transport emissions schedule, relating to the urban and rural areas of the North West of England, is outlined. In Section 6.3, the background technological pathways of diffusion of low emissions vehicles, with and without government intervention, are introduced. In Section 6.4, stewardship intervention baseline pathways are described. In Section 6.5 terrestrial transport cumulative CO_2 emissions associated with these pathways are then quantified and compared to cumulative emissions associated with the Paris Agreement. The gap that exists between the pathways and Paris Agreement commitments, is described. Policy pathway alternatives to bridge this gap are then explored. Key conclusions are summarised in Section 6.6.

6.2 North West of England emissions activity

Introduction

In this section a schedule of emissions activity is derived for the North West of England. This derivation has been undertaken specifically as part of the research described in this thesis. It has been undertaken in four stages. Each stage is illustrated in tables that represent data newly derived for this thesis. Firstly, a schedule of overall transport activity for the region is derived (Table 6.1). Secondly, transport mode characteristics are derived from national data (Tables 6.2 and 6.3). Thirdly, a North West of England population distribution schedule is derived (Tables 6.4). Finally, schedules are combined, to provide an indication of transport and emissions in the North West of England, in terms of rural and urban populations (Tables 6.5, 6.6 and 6.7).

Data on transport activity in the UK is compiled by the Department for Transport (DfT), as part of the annual National Transport Survey (NTS). Cornick et al. (2020) report that 6,000 members of the public are interviewed to compile the survey. They also note that, in calibrating data, greater adjustments are required for low frequency longer trips, than for higher frequency shorter trips. The NTS is, hence, likely to be a better indication of trip activity for short intracity trips than it is for less frequent, long intercity and interregional trips.

The NTS does not provide a complete record of travel activity. It only provides a record of activity from a household viewpoint and does not provide a full record of commercial activity, undertaken during business operations. Commercial travel is included in the NTS where it has the purpose of reaching an end point, such as a work place and not where it has the purpose of delivering goods and people (DfT, 2020g). The fact that travel is not completely covered by the NTS is illustrated by the fact that, whilst the NTS has recorded a slight drop in per capita travel activity, over the last five years (DfT, 2020f), the separate inventory of per capita traffic levels prepared by the DfT, based on traffic counts across the country, has recorded a slight rise in overall per capita vehicle movements (DfT, 2020k). For the NTS to be used as a baseline this discrepancy, between recorded household activity and recorded traffic levels, needs to be understood. This discrepancy is specifically addressed in stage four of the derivation, described in the remainder of this section.

Overall transport activity

As a first stage in deriving a regional emissions schedule, NTS data has been used to define overall transport activity in the North West of England. NTS Table 9904 (DfT, 2020f) has been used as the basis of this derivation. This table shows distance travelled for the whole of England, for regions and for different urban and rural classifications. To define regional activity, two adjustments are applied to this NTS data. The first adjustment involves applying a regional modifier to national trip distances, for each mode and for each urban/rural classification. For the North West of England, individual transport activity is recorded to be 92.2% of national activity (DfT, 2020f). A second adjustment is then made to benchmark individual activity against overall regional activity, so that individual activities match anticipated regional activity for all modes. Derived regional transport activities, together with these adjustments, are shown in Table 6.1.

Adjusted regional data, shown in Table 6.1, indicates significant differences in activity, associated with large and small cities. Within large conurbations, activity is indicated to be a third less than the North West of England average. However, in rural areas activity is shown to be a third greater than the average. Rural activity is hence nearly double that of activity occurring in large conurbations.

Cornick et al. (2020) provide descriptions of NTS mode categories used in Table 6.1. 'Other private transport' relates to use of private buses, including school buses. 'Other public transport' relates to light rail, ferries and domestic flights. International trips are specifically excluded from the NTS and, in addition, where domestic flights occur as a stage in an international trip, they will not be recorded. Longer trips are also less likely to be recorded due to their low frequency. The category of other public transport is hence more likely to record light rail usage, in shorter more frequent intracity trips.

Table 6.1 – Transport activity schedule 2018/2019 derived from NTS Table 9904 (DfT, 2020f)

	Table NTS9904 - Average km travelled by mode, region and Rural-Urban Classification: England, 2018/2019													
Rural-Urban Classification	**Walk**	**Bicycle**	**Car / van driver**	**Car / van passenger**	**Motorcycle**	**Other private transport**	**Bus in London**	**Other local bus**	**Non-local bus**	**London Under-ground**	**Surface Rail**	**Taxi / minicab**	**Other public transport**	**All Modes**
North West	317	89	5,013	2,702	16	139	1	364	78	6	755	127	61	9,667
England	333	90	5,190	2,893	35	174	108	267	63	170	999	98	64	10,484
% North West of England	95.2%	97.9%	96.6%	93.4%	46.5%	79.7%	0.6%	136.4%	123.5%	3.4%	75.6%	130.0%	94.7%	**92.2%**
Urban Conurbation	341	84	3,373	2,055	20	105	269	231	56	370	977	125	99	8,106
Apply North West %	325	82	3,258	1,920	9	83	2	315	69	13	739	163	94	7,474
Distribute to All Modes	344	87	3,444	2,029	10	88	2	333	73	13	781	172	99	**7,474**
Urban City and Town	358	96	5,526	3,074	45	189	6	281	78	45	1,086	83	35	10,899
Apply North West %	341	94	5,337	2,871	21	151	-	384	96	2	821	107	33	10,049
Distribute to All Modes	334	92	5,229	2,813	20	148	-	376	94	1	804	105	32	**10,049**
Rural Town and Fringe	294	86	7,630	4,204	49	221	7	376	49	35	733	61	88	13,834
Apply North West %	280	84	7,369	3,927	23	176	-	514	60	1	554	80	84	12,755
Distribute to All Modes	272	82	7,147	3,809	22	171	-	498	58	1	537	77	81	**12,755**
Rural Village, Hamlet and Isolated Dwelling	211	97	9,197	4,426	38	364	2	245	33	38	926	90	33	15,700
Apply North West %	201	95	8,883	4,134	18	290	-	334	41	1	700	117	31	14,476
Distribute to All Modes	196	93	8,662	4,031	17	283	-	326	40	1	683	114	30	**14,476**

Transport characteristics

In the second derivation stage, national DfT data has been used to determine characteristics of different transport modes in the UK. To relate transport regimes to vehicle emissions, transport movements per vehicle are required. Movements per person and movements per vehicle are related by occupancy, given as:

Occupancy = movements per person/movements per vehicle

The NTS provides a distinction between car drivers and passengers, thus allowing occupancy to be determined for private vehicles. As shown in Table 6.1, in the North West of England in 2018/2019, there were 2,702 passengers for 5,013 drivers. This relates to an occupancy of 1.54. However, for other private transport and for public transport, no indication of occupancy is provided in the NTS. To relate individual transport activity to greenhouse gas emissions an indication of occupancy is required for all transport modes. A bus with ten passengers emits a similar amount of CO_2 emissions to a bus with five passengers (Alam & Hatzopoulou, 2014). However, by doubling the occupancy of the bus, the emissions per capita are halved.

Data on other UK on road vehicle movements is provided in tables TSGB0101 (DfT, 2020e) and TRA0206 (DfT, 2020n). Data on public transport is provided in tables RAI0103, for heavy rail and LRT0104/0106, for light rail (DfT, 2020o). These tables provide data on passenger movements and vehicle movements and, hence, can be used to provide an indication of occupancy. This data is presented in Table 6.2.

Table 6.2 – Derived UK public transport occupancy 2018 (TSGB0101 (DfT, 2020e), TRA0206 (DfT, 2020n), RAI0103, LRT0104 and LRT0106 (DfT, 2020o)).

Vehicle type	Passenger distances (Mkm)	Vehicle distances (Mkm)	Occupancy passenger distances /vehicle distances
Buses and coaches	35,000	4,000	8.75
All rail	68,389	562	122

National transport data can also be used to derive vehicle emission intensities, using DfT data relating to vehicle movements and BEIS data, relating to transport emissions. This derivation is shown in Table 6.3. Emissions are based on transport CO_2 emissions recorded in DfT Table ENV0202 (DfT, 2020c) which, in addition to Scope 1 emissions, include Scope 2 emissions relating to generation of electricity for electric cars and rail (Vieweg, 2017). DfT emissions data is derived from an assessment of fleet characteristics through a number plate sampling exercise (Ricardo Energy and Environment, 2020). Vehicle distances are taken directly from DfT tables for Great Britain (DfT, 2020n). To match these distances to UK emissions an allowance of 3.5% has been added to take into account traffic on Northern Ireland roads.

Table 6.3 – Derived UK transport emissions intensity 2018 (ENV0202 (DfT, 2020c), TRA0206 (DfT, 2020n), RAI0103, LRT0104 and LRT0106 (DfT, 2020o))

Vehicle Type	UK national emissions ($MtCO_2$)	UK vehicle movements (bkm)	Emissions intensity (gCO_2/km)
Cars and taxis	75.6	453.6	166.6
HGVs	22.4	28.9	777.1
LGVs	21.3	90.7	234.6
Buses and coaches	3.4	4.1	833.3
Motorcycles & mopeds	0.6	5.0	112.2
All rail	3.1	0.562	5516.0

Population schedule

The third stage, in determination of regional emissions data, involves compiling a regional population schedule. To assign regional emissions to specific local activities, undertaken in the cities of the region, each area needs to be defined in terms of the urban/rural characteristics shown in Table 6.1. Rural and urban classifications, in different local authorities in the region, have been compiled from data collected in the 2011 census of the UK (ONS, 2018b). This census data can be applied to 2018 population data sets (ONS, 2020c).

Rural and urban classifications, of the 39 local authorities in the North West of England, are shown in Table 3.1. The table shows that all mayoral and municipal authorities, apart from Wirral, are classed in terms of the highest categorisation (urban with major conurbation). Wirral local authority is classed in terms of the second highest categorisation (urban with minor conurbation). The four unitary authorities, outside Cheshire, are classed in terms of the second and third categorisations (urban with minor conurbation and urban with city and town), whilst the two Cheshire unitary authorities are classed in terms of the fourth and fifth categorisations (urban with significant rural and largely rural). The eighteen district councils are generally classed between the third classification (urban with city and town) and the lowest classification (mainly rural). Of the district councils, only the two central Lancashire authorities, of Preston and South Ribble, have a higher categorisation (urban with minor conurbation).

The rural and urban split that occurs across the North West of England is shown in Table 6.4. Due to the significant differences between the unitary authorities in Cheshire and the unitary authorities in the rest of the region, these have been listed separately. Similarly, the two district authorities of Preston and South Ribble have also been listed separately, as they have been categorised as being significantly more urban than other district authorities.

Table 6.4 – Derived North West of England urban and rural population 2018 (ONS, 2018b)

Authority type	Total population	Percentage rural	Percentage urban	Rural population	Urban population
Mayoral authorities	1,042,441	0.0%	100%	111	1,042,330
Municipal authorities	3,193,193	1.5%	98.5%	47,106	3,146,087
Unitary other than Cheshire	626,226	5.8%	94.2%	36,302	589,924
Preston and South Ribble	252,345	4.0%	96.0%	10,140	242,205
Unitary Cheshire	721,292	22.4%	77.6%	161,742	559,550
Other district authorities	1,456,596	35.1%	64.9%	511,688	944,908
Total	7,292,093	11%	89%	767,083	6,525,010

Based on these distributions the population of the North West of England can be split in terms of the four categories used by the NTS.

Urban conurbation – all populations classed as major conurbations with no significant (less than 2%) rural characteristics. Mayoral and municipal urban populations – 4.19 million.

Urban city and town – all populations classed as predominantly urban with only minor (2% to 10%) rural characteristics. All unitary authorities, except Cheshire, together with South Ribble/Preston district authorities, urban populations – 0.83 million.

Rural town and fringe – all urban populations associated with significant (greater than 10%) rural characteristics. All other district and Cheshire urban populations – 1.50 million.

Rural village, hamlet and isolated dwelling – all populations classed as rural – 0.77 million.

Regional transport emissions

For the final derivation stage, a breakdown of travel distances in the North West of England has been calculated, as shown in Table 6.5. The population splits are taken from census data (ONS, 2018b), shown in Table 6.4. Distances per person, within each population grouping, are taken from NTS data (DfT, 2020f), shown in Table 6.1. Travel distances are calculated to be the product of the populations and the distances covered per person. Results are shown in billion kilometres (bkm) travelled in the North West of England.

Table 6.5 – Derived North West of England primary distances travelled 2018

Urban rural classification	**Population (millions) (A)**	**% Total**	**Distance/ person (km) (B)**	**Total distance (bkm) (A*B)**	**% Total**
Urban conurbation	4.19	57%	7,474	31.31	45%
Urban city and town	0.83	11%	10,049	8.36	12%
Rural town and fringe	1.50	21%	12,755	19.19	27%
Rural village, hamlet and isolated dwelling	0.77	11%	14,476	11.10	16%
Total	7.29	100.0%		69.96	100%

The total regional distance travelled, of 70bkm, can be correlated against emissions recorded in the sub national CO_2 tables, compiled by BEIS (BEIS, 2020d). Ricardo Energy and Environment (2020) describe the process of emission data collection, in terms of transport flows and fleet characteristics, through use of the COPERT 5 model. They report that emissions are benchmarked against top-down data on overall sales of fuel, compiled as part of the Digest of UK Energy Statistics (DUKES) (BEIS, 2020c).

Before the NTS data and the emissions data can be correlated, an allowance has to be added to take into account the fact that the NTS does not capture commercial vehicle activity. These commercial activities include a proportion of private cars and LGV movements and all HGV movements. Assessment by Browne et al. (2014) records that about one third of all LGV movements relate to commuting activity, that will be captured in NTS diaries, and about two thirds of activity relates to commercial activity associated with delivery of goods and services, that will not be captured by the NTS.

NTS private car movements, recorded in the North West of England, can be calculated from the 'car van driver' and 'taxi/minicab' distances shown in Table 6.1, together with the populations in each urban/rural category shown in Table 6.4. The product of the average annual car and taxi movements and the local populations, calculated from this data, is 37.2bkm. This can be compared against the car and taxi movements and LGV movements recorded in traffic counts by the DfT and shown in Table TRA0206 (DfT, 2020n). For the North West of England, Table TRA0206 indicates that total car and taxi movements, together with a third of LGV movements, are 52.9bkm. Hence it is estimated that there are about 15.7bkm of commercial car, van and taxi movements that are not recorded in the NTS for the North West of England.

Based on population distributions, shown on Table 6.5, a bottom-up estimate of transport CO_2 emissions, in the North West of England, can be derived. Based on the assumption that a third of LGV movements are recorded in the NTS, it is assumed that about 3.1bkm, of the NTS regional annual 37.2bkm, car and van total, consists of LGVs. Hence, about 10% of NTS recorded private vehicles are assumed to be vans, rather than cars, and emission intensities have been modified based on this assumption. The mileage shown for LGVs and HGVs are taken from DfT traffic counts shown in DfT Table TRA0206 (DfT, 2020n), but only two thirds of LGVs have been included, on the assumption that one third are already included in the NTS. For buses and rail, the distances shown are passenger distances derived from the NTS using activity data shown in Table 6.1 and population splits shown in Table 6.4. To calculate emissions for these transport modes, these passenger distances have been converted into vehicle distances through use of the occupancy rate shown in Table 6.2. The derived estimate of emissions is shown in Table 6.6.

Table 6.6 – Derived North West of England terrestrial transport CO_2 emissions 2018

Vehicle type	Total distances (bkm)	Emission intensity (gCO_2/km)	Occupancy	Calculated emissions ($MtCO_2$)	Percentage (%)
Cars, vans and taxis recorded in NTS.	37.2	173 (90% car and 10% LGV)	NA	6.45	47.1
Cars, vans and taxis not recorded in NTS	15.7	173 (90% car and 10% LGV)	NA	2.72	19.9
Motorcycles & mopeds	0.1	113	NA	0.01	0.1
Other LGV	6.1	235	NA	1.43	10.5
HGVs	3.1	777	NA	2.41	17.6
Buses and coaches	4.2	833	8.75	0.40	2.9
Rail	5.9	5516	122	0.26	2.0
Total				**13.68**	**100.0**

The total emissions calculated can be compared to the transport emissions, calculated for the North West of England by BEIS, of 13.65$MtCO_2$. The calculated emissions shown in Table 6.6 and the BEIS calculated emissions are within 1% of each other. The population distribution derived, together with NTS average activity, therefore, appears to be a reasonable proxy for the transport CO_2 emissions occurring in the North West of England.

Based on this activity distribution a breakdown of regional transport emissions per mode is shown in Table 6.7.

Table 6.7 – Derived North West of England rural/urban terrestrial transport emissions 2018

Rural/urban classification	Population		Private cars/LGVs	Motor-bikes	Buses and coaches	Rail	Other LGVs	HGVs	Totals	
	millions	%	ktCO$_2$ per year							%
Urban conurbation mayoral	1.04	14%	929	1	49	42	205	344	1571	11%
Urban conurbation municipal	3.15	43%	2805	4	149	127	617	1039	4740	35%
Urban city and town	0.83	11%	1094	2	49	31	163	275	1615	12%
Rural town and fringe	1.50	21%	2679	4	104	42	295	497	3622	26%
Rural village, hamlet and isolated dwelling	0.77	11%	1660	1	47	25	151	253	2137	16%
Total	**7.29**	**100%**	**9167**	**12**	**398**	**267**	**1431**	**2409**	**13684**	**100%**

The data shown in Table 6.7 represents an emissions schedule for the urban and rural areas of the North West of England based on the four-stage process described in this section. This schedule and the schedules shown in Tables 6.1 to 6.6, represent new data sets that have been derived for this thesis in order to assess emissions in the North West of England.

6.3 Technological pathways

Introduction

New technological pathways have been derived, for this thesis, to explore how EV numbers may change under a number of different assumptions. An introduction to the methodology used in deriving these pathways is contained in Section 2.4. In the following section technological pathways are described in terms of modelling methodology, the background growth of vehicle mileage, the growth of EVs, change in emissions from individual cars and the effect these changes have on the overall UK car fleet. Assumptions investigated include the different growth regimes associated with purchase of EVs and the effects of specific governmental interventions.

Technological pathways will have the effect of changing the makeup of the fleet of cars operating within a region. Through changing the car fleet makeup, the vehicle emissions intensities, calculated in Table 6.3, will be reduced. The nearly 4 million cars, vans and motorbikes present in the North West of England cannot, however, be replaced overnight. Although government in the UK has the power to ban vehicles with high emissions from UK roads, they do not believe that they should impose such restrictions on the public and instead prefer to pass responsibility onto individual car owners (Bloyce & White, 2018).

Whilst the UK Government does not want to impose a ban on use of specific cars on UK roads, they have stated that they will abide by CCC advice to restrict sale of new cars to EV models in the UK. However, whilst the CCC have called for a restriction on sales of new cars to EVs by 2032, together with increased tax incentives (CCC, 2020b, p19), the Government's current plan (HM Government, 2020b) only provides for a requirement that all new cars are wholly EVs by 2035. The Government's plan does restrict purchase of wholly diesel and petrol vehicles after 2030 but allows hybrid cars to be purchased between 2030 and 2035 (HM Government, 2020b). Up until the requirement to only buy EVs in 2035, the Government, hence, relies on the decisions of each individual car owner to bring about change. Even after this point conventionally fuelled vehicles will be allowed on to UK roads and the decision to scrap and replace these vehicles will be in the hands of individual and fleet vehicle owners.

Modelling methodology

As discussed in Section 2.4 modelling of decisions made by millions of individuals is best undertaken by a statistical methodology. In particular, a 'diffusion of innovation' model, described by Rogers, has been used to predict how the car market may change over time (Pettifor, Wilson, McCollum, et al., 2017). Rogers (2003) describes a regime where the growth, in adopting a new technology, changes over time as different portions of society become involved. In his model society is split into five components, depending on progress in technology adoption. These components are innovators (0.0% to 2.5%), early adopters (2.5% to 16%), early majority (16% to 50%), late majority (50% to 84%) and laggards (84% to 100%). A survey reported by Brand et al. (2017), specific to the UK EV car market, indicates that pioneers make up 2% of the population and rejectors make up 18% of the population. This survey can be compared to the diffusion of innovation model that predicts 2.5% of the population as innovators and 16% of the population as laggards. The survey, hence, indicates that the diffusion of innovation model is broadly consistent with how the UK population view the adoption of EVs as a new technology.

The model assumes that technology adoption occurs as a normal distribution, following an S shaped curve, with inflection points at 16%, 50% and 84%, at the junctions where new societal groupings become involved. Nagamatsu et al. (2006) state that diffusion of innovation can mathematically be modelled as a logistic curve where constant growth initially occurs. They indicate that growth decreases as external limits become important and becomes negative as these are reached. They suggest that the diffusion process is analogous to a contagion outbreak; the contagion being a spreading of ideas and norms relating to use of and adoption of new technology. They state that in the early stages of diffusion adoption increases exponentially with a constant rate of growth, as each new innovator demonstrates feasibility to potential new adopters and external limits do not have a significant impact. In the final stages of diffusion external limits are dominant, as most receptive adopters have already taken up the new innovation and adoption decreases exponentially. Hence an S shaped innovation curve is formed.

Al-Alawi & Bradley (2013) provide a discussion of various mathematical formulisations of Rogers' diffusion model, including those suggested by Bass and Gompertz, to allow alternative more complex parameters to be introduced. They state that in some specific diffusion cases the more complex models are appropriate. However, Fluchs (2020), argues that, in assessment of adoption of EVs, societal networks mean that a model relating to contagion of ideas, as described by Rogers, is valid. She states that the model is useful as it provides a clear and simple explanation of variation between different assumptions. In developing technological pathways this clear and simple explanation of diffusion in a statistical model is required.

Review of data relating to adoption of alternative fuelled vehicles in Norway's 2.7 million car fleet, where at the end of 2020 the 16% inflection point had just been reached, indicate growth in adoption rates of between about 20% and 120% have been maintained over the last ten years (EAFO, 2021a). The data shows an average growth rate of 52% for all alternative fuelled vehicles in Norway and, for EVs, an average annual adoption growth rate of 63%. Hence, for this data, the Rogers model, of continued growth in early adoption up to the first diffusion inflection point, appears to be appropriate. Based on these observations the simple diffusion of new technology model has been applied in construction of alternative technological pathways relating to adoption of EVs.

The model indicates the rate at which the first societal group (innovators) adopt a technology provides an indication for the rate at which the technology will be adopted by the remainder of society. In particular, it is assumed that, for early adopters, early majority and late majority, adoptions occur over equal time periods (Rogers, 2003, p281). Hence adoption of a new technology can be modelled in terms of a time period (T) that is defined as:

T1 = Time between adoption by 2.5% of society and adoption by 16% of society (early adopters)

T2 = Time between adoption by 16% of society and adoption by 50% of society (early majority)

T3 = Time between adoption by 50% of society and adoption by 84% of society (late majority)

Where **T1=T2=T3** **(Equation 6.1)**

If the time required for early adopters (2.5% to 16% of society) to take up a new technology can be estimated, the time period over which the remainder of society take up the technology, can also be calculated. In order to utilise this model, in relation to uptake of EVs, the time period over which purchases of new EVs increases from 2.5% to 16% is, therefore, required. The diffusion of innovation model assumes that, up until this first inflection point, growth generally occurs at a constant rate. Initial adoption trends can hence be used to estimate the time required to reach the 16% inflection point. Extrapolating existing trends to estimate the time required to reach the first inflection point, however, introduces uncertainty into calculations. The greater the requirement for extrapolation the greater the potential for uncertainty. Fluchs (2020), however, states that the degree of uncertainty, in extrapolating trends, should be balanced against the usefulness of the results. She states that if results are only presented once a time period has elapsed, sufficient to establish certainty, delays in data presentation may limit usefulness. In addition, van der Heijden (2005) suggests that, through exploring multiple pathways, dimensions of uncertainty can be mapped out. Hence multiple pathways can be constructed for the purpose of exploring different possibilities and overall trends can be defined in terms of the range of possibilities revealed by the different assumptions that underpin the pathways.

Conventional vehicle trends

To establish trends from which future states can be extrapolated, a data set is required that is large enough to allow existing conditions to be adequately defined and reduce uncertainty. The data set should cover a period where external factors do not dramatically change. In the UK, the period 2010 to 2019 appears to meet these criteria. Prior to 2010, the effects of the 2008 recession were being experienced. After 2019, the recent Covid 19 pandemic affected use of vehicles. However, the intermediate years represent a more stable period over which underlying technological adoption trends can be established and extrapolated into the future. If, in the future, external factors, such as governmental policy interventions, are introduced then this change would need to be considered in adjustment of diffusion time periods.

The UK car fleet is, however, not itself static and is subject to its own continued growth, due to the differences, each year, in vehicles entering the fleet and vehicles leaving the fleet. The DfT provide quarterly updates of existing and newly registered cars in the UK. Table VEH0101 (DfT, 2020m) provides a record of registered vehicles in the UK and Table VEH0150 (DfT, 2020m) provides a record of vehicles that have been newly registered in a specific year. The number of cars within the UK fleet, at a particular point in time (t), can be defined in terms of the number of vehicles in a previous time period (t-1) as:

$$\mathbf{VF(t) = VF\ (t-1) + PV\ (t-1) - SV\ (t-1)} \qquad \textbf{(Equation 6.2a)}$$

Where VF is vehicle fleet, PV is purchased vehicles and SV is scrapped vehicles.

Purchase rates can be taken directly from Table VEH0150. Scrappage rates can be deduced from a rearrangement of the vehicle fleet relationship, giving:

$$\mathbf{SV\ (t-1) = VF\ (t-1) - VF\ (t) + PV\ (t-1)} \qquad \textbf{(Equation 6.2b)}$$

Where VF is vehicle fleet, PV is purchased vehicles and SV is scrapped vehicles.

This data is shown for the last 10 years in Table 6.8.

Table 6.8 – UK cars - vehicles registered, purchased and scrapped (DfT Tables VEH0101 and VEH0150 (DfT, 2020m))

	Vehicle fleet	Growth	Purchased	Scrapped	Scrapped
Year	Table VEH0101 1000s	%	Table VEH0150 1000s	1000s	%
2010	28320		1996		
2011	28513	0.7%	1907	1803	6.3%
2012	28581	0.2%	2011	1839	6.4%
2013	28842	0.9%	2225	1750	6.1%
2014	29372	1.8%	2438	1695	5.8%
2015	29766	1.3%	2602	2044	6.9%
2016	30461	2.3%	2665	1907	6.3%
2017	31074	2.0%	2509	2053	6.6%
2018	31348	0.9%	2342	2235	7.1%
2019	31687	1.1%	2295	2002	6.3%
Average		1.3%			6.4%

Table 6.8 shows a steady growth in the UK vehicle fleet with car numbers rising from 28 million to nearly 32 million between 2010 and 2019. Overall, the data indicates an annual average growth rate of 1.3%. It is noted that the DfT (DfT, 2018a, p62) indicates that congestion on UK roads is expected to only increase from 7% to about 12% between 2020 and 2050. In addition, they report that this congestion is likely to be associated with motorways where investment is being applied to increase capacity. There are, therefore, few significant constraints present that are likely to lead to a break in growth in the short term. It is, therefore, assumed, as discussed in Section 4.5.3, that growth in car numbers will continue at the rate that is currently occurring.

In terms of overall car numbers, increases are driven by differences between cars entering the fleet, as new purchases (average about 2.3 million per year) and cars leaving the fleet, as scrappage (average about 1.9 million per year). Rates of new purchase and scrappage have not varied significantly in the 10 years prior to 2019. Scrappage rates, shown in Table 6.8, are, on average, about 6.4%, with variation only between 5.8% and 7.1%. 6.4% scrappage relates to a 100% turnover of the vehicle fleet in 15 years. Hence, based on this model, even if EVs were introduced for all new cars in 2021, it would not be until 2035 before most petrol and diesel vehicles would be expected to leave UK roads.

Low emission vehicle trends

Data on new and existing EVs in the UK is collected by the European Alternative Fuels Observatory (EAFO) (EAFO, 2021b). Existing and new EVs are, over the last 10 years, shown in Table 6.9. Scrappage rates are calculated using Equation 6.2b.

Table 6.9 – Derived UK EV cars purchased and registered from EAFO data (EAFO, 2021b)

	Vehicle fleet	Growth	Purchased	Growth	Scrapped
Year	1000s	%	1000s	%	1000s
2010	0		0.1		
2011	1	275.1%	1.1	1092.2%	0
2012	3	90.1%	1.4	32.0%	0
2013	5	89.0%	2.6	80.2%	0
2014	10	85.9%	6.7	162.1%	2
2015	20	102.7%	9.9	48.6%	0
2016	30	50.5%	10.2	3.1%	0
2017	43	42.2%	13.7	33.5%	1
2018	61	43.3%	17.5	28.0%	-1
2019	99	62.0%	38.0	116.9%	0
Average		93.4%		63.1% (Note 1)	

(Note 1 – this average does not include 2011 data which is anomalous due to small 2010 sales)

As shown in Table 6.9, the numbers of new UK EV purchases have been increasing dramatically over the last ten years. In 2011 less than 1,000 EVs were purchased. However, by 2019, annual purchases of EVs had increased to nearly 40,000. The proportion of all new car purchases, that relate to EVs, has hence increased from less than 0.5% to over 1.5%.

EAFO also provide data on EV sales for LGVs and buses (EAFO, 2021b). For HGVs and motorbikes sales data is provided by the DfT, although this data (Table VEH0130/0170) relates to low emissions vehicles (less than 75gCO_2/km) rather than specifically to EVs (DfT, 2020m). Table 6.10 shows EAFO and DfT data relating to purchases of vehicle types, other than private cars, in the UK, and derived growth in purchases of these vehicles. For each vehicle type, the table also shows background growth and scrappage for conventional vehicles derived from 2010 to 2019 sales data (DfT, 2020m).

Table 6.10 – Derived UK EV and low emission vehicle growth and scrappage rates based on EAFO and DfT data tables (EAFO, 2021b; DfT, 2020l)

EVs	Sales per year (2019)	% of total sales	Conventional background growth	Conventional background scrappage	EV/low emissions growth
Year	2019		2010 to 2019		
Cars	37,993	1.66%	1.3%	6.5%	63.1%
LGV	3,236	0.88%	2.7%	6.5%	64.8%
HGV	19	0.04%	0.6%	9.4%	32.5%
Motorbikes	1,706	1.44%	0.1%	9.2%	27.4%
Buses and coaches	144	2.04%	-1.3%	6.8%	24.7%

Table 6.10 shows a variety of adoption penetrations into UK markets by different vehicle types. All EV vehicle types, apart from HGVs, have recorded about 1.0% and over, sales penetration. For HGVs, the development of low emissions vehicles is starting from practically nothing. Growth rates in low emissions sales vary between about 25% and over 50%. For buses and coaches, growth in low emissions vehicles is occurring against a backdrop of overall falling numbers of vehicles. For other vehicle types, continued background growth in vehicle sales is recorded. Scrappage rates shown, are all between 5% and 10%. Higher scrappage rates are indicated for large vehicles with high mileages, such as buses, coaches and HGVs. The turnover of motorbikes, associated with lower costs, is also higher than that for cars.

Policy pathways

In this section the Rogers diffusion model is used to make some predictions of uptake in EVs in UK society. Pathways have been used to illustrate a range of possible futures. As noted by van der Heijden (2005), exploring multiple pathways allows uncertainty to be investigated and reduced. Through investigating a range of possible futures, an assessment can be undertaken of the relative importance of different factors which might shape the UK car market in ten, twenty and thirty years. The possible futures can also be used to provide a baseline assessment of actual CO_2 emissions budgets relative to Paris Agreement goals.

The data shown in Table 6.9 and Table 6.10 provides a starting point for development of policy pathways to model diffusion of EVs in the UK in the next 30 years. The diffusion model requires an estimate of the time over which sales of a particular product grow from

2.5% to 16.0%, over the period where early adopters are purchasing the new technology. The diffusion model then indicates that early and late majorities will adopt technology over the same time period. In the early stages of the diffusion model, constant growth is predicted, as external boundaries associated with innovation resistance are not significant. Extrapolating existing growth rates up to the 16% inflection point and the start of early majority purchases, is, therefore a reasonable means of defining the early adoption time period.

For EV cars, cases can be made for a variety of growth rates. Annual growth rates have varied from less than 10% to over 100%. Lower growth rates are associated with 2016 and 2017 when the Government reduced 'vehicle excise duty' (VED) incentives (HM Government, 2015). Wadud (2014) notes that VED policy may have a significant effect on purchase of low emissions vehicles and hence relaxation of incentives may have resulted in lower interest in EVs. 2019 growth rates in sales were, however, over 100%. Over the whole period between 2010 and 2019, sales growth rates averaged over 50%. Rietmann & Lieven (2019) note that EV sales growth rates, in most industrialised countries in the world, have been about 50%. Average sales growth rates for LGVs match those for cars whilst growth rates for other vehicles are all, on average, about 25%. For HGVs, it should also be noted that a low emissions solution may involve hydrogen fuel cell diffusion, rather than EV technology (Smallbone et al., 2020). For motorbikes, although growth rates are not high, Santucci et al. (2016) state that a significant potential exists for EV motorbikes, as a low-cost travel option that has not, as yet, been fully explored.

To investigate the possible scope of change in technology, diffusion pathways have been developed to illustrate low, medium and high growth assumptions. Hence, three different reference pathways have been defined. In these three pathways EV adoption is modelled with a low (25%), medium (50%), or high (75%) initial growth rate. In addition, to these reference pathways three government intervention pathways have also been investigated. In government intervention pathways all private cars purchased after an intervention date are assumed to be EVs. Possible intervention dates are 2035 (current UK Government policy), 2030 (Government policy for hybrid vehicles and better relating to CCC recommendations) and 2025 (potential earliest practical intervention).

Overall rates at which new vehicles are purchased and scrapped are those shown in Table 6.10. It is assumed that scrappage rates for EVs are the same as those applied to conventional vehicles. This is based on the observation that, even though EVs may be more technologically robust than conventional cars, the technological robustness of a vehicle is only one of the factors that influences a replacement decision (Marell et al., 2004). It is assumed that these non-technical factors remain constant and hence car replacement rates do not substantially change where EVs have been adopted. The six pathways are illustrated in Table 6.11. Worksheets for each of the pathways are contained in Appendix B.

Table 6.11 – Indicative technological pathway adoption results

Pathway	Vehicle	Initial growth assumption	Time for 16% adoption	Time to 84% adoption
Reference 25	Private cars	25%	2027	2047
Reference 50	Private cars	50%	2024	2036
Reference 75	Private cars	75%	2023	2032
Intervene 25	Private cars	50%	2024	2025
Intervene 30	Private cars	50%	2024	2030
Intervene 35	Private cars	50%	2024	2035
Reference 50	LGVs	50%	2027	2039
	HGVs	50%	2034	2044
	Motorbikes	50%	2025	2035
	Buses and coaches	50%	2024	2037

Table 6.11 shows the impact of current diffusion on possible sales of low emission vehicles. The table shows private cars reaching the first diffusion inflection point in less than 5 years if growth rates are assumed to be 50% or greater. However, if a low growth rate is assumed, the first inflection point is reached in nearly twice this time. It is at this first inflection point that a move occurs from early adopters to early majority and rates of growth are reduced. For other vehicle types this first transition occurs in 3 to 7 years' time. However, for HGVs, diffusion is starting from a very low base and, despite a low background growth and a high scrappage rate, according to the model they need nearly 15 years to achieve significant market penetration.

In terms of reaching the final diffusion inflection point, where population majorities have adopted new technologies and only laggards remain with old technologies, Table 6.11 indicates the enhanced initial growth rates in the Reference 75 pathway, lead to substantial adoption of vehicles in the early 2030s. For the medium initial growth rates, substantial adoption will be achieved by mid to late 2030s for all vehicles, apart from HGVs. However, if a low growth rate is assumed, as in the Reference 25 pathway, the model indicates that substantial adoption will not be complete until nearly 2050. In all the intervention pathways prohibition of sale of conventional vehicles occurs after the first inflection point is reached, but before the final inflection point. However, in all these pathways large numbers of conventional vehicles will still be present in the UK fleet, at the point of intervention, and will only be replaced as they reach the end of their useful life and are scrapped.

Emissions intensities

The final stage in assessment of technological change involves calculating the effect of adoption of new vehicles on CO_2 emissions. As outlined in Chapter 1, the impact of implementing policy, on regional CO_2 emissions, represents a knowledge gap that is addressed by this thesis. The calculation of technology pathway CO_2 emissions, described in this section, represents new knowledge, that will be used in Section 6.3 to address this knowledge gap.

Up until the point where the last conventional vehicle is retired, UK emissions will be characterised by a mixture of drive systems. The fleet emission rate will improve; as the percentage of EVs increases, as efficiencies improve for conventional and EV engines and as electricity generation efficiencies are improved. The percentage of EVs in the fleet can be taken from the pathways shown on Table 6.11. To allow future emissions to be modelled, current and potential emission intensities for conventional vehicles (gCO_2/km) and electric vehicles (kWh/km) need to be defined. In addition, the current and potential future UK electricity carbon intensities (gCO_2/kWh) need to be defined. Improvements in these efficiencies are discussed below.

For conventional vehicles, current emission intensities are shown in Table 6.3. For small and medium electric vehicles, existing energy efficiencies are shown in Table 4.8 (0.05 to 0.25kWh/km). For large zero emissions vehicles a wide range of energy efficiencies are possible. Zhou et al. (2016) report that electric buses achieved between about 0.75kWh/km, for a small 8m bus, and 1.25kWh/km, for a larger 12m bus. An average of these relates to an emission intensity of about 1.0kWh/km. González Palencia et al. (2017) report efficiencies for large heavy duty freight vehicles of 0.9kWh/km, for electric drive systems and 1.8kWh/km, for vehicles using fuel cells. For medium freight vehicles, they report that equivalent emissions are 0.4kWh/km and 0.7kWh/km. As noted by Smallbone et al. (2020), freight logistics mean that reliance on electric drive systems, on their own, is unlikely to be feasible for HGVs. Any low emissions technology freight regime would hence be a mix of large and medium vehicles, driven using both electric and fuel cell technologies. This represents an average emissions intensity of about 1.0kWh/km.

Over the next 30 years it is likely that vehicle emission intensities will improve. For conventional vehicles, over the last 10 years, some improvement in intensities has occurred, as EU regulations have required manufacturers to improve the efficiency of newly registered vehicles. A review of these improvements can provide an indication of the rate at which engine efficiency enhancements can occur. For conventional vehicles, reduction in emission intensity is associated with improvements in engine efficiency and reduction in vehicle weight. Engine efficiency can be improved through use of lighter materials, alternative fuels, computerised control systems and revised drive systems, including hybridised engines (George, 2011). Development of computerised design and new innovative material also provides opportunities for significant vehicle weight reduction (Baskin, 2016). Engine improvements and weight reductions will be a result of government regulation, such as the EU directives, and manufacturers own initiatives. It is, however, noted that manufacturers have generally been trailing government initiatives, in improvement of engine efficiency and hence government regulatory initiatives are likely to be of more importance (Tietge et al., 2018).

Figure 6.1 shows new car and fleet energy intensities, for the period 2003 to 2021. Data on new car energy intensities has been taken from DfT Table VEH0156 (DfT, 2020m). It is noted that 2020 data is only partially complete. Data is shown for the vehicle test system used before 2018 (NEDC), the new system (WLTP) and an estimation of real world emissions, using conversion figures as discussed in Chapter 4 (Tietge et al., 2018). The data point for 2021 relates to the EU regulatory requirement, of 95 gCO_2/km NEDC. On the same figure estimations of overall fleet efficiencies are shown. These efficiencies are calculated as set out in Table 6.3, with traffic flows measured through monitoring across UK road networks

(DfT, 2018b) and fleet characteristics determined through number plate sampling (Ricardo Energy and Environment, 2020).

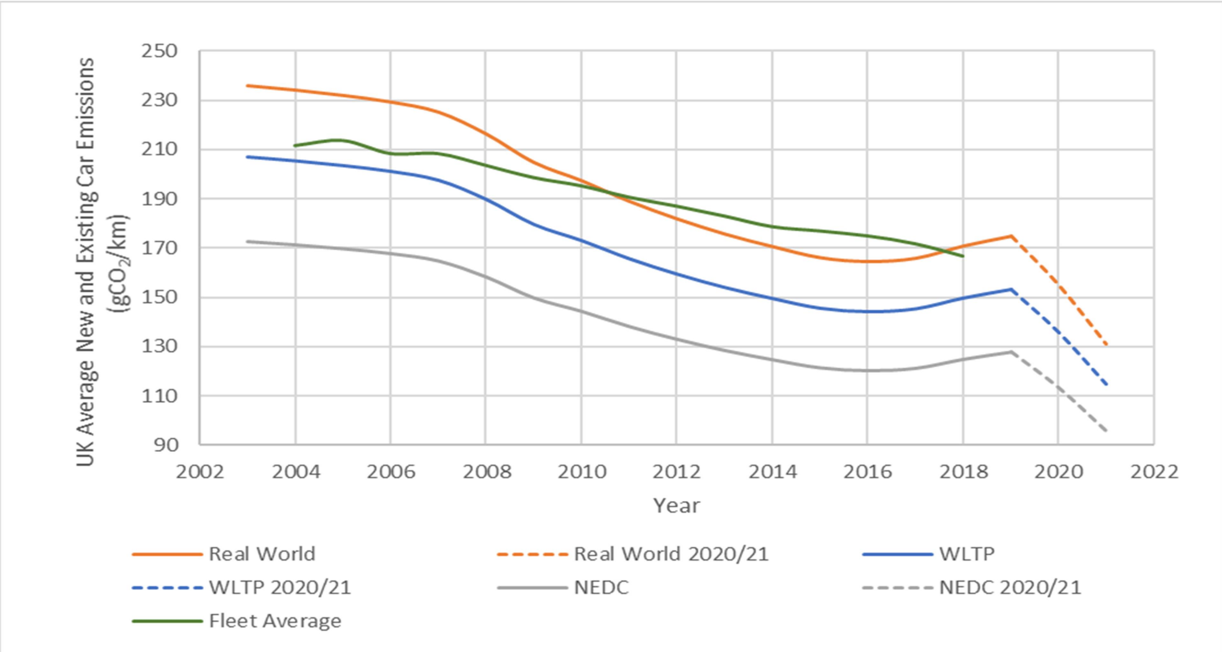

Figure 6.1 – UK new car and car fleet average emissions (DfT Tables ENV0202 (DfT, 2020c), TRA0206 (DfT, 2020n) and VEH0156 (DfT, 2020m))

Figure 6.1 shows that both new car efficiencies and fleet efficiencies have generally been improving since the beginning of the century, with an overall trend of reduction in fleet emissions of about 1.8% per year. This can be compared to the reduction in emissions from new cars of over 3.0% per year between 2010 and 2016. The trend in fleet emissions is likely to lag the trend in new car emissions as old inefficient cars, within the fleet, remain in service. However, as old cars eventually become redundant the fleet trend is likely to increase to match the new car trend. Brand et al. (2017) proposed an improvement rate of 1.5% for new cars, although at the time new car efficiencies were improving at over 3.0% per year. A fleet improvement rate of 1.8% per year relates to an overall improvement in emissions of about 40%, over the thirty years between 2020 and 2050. Leach et al. (2020) conclude that between 30% and 50% improvement in efficiencies of internal combustion engines is possible. Based on the fleet improvements that have occurred previously and the underlying greater improvements in registered new vehicles, it is considered reasonable to assume that this 40% improvement in conventional vehicle efficiencies can occur before 2050. However, it is noted that, as EV vehicles replace conventional vehicles, the impact of efficiency improvements in conventional vehicles will reduce and, at the point when 100%

EV adoption occurs, conventional engine efficiencies will have no impact on overall transport emissions.

Predictions of improvement in engines for other vehicle types also need to be made, to establish forward projection of overall UK transport emissions. For motorbikes and LGVs, as engines are broadly similar, the predictions made for private cars, of improvement by 1.8% per year, can also be applied. For larger vehicles, such as buses and HGVs, a separate assessment is required. González Palencia et al. (2017) predict that emission intensity improvements for large vehicles of about 20% can occur before 2050. This relates to half the efficiency improvement that can be envisaged for smaller vehicles. Given the lower numbers of HGVs and buses and complexity of drive systems to power such large vehicles, this smaller improvement in large vehicle emissions intensities, appears reasonable.

There are also potentials for engine efficiency improvements in EV drive systems. Data from Tesla indicates that, over the last ten years, they have achieved efficiency savings of about 3% per year, in their engine design (Electrek, 2019). Pereirinha et al. (2018) note that substantial achievements in battery design have been made over the last few years, but that there is still potential for improvements. Farfan-Cabrera (2019) lists over a dozen systems within EVs where there is potential for efficiency improvements. The weight reduction potentials, offered by development of new lightweight materials, as discussed by Baskin (2016), also provide opportunities for improvement of efficiencies in EVs. Continued improvements of 3% per year would lead to efficiency increases of about 60% over the next 30 years. A reasonable assessment is that about half this improvement can be achieved and 2050 electric engines can have efficiencies 30% better than current engines.

In terms of electricity generation, over the last 20 years emissions have reduced by over 60% in the UK, as coal fired power has been reduced and, more recently, the proportion of renewables has increased (BEIS, 2020b). The National Grid (2020) has produced a number of scenarios relating to future UK electricity generation. In these scenarios carbon capture technology is used to achieve negative emissions intensities by 2050. Mander et al. (2017), however, caution that large scale deployment of carbon capture may not be technically feasible by 2050, given the current state of technological development. Workman et al. (2020) argue that assumptions made with relation to carbon capture should take into account the uncertainty associated with deployment of new technology. Daggash et al.

(2019) note that zero emission intensities, without carbon capture, are possible but unlikely, given challenges in reducing electricity demand and increasing zero carbon supply. It is, therefore, concluded that generation intensity should be assumed to meet the UK's net zero aspirations by 2050 but not to significantly exceed these. In modelling a UK energy generation future, a 95% reduction in emissions intensity is, therefore, assumed, reducing current emissions of about 160gCO_2/kWh to less than 10gCO_2/kWh.

Terrestrial transport emissions also include those associated with rail systems. Network Rail have produced UK network decarbonisation scenarios (Network Rail, 2020). These indicate that, given adequate investment, all trains can be run on low emission systems, derived from electricity, by 2050. Given a reduction in carbon intensity of the grid to net zero by 2050, a linear reduction in rail emissions can be assumed, from current average levels of over 5000gCO_2/km (Table 6.3), to less than 100gCO_2/km in 2050. Rail decarbonisation can hence also be incorporated in terrestrial transport technological pathways.

Technology pathway results

Using the EV pathway adoption figures shown in Table 6.11 and derived vehicle and generational efficiencies, calculation of possible average vehicle emissions can be made. It is assumed that significant changes in technology have not occurred in 2019/20 and hence the emissions figures derived from the latest DfT and BEIS data, relating to 2018/19, shown in Tables 6.1 to 6.7, are still relevant. The results of these calculations are shown in Table 6.12.

Table 6.12 – Calculated fleet emission pathways

Pathway	Vehicle	Average emissions per vehicle (gCO2/km)			
	Year	**2020**	**2030**	**2040**	**2050**
Reference 25	Private cars	166	132	83	22
Reference 50	Private cars	166	119	41	1
Reference 75	Private cars	166	108	25	1
Intervene 2025	Private cars	166	86	9	1
Intervene 2030	Private cars	166	115	23	1
Intervene 2035	Private cars	166	119	37	1
Reference 50	LGVs	226	169	69	2
	HGVs	777	712	501	13
	Motorbikes	108	73	11	0
	Buses and coaches	830	682	346	7

The evolutions of emissions for private cars in the six technology pathways are shown in Figure 6.2.

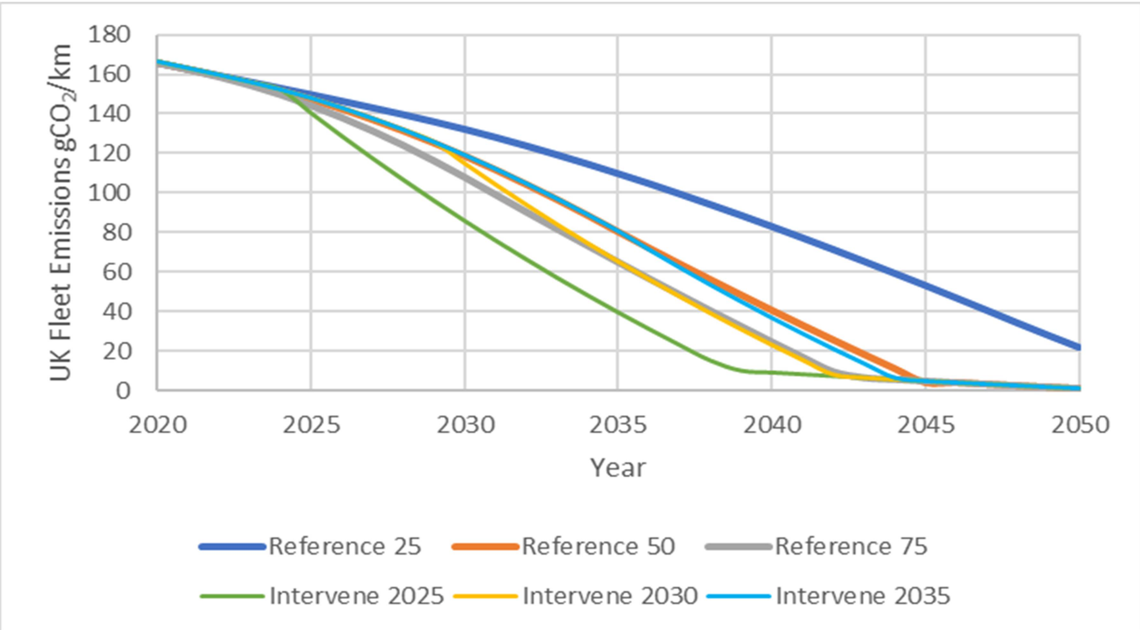

Figure 6.2 – Calculated UK technological policy pathway average fleet emissions intensities

The results of the technology pathways, derived within this thesis (Figure 6.2), indicate the relative importance of growth rates and intervention dates, in determining the point at which 95% reduction in average fleet emissions intensities is achieved. If a low 25% initial growth rate, rather than a 50% rate, is assumed, then significant decarbonisation of the UK car fleet is delayed from the early 2040s to after 2050. Further improvements in initial growth rates, however, only bring forward the point at which significant decarbonisation occurs by a few years. In terms of intervention pathways, an early ban on sales of conventional vehicles has the greatest effect on fleet decarbonisation. Early intervention leads to significant decarbonisation before 2040. Later bans, however, do not significantly alter the point at which this decarbonisation occurs, relative to a pathway where no intervention is introduced (Reference 50).

The evolution of emissions from vehicles, other than private cars, based on an initial diffusion rate of 50%, with no intervention, is shown in Figure 6.3.

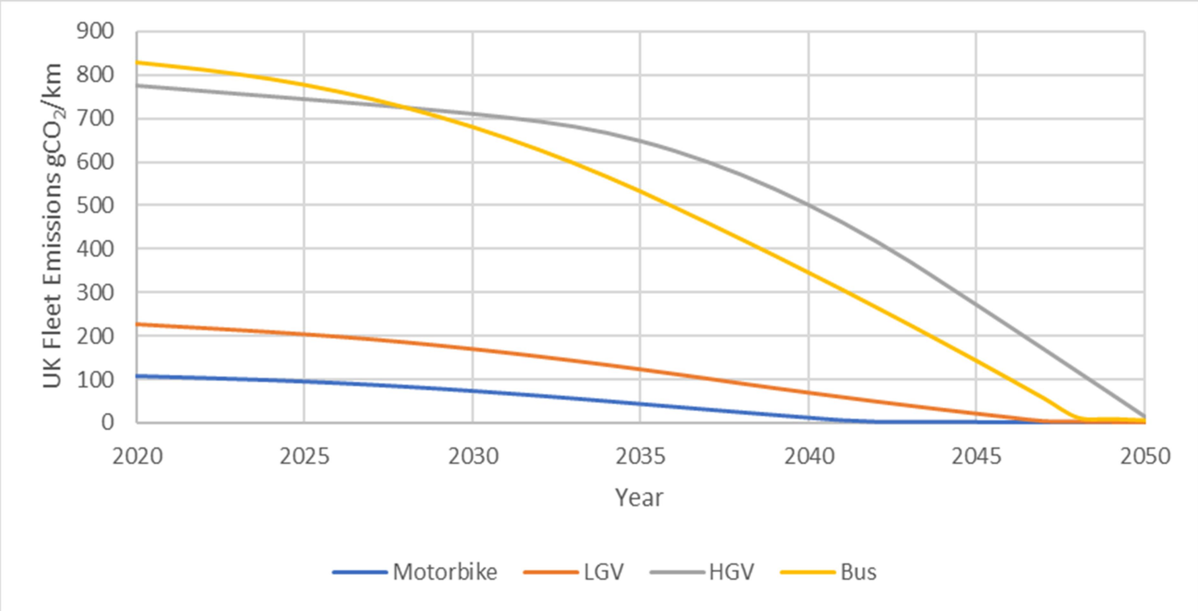

Figure 6.3 – Calculated UK technological policy pathway average emissions intensities for vehicles other than private cars

Figure 6.3 shows the continued high emissions associated with large vehicles, such as HGVs and buses, if reducing emissions for these only occurs through diffusion with no intervention. As shown on Table 6.6, these large vehicles currently account for about 20% of emissions and, if they are left out of any intervention initiatives, this percentage would rise.

The pathways indicate that early and significant intervention, to restrict sales of diesel and petrol cars and improve sales of EVs, is required to substantially affect UK fleet average emissions. Without early restrictions, on sales of diesel and petrol cars, and incentives to improve growth in sales, a 95% reduction point may be as late as 2050. With early intervention and incentives to increase growth in sales, a 95% reduction point earlier than 2040, can in theory be achieved.

6.4 Stewardship pathways

New stewardship pathways have been derived, for this thesis, to explore how terrestrial transport CO_2 emissions may change under a number of different assumptions, particularly relating to local authority interventions. Local authority stewardship interventions are associated with the transport activities shown in Table 6.1. Through altering local activities, transport greenhouse gas emissions, shown in Table 6.7, can be reduced. In this section, potential interventions derived from the qualitative interviews are quantified in terms of their impact on local transport emissions and timescales associated with each intervention are also discussed. In the first instance, these interventions are presented and discussed in isolation of the technological interventions, covered in the previous section. This is justified because the technology interventions are predominantly controlled by the action of national government and represent a background for stewardship interventions, that are predominantly controlled by the action of local government (Browne et al., 2012).

In characterising stewardship interventions, a distinction can be made between the short-term quick fix initiatives, that can be applied over a five-year timeframe and the long-term societal change initiatives that required 10 to 20 years to implement. Short term initiatives require that local planners have power to implement change, through oversight of transport systems, local businesses, schools and leisure enterprises. The mechanisms for these interventions are local travel plans, local restrictions in use of cars and local support of alternatives. Long-term interventions involve actions on a community wide basis, to engage all sectors of society in public and active travel schemes, together with time to plan and implement large scale infrastructure schemes. Factors influencing these mechanisms are discussed in Chapter 4.

In looking at individual interventions and their consequences, interactions between different policies need to be borne in mind. One policy intervention may allow a second intervention to be more easily applied or present a conflict. Initial acceptance of a road pricing scheme makes introducing subsequent policies, associated with tighter restrictions, easier to apply (Krabbenborg et al., 2020). Kenworthy (2018) notes that, once a member of the public gives up their car for one transport purpose, they are likely to give up private car travel for other purposes and hence there is a leverage effect associated with promoting a public transport regime and discouragement of use of private cars. Members of the public giving up the car for their commuting activities also live without a car for their shopping and leisure activities. The ability to live without a car, in areas outside large cities, is, however, not simple. Watson (2012) describes a decision to do without a car as a complex process integrated with daily practices and social norms. He, however, states that, although there is resistance, such changes in practices and norms can be achieved.

Transport efficiency savings also have the potential to free up time and money and allow personal travel regimes to be expanded, wiping out some, or all, of efficiency savings. Zhang et al. (2015) report studies that indicate direct rebound effects from improving transport systems of between about 10% and 90%. The scenarios prepared by the DfT (DfT, 2018a) indicate that lower fuel pricing, associated with EVs, could lead to a significant increase in private vehicle use. Barker et al. (2007) characterise rebound in terms of direct effects, indirect effects and macroeconomic effects. They state that direct effects relate to increased use of a more efficient service. Indirect effects relate to the impact of freeing up money on consumer behaviour in other sectors and macroeconomic effects may lead to overall growth in the economy, wiping out some efficiency improvements. They state that direct effects may be assumed to be about 15% of energy savings and that another 10% to 15% of rebound is associated with indirect effects. They, however, state that, even with these rebound effects, interventions can still lead to significant emissions reduction.

Mode switch relates to a reduction in car journeys balanced by an increase in transport using other travel modes. In parallel, purpose switch relates to reducing activity, that involves use of cars, and increasing activity undertaken using public and active travel systems. These two sets of interventions act together to reduce use of cars. They are complimentary in that a mode intervention, introduced through an areal car restriction, may aid a purpose intervention to make local shopping easier. However, mode interventions, without complementary purpose interventions, may not be sustainable, as they are likely to leave members of the public without adequate means to get to work, shop and undertake leisure activities. Mattioli et al. (2018) describe sections of society that already face exclusion, as they do not have sufficient income to undertake daily transport activities. They note that the unemployed in rural areas are, at present, particularly prone to this fuel poverty.

To maintain current travel regimes, reduction in use of cars, through mode and purpose interventions, needs to be balanced by increase in use of alternative travel systems. The issue with increasing other modes of travel, to replace car journeys, is that, relative to car journeys, other modes of travel in the UK are at a low starting point. The factor controlling reducing transport emissions may be ability to reduce cars or ability to increase public transport and active travel. Where it is not possible to adequately increase active travel and public transport options, car reduction will not occur. However, even where sufficient public and active transport options are available, if reducing use in cars cannot be achieved, then increased use of public and active transport will not occur.

Table 6.13 shows percentage increase in modes of travel, other than private cars, that would be required to balance 20% reduction in car distance travelled. Total distances are taken from Table 6.1.

Table 6.13 – Switch between car and public and active transport (based on North West of England transport activity shown in Table 6.1 (DfT, 2020f))

Rural-urban classification	Total car (km/per/yr) (A)	Total other (km/per/yr) (B)	20% reduction in car use (km/per/yr)	Equivalent increase in use of other transport modes (%)	Leverage (A/B)
Urban conurbation	5,473	2,001	1,095	55%	2.7
Urban city and town	8,042	2,007	1,608	80%	4.0
Rural town and fringe	10,955	1,800	2,191	122%	6.1
Rural village, hamlet and isolated dwelling	12,693	1,784	2,539	142%	7.1

Table 6.13 shows that, for distance travelled to remain the same, a 20% reduction in annual car use, in an urban conurbation, requires 1,095km per person to be taken up by other modes of transport. This relates to a 55% increase in other modes of transport. For rural populations, a 20% reduction in annual car use would lead to 2,539km per person, that would need to be taken up by other modes of transport, requiring a 142% increase in other transport modes. The leverage between reduction in car travel and increase in other modes hence increases in more rural areas, where cars are, at present, dominant. With a leverage

factor of 2.7, increase in public and active travel, to compensate for reduced car use, is difficult in existing urban conurbations. However, it is over twice as difficult in rural areas. In large cities, the controlling factor, in reducing transport CO_2 emissions, is likely to be ability to reduce car numbers, as sufficiently increasing public and active transport is likely to be practical. However, in rural areas, the controlling factor is likely to be ability to provide adequate public and active transport options.

Review of literature relating to local interventions, outlined in Section 4.4 and 4.5 of Chapter 4, indicates that, in the short-term, integrated stewardship initiatives undertaken by planners, given powers to control business and school activities, together with local transport systems, can achieve 10% reductions in transport CO_2 emissions, relating to commuting, education, shopping, leisure and local freight. In the large city authorities, the literature review indicates that an extra 10%, short term reduction in transport CO_2 emissions, can be envisaged, through imposing traffic control systems analogous to those in place in London. In suburban areas this extra impact of areal mode restrictions is, however, indicated to only be about 5%. In large cities these reductions would be balanced by an increase in light rail and bus public transport systems, together with an increase in local active travel. In small cities reduction in cars would need to be balanced by increase in bus public transport systems. In small cities there may, however, also be greater potential for increase in active travel as intracity travel is associated with smaller distances. However, in addition, in small cities, the potential for intercity travel is greater as smaller populations may not be able to locally support all necessary goods and services (Meijers & Burger, 2017). In more rural areas, in the short term, it is the ability to increase public and active transport that is likely to control reduction in use of cars. Combined increases in rail and bus public transport systems of 50% relate to a decrease in use of cars by less than 10%, taking into account leverages shown in Table 6.13. In this environment longer term interventions to support larger increases in public and active travel, together with local shopping and working practices, are required.

In the longer-term the literature review indicates that societal changes in urban environments can achieve 50% reduction in commuting, education, shopping, leisure and local freight transport activities. These reductions will be matched by increases in public and active travel. In this longer-term pathway, sufficient time and resources are required, through provision of infrastructure and marketing, to support a Dutch style active transport system. In addition, introducing e-bikes is indicated to have the potential to substantially reduce distance and topographical limitations. In rural areas, as indicated in Table 6.13, reducing car use by 50% will need to be compensated for by an increase in alternative transport systems of 350%. It is only through a concerted move to a transport regime characterised by Dutch levels of cycling that this degree of increase in alternative low energy transport can be achieved. It is noted that that although the Dutch use cycles in a substantially greater proportion of their travel activities, they, however, use public transport less than in the UK (Fiorello et al., 2016). Per capita transport emissions in both countries have hence been similar, varying around $2.0tC0_2$ per person, in the last twenty years (Climate Watch, 2021). To achieve significant reduction in stewardship related emissions, adoption of Dutch cycling levels in the UK would hence need to be established whilst maintaining and improving use of public transport in line with leverage rates shown in Table 6.13. These changes are summarised in Table 6.14.

Table 6.14 – Stewardship pathway intervention assumptions

Population	**Short term change**			**Long term change**		
Rural-urban classification	**Cars**	**Public and active transport**	**Rationale**	**Cars**	**Public and active transport**	**Rationale**
Urban conurbation – city centre	-20%	+50%	Travel plans, congestion charge	-50%	+150%	Dutch societal change
Urban conurbation – suburban	-15%	+50%		-50%	+150%	
Urban city and town	-10%	+50%	Travel plans.	-50%	+200%	
Rural town and fringe	-10%	+50%	Travel plans.	-50%	+300%	
Rural village, hamlet and isolated dwelling	-5%	+50%	Travel plans.	-50%	+350%	

Assessment is also required of potential short and long term changes in regional freight movements associated with HGVs. As discussed in Chapter 4, in the short term only very small HGV emission reductions, of a few percent, can be envisaged, through support for local food production. The long-term effects on regional HGV movements are difficult to assess. It is envisaged that a concerted effort to support local producers could bring about a reduction in regional freight movements of up to about 10%.

6.5 Gap analysis

Introduction

In this section, in response to the identified knowledge gap outlined in Chapter 1, calculated CO_2 emissions, associated with background technological pathways and baseline stewardship pathways, are compared to cumulative emission budgets associated with Paris Agreement commitments. The gap between these pathways and Paris Agreement commitments is then defined and additional speculative pathways are explored in terms of bridging this gap.

UK cumulative CO_2 emissions targets

Possible terrestrial (excluding aviation and shipping) UK Paris Agreement CO_2 budgets are shown in Table 4.2. The central budgets are associated with UK 2020 to 2050 cumulative emissions of between 2,200MtCO_2 and 4,500MtCO_2. Lower budgets, as described by Anderson et al. (2020), represent apportioning method based on differential allowances for developing and developed countries. Higher budgets are derived from the general aspiration of the CCC Technical Report (CCC, 2019a), to achieve net zero emissions by 2050. Based on the UK population, representing about 0.8% of the world's population in the next 30 years (World Statistics, 2021), a UK terrestrial greenhouse gas budget of about 4,500MtCO_2 would be compatible with a per capita split of the total world quota of 720GtCO_2, shown in Table 4.1, assuming an allowance of 1,500MtCO_2 for aviation and shipping. This can be compared with an assumed CCC terrestrial budget, of about 4,500MtCO_2, shown in Table 4.2, based on a linear reduction in CO_2 emissions between 2020 and 2050. It is noted that the latest recommended CCC budget represents some acceleration relative to this linear pathway and extrapolation of recent CCC proposals (CCC, 2020c) suggest that the final CCC terrestrial budget will be slightly below a budget derived based on a global per capita calculation. However, the exact rationale for setting of CCC budgets is not clear and it is noted by Holz et al. (2018) that, in general, equity details, of how national budgets are derived, are poorly explained.

In order to derive targets specific to North West of England transport, national targets need to be subdivided to enable regional targets to be set. A North West of England regional target has been defined by Kuriakose et al. (2021) on the basis of regional grandfathering, assuming 11% of UK emissions relate to the North West of England. The proportion of UK CO_2 emissions, that relate to transport over time, excluding domestic and international aviation and shipping, is shown in Figure 6.4.

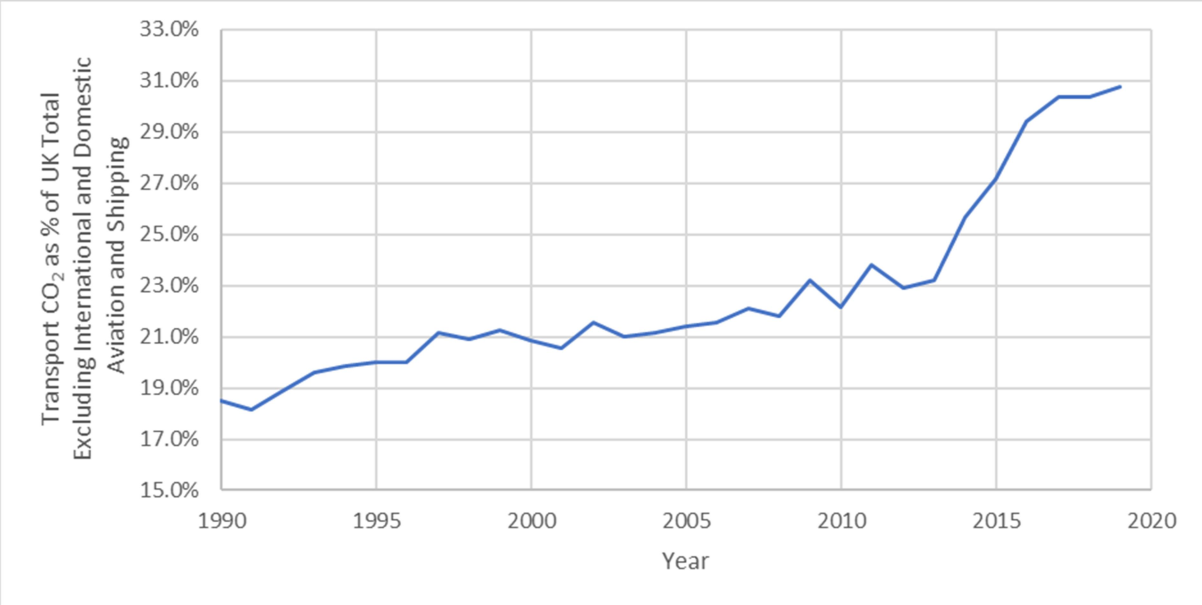

Figure 6.4 – Terrestrial transport CO_2 as % of UK total (BEIS, 2020b)

Figure 6.4 indicates that terrestrial transport CO_2 emissions have risen from about 23% of total CO_2, in 2010, to just over 30% in 2018. This rise in the relative importance of transport has occurred as overall emissions have fallen whilst transport emissions have remained broadly static. Tight et al. (2005) argue that, because of the high cost of decarbonising transport, relative to other greenhouse gas sectors, the transport sector should be allowed to rise, as a proportion of total emissions, to over 40% by 2050. In contrast, National Grid scenarios indicate that, in 2050, transport related electricity generation will only make up about 20% of national power use (National Grid, 2020, p30). However, 2050 emission proportions do not significantly affect the overall transport budget, as by 2050 it is planned that emissions will have been reduced to a very low level and the transport proportion will, hence, itself be very low. Emissions occurring over the period 2020 to 2025, when all emissions are at their greatest, will more significantly affect the proportion of the regional budget that should be allocated to transport. As shown in Figure 6.4, extrapolating current trends indicates that, in this period, transport is likely to make up about 30% of all CO_2 emissions. It, therefore, appears reasonable to assume that transport will make up about 30% of all cumulative emissions over the whole period 2020 to 2050. Based on the UK terrestrial CO_2 budgets shown in Table 4.2, the assumption that the North West of England represents 11% of the UK emissions and the assumption that transport constitutes 30% of regional emissions, a North West of England terrestrial transport budget of between 75MtCO_2 and 150MtCO_2 can, therefore, be set where:

- 75MtCO_2 = 11% of 30% of a national target of 2,200MtCO_2
- 150MtCO_2 = 11% of 30% of a national target of 4,500MtCO_2

As shown in Table 6.7, current emissions relating to transport in the North West of England are reported to be about 13.6MtCO_2 per year. If these emissions continued without any reduction, over the period 2020 to 2050, about 410MtCO_2 would be released from local transport systems. If predictions of a 10% increase in the UK population between 2020 and 2050 (ONS, 2020b) are taken into account, then baseline emissions, with no reduction per person, would equate to about 430MtCO_2. At the end of this period, in 2050, net zero would not have been reached and emissions would continue into the period 2050 to 2100. No progress would have been made and the region would still need to change systems to achieve net zero but in an environment where significant climate change and associated global temperature rises are occurring. The technology scenarios, described in Section 6.3, do reach net zero by the year 2050, but at different rates and, hence, with associated different cumulative emissions. The stewardship pathways, described in Section 6.4, do not, on their own, reach net zero. They only reach net zero when combined with technological pathways. They do, however, enhance and accelerate the rates at which the technological pathways reach net zero. In the following section the CO_2 budgets, related to each of the technological and stewardship pathways, are presented.

Baseline interventions

Stewardship interventions (Table 6.14), reduce overall regional emissions, taking into account a 10% population increase, by about 20% from 430MtCO_2 to 340MtCO_2. Only about a quarter of these savings are associated with the short-term interventions occurring between 2020 and 2025. The remaining three quarters of stewardship budget savings are associated with larger societal changes, assumed to occur between 2025 and 2035. Annual emissions associated with long-term end states are still about 10MtCO_2 per year. Without the switch to EVs, associated with technological interventions, the stewardship pathways are still a long way from reaching a net zero end point. The technological pathways generally reduce 2050 annual North West of England transport emissions to less than 0.5MtCO_2 and, hence, relate to a greater than 95% reduction in emissions. Cumulative emissions, with an allowance for population increase, associated with technological pathways, with and without the inclusion of the stewardship interventions, are shown in Table 6.15. Worksheets relating to assessments of these cumulative emissions are contained in Appendix B.

Table 6.15 – Calculated pathway cumulative emissions 2020 to 2050

Pathway results	**Technology pathway only (MtCO_2 2020 to 2050)**	**Technology + Stewardship (MtCO_2 2020 to 2050)**
Reference 25	265	210
Reference 50	220	195
Reference 75	195	190
Intervene 25	190	175
Intervene 30	210	190
Intervene 35	220	195

The cumulative emissions shown in Table 6.15 generally relate to a halving of emissions that would have occurred if no interventions were instigated in North West of England transport. If regional diffusion of EV technologies is assumed to occur at a low growth rate, without any associated intervention to restrict sale of diesel and petrol cars and without any stewardship interventions, the associated cumulative emissions, over the period 2020 to 2050, are calculated to be about 265MtCO_2. This relates to a 40% reduction in emissions. In addition, as shown in Figure 6.2, in this pathway a 95% reduction in emissions has not been reached by 2050. If rapid growth in EV sales (Reference 75) or early intervention (Intervene 25) is assumed, then the technological pathways achieve cumulative terrestrial transport emissions of less than 200MtCO_2.

The impact of adding the stewardship pathways to the technological pathways varies. Where technological growth is slow, the stewardship pathways create a substantial additional impact on emissions, as inefficient vehicles are not used by members of the public. However, in the more rapid diffusion pathways, the stewardship impact reduces, as some of the vehicle trips removed are already being undertaken by more efficient EV technologies.

The figures shown in Table 6.15 indicate that the largest reduction that can be envisaged, using the assumptions described in Sections 6.3 and 6.4, is a 60% reduction in cumulative emissions from a case where no interventions occur. This reduction relates to cumulative emissions of 175MtCO_2 and is described by a pathway with medium technological growth, early intervention and all stewardship assumptions being valid. This cumulative emissions total is 20% above a CCC derived target and over twice the Anderson et al. (2020) derived cumulative emissions target. Further consideration of interventions is, therefore, required. These possible further interventions are discussed in the following section.

Speculative interventions

In their 2019 Net Zero Technical Report the CCC (CCC, 2019a, p12) describe interventions in terms of core options, further ambitious options and speculative options. The pathways described explore the core options and, particularly with the long-term stewardship interventions, some of the further ambitious options, that can be adopted in the North West of England. Some of the speculative options, that can be applied to regional transport to try to meet specified cumulative emissions targets, are described in this section.

Conventional petrol and diesel vehicles at present represent the greatest contribution to regional transport emissions, and hence exploring further options should start with these vehicles. One additional aspect of private journeys that can be investigated is the car occupancy rate. No significant changes have occurred in UK private car occupancy rates in the last 10 years, with NTS Table 0905 (DfT, 2020f) only recording a small reduction from about 1.56 to about 1.55. Increased occupancy has the potential to reduce private car trips and hence to reduce emissions. Zavaglia (2016) reports that commercial car sharing enterprises have reduced local emissions by between 10% and 15%. Cairns et al. (2010) argue that car sharing can be an integral part of travel plan initiatives and, through preferential treatment of cars with multiple occupants, can increase occupancy by 20% at specific locations. High occupancy vehicle lanes, incorporated into local road networks, are another method of increasing rates of car sharing. However, assessment of these schemes has mainly dealt with effects relating to peak time reduction in cost of travel, reduction in local congestion and improvements in local air quality, rather than overall reduction in distances travelled (Wang et al., 2016; Boysen et al., 2021). Shewmake (2012) argues that, on these criteria, it is debateable whether introducing high occupancy lanes is effective. In the longer term, however, Manders et al. (2020) argue that high occupancy initiatives can reduce trips by 50% through introducing clean and efficient multi occupancy vehicle hiring schemes. Based on these options a speculative pathway has been investigated where local travel plans increase occupancy by 10% in the next 5 years, and societal changes, through adopting car share hiring schemes, increase occupancy by 50% by 2035.

The second most important contribution, to the North West of England transport CO_2 budget, is the HGV network, transporting raw materials and goods across the region. Mckinnon (2007) reports that historically there has been significant correlation between GDP and HGV growth. He, however, notes that this correlation has weakened since the beginning of the century, as the UK moved towards a service economy with greater off shoring of manufactured goods. As shown on Figure 4.3, HGV movements have remained broadly stable, in terms of distance covered per person, since 1990, whilst GDP has continued to rise. Mulholland et al. (2018) estimate that logistical improvements can decrease CO_2 emissions relating to rail freight by over 10%. Zuo et al. (2018) estimate emissions reduction of greater than 5% if rail terminals were constructed at quarry sites and rail freight incentivized through preferential funding. Mckinnon (2007) presents a scenario where rail freight is increased by 30% and logistical and vehicle efficiencies improved by 10% each and concludes that, through these stewardship initiatives, emissions savings of greater than 25% could be achieved. For technological interventions, development of low emissions large freight vehicles is in its infancy and hence, as shown in Figure 6.3, without intervention, full integration of low emissions vehicles will not be achieved until after 2050. However, Ainalis et al. (2020) describe technology, already tested in Germany, that involves constructing electrical catenary systems overhanging the inside lanes of the UK motorway network, that would allow EV HGVs to continuously recharge, thus removing the distance constraints that currently restrict use of electric technology in longer and larger freight movements. They indicate that such a system could be economically rolled out in the UK over a fifteen-year period. Based on these discussions a speculative pathway relating to freight would involve HGVs diffusing at the same rate as for cars and reducing HGV freight emissions through logistical improvements and transference to rail by 25% in 2035.

As shown in Table 6.6, buses and coaches currently represent less than 5% of regional transport emissions. In stewardship pathways they are, however, modelled, taking into account leverages of up to 7, as experiencing increases in use by 50% in the short term and, in rural areas, by over 300% in the long term. The factors that control emissions from buses are emissions intensities and occupancy. Currently calculated average bus occupancies, shown in Table 6.2, are less than 10. Oldfield & Bly (1988) state that, in an urban setting, in order to run an economically efficient service, buses with over 40 seats are required. Teal & Becker (2011) also indicate that buses with a large capacity are required for economic sustainability, in urban areas, but also note that small capacity services with only 10 boardings per hour can be economically viable where a flexible approach to routes and services is introduced in a specific demand response niche. In rural areas, provision of journey options with a smaller demand responsive bus service may be a practical alternative to car journeys (Wang et al., 2015). However, in urban areas with fewer route options Silva (2013) argues that consolidating buses in order to increase occupancy is an efficient way of reducing overall greenhouse gas emissions and Hwe et al. (2006) note that consolidating bus services will, at the same time, reduce congestion and air pollution. These discussions highlight the importance of increasing bus occupancy and, therefore, a speculative pathway, relating to achieving bus occupancy of at least 20, has been investigated. It is assumed that this will be achieved through increased demand on existing bus services and careful matching of demand to service.

The provision of efficient public transport is closely tied to the stewardship pathways, described in Section 6.4. It is noted, in discussion of these pathways, that, in the short-term, potential for reducing car transport is likely to be constrained by the requirements for leveraged increase in public transport. In a speculative pathway it can be envisaged that these constraints on increases in public transport are removed. These constraints are partly associated with the long periods required to provide large-scale metro system infrastructure. They are, however, also associated with the limited control that local planners have on provision of public transport systems. If these control limits were removed and local authorities could run heavily subsidized public transport systems, it can be envisaged that constraints on reducing car journeys and mode switch to public transport systems could be significantly reduced. Hence a speculative pathway is envisaged that doubles the short-term reduction in use of cars to 40% in large cities and 10% in rural areas. In this enhanced stewardship pathway, leverage growth in public transport distance per person would be increased from, a previously envisaged 40% to 60%, to a revised percentage of 60% to 100%.

The final area where speculative pathways might be applied relates to the efficiency of energy generation. The National Grid (2020) presents scenarios in which, by 2030, electricity generation in the UK is achieved with zero emissions and by 2035 carbon capture technology leads to negative emissions of $100gCO_2/kWh$. In core pathways, employment of carbon capture technology has not been assumed as existing evidence currently questions the feasibility of development of new large scale systems (Mander et al., 2017). However, as a speculative pathway, to meet the gap between baseline pathway emission budgets and target budgets, it is envisaged that sufficient resources are made available to develop such large-scale carbon capture technology in the next 20 years.

The results of these speculative pathways are shown in Table 6.16. As a baseline the pathway that relates to restricting sale of conventional vehicles in 2030, with associated stewardship interventions, has been taken. As shown in Table 6.15 this pathway is calculated to have CO_2 emissions of $190MtCO_2$. Worksheets relating to assessments of speculative emission pathways are contained in Appendix B.

Table 6.16 – Calculated impact of speculative pathways (relative to Intervene 30 technology + stewardship pathway baseline of 190MtCO$_2$)

Speculative pathways	Assumption	Cumulative emissions (MtCO$_2$ 2020 to 2050)	Emissions savings relative to baseline (MtCO$_2$ 2020 to 2050)
Private vehicles	50% increase in occupancy by 2035	180	10
HGVs	25% decrease in HGVs by 2035 and diffusion as for cars	170	20
Buses and coaches	Increase occupancy to 20	180	10
Double stewardship	Double short term stewardship rates	180	10
All speculative stewardship pathways	All stewardship speculative pathways applied	150	40
All speculative stewardship and technological pathways	Additional effect of negative emissions by 2035	125	65

Table 6.16 shows that each of the speculative pathways provides some additional reduction in cumulative CO_2 emissions, of up to about 20MtCO$_2$. The most effective of the speculative pathway is that relating to freight transport. This is because, in the baseline pathway, it is noted that diffusion of HGV low emissions technologies is currently at a very early stage and extrapolation indicates full fleet conversion after 2050. The speculative assumption that this technology can be rolled out at the same rate as that associated with EV private cars, hence, represents a significant improvement. Other speculative interventions deliver smaller budget savings. The four stewardship speculative pathways acting together are indicated to save an additional 40MtCO$_2$ and are responsible for a budget reduction to about 150MtCO$_2$. An allowance for negative emissions is indicated to save an additional 25MtCO$_2$, although as noted by Workman et al. (2020) there is significant risk associated with reliance on the unproven technology required to deliver generation of electricity with negative emissions. As an alternative, a review can be made of these speculative pathways acting on a baseline of interventions to restrict sale of conventional cars in 2025, instead of 2030, with initial growth in sales of low emissions private cars of 75%, instead of 50%. In this case an additional saving in emissions of about 25MtCO$_2$ is achieved and transport CO_2 emissions realised between 2020 and 2050, prior to reaching net zero, are about 100MtCO$_2$.

The emissions estimates shown on Table 6.15 and 6.16, can be compared to the targets indicated at the beginning of this section. The tables show that the CCC cumulative emissions target of 150MtCO_2 may be reached if the most ambitious of the core pathways are implemented, together with a proportion of the speculative pathways. These pathways, especially those associated with long term stewardship interventions and speculative options, describe significant changes in UK society.

However, the target of 75MtCO_2, defined on the basis of assessment by Anderson et al. (2020), is not reached in any of the pathways, including the speculative pathways. This target relates to allowance for differing emissions reduction profiles for developed and developing countries, as set out in Clause 4 of the Paris Agreement. Based on this assessment, it is difficult to envisage meeting the Anderson et al. (2020) target, taking into account the current economic and societal assumptions discussed in this section and in Sections 6.3 and 6.4. There is, hence, significant uncertainty in achieving the Anderson et al. (2020) defined budget goal. Watson et al. (2015) note that uncertainty can lead to inaction but that, where uncertainty is present, solutions that have previously been rejected, may be relevant. In his assessment of uncertainty Grubler (2012) stresses that concerted and persistent efforts to demonstrate and accept new technology and new ways of thinking are required.

Analysis suggests that a reliance on a gradual diffusion of technology and societal alteration may only just be sufficient to reach Paris Agreement goals as they are interpreted by the CCC, but may be insufficient to meet more stringent interpretations of these goals. Instead of a gradual diffusion of change in current technology and stewardship, a pathway might be required in which step changes in societal behaviours occur. However, these step changes, such as immediate reduction in use of conventional vehicles through banning them from existing roads, would only be achievable through significant legislative interventions.

The consequences of not reaching the CCC and the Anderson et al. (2020) targets can be discussed in terms of overall UK emissions budgets. The North West of England transport sector represents one of many sectors of the UK environment, that need to decarbonise if overall UK budgets are to be met. In their net zero technical report the CCC discusses decarbonisation in terms of several separate sectors (CCC, 2019a). It is assumed that all sectors of the economy are required to reduce their emissions to reach a net zero end point.

Assessment, by Li et al. (2020), of different pathway clusters, indicates interchange potential between different solutions within specific sectors but assumes that each sector needs to reach its own decarbonisation goals. If the transport sector cannot reach its own goal, then other sectors need to decarbonise at greater rates. Whilst energy generation and industry in the UK have, in the last twenty years, been successful at reducing their greenhouse gas emissions, there are significant constraints on achieving greenhouse gas emission reduction in other sectors, such as housing and agriculture. The transport sector needs to pull its own weight for the UK to achieve designated targets. By not meeting local regional targets, the sector has the potential to substantially disrupt the capability of the whole of the UK, in terms of reaching its national target.

If the UK, as a whole, does not meet CCC or Anderson et al. (2020) targets, then there is increased risk of significant global temperature rises. The IPCC (2018, p108) indicate that a 50% increase in emissions is associated with potential increases in global temperatures of about 0.25^{o}C. A doubling of emissions has the potential to increase global temperature rises by about 0.5^{o}C, from about 1.7^{o}C to about 2.2^{o}C, with a 50% probability (IPCC, 2018, p108). The aspiration of achieving well below 2^{o}C of global warming is strained by a 50% increase in emissions but is not sustainable at all if emissions are doubled. A strategy that achieves the CCC budget, but not the Anderson et al. (2020) budget, also has the potential to frustrate less developed countries, in their efforts to reduce greenhouse gas emissions, through insufficient attention to the consideration of different responsibilities and capabilities, set out in Article 4 of the Paris Agreement. If the UK does not meet its Paris Agreement commitments, then other countries may question whether they should meet their own commitments.

6.6 Chapter summary

The analysis outlined in this chapter indicates the importance of areas outside large cities, in determining cumulative emissions intervention pathways. Areas outside large cities account for over 80% of the population of the North West of England and nearly 90% of all terrestrial transport emissions. These areas are, however, constrained, in terms of interventions, by existing high levels of car use relative to public and active transport use. Modelling of technological and stewardship interventions indicates that technological interventions, on their own, will not meet cumulative budget targets. The modelling highlights requirements for stewardship interventions outside large cities of the region. Societal change, particularly targeted at these areas, is required to realise the potential to meet UK Government cumulative emissions targets, broadly associated with per capita apportioning of global emissions. Analysis shows that meeting more onerous targets, associated with a more equitable interpretation of Paris Agreement commitments, is currently difficult to envisage without there being a re-evaluation of the relationship between government regulation and individual responsibility. In Chapter 7, a discussion is presented of regional hierarchical issues indicated by qualitative analysis described in Chapter 5 and quantitative analysis described in Chapter 6, to derive conclusions and recommendations relating to North West of England transport greenhouse gas emissions.

CHAPTER SEVEN – DISCUSSION

7.1 Introduction

In Chapter 5, results of interviews with local authority planners are described. These interviews were undertaken to meet the first three objectives of the thesis; relating to identifying the relationship between local authority characteristics and ability and motivation to reduce transport greenhouse gas emissions. In Chapter 6, the results of pathway modelling are presented, to meet the next three objectives of the thesis; to assess potential transport greenhouse gas reduction in the North West of England, taking into account ability and motivation of different parts of the region. These objectives were defined to investigate knowledge gaps relating to; variations in local authority motivation and ability outside large cities and impact of these on capability to locally reduce transport greenhouse gases and to deliver local, regional and national Paris Agreement goals.

In this chapter, in line with Objective 7 of the thesis, results of these two assessments are summarised and a discussion is outlined relating to how a region, such as the North West of England, could achieve reduction of transport greenhouse gas emissions, in line with Paris Agreement commitments. In Section 7.2, the existing landscape, revealed by interviews and modelling, is outlined. In Section 7.3, potential changes in this landscape, that might enable local authorities to reduce transport greenhouse gas emissions, are presented. These changes are summarised in Section 7.4.

7.2 Existing local authority landscape

The interviews discussed in Chapter 5 confirm the finding of researchers, such as Bell & Jayne (2006) and McTigue, Rye, et al. (2018), that small cities face restrictions, not present in large cities. The research provides deeper insight into why these restrictions occur, how they relate to reducing transport greenhouse gases and how hierarchical status and bottom-up initiatives might change them. The interviews undertaken explore the substantial differences in ability and motivation of authorities, depending on availability of resources. For authorities associated with small cities, ability and motivation are constrained by limitations in personnel, power and funding. These limitations are experienced much less in authorities covering large cities. The interviews also, however, revealed differences between engaged and optimistic authorities and non-engaged and pessimistic authorities. The engaged authorities were prepared to develop and implement proactive policies, relating to reducing transport greenhouse gases, whilst the more pessimistic authorities tended to only apply reactive policies. Authority size was associated with engagement. However, the interviews also indicated that engagement was associated with authority hierarchical status and support and encouragement from local political champions.

The interviews (Chapter 5) and the literature review (Chapter 4), highlight actual and perceived barriers experienced by planners within the region, particularly those outside large cities, in development of policy to reduce transport greenhouse gas emissions in terms of motivation characterised by perception and practicalities and ability characterised by powers and resources.

Planners stated that reducing transport greenhouse gas emissions in small cities was "a hard sell," indicating a perception that local populations were resistant to change. The economic lag, that exists between a region, such as the North West of England and wealthier parts of the country around the capital, was highlighted through statements such as "we are poor," expressing a view that the region was being ignored by a London centric government. For small cities, a parallel lag was also emphasised with statements pointing out that the situation was "easier in Manchester," indicating that authorities perceived that they were being left behind, not just by the national capital city, but by the large regional cities of Manchester and Liverpool. Small city authorities also noted that they did not have sufficient local populations to enable development of a metro system and that they had few powers to promote bus systems with operators and local developers who could "tell us where to go." The interviews revealed that active travel was being promoted in small cities, as an alternative to cars, but that this was hampered by existing low levels of walking and cycling and local perceptions that people would be "knocked down and get wet."

The existing layout of small cities, developed over 200 years, was highlighted in interviews. A history of cuts to public transport and building of roads has created a landscape where people regard cars as their default method of travel. In large cities, a substantial reduction in use of cars was being envisaged but, outside these, it was stated that "a car free future is not achievable." In a future where cars are still dominant, the use of low emissions vehicles was also questioned. It was stated that such vehicles were still regarded as luxury items, beyond the means of local populations. In addition, local planners argued that existing electricity grids could not cope with increased charging demands and that those in flats and terraced houses had no means to charge their cars.

Problems associated with charging of cars in flats and terraced houses are illustrated in Figure 7.1. The figure shows a plot of the proportion of households with a car, for each local authority in the North West of England, against the proportion of flats and terraced houses.

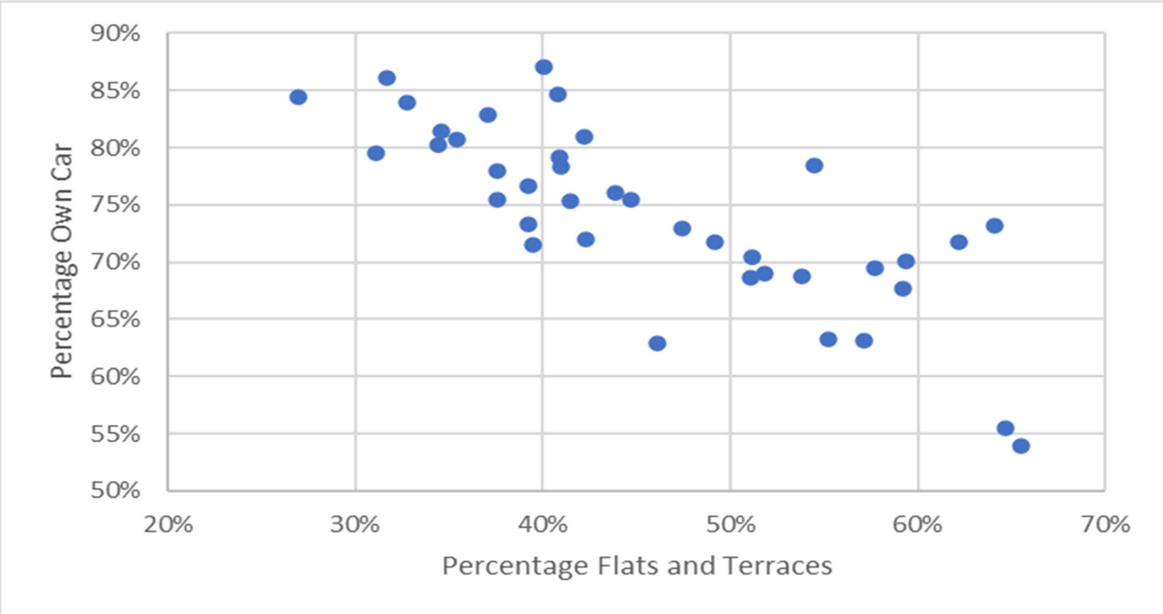

Figure 7.1 – Correlation between households with a car and households that are flats or terraced for 39 local authorities in the North West of England (based on 2011 census (Nomis, 2011a; Nomis, 2011b))

Figure 7.1 indicates that areas where fewer households own a car, are associated with greater numbers of flats and terraces. These areas, in general, correspond to the large cities of the region. However, even in the most rural areas of the region, a third of households consist of flats and terraces. In these areas over three quarters of households own a car. For car owning households, without a dedicated parking space, in both rural and urban areas, a charging system needs to be developed for EVs to be adopted. Although kerb side charging systems are being installed in some areas of London (Rajon et al., 2020), North West of England small city local authorities indicate that such systems have not been locally developed.

Resources present in small cities were also highlighted. In large cities, it was stated that authorities had their "own strategy team." Outside these areas policy was observed to be developed by personnel who had problems associated with reduction in transport greenhouse gas emissions "added to their day job." A lack of dedicated personnel was, hence, observed to be a substantial constraint on ability to implement change.

Modelling (Chapter 6) revealed new insights into how city hierarchy, within a region such as the North West of England, affects capability to reduce transport greenhouse gases and meet Paris Agreement goals. There are substantial differences, in potential to reduce transport greenhouse gas emissions, for the over 7 million people of the North West of England. For the million people living in large cities, growth in cars may be plateauing. There is potential for stewardship interventions, to significantly reduce use of cars in these locations, in conjunction with balancing increases in public and active transport. However, for the remainder of the region's population, growth in use of cars is likely to be continuing and reducing car use is hampered by the lock in of car culture and by practical limitations on expansion of existing public and active transport. These limitations are especially experienced by the nearly million people in the region who live in rural areas.

Chapter 6 results indicate that, if regional terrestrial transport greenhouse gas emissions remain at about current levels, then cumulative emissions of CO_2 between 2020 and 2050 would relate to about 430MtCO_2. If moderate technological interventions and stewardship interventions, compatible with current policy initiatives, are applied to regional transport systems, then these emissions could be reduced to about 200MtCO_2. A substantial increase in policy initiatives reduces cumulative emissions down to about 150MtCO_2. However, to bring cumulative regional terrestrial transport emissions down to 100MtCO_2, very early technological interventions are required, coupled with stewardship interventions relating to societal changes in the way that the UK uses cars and public and active transport. In addition, this level of cumulative emissions is associated with a requirement for development and widespread deployment of carbon capture technology.

Chapter 6 modelling can be compared with regional terrestrial transport cumulative emission targets, derived from Paris Agreement commitments. A target of about 150MtCO_2 can be derived from official UK Government policy, outlined by the CCC. This target is broadly related to per capita apportioning of global emissions, without differing allowances for developed and developing countries, as required by Clause 4 of the Paris Agreement. Modelling indicates that this target might be met, but that substantial expansion of current policy initiatives is required to achieve this goal. However, when policy pathways are compared to more stringent targets, derived from apportioning of emissions undertaken by Anderson et al. (2020), on the basis of differing requirements for developed and developing countries, an even more difficult picture emerges. This derived target of 75MtCO_2 is below even the pathway related to early and intensive interventions coupled with carbon capture. For this target to be met, new and substantial initiatives, such as restricting use of conventional cars from the road, would have to be considered. If, as suggested by Workman et al. (2020) and Mander et al. (2017), pathways should not include assumptions relating to necessity of developing substantial carbon capture technology, then in order to meet regional cumulative emissions targets lower than 100MtCO_2, given current annual regional transport emissions of greater than 10MtCO_2, such restrictions are necessary well before the end of the current decade.

7.3 Potential revisions to local authority landscape

The existing landscape facing local authorities, described in Section 7.2, creates an environment where it is difficult to envisage substantial reduction in regional transport greenhouse gas emissions. In this section an outline is presented of how some of these inhibitors, relating to development of necessary policy, might be addressed.

In their recently released report, on the response of UK local authorities to the 6th Carbon Budget, the CCC (2020a) asserts that local actions are necessary to achieve the committee's emission reduction targets. In the report the CCC provides recommendations to local authorities under the headings of framework, funding, facilitation and flexibility. Actions that can deal with the inhibiters revealed by the interviews outlined in Chapter 5 and the modelling presented in Chapter 6 and summarised in Section 7.2, are discussed in this section in terms of these four headings.

Framework

The framework under which local authorities act consists of the capabilities and systems that are locally present to allow policy to be developed. Currently authorities covering small cities are constrained by lack of personnel who have the time and expertise to develop and deliver policy. A lack of time and expertise is recorded in all authorities, outside large cities.

A crucial stage in delivery of reduction in transport greenhouse gases is, therefore, to provide suitable personnel at every level of local authority. Given the current situation where responsibility for reduction in transport emissions in small cities is only an add on to existing job descriptions, little is currently being done unless particularly motivated personnel are present. Current fragmented funding hinders expansion of core local authority staff. New funding streams tend to be associated with short term initiatives rather than long term goals. To provide a framework for actions to be taken, appointment of a planning officer dedicated to reducing transport emissions is likely to be required. Given the legacy of job cuts, relating to historical government austerity policies noted by local authorities in interviews, provision of a dedicated officer is likely to be only practical if it becomes a specific requirement for local authorities. This requirement would need to be backed up with necessary funding for such a post and training specific to problems and solutions relating to transport greenhouse gas emissions.

The delivery of local personnel is, however, only part of the problem. The reluctance of populations to get behind policy initiatives is currently restricting the motivation and ability of local authorities to deliver policy. Local planners are reluctant to suggest and develop policy that they see as against the wishes of local populations. To engage local planners to develop policy, local populations also need to be engaged in issues associated with transport greenhouse gas emissions. Engagement of local populations in small cities, with relatively small horizons, may be more difficult than engagement of populations in large cities (Knox & Mayer, 2013, p12).

New sustainable technology, such as EVs, is required in all regional cities. Innovators within the local population are reported to be willing to pay a premium for new low carbon technology but, for the majority of the population, new technology will only be supported if it is provided at the same cost as existing technology (Brand et al., 2017). In addition, if high growth rates, as indicated in the Reference 75 pathways (Chapter 6), are to be delivered, premiums need to be available in adoption of new technology. National government need to decide how local cost incentives should be delivered in a manner that balances new technology promotions against their revenue aspirations. National government’s reluctance to impose changes on local populations, however, appears to be currently restricting imposition of policy to promote new technology.

To deliver a low carbon future, local authority funding needs to be available, targeted at delivering facilities compatible with active and public transport. However, in areas where it is difficult to restrict car travel, it is necessary to provide infrastructure that allows charging to be delivered to growing numbers of EVs. Given that research indicates that reluctance in adoptions of EVs is associated with fear of running out of charge, new infrastructure should be delivered in conspicuous locations, sufficient to demonstrate that such fears are unfounded. It is noted that EVs have significant advantages over conventional cars in that, for most of the population, refuelling can be undertaken at home overnight. However, for those who do not have a dedicated parking spot, as shown in Figure 7.1, an alternative is required.

Funding

As stated by the planners interviewed, without adequate finance, there is no point in developing transport mitigation policy. The aim of the Northern Hub initiative is to grow the North West of England, to allow it to catch up with wealthier parts of the country. However, the associated TfN initiative has focused on development and growth of both rail and road transport between cities. This approach continues to rely on growth in car travel and does not deliver small scale development necessary to alter local transport systems. The planners interviewed talked of being by passed by TfN aspirations. The alternative approach is to prioritize growth in intracity transport. At this scale transport can be matched to small community structures, that may be of particular relevance in small cities.

Local finance, that can be used to develop infrastructure, is currently limited in its application. The 106 Notice and CIL funding, currently available to local authorities to deliver local infrastructure, is tied to local developers. Authorities, wary of restricting new development, are reluctant to require developers to contribute to these funding streams. The relative powers of local authorities and developers depend on the size of the authority. Whilst large city authorities have perceived power over developers, small city authorities see developers as having more power and are hence reluctant to require them to provide additional funding for local infrastructure.

The pathways, through which a low emission transport system might be delivered, require construction of significant infrastructure. This is, however, not the large-scale intercity infrastructure that is currently being planned by TfN, but small scale intracity infrastructure connecting communities. Necessary infrastructure includes new cycleways and pedestrian routes and, as appropriate, systems that restrict use of cars. To deliver this smaller scale infrastructure, local authorities need to have access to necessary funding. Where funding is gated by bidding processes, smaller authorities, with less time and resources to prepare bids, are disadvantaged. Successful expansions of metro systems in Manchester, and rail systems in Cheshire, show that there is a place for larger scale infrastructure to be built. For public transport to develop, bottlenecks, such as rail routes into Manchester, need to be relieved. However, these larger scale schemes should not overwhelm the equal need for smaller scale initiatives.

In addition, in providing funding, the urgency of delivery of climate change initiatives needs to be considered. Modelling (Chapter 6) shows that, to achieve savings in CO_2 related to transport, both short-term initiatives and long-term societal changes are required. Short term initiatives may be deliverable in the next five to ten years, whilst developing larger scale community wide initiatives is likely to require ten to twenty years of policy commitments. Given the significant impact on overall emissions that even small delays in provision of savings can create and the lag in development of infrastructure associated with planning and construction, funding needs to be provided well ahead of these deadlines.

Development of alternative work and shopping facilities can also be a focus in supporting communities, in delivery of small-scale travel options. Recent Covid 19 restrictions have highlighted a significant potential to increase home working. Working from home may, however, be associated with increased leisure travel. Through delivery of local facilities where local populations can work and shop, these rebound effects can be reduced. This is particularly important in more rural areas of the region where existing travel patterns currently relate to longer trips.

Provision of local infrastructure is also important in the context of regional freight systems. Increased use of LGVs is associated with greater than ever levels of internet shopping. Facilities that allow dropping off and picking up of home shopping, through consolidation systems, is vital to reverse this trend. A network of local delivery points tied to local communities, as suggested by Carling et al. (2015), or an equivalent low emissions delivery of goods system, is hence required. Local delivery networks such as those run by the Post

Office relate to a small percentage of transactions (parcels currently make up less than 5% of all UK freight movements (DfT, 2020b, Table RFS0105)) but such networks, expanded into wider fields, may have the potential to significantly contribute to local last mile sustainability (Melkonyan et al., 2020).

Facilitation

Facilitation relates to the legal powers available to local authorities, to allow them to restrict high emitting vehicles and promote alternatives. The powers available to local authorities currently do not allow them to deliver policies that are required to reduce terrestrial transport greenhouse gas emissions.

Powers are governed by the framework into which policy is delivered and the funding that is used to support this policy. If the public are not educated and informed about their role in adoption of low emissions systems, they will not accept local authority imposition of powers. If knowledgeable local authority personnel are not in place to develop policy, then it will not be put in place. If funding is not available to implement policy, then it will not be delivered. By removing these constraints, the powers of local authorities to do 'anything' that promotes the wellbeing of their local populations, can be unlocked.

There are some specific powers that can aid local authorities in delivery of a low carbon future. These relate to restrictions on constructing their own infrastructure, running their own public transport systems and providing training to local children, taken outside their control through academisation of schools. These restrictions currently mean that local authorities do not have the outreach to present and deliver necessary changes in local transport systems. Additional powers allowing local authorities to directly deliver these changes or require outside enterprises to cooperate with them in this provision are, therefore, required.

One particular power that is also required, for local authorities to effectively manage emissions from their local transport systems, relates to the monitoring regime that is currently used to measure transport greenhouse gas emissions. As shown in Figure 3.1, greenhouse gas emissions data is available and can readily be adjusted to indicate differing responsibility for transport emissions. However, interviews indicate that this data is not being used in the planning and monitoring of implementation of policy. In contrast data on NO_x and PM is widely being collected and acted upon. This discrepancy is because there is a legal requirement to monitor and act on NO_x and PM emissions, whilst there are no specific legal requirements relating to local transport CO_2. To ensure that local CO_2 levels are monitored and tracked, a legal requirement, similar to that already present for other vehicle emissions, could be introduced.

Flexibility

The final heading relating to local authority actions, defined by the CCC, is flexibility. Variations revealed by interviews (Chapter 5) and by pathways (Chapter 6), between large and small city authorities, indicate requirements for varied approaches across the North West of England. In large cities, personnel, power and funding, currently in place, have the potential to deliver low carbon transport systems, in an environment where car growth may be plateauing, and promoting public and active travel is practical. However, outside these large cities most of the population do not live in this environment. They live in areas where growth in cars is likely to be continuing and facilities are not located where access by public and active transport is available.

In large cities, to deliver low emission transport systems, it is possible that current policies may achieve targets. In small cities enhancements to framework, funding and facilitation are required. These small cities need to be remodelled, so that low emission transport is possible, through both extensive support for roll out of EVs and support to transport initiatives on a community wide level, taking into account inherent limitations on provision of infrastructure associated with city size.

7.4 Chapter summary

In their 6th Carbon Budget local authority report, the CCC give a series of recommendations, relating to actions taken by local authorities (CCC, 2020a). The CCC call on authorities to develop a plan, monitor and review this plan and, in parallel, to develop capabilities of staff to deliver this plan. These recommendations represent a starting point, in the pathways necessary to reduce greenhouse gas emissions in the terrestrial transport systems that exist across the North West of England and within the geographical boundaries of the 39 local authorities covering the over seven million people of the region. As explored in Chapter 5, the local authorities in the region are varied and their ability and motivation to bring about changes in local transport systems are very different. Large city authorities may have the personnel, power and funding to deliver a low carbon future but for most of the local authorities present in the region, the personnel, power and funding, necessary for a low emissions future, are not present.

Modelling, outlined in Chapter 6, indicates that, at present, North West of England local authorities lack the personnel, power and funding to enact changes necessary to meet official UK Government terrestrial transport cumulative emissions targets. In addition, even with these provisions, delivery of more stringent interpretations of the Paris Agreement, as presented in Anderson et al. (2020), do not appear to be feasible. For either of these targets to be met, a review of how transport is controlled in areas outside large cities is required. In the final chapter of this thesis a summary of conclusions that can be drawn is presented to provide a basis for such a review to be undertaken.

CHAPTER EIGHT – CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

In this chapter a summary of conclusions is presented, together with recommendations. Conclusions are drawn from each thesis chapter, as they relate to objectives set out in Chapter 1. Recommendations are then presented, as they relate to the UK and, as appropriate, to the rest of the world. Suggestions are also given of future academic research that would be useful in further defining and addressing knowledge gaps. Section 8.2 summarises conclusions. Section 8.3 then presents recommendations. Section 8.4 outlines limits on these recommendations associated with the boundaries of the research covered in this thesis. Section 8.5 suggests future academic research. Section 8.6 then contains some final thoughts.

8.2 Conclusions

In Chapter 1, a series of knowledge gaps is identified. These knowledge gaps relate to the study of areas outside large cities and particularly those that are subject to relative economic disadvantage. Robinson (2006) describes small cities in areas of economic disadvantage as 'ordinary cities,' as they are the places where most of the population in the industrialised world, actually live. In the North West of England small cities account for over three quarters of the population and nearly 90% of greenhouse gas terrestrial transport emissions (Table 6.6). For these communities, knowledge gaps exist relating to ability and motivation to reduce transport emissions and consequent impact on regional and national capability to meet Paris Agreement goals. The North West of England has been chosen as a study area, as it is a region of the industrialised world that has been arguably economically left behind in Post-Fordian transitions from a manufacturing to a service economy (Nurse, 2015).

In response to identified knowledge gaps, eight objectives are defined. Assessment, outlined in Chapter 3 to Chapter 7, against these objectives, using the methodology described in Chapter 2, provides new insights relating to knowledge gaps outlined in Chapter 1. Through undertaking desk based research and interviews with local planners, the constraints on local authority development and implementation of transport policy, described by McTigue, Monios, et al. (2018), have been explored and the links between these constraints and city size determined. The disadvantages others have identified as inherent in small cities are confirmed (Hall & Barrett, 2018). Taking account of these constraints, the capability of the region, to meet national climate change commitments, has been explored in order to allow the level of ambition dictated by global cumulative emissions targets to be compared against the practicalities of local initiatives, as outlined by Gambhir et al. (2019).

The first two objectives relate to investigating characteristics of local authorities in the North West of England, particularly those covering areas outside large cities, and policies that these authorities could employ to reduce transport greenhouse gas emissions. These objectives are explored in literature reviews presented in Chapters 3 and 4. In the North West of England, 37 of the 39 local authorities represent small cities with less than 500,000 population. The literature reviews indicate that, in these authorities, available transport greenhouse gas reduction policies are significantly constrained, particularly by powers available, both in terms of absolute power to instigate policy and relative power over stakeholders. Review, assessment and analysis, presented in the thesis, provide new insight into these constraints. As indicated in Section 7.2, small cities are lacking:

- Personnel to develop policy, due to the historical impact of national austerity and a lack of long-term funding streams that would support hiring new staff.
- Overall funding, due to the historical impact of national austerity and a relatively low potential to generate local tax revenue, particularly in areas that are relatively economically deprived. As noted in Chapter 3, the ability to generate local funding may in the future be further compromised, as it is proposed to base an increased proportion of local government income on business rates. These proposals particularly disadvantage small city authorities situated in less wealthy areas.
- Dedicated funding streams, due to piecemeal delivery of grants gated by bidding processes and by commercial interests represented by LEPs.
- Knowledge and training, in terms of issues relating to climate change impact and mitigation.
- Local population numbers that would allow specialist services and infrastructure to be economically viable without substantial subsidy. In particular, where small city

populations are less than about 500,000, large scale intracity metro systems are not viable.

- Vehicle and road infrastructure to support local public transport alternatives, particularly bus route options.
- Dedicated route infrastructure to support local active transport alternatives, particularly connected pedestrian tracks and cycleways.
- Local shop and business centre infrastructure to support reduced travel, where populations are relatively low in density and relatively dispersed. Hence trips are longer than those taking place in more urban areas.
- Legislative powers to control local enterprises and developers.
- Relative powers, dependent on authority size and funding, to influence local enterprises, developers and media.
- Commitment of the local population, as perceived by local planners and politicians, to address global issues, associated with smaller scale horizons of residents outside more connected large cities.
- Commitment of local populations to support public and active transport, over private car alternatives. This is associated with a continued positive image of car ownership and negative image of alternative transport options. Outside large cities cars are regarded as essential, but alternatives associated with low emissions are perceived to be of poor quality and overly expensive.

Some of these issues also affect large cities but all are indicated to be more pronounced in small cities. Whilst constraints relating to funding and power over stakeholders are relative to city size, constraints relating to legislative power and economic viability of infrastructure alternatives only apply outside large cities. Smaller communities may be associated with shorter distances to local services, but they are also associated with a greater proportion of longer trips to larger urban centres that support more diverse facilities. In large cities, growth in use of cars appears to be plateauing and powers to restrain this growth, due to elevated NO_x and PM emissions, are available. In contrast, outside large cities, growth in cars appears to be continuing and health issues, relating to elevated emissions, do not provide justification for local authorities to control this growth.

In Chapter 5, to meet the third thesis objective, the consequences of these constraints are explored, to provide new knowledge on motivation and ability to develop and implement policy in small city local authorities. This investigation has been undertaken through interviews with a sample of planners who are responsible for local transport. Planners were selected for interview to provide at least two examples of each type of local government working landscape present in the North West of England. The interviews provide new insights into the effects of local constraints on motivation and ability to make changes in local transport systems. New knowledge reveals details of how planners view and react to each constraint. Only in large cities is a commitment given by planners to reduce transport greenhouse gases, with an expectation that significant reduction in emissions can be achieved. In about half of the other local authorities, planners are proactively committed to reducing emissions but do not consider, in the current environment, that they are able to achieve significant changes in their local transport systems. In the remainder of the authorities, there is no proactive commitment to reduce emissions. Policy is only applied reactively as opportunities arise within development proposals. In a small number of authorities, no commitment to reduce emissions is present. Interviews, however, indicate changing priorities, illustrated by a cascade of motivation and ability from large to small cities and a cascade of bottom-up initiatives in smaller communities.

In Chapter 6, the next three objectives are investigated. Taking into account new insights relating to local authority ability and motivation, investigations are undertaken of; regional transport emissions, potential reduction of these and impact on cumulative emissions targets, derived from different interpretations of Paris Agreement commitments. Analysis indicates the relative importance of small cities in reducing transport greenhouse gas emissions and provides new knowledge relating to how ability of local authorities in these cities, to implement local stewardship policy against a background of national technological policy, affects regional reduction capability. The UK Government's interpretation of Paris Agreement commitments, as represented by CCC budgets (CCC, 2020c), relates broadly to a global per capita allocation of emissions and hence does not specifically consider differences in responsibilities and capabilities between developed and developing nations (Robiou Du Pont et al., 2017). More stringent interpretations, based on equity principles outlined in the Paris Agreement and taking into account these differences, lead to substantially lower budgets (Anderson et al., 2020). Analysis indicates that imposing early and intensive national technological interventions and short-term and long-term local stewardship interventions, may, in conjunction with reducing local planning constraints, have the potential to meet CCC budgets. However, this analysis also indicates that it is difficult to envisage meeting Anderson et al. (2020) budgets, compatible with different allowances for developing and developed parts of the world.

In Chapter 7, interviews, described in Chapter 5 and analysis, outlined in Chapter 6, are integrated to draw conclusions and provide recommendations. New insights indicate that small city local authorities are lacking in personnel, funding and power to deliver the changes needed in their local transport systems, meaning that capabilities of the region to meet commitments are significantly compromised. Expansion of ability and motivation, through a hierarchical and bottom-up diffusion of priorities, provides increased potential to meet defined goals. However, given the urgency of climate change mitigation and the significant impact of delays, Paris Agreement goals are not likely to be met if this diffusion potential is solely relied upon. Chapter 7 provides a discussion of additional actions that could be taken to remove constraints on capabilities of small cities to change their transport emissions. These recommendations are summarised in Section 8.3.

Previous research into the development of low carbon transport systems highlights the importance of dealing with constraints relating to motivation and ability (Biresselioglu et al., 2018). The research, outlined in this thesis, illustrates how constraints relate specifically to a lack of personnel, power and funding and how they vary with city size. Whilst McTigue et al. (2020) conclude that local champions are one of several important factors affecting implementation of policy, this research indicates that, outside large cities, local champions may be the determining factor in whether local authorities proactively engage in developing low carbon transport systems. Taking these constraints into consideration, the research provides a quantified model of capability of a whole region to decarbonise transport and meet Paris Agreement targets. Pathway modelling confirms that in order to meet cumulative emission regional targets, early and intensive technological interventions need to be coupled with stewardship interventions associated with lifestyle changes (Brand et al., 2020).

The last objective, outlined in Chapter 1, relates to applicability of the findings of the research to other areas of the world. In order to address this objective, it is necessary to assess whether the North West of England and the analysis of small cities within this region, can be used to illustrate conditions in other parts of the industrialised world. Assessment indicates that city distributions and economic relationships that exist in the North West of England, are replicated in other industrialised areas of the world (Parr, 2017a). Historical trends towards Post-Fordian economies that have occurred in the region, have also occurred in other developed regions of the world (Martinez-Fernandez et al., 2016). In addition, whilst available powers vary between different local government systems, with federalist systems such as Germany having more local powers than equivalent UK local authorities (Ehnert et al., 2018), local government is formed in a similar way in all Western developed countries (Leach et al., 2018). Therefore, it is likely that other parts of the industrialised world are experiencing similar constraints, outside large cities and, in particular, away from large capital cities. Recommendations made within this thesis are, therefore, also likely to apply to some other parts of the industrialised world.

Through establishing how identified constraints relate to city size and to national and global targets, recommendations can be made in terms of how they can be reduced or eliminated. A basis on which these recommendations can be determined is discussed in Chapter 7 and Section 8.2. Recommendations are then summarised in Section 8.3.

8.3 Recommendations

Section 7.2 describes the existing landscape in which small city local authorities act, in developing and implementing policy relating to reducing transport greenhouse gases. Section 7.3 describes potential changes in this landscape. Section 8.2 outlines conclusions drawn from these descriptions. In this section recommendations are given, taking into account the landscape described in Chapter 7 and the conclusions outlined in Section 8.2.

In Chapter 5, in discussion relating to responsibility, local authority planners at all levels agreed that responsibility for reducing transport greenhouse gas emissions was shared between national government, local government and local populations. In discussion relating to constraints on development and implementation of policy, the actions of national government, local government funding, and local population attitudes, were the three most prominent barriers indicated by small city local authority planners. To provide a landscape where local authorities can deliver policy necessary to reduce transport greenhouse gases, these three barriers need to be removed and hence all sectors of society need to be involved in delivery of policy. Based on the small city deficits outlined in Section 8.2, recommendations are, therefore, presented relating to national government, local government and local populations.

National government needs to implement technological policy relating to rapid growth in EVs, through supporting restrictions on conventional cars and encouraging low emission alternatives. In addition, to allow local government to deliver stewardship initiatives, national government needs to put in place policy relating to:

- Personnel
    - Require all authorities to actively engage in reducing transport greenhouse gases and to plan and report on progress against specified targets.
    - Provide a clear mandate for, and endorsement of, local authority actions in changing local transport.
- Power
    - Allow local authorities to encourage and, as necessary require, local businesses, enterprises and establishments to cooperate in preparing, implementing and monitoring transport reduction policy initiatives.
    - Allow local authorities to directly engage in running local transport, particularly bus networks and innovative active travel systems.
- Funding
    - Provide funding in a constant straightforward manner that allows local authorities to plan ahead and, as necessary, appoint and train appropriate personnel.
    - Provide funding mechanisms that allow local authorities to:
        - Construct small scale local active cycle and walking route infrastructure.
        - Provide local improvements in public transport.
        - Provide local improvements in community shopping and work facilities, to allow trip lengths to be shortened.
        - Instigate local improvement in low emission freight consolidation centres.

        - Support a roll out of EV charging networks, with particular reference to conspicuous and kerb side locations where charging is constrained by housing types.

For local authorities, targeted personnel, power and funding recommendations relate to:

- Personnel
    - Develop a detailed plan with specific monitored transport greenhouse gas reduction targets. As necessary assign and train dedicated personnel to implement and monitor this plan.
    - Utilize national government endorsements of transport greenhouse gas reduction policies to engage with all sectors of local society to motivate local populations in delivery of this plan. Act as proactive trailblazers rather than as reactive stragglers.
- Power
    - Utilise powers to encourage and, as necessary, require local businesses, enterprises and establishments to cooperate in delivery of local plans.
    - Utilize powers to develop local low emissions public and active transport systems appropriate to city sizes and community scales, and, as necessary, utilising new and innovative technologies.
- Funding
    - Use funding to actively develop infrastructure to improve active transport networks, public transport infrastructure, local shopping and business facilities, freight consolidation systems and EV charging grids.

Local populations need to engage with national and local government in implementation of policy. Where current horizons are limited in small city settings the research indicates that work is required to alter current norms. This will only be accomplished through concerted efforts by national and local government to change societal norms together with encouragement of bottom-up initiatives. Societal changes have been accomplished in the Netherlands, in development of their active transport networks and in Norway, in development of their EV network. These changes have, however, taken ten to twenty years of concerted effort to accomplish. In the UK both national and local government need to learn from these efforts in educating and motivating local populations in the necessities of change and delivery of low emission transport systems.

In summary, it is recommended that there is a substantial shift in policies, away from those that predominantly support and encourage innovation in large cities, to policies that support and encourage change in small cities. It is currently difficult to initiate change in these small cities, in environments where innovation is required to bring about technical and societal transformations to reduce transport greenhouse gas emissions. Whilst the emphasis remains on large cities, rapid and substantial technical and societal changes, compatible with national and global climate change targets, are not likely to occur. Through neglecting small cities over three quarters of the population and of associated transport emissions will continue to be side-lined.

8.4 Research limitations

The research described in the thesis investigates motivations and abilities of local authorities in the North West of England to illustrate how these might affect regional capability in terms of reducing transport greenhouse gas emissions and meeting national and global emission targets. The insights presented, however, have some limitations. Insights are given by local authority planners and may not be representative of the local government organisations in which they work. Insights are restricted to those associated with local authorities and hence do not include those of other local government organisations and stakeholders. Due to limits on time and resources, only twelve local authorities were contacted as part of the research. A more comprehensive investigation of a wider range of authorities and stakeholders would likely provide a fuller picture of the regional capabilities that shape transport greenhouse gas reduction potential. The interviews undertaken do, however, provide an important insight into the local authority niche, associated with small and large cities, that acts as a vital source in development of transport greenhouse gas reduction policy. Findings outlined in the thesis hence provide new knowledge relating to development of policy across governmental hierarchical boundaries that may increase understanding of similar settings in the industrialised world.

8.5 Further research

The research illustrates the importance of a cascade of motivation and ability, in delivery of Paris Agreement emissions reduction. Future research, that would add to the development of knowledge, could be aimed at investigating this cascade, in a variety of regions, through exploring the interactions between personnel in different national and regional hierarchical settings. In addition, further investigation of the upwards cascade of motivation, from grassroots environmental groups, would provide useful information in determining factors that influence development of local policy. In particular, perceived attitude variations between populations in large cities and those in small cities, appear to be important in determining motivations of local planners. Investigating variations in attitudes, and possible sociological explanations for these, would, therefore, provide useful new knowledge.

The research identifies the importance of implementation of policy outside large cities. Further investigation of the potential for changes in transport, in these areas, is necessary to develop policy that is practical and effective in reducing terrestrial transport greenhouse gas emissions. In particular, the practicalities of newly developed technology, such as e-bikes, or provision of on demand transport facilities, need to be investigated and developed in these environments. Modelling also highlights the importance of LGVs and HGVs in developing terrestrial transport emissions reduction pathways. Whilst pathways have been identified that may relate to reducing LGV emissions, the pathways that relate to reducing HGV emissions have not been extensively investigated. Given the significant impact of speculative modelling associated with improving diffusion of low emission HGV transport, further research relating to how longer road freight movements might be decarbonised, is also necessary.

8.6 Final thoughts

In sectors such as energy generation, some progress has been made in reducing greenhouse gas emissions in the industrialised world, but to meet national and global cumulative emission targets other sectors need to follow this lead. Decarbonisation efforts are now focusing on transport. The research highlights difficulties inherent in decarbonising transport systems outside large cities. In these areas, feasible decarbonisation pathways need to be developed. If transport cannot reduce greenhouse gas emissions at rates required to meet defined cumulative emissions budgets, then the feasibility of meeting overall national and global targets will be substantially compromised.

The research indicates that UK Government defined transitions will only be achieved if targeted personnel, power and funding are available in all regional small cities. However, if transitions associated with more stringent interpretations of the Paris Agreement are to be met, then an urgent rethink of mobility in all parts of the industrialised world is required. In the absence of this, the relationship between the developing and developed world, in terms of provision of financial and technological resources to reduce impacts of climate change, needs to be reassessed.

As indicated in Figure 1.1, current transport systems are being disrupted by Covid 19 lockdowns. Disruptions represent an opportunity to question how transport in society in an industrialised part of the world is facilitated and could be used to kick start necessary mobility transformations. The research described in this thesis provides an insight into local authority constraints on reducing terrestrial transport greenhouse gas emissions. The model defined in Chapter 6 provides pathways that can be applied to typical small cities, and in Chapter 5 policies and associated limitations that can be applied to each area of the region, are described. Whilst authorities in large cities, such as Manchester, are producing plans outlining how greenhouse gas emission budgets may be achieved, similar plans need to be produced for small cities, to illustrate how low carbon mobility compatible with national net zero aspirations and in time scales compatible with global cumulative emission targets, can be delivered in a variety of settings. Plans, hence, need to be urgently developed and implemented not just in large cities, but in every community within a region.

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Appendix A: Question Guide

What policy is currently in place?

1. What is the local authority's main focus relating to mitigation of transport carbon emissions?

2. Can you provide a quick summary of the local authority's key challenges relating to mitigation of transport carbon emissions?

3. How are the local authority's policies documented relating to mitigation of transport carbon emissions?

How has policy been developed?

4. What relative responsibility does the local authority think various stakeholders have or should have in mitigation of transport carbon emissions?
   - Central government.
   - Local authorities.
   - Local transport executives.
   - Local businesses.
   - Members of public.
   - Other stakeholders.

5. What national documentation or resources have been used to support local authority policy development relating to mitigation of transport emissions?

6. What local documentation or resources have been used to support local authority policy development relating to mitigation of transport emissions?

7. What are the main constraints on the local authority in developing policy relating to mitigation of transport carbon emissions?

8. Are there any specific local opportunities in developing policy relating to mitigation of transport carbon emissions?

9. How is mitigation of transport carbon emissions viewed in terms of prioritisation and synergies/conflicts relative to other local authority policies?

10. What measures has the local authority considered in relation to mitigation of transport carbon emissions?
    - Switch to private low carbon technology (eg electric cars).
    - Switch to public low carbon technology (eg electric buses).
    - Switch to rail low carbon technology (eg rail electrification).
    - Switch journeys from personal transport to public transport.
    - Switch journeys away from mechanised transport (eg walking and cycling).
    - Reducing overall numbers or lengths of journeys (eg virtual commerce).

How effective is policy likely to be?

11. Does the local authority monitor local transport carbon emissions and if monitoring is undertaken what is the rational and methodology of this monitoring?

12. Is the local authority aware of current transport carbon emission within their boundaries and how these relate to other areas of the country?

13. Does the local authority have specific targets relating to mitigation of transport carbon emissions?

14. If there are specific targets how have these been derived and do they relate to specific commitments?
    - Climate Change Act.
    - Paris Agreement.
    - Other commitment.

15. What do the local authority think will be the relative effectiveness of policy relating to mitigation of transport carbon emissions in terms of overall mitigation achieved?
    - Switch to private low carbon technology (eg electric cars).
    - Switch to public low carbon technology (eg electric buses).
    - Switch to rail low carbon technology (eg rail electrification).
    - Switch journeys from personal transport to public transport.
    - Switch journeys away from mechanised transport (eg walking and cycling).
    - Reducing overall numbers or lengths of journeys (eg virtual commerce).
    - Other mitigation policy.

16. How effective does the local authority feel that mitigation of local transport emissions within their boundaries will actually be, relative to commitments set out in the Climate Change Act or Paris Agreement?

17. If these commitments might not be met what extra resources or other support or initiatives does the local authority feel would be required in order to meet commitments and what necessary extra policy would be implemented with additional resources?

Appendix B: Policy Pathway Workbooks

Workbook	Title	Description
Growth workbooks		
1	Cars	Private car growth
2	2W	Motorbike growth
3	Bus	Bus and coach growth
4	LGV	LGV growth
5	HGV	HGV growth
6	Intervene 25	Banning of conventional cars in 2025
7	Intervene 30	Banning of conventional cars in 2030
8	Intervene 35	Banning of conventional cars in 2035
Pathway workbooks		
1	Stewardship	Stewardship interventions only
2	Reference 25	25% initial growth in adoption of EVs
2a	Reference 25S	25% initial growth in adoption of EVs with stewardship
3	Reference 50	50% initial growth in adoption of EVs
3a	Reference 50S	50% initial growth in adoption of EVs with stewardship
4	Reference 75	75% initial growth in adoption of EVs
4a	Reference 75S	75% initial growth in adoption of EVs with stewardship
5	Intervene 25	50% initial growth in adoption of EVs with banning of conventional cars in 2025
5a	Intervene 25S	50% initial growth in adoption of EVs with banning of conventional cars in 2025 with stewardship
6	Intervene 30	50% initial growth in adoption of EVs with banning of conventional cars in 2030
6a	Intervene 30S	50% initial growth in adoption of EVs with banning of conventional cars in 2030 with stewardship
7	Intervene 35	50% initial growth in adoption of EVs with banning of conventional cars in 2035
7a	Intervene 35S	50% initial growth in adoption of EVs with banning of conventional cars in 2035 with stewardship
8	Speculative Car	50% increase in occupancy by 2035
9	Speculative Freight	25% decrease in HGVs by 2035 and diffusion as for cars
10	Speculative Bus	Increase occupancy to 20
11	Speculative Stewardship	Double short term stewardship rates
12	Speculative Emissions	Electricity generated by negative emissions by 2035

GROWTH 1 - CARS

CURRENT

	ALL CARS						EVs						EVs/All Cars	
	Car Fleet	**Growth**	**New**	**Scrappage**		**gCO2/km**	**Exist**	**Growth**	**New**	**Growth**	**Scrappage**		**EVs/All Cars**	
Year	**Table VEH0101 1000s**	**% Av. 1.3%**	**Table VEH0150 1000s**	**1000s**	**% Av. 6.5%**	**Table VEH0150/ VEH0156**	**Table EAFO 1000s**	**% Av. 93.4%**	**Table EAFO 1000s**	**% Av. 63.1%**	**1000s**	**% Av. 2.7%**	**Fleet %**	**New %**
2010	28320		1996			197	0		0.1				0.00	
2011	28513	0.7	1907	1714	6.0%	189	1	**275.1**	1.1	1092.2	0	-0.7	0.01	0.06
2012	28581	0.2	2011	1943	6.8%	182	3	**90.1**	1.4	32.0	0	3.0	0.01	0.07
2013	28842	0.9	2225	1964	6.8%	176	5	**89.0**	2.6	80.2	0	0.9	0.02	0.11
2014	29372	1.8	2438	1908	6.5%	171	10	**85.9**	6.7	162.1	2	21.5	0.03	0.27
2015	29766	1.3	2602	2208	7.4%	166	20	**102.7**	9.9	48.6	0	-1.0	0.07	0.38
2016	30461	2.3	2665	1971	6.5%	165	30	**50.5**	10.2	3.1	0	0.4	0.10	0.38
2017	31074	2.0	2509	1897	6.1%	166	43	**42.2**	13.7	33.5	1	2.3	0.14	0.55
2018	31348	0.9	2342	2067	6.6%	171	61	**43.3**	17.5	28.0	-1	-1.7	0.20	0.75
2019	31687	1.1	2295	1956	6.2%	175	99	**62.0**	38.0	116.9	0	-0.1	0.31	1.66

FUTURE

	All Cars 1000s	**All New 1000s**	**gCO_2/ kWh**	**kWh/km**	**gCO_2/km**					**New EV Cars 1000s**			**Scrapped EV Cars 1000s**			**Total EV 1000s**			**New EV/All New %**		
	Growth	**Growth +Scrap**	**Nat Grid**	**Mid Car**	**EV**	**Diesel+ Petrol**	**Fleet Mix Growth Assumption**			**Growth Assumption**			**Growth Assumption**			**Growth Assumption**			**Growth Assumption**		
	1.3%	**7.8%**					**25%**	**50%**	**75%**	**25%**	**50%**	**75%**	**25%**	**50%**	**75%**	**25%**	**50%**	**75%**	**25%**	**50%**	**75%**
2020	32086	2503	160	0.20	32	167	166	166	166	47	57	66	3	4	4	144	153	162	1.9	2.3	2.7
2021	32490	2534	155	0.20	31	164	163	163	162	59	85	116	4	6	8	199	233	270	2.3	3.4	4.6
2022	32898	2566	150	0.20	29	161	160	159	159	74	128	204	5	8	13	269	352	461	2.9	5.0	7.9
2023	33312	2598	145	0.19	28	158	156	156	155	93	192	356	6	13	23	355	532	794	3.6	7.4	13.7
2024	33732	2631	140	0.19	27	155	153	152	150	116	289	584	8	19	38	464	802	1340	4.4	11.0	22.2
2025	34156	2664	135	0.19	26	152	150	148	144	145	473	818	9	31	54	599	1244	2105	5.4	17.8	30.7
2026	34586	2698	130	0.19	24	149	147	143	138	181	663	1058	12	43	69	768	1864	3093	6.7	24.6	39.2
2027	35021	2732	125	0.18	23	147	143	137	131	226	857	1303	15	56	85	980	2664	4311	8.3	31.4	47.7

GROWTH 1 - CARS

2028	35462	2766	120	0.18	22	144	140	132	124	283	1024	1555	19	67	102	1245	3622	5764	10.2	37.0	56.2
2029	35908	2801	115	0.18	21	141	136	125	116	354	1228	1812	23	80	119	1575	4769	7458	12.6	43.8	64.7
2030	36360	2836	110	0.18	20	139	132	119	108	465	1436	2076	30	94	136	2010	6111	9399	16.4	50.6	73.2
2031	36817	2872	105	0.18	18	136	128	112	99	580	1649	2347	38	108	154	2552	7652	11592	20.2	57.4	81.7
2032	37280	2908	100	0.17	17	134	124	105	91	697	1868	2434	46	122	159	3204	9398	13867	24.0	64.2	83.7
2033	37749	2944	95	0.17	16	132	119	97	82	817	2091	2524	53	137	165	3967	11352	16226	27.7	71.0	85.7
2034	38224	2981	90	0.17	15	129	115	89	74	940	2321	2615	61	152	171	4845	13521	18670	31.5	77.8	87.7
2035	38705	3019	85	0.17	14	127	110	81	65	1066	2555	2708	70	167	177	5841	15909	21201	35.3	84.6	89.7
2036	39192	3057	80	0.16	13	125	105	72	57	1195	2636	2804	78	172	183	6958	18373	23821	39.1	86.2	91.7
2037	39686	3095	75	0.16	12	122	100	64	49	1327	2719	2901	87	178	190	8198	20914	26532	42.9	87.8	93.7
2038	40185	3134	70	0.16	11	120	94	56	41	1462	2803	3000	96	183	196	9564	23533	29336	46.6	89.4	95.7
2039	40691	3174	65	0.16	10	118	89	49	33	1600	2889	3101	105	189	203	11059	26234	32234	50.4	91.0	97.7
2040	41203	3214	60	0.16	9	116	83	41	25	1741	2977	3214	114	195	210	12686	29016	35238	54.2	92.6	100.0
2041	41721	3254	55	0.15	8	114	77	33	17	1886	3066	3254	123	201	213	14449	31882	38279	58.0	94.2	100.0
2042	42246	3295	50	0.15	8	112	71	26	10	2035	3158	3295	133	207	216	16351	34833	41359	61.7	95.8	100.0
2043	42778	3337	45	0.15	7	110	65	19	7	2186	3251	3337	143	213	218	18394	37871	42778	65.5	97.4	100.0
2044	43316	3379	40	0.15	6	108	59	11	6	2341	3346	3379	153	219	221	20582	40998	43316	69.3	99.0	100.0
2045	43861	3421	35	0.15	5	106	53	4	5	2500	3421	3421	164	224	224	22919	44195	43861	73.1	100.0	100.0
2046	44413	3464	30	0.14	4	104	47	4	4	2662	3464	3464	174	227	227	25407	44413	44413	76.9	100.0	100.0
2047	44972	3508	25	0.14	4	102	41	4	4	2828	3508	3508	185	229	229	28050	44972	44972	80.6	100.0	100.0
2048	45537	3552	20	0.14	3	100	34	3	3	2998	3552	3552	196	232	232	30852	45537	45537	84.4	100.0	100.0
2049	46110	3597	15	0.14	2	98	28	2	2	3068	3597	3597	201	235	235	33720	46110	46110	85.3	100.0	100.0
2050	46691	3642	10	0.13	1	97	22	1	1	3139	3642	3642	205	238	238	36653	46691	46691	86.2	100.0	100.0

GROWTH 2 - MOTORBIKES

CURRENT

	ALL 2W					EVs							
	2W Fleet	**Growth**	**New**	**Scrappage**		**Exist**	**Growth**	**New**	**Growth**	**Scrappage**		**EVs/All 2W**	
Year	**Table VEH0101 1000s**	**% Av. 1.3%**	**Table VEH0150 1000s**	**1000s**	**% Av. 6.5%**	**Table VEH0130 1000s**	**% Av. 93.4%**	**Table VEH0170 1000s**	**% Av. 63.1%**	**1000s**	**% Av. 2.7%**	**Fleet %**	**New %**
2010	1251		100			1.37		0.55				0.11	
2011	1237	-1.2	99	114	9.2	1.46	6.7	0.45	-19.2	0.35	24.1	0.12	0.45
2012	1238	0.1	100	99	8.0	1.29	-11.5	0.25	-44.9	0.41	31.9	0.10	0.24
2013	1199	-3.1	98	137	11.4	1.03	-20.3	0.14	-41.2	0.41	39.5	0.09	0.15
2014	1218	1.6	108	89	7.3	0.91	-11.5	0.23	57.6	0.35	37.9	0.07	0.21
2015	1205	-1.1	123	137	11.3	0.92	1.0	0.32	41.4	0.31	33.9	0.08	0.26
2016	1229	2.0	138	114	9.3	1.04	13.0	0.43	33.3	0.31	29.6	0.08	0.31
2017	1247	1.5	114	96	7.7	1.06	1.8	0.38	-11.2	0.36	34.1	0.09	0.33
2018	1219	-2.2	116	143	11.8	1.44	35.8	0.67	75.8	0.29	20.0	0.12	0.58
2019	1257	3.1	119	81	6.5	2.79	93.8	1.71	155.4	0.36	12.7	0.22	1.44

FUTURE

	All 2W 1000s	**All New 1000s**	**gCO_2/kWh**	**kWh/km**	**gCO_2/km**			**New EV 2W 1000s**	**Scrapped EV 2W 1000s**	**Total EV 1000s**	**New EV/All New %**
	Growth	**Growth +Scrap**	**Nat Grid**	**2W**	**EV**	**Diesel+ Petrol**	**Fleet Mix Growth Assumption**	**Growth Assumption**	**Growth Assumption**	**Growth Assumption**	**Growth Assumption**
	0.1%	**9.2%**					**50%**	**50%**	**50%**	**50%**	**50%**
2020	1258	116	160	0.05	8	108	108	3	0	5	2.2
2021	1258	116	155	0.05	8	106	106	4	0	9	3.3
2022	1259	116	150	0.05	7	104	103	6	1	14	5.0
2023	1260	116	145	0.05	7	102	101	9	1	22	7.4
2024	1261	116	140	0.05	7	101	98	13	1	33	11.1
2025	1262	117	135	0.05	6	99	95	19	2	51	16.7
2026	1263	117	130	0.05	6	97	92	28	3	76	23.7

GROWTH 2 - MOTORBIKES

2027	1264	117	125	0.05	6	95	88	36	3	109	30.7
2028	1265	117	120	0.05	5	94	83	44	4	149	37.7
2029	1266	117	115	0.05	5	92	78	52	5	196	44.7
2030	1266	117	110	0.04	5	90	73	60	6	251	51.7
2031	1267	117	105	0.04	5	89	68	68	6	313	58.5
2032	1268	117	100	0.04	4	87	62	76	7	383	65.3
2033	1269	117	95	0.04	4	85	56	84	8	459	72.1
2034	1270	117	90	0.04	4	84	50	93	8	543	78.9
2035	1271	117	85	0.04	4	82	43	101	9	635	85.7
2036	1272	117	80	0.04	3	81	36	103	9	728	87.3
2037	1273	118	75	0.04	3	79	30	104	10	823	88.9
2038	1274	118	70	0.04	3	78	24	106	10	919	90.5
2039	1274	118	65	0.04	3	77	17	108	10	1018	92.1
2040	1275	118	60	0.04	2	75	11	110	10	1118	93.7
2041	1276	118	55	0.04	2	74	5	112	10	1220	95.3
2042	1277	118	50	0.04	2	73	2	114	10	1277	96.9
2043	1278	118	45	0.04	2	71	2	116	11	1278	98.5
2044	1279	118	40	0.04	1	70	1	118	11	1279	100.0
2045	1280	118	35	0.04	1	69	1	118	11	1280	100.0
2046	1281	118	30	0.04	1	67	1	118	11	1281	100.0
2047	1282	118	25	0.04	1	66	1	118	11	1282	100.0
2048	1282	118	20	0.03	1	65	1	118	11	1282	100.0
2049	1283	119	15	0.03	1	64	1	119	11	1283	100.0
2050	1284	119	10	0.03	0	63	0	119	11	1284	100.0

GROWTH 3 – BUSES AND COACHES

CURRENT

	ALL BUS					EVs							
	BUS Fleet	**Growth**	**New**	**Scrappage**		**Exist**	**Growth**	**New**	**Growth**	**Scrappage**		**EVs/All BUS**	
Year	**Table VEH0101 1000s**	**% Av. -1.3%**	**Table VEH0150 1000s**	**1000s**	**% Av. 6.7%**	**Table EAFO 1000s**	**% Av. 23.7%**	**Table EAFO 1000s**	**% Av. 24.7%**	**1000s**	**% Av. -5.4%**	**Fleet %**	**New %**
2010	173		9			0.08		0.00				0.04	
2011	170	-1.4	9	11	6.4	0.08	-1.3	0.00		0.00	1.3	0.04	0.00
2012	168	-1.6	10	13	7.5	0.09	22.4	0.00		-0.02	-18.3	0.06	0.00
2013	166	-0.9	9	11	6.4	0.12	25.8	0.00		-0.02	-20.5	0.07	0.00
2014	164	-1.2	8	10	6.3	0.16	39.3	0.00		-0.05	-28.2	0.10	0.00
2015	163	-0.9	10	11	6.8	0.19	15.3	0.01		-0.02	-8.5	0.12	0.09
2016	162	-0.4	10	11	6.6	0.26	36.2	0.08	744.4	0.01	3.1	0.16	0.76
2017	161	-0.7	9	10	6.1	0.30	17.6	0.09	14.5	0.04	14.0	0.19	1.00
2018	158	-2.2	8	11	7.3	0.39	30.9	0.10	12.6	0.00	1.3	0.25	1.23
2019	154	-2.4	7	11	7.0	0.50	27.2	0.14	46.9	0.04	7.4	0.33	2.04

FUTURE

	All Bus 1000s	**All New 1000s**	**gCO_2/kWh**	**kWh/km**	**gCO_2/km**			**New EV Bus 1000s**	**Scrapped EV Bus 1000s**	**Total EV 1000s**	**New EV/All New %**
	Growth	**Growth +Scrap**	**Nat Grid**	**BUS**	**EV**	**Diesel+ Petrol**	**Fleet Mix Growth Assumption**	**Growth Assumption**	**Growth Assumption**	**Growth Assumption**	**Growth Assumption**
	-1.3%	5.4%					**50%**	**50%**	**50%**	**50%**	**50%**
2020	152	8	150	1.00	150	833	830	0.2	0.0	1	2.6
2021	150	8	145	0.99	144	827	822	0.3	0.0	1	4.0
2022	148	8	141	0.98	138	820	813	0.5	0.0	1	6.1
2023	146	8	136	0.97	132	813	803	0.7	0.0	2	9.2
2024	144	8	131	0.96	126	807	792	1.1	0.1	3	14.0
2025	142	8	127	0.95	120	800	779	1.5	0.1	5	19.7
2026	140	8	122	0.93	114	794	763	1.9	0.1	6	25.4

GROWTH 3 – BUSES AND COACHES

2027	139	8	117	0.92	108	788	746	2.3	0.2	9	31.0
2028	137	7	113	0.91	103	781	726	2.7	0.2	11	36.7
2029	135	7	108	0.90	97	775	705	3.1	0.2	14	42.4
2030	133	7	103	0.89	92	769	682	3.5	0.2	17	48.0
2031	132	7	99	0.88	87	763	656	3.8	0.3	21	53.7
2032	130	7	94	0.87	82	757	629	4.2	0.3	25	59.4
2033	128	7	89	0.86	77	751	599	4.5	0.3	29	65.0
2034	126	7	85	0.85	72	745	567	4.8	0.3	33	70.7
2035	125	7	80	0.84	67	739	533	5.2	0.3	38	76.4
2036	123	7	75	0.82	62	733	497	5.5	0.4	43	82.0
2037	122	7	71	0.81	57	727	460	5.5	0.4	48	83.4
2038	120	7	66	0.80	53	721	423	5.5	0.4	54	84.7
2039	119	6	61	0.79	49	715	385	5.5	0.4	59	86.0
2040	117	6	57	0.78	44	710	346	5.5	0.4	64	87.4
2041	115	6	52	0.77	40	704	307	5.5	0.4	69	88.7
2042	114	6	47	0.76	36	698	267	5.6	0.4	74	90.0
2043	113	6	43	0.75	32	693	226	5.6	0.4	79	91.4
2044	111	6	38	0.74	28	687	185	5.6	0.4	85	92.7
2045	110	6	33	0.73	24	682	143	5.6	0.4	90	94.0
2046	108	6	29	0.71	20	676	100	5.6	0.4	95	95.4
2047	107	6	24	0.70	17	671	57	5.6	0.4	100	96.7
2048	105	6	19	0.69	13	665	13	5.6	0.4	105	98.0
2049	104	6	15	0.68	10	660	10	5.6	0.4	104	99.4
2050	103	6	10	0.67	7	655	7	5.6	0.4	103	100.0

GROWTH 4 – LGVs

CURRENT

	ALL LGVs					EVs							
	LGV Fleet	**Growth**	**New**	**Scrappage**		**Exist**	**Growth**	**New**	**Growth**	**Scrappage**		**EVs/All LGVs**	
Year	**Table VEH0101 1000s**	**% Av. 2.7%**	**Table VEH0150 1000s**	**1000s**	**% Av. 6.5%**	**Table EAFO 1000s**	**% Av. 51.1%**	**Table EAFO 1000s**	**% Av. 64.8%**	**1000s**	**% Av. -11.9%**	**Fleet %**	**New %**
2010	3189		226			0.00		0.00				0.00	
2011	3227	1.2	263	225	7.0	0.00		0.03		0.03		0.00	0.01
2012	3252	0.8	242	217	6.7	0.00		0.27	706.1	0.27		0.00	0.11
2013	3298	1.4	274	228	6.9	0.00		0.18	-31.6	0.18		0.00	0.07
2014	3386	2.7	324	236	7.0	0.00		0.66	260.4	0.66		0.00	0.20
2015	3508	3.6	375	254	7.2	1.65		0.80	21.5	-0.85	-51.7%	0.05	0.21
2016	3674	4.8	379	212	5.8	3.00	81.5	0.95	18.9	-0.40	-13.3%	0.08	0.25
2017	3820	4.0	364	219	5.7	4.13	37.9	1.18	24.3	0.04	1.0%	0.11	0.32
2018	3930	2.9	362	252	6.4	5.36	29.6	1.29	9.8	0.07	1.3%	0.14	0.36
2019	4052	3.1	369	248	6.1	8.33	55.6	3.24	150.1	0.26	3.1%	0.21	0.88

FUTURE

	All LGV 1000s	**All New 1000s**	**gCO_2/kWh**	**kWh/km**	**gCO_2/km**			**New EV LGVs 1000s**	**Scrapped EV LGVs 1000s**	**Total EV 1000s**	**New EV/All New %**
	Growth	**Growth +Scrap**	**Nat Grid**	**LGVs**	**EV**	**Diesel+ Petrol**	**Fleet Mix Growth Assumption**	**Growth Assumption**	**Growth Assumption**	**Growth Assumption**	**Growth Assumption**
	2.7%	9.2%					**50%**	**50%**	**50%**	**50%**	**50%**
2020	4161	384	160	0.25	40	226	226	5	0	13	1.3%
2021	4274	395	155	0.25	38	222	221	7	0	20	1.8%
2022	4390	406	150	0.24	37	218	217	11	1	30	2.7%
2023	4508	417	145	0.24	35	214	212	16	1	45	3.9%
2024	4630	428	140	0.24	33	210	208	25	2	68	5.7%
2025	4756	439	135	0.24	32	207	203	37	2	103	8.4%
2026	4884	451	130	0.23	30	203	197	55	4	154	12.3%

GROWTH 4 – LGVs

2027	5017	463	125	0.23	29	199	191	84	5	233	18.1%
2028	5152	476	120	0.23	27	196	185	114	7	339	23.9%
2029	5292	489	115	0.23	26	192	177	145	10	475	29.8%
2030	5435	502	110	0.22	24	189	169	179	12	642	35.6%
2031	5582	516	105	0.22	23	185	161	214	14	842	41.4%
2032	5733	530	100	0.22	22	182	152	250	16	1076	47.3%
2033	5888	544	95	0.21	20	179	142	288	19	1345	52.9%
2034	6047	559	90	0.21	19	175	133	327	21	1651	58.6%
2035	6211	574	85	0.21	18	172	123	369	24	1995	64.3%
2036	6379	589	80	0.21	16	169	112	412	27	2380	69.9%
2037	6552	605	75	0.20	15	166	101	458	30	2808	75.6%
2038	6729	622	70	0.20	14	163	90	505	33	3280	81.3%
2039	6911	638	65	0.20	13	160	80	527	34	3773	82.6%
2040	7098	656	60	0.20	12	157	69	550	36	4287	83.9%
2041	7290	673	55	0.19	11	154	59	574	38	4824	85.3%
2042	7487	692	50	0.19	9	152	49	599	39	5384	86.6%
2043	7690	710	45	0.19	8	149	40	625	41	5967	87.9%
2044	7898	730	40	0.18	7	146	31	651	43	6576	89.3%
2045	8112	749	35	0.18	6	144	22	679	44	7211	90.6%
2046	8331	770	30	0.18	5	141	13	707	46	7872	91.9%
2047	8556	790	25	0.18	4	139	4	737	48	8556	93.3%
2048	8788	812	20	0.17	3	136	3	768	50	8788	94.6%
2049	9026	834	15	0.17	3	134	3	800	52	9026	95.9%
2050	9270	856	10	0.17	2	131	2	833	54	9270	97.3%

GROWTH 5 – HGVs

CURRENT

	ALL HGVs					**EVs**							
	HGV Fleet	**Growth**	**New**	**Scrappage**		**Exist**	**Growth**	**New**	**Growth**	**Scrappage**		**EVs/All HGVs**	
Year	**Table VEH0101 1000s**	**% Av. 0.6%**	**Table VEH0150 1000s**	**1000s**	**% Av. 9.4%**	**Table VEH0130 1000s**	**% Av. -9.8%**	**Table VEH0170 1000s**	**% Av. 32.5%**	**1000s**	**% Av. 13.1%**	**Fleet %**	**New %**
2010	473		30			0.97		0.01				0.20	
2011	468	-1.0	41	45	9.7	0.89	-8.5	0.01	-37.5	0.09	9.8	0.19	0.01
2012	462	-1.2	42	47	10.3	0.73	-17.9	0.01	20.0	0.16	22.6	0.16	0.01
2013	458	-0.9	53	57	12.5	0.59	-19.0	0.00	-100.0	0.14	23.4	0.13	0.00
2014	466	1.7	39	31	6.7	0.51	-13.4	0.00	NA	0.08	16.3	0.11	0.01
2015	473	1.5	49	42	8.9	0.42	-17.3	0.00	-25.0	0.09	21.6	0.09	0.01
2016	482	2.0	51	42	8.7	0.42	-1.7	0.01	200.0	0.02	3.9	0.09	0.02
2017	492	1.9	51	42	8.5	0.38	-7.5	0.00	-55.6	0.04	9.1	0.08	0.01
2018	497	1.0	49	44	8.8	0.36	-6.0	0.01	200.0	0.04	9.7	0.07	0.02
2019	498	0.3	54	52	10.5	0.37	3.3	0.02	58.3	0.01	1.9	0.07	0.04

FUTURE

	All HGV 1000s	**All New 1000s**	**gCO_2/kWh**	**kWh/km**	**gCO_2/km**			**New EV HGV 1000s**	**Scrapped EV HGV 1000s**	**Total EV 1000s**	**New EV/All New %**
	Growth	**Growth +Scrap**	**Nat Grid**	**HGVs**	**EV**	**Diesel+ Petrol**	**Fleet Mix Growth Assumption**	**Growth Assumption**	**Growth Assumption**	**Growth Assumption**	**Growth Assumption**
	0.6%	**10.0%**					**50%**	**50%**	**50%**	**50%**	**50%**
2020	501	50	160	1.00	160	777	777	0	0	0	0.1%
2021	504	50	155	0.99	153	771	770	0	0	0	0.1%
2022	507	51	150	0.98	147	765	764	0	0	0	0.1%
2023	510	51	145	0.97	140	759	758	0	0	1	0.2%
2024	513	51	140	0.96	134	753	752	0	0	1	0.3%
2025	516	51	135	0.95	128	747	745	0	0	1	0.4%
2026	519	52	130	0.93	121	741	739	0	0	1	0.6%

GROWTH 5 – HGVs

2027	522	52	125	0.92	115	735	733	0	0	2	0.9%
2028	526	52	120	0.91	109	729	726	1	0	2	1.4%
2029	529	53	115	0.90	104	723	719	1	0	3	2.1%
2030	532	53	110	0.89	98	717	712	2	0	5	3.1%
2031	535	53	105	0.88	92	711	703	2	0	7	4.6%
2032	538	54	100	0.87	87	706	694	4	0	10	6.9%
2033	541	54	95	0.86	81	700	682	6	1	15	10.3%
2034	545	54	90	0.85	76	694	667	9	1	24	17.1%
2035	548	55	85	0.84	71	689	649	13	1	36	23.9%
2036	551	55	80	0.82	66	683	626	17	2	51	30.7%
2037	554	55	75	0.81	61	678	600	21	2	70	37.5%
2038	558	56	70	0.80	56	672	571	25	2	92	44.3%
2039	561	56	65	0.79	51	667	538	29	3	118	51.1%
2040	564	56	60	0.78	47	662	501	33	3	147	57.9%
2041	568	57	55	0.77	42	656	461	37	3	181	64.7%
2042	571	57	50	0.76	38	651	418	41	4	217	71.5%
2043	574	57	45	0.75	34	646	371	45	4	258	78.3%
2044	578	58	40	0.74	29	641	321	49	5	302	85.1%
2045	581	58	35	0.73	25	636	270	50	5	348	86.7%
2046	585	58	30	0.71	21	631	220	51	5	395	88.3%
2047	588	59	25	0.70	18	626	168	53	5	442	89.9%
2048	592	59	20	0.69	14	621	117	54	5	491	91.5%
2049	595	59	15	0.68	10	616	65	55	5	541	93.1%
2050	599	60	10	0.67	7	611	13	57	5	593	94.7%

GROWTH 6 – INTERVENE 25

FUTURE

	All Cars 1000s	All New 1000s	gCO_2/kWh	kWh/km	gCO_2/km					New EV Cars 1000s			Scrapped EV Cars 1000s			Total EV 1000s			New EV/All New %		
	Growth	Growth +Scrap	Nat Grid	Mid Car	EV	Diesel+ Petrol	Fleet Mix Growth Assumption			Growth Assumption			Growth Assumption			Growth Assumption			Growth Assumption		
	1.3%	**7.8%**					**25%**	**50%**	**75%**	**25%**	**50%**	**75%**	**25%**	**50%**	**75%**	**25%**	**50%**	**75%**	**25%**	**50%**	**75%**
2020	32086	2503	160	0.20	32	167	166	166	166	47	57	66	3	4	4	144	153	162	1.9	2.3	2.7
2021	32490	2534	155	0.20	31	164	163	163	163	59	85	116	4	6	8	199	233	270	2.3	3.4	4.6
2022	32898	2566	150	0.20	29	161	160	160	159	74	128	204	5	8	13	269	352	461	2.9	5.0	7.9
2023	33312	2598	145	0.19	28	158	157	156	155	128	192	356	8	13	23	388	532	794	4.9	7.4	13.7
2024	33732	2631	140	0.19	27	155	153	152	150	221	289	584	14	19	38	595	802	1340	8.4	11.0	22.2
2025	34156	2664	135	0.19	26	153	141	140	138	2664	2664	2664	174	174	174	3084	3292	3830	100.0	100.0	100.0
2026	34586	2698	130	0.19	24	150	129	129	127	2698	2698	2698	176	176	176	5606	5813	6351	100.0	100.0	100.0
2027	35021	2732	125	0.18	23	147	118	117	116	2732	2732	2732	179	179	179	8159	8366	8904	100.0	100.0	100.0
2028	35462	2766	120	0.18	22	144	107	107	105	2766	2766	2766	181	181	181	10744	10951	11489	100.0	100.0	100.0
2029	35908	2801	115	0.18	21	142	97	96	94	2801	2801	2801	183	183	183	13361	13568	14106	100.0	100.0	100.0
2030	36360	2836	110	0.18	20	139	87	86	84	2836	2836	2836	186	186	186	16012	16219	16757	100.0	100.0	100.0
2031	36817	2872	105	0.18	18	137	77	76	74	2872	2872	2872	188	188	188	18695	18903	19441	100.0	100.0	100.0
2032	37280	2908	100	0.17	17	134	67	66	65	2908	2908	2908	190	190	190	21413	21620	22158	100.0	100.0	100.0
2033	37749	2944	95	0.17	16	132	58	57	56	2944	2944	2944	193	193	193	24165	24372	24910	100.0	100.0	100.0
2034	38224	2981	90	0.17	15	130	49	48	47	2981	2981	2981	195	195	195	26951	27158	27696	100.0	100.0	100.0
2035	38705	3019	85	0.17	14	127	40	40	38	3019	3019	3019	197	197	197	29773	29980	30518	100.0	100.0	100.0
2036	39192	3057	80	0.16	13	125	32	31	30	3057	3057	3057	200	200	200	32630	32837	33375	100.0	100.0	100.0
2037	39686	3095	75	0.16	12	123	24	23	22	3095	3095	3095	202	202	202	35522	35730	36268	100.0	100.0	100.0
2038	40185	3134	70	0.16	11	120	16	15	14	3134	3134	3134	205	205	205	38452	38659	39197	100.0	100.0	100.0
2039	40691	3174	65	0.16	10	118	10	10	10	3174	3174	3174	208	208	208	40691	40691	40691	100.0	100.0	100.0
2040	41203	3214	60	0.16	9	116	9	9	9	3214	3214	3214	210	210	210	41203	41203	41203	100.0	100.0	100.0
2041	41721	3254	55	0.15	8	114	8	8	8	3254	3254	3254	213	213	213	41721	41721	41721	100.0	100.0	100.0
2042	42246	3295	50	0.15	8	112	8	8	8	3295	3295	3295	216	216	216	42246	42246	42246	100.0	100.0	100.0
2043	42778	3337	45	0.15	7	110	7	7	7	3337	3337	3337	218	218	218	42778	42778	42778	100.0	100.0	100.0
2044	43316	3379	40	0.15	6	108	6	6	6	3379	3379	3379	221	221	221	43316	43316	43316	100.0	100.0	100.0
2045	43861	3421	35	0.15	5	106	5	5	5	3421	3421	3421	224	224	224	43861	43861	43861	100.0	100.0	100.0
2046	44413	3464	30	0.14	4	104	4	4	4	3464	3464	3464	227	227	227	44413	44413	44413	100.0	100.0	100.0
2047	44972	3508	25	0.14	4	102	4	4	4	3508	3508	3508	229	229	229	44972	44972	44972	100.0	100.0	100.0
2048	45537	3552	20	0.14	3	100	3	3	3	3552	3552	3552	232	232	232	45537	45537	45537	100.0	100.0	100.0
2049	46110	3597	15	0.14	2	99	2	2	2	3597	3597	3597	235	235	235	46110	46110	46110	100.0	100.0	100.0
2050	46691	3642	10	0.13	1	97	1	1	1	3642	3642	3642	238	238	238	46691	46691	46691	100.0	100.0	100.0

GROWTH 7 – INTERVENE 30

FUTURE

	All Cars 1000s	All New 1000s	gCO_2/ kWh	kWh/km	gCO_2/km					New EV Cars 1000s			Scrapped EV Cars 1000s			Total EV 1000s			New EV/All New %		
	Growth	Growth +Scrap	Nat Grid	Mid Car	EV	Diesel+ Petrol	Fleet Mix Growth Assumption			Growth Assumption			Growth Assumption			Growth Assumption			Growth Assumption		
	1.3%	7.8%					25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
2020	32086	2503	160	0.20	32	167	166	166	166	47	57	66	3	4	4	144	153	162	1.9	2.3	2.7
2021	32490	2534	155	0.20	31	164	163	163	163	59	85	116	4	6	8	199	233	270	2.3	3.4	4.6
2022	32898	2566	150	0.20	29	161	160	160	159	74	128	204	5	8	13	269	352	461	2.9	5.0	7.9
2023	33312	2598	145	0.19	28	158	157	156	155	93	192	356	6	13	23	355	532	794	3.6	7.4	13.7
2024	33732	2631	140	0.19	27	155	154	152	150	116	289	584	8	19	38	464	802	1340	4.4	11.0	22.2
2025	34156	2664	135	0.19	26	153	150	148	145	145	473	818	9	31	54	599	1244	2105	5.4	17.8	30.7
2026	34586	2698	130	0.19	24	150	147	143	139	181	663	1058	12	43	69	768	1864	3093	6.7	24.6	39.2
2027	35021	2732	125	0.18	23	147	144	138	132	226	857	1303	15	56	85	980	2664	4311	8.3	31.4	47.7
2028	35462	2766	120	0.18	22	144	140	132	124	283	1024	1555	19	67	102	1245	3622	5764	10.2	37.0	56.2
2029	35908	2801	115	0.18	21	142	137	126	117	354	1228	1812	23	80	119	1575	4769	7458	12.6	43.8	64.7
2030	36360	2836	110	0.18	20	139	125	115	106	2836	2836	2836	186	186	186	4226	7419	10109	100.0	100.0	100.0
2031	36817	2872	105	0.18	18	137	115	104	96	2872	2872	2872	188	188	188	6910	10103	12793	100.0	100.0	100.0
2032	37280	2908	100	0.17	17	134	104	94	86	2908	2908	2908	190	190	190	9627	12821	15510	100.0	100.0	100.0
2033	37749	2944	95	0.17	16	132	94	84	76	2944	2944	2944	193	193	193	12379	15573	18262	100.0	100.0	100.0
2034	38224	2981	90	0.17	15	130	84	75	67	2981	2981	2981	195	195	195	15165	18359	21048	100.0	100.0	100.0
2035	38705	3019	85	0.17	14	127	75	65	57	3019	3019	3019	197	197	197	17987	21180	23870	100.0	100.0	100.0
2036	39192	3057	80	0.16	13	125	65	56	49	3057	3057	3057	200	200	200	20844	24037	26727	100.0	100.0	100.0
2037	39686	3095	75	0.16	12	123	57	48	40	3095	3095	3095	202	202	202	23737	26930	29620	100.0	100.0	100.0
2038	40185	3134	70	0.16	11	120	48	39	32	3134	3134	3134	205	205	205	26666	29860	32549	100.0	100.0	100.0
2039	40691	3174	65	0.16	10	118	40	31	24	3174	3174	3174	208	208	208	29632	32826	35515	100.0	100.0	100.0
2040	41203	3214	60	0.16	9	116	32	23	16	3214	3214	3214	210	210	210	32636	35829	38519	100.0	100.0	100.0
2041	41721	3254	55	0.15	8	114	24	16	9	3254	3254	3254	213	213	213	35677	38871	41560	100.0	100.0	100.0
2042	42246	3295	50	0.15	8	112	16	8	8	3295	3295	3295	216	216	216	38757	41950	42246	100.0	100.0	100.0
2043	42778	3337	45	0.15	7	110	9	7	7	3337	3337	3337	218	218	218	41875	42778	42778	100.0	100.0	100.0
2044	43316	3379	40	0.15	6	108	6	6	6	3379	3379	3379	221	221	221	43316	43316	43316	100.0	100.0	100.0
2045	43861	3421	35	0.15	5	106	5	5	5	3421	3421	3421	224	224	224	43861	43861	43861	100.0	100.0	100.0
2046	44413	3464	30	0.14	4	104	4	4	4	3464	3464	3464	227	227	227	44413	44413	44413	100.0	100.0	100.0
2047	44972	3508	25	0.14	4	102	4	4	4	3508	3508	3508	229	229	229	44972	44972	44972	100.0	100.0	100.0
2048	45537	3552	20	0.14	3	100	3	3	3	3552	3552	3552	232	232	232	45537	45537	45537	100.0	100.0	100.0
2049	46110	3597	15	0.14	2	99	2	2	2	3597	3597	3597	235	235	235	46110	46110	46110	100.0	100.0	100.0
2050	46691	3642	10	0.13	1	97	1	1	1	3642	3642	3642	238	238	238	46691	46691	46691	100.0	100.0	100.0

GROWTH 8 – INTERVENE 35

FUTURE

	All Cars 1000s	All New 1000s	gCO_2/ kWh	kWh/km	gCO_2/km					New EV Cars 1000s			Scrapped EV Cars 1000s			Total EV 1000s			New EV/All New %		
	Growth	Growth +Scrap	Nat Grid	Mid Car	EV	Diesel+ Petrol	Fleet Mix Growth Assumption			Growth Assumption			Growth Assumption			Growth Assumption			Growth Assumption		
	1.3%	7.8%					25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
2020	32086	2503	160	0.20	32	167	166	166	166	47	57	66	3	4	4	144	153	162	1.9	2.3	2.7
2021	32490	2534	155	0.20	31	164	163	163	163	59	85	116	4	6	8	199	233	270	2.3	3.4	4.6
2022	32898	2566	150	0.20	29	161	160	160	159	74	128	204	5	8	13	269	352	461	2.9	5.0	7.9
2023	33312	2598	145	0.19	28	158	157	156	155	93	192	356	6	13	23	355	532	794	3.6	7.4	13.7
2024	33732	2631	140	0.19	27	155	154	152	150	116	289	584	8	19	38	464	802	1340	4.4	11.0	22.2
2025	34156	2664	135	0.19	26	153	150	148	145	145	473	818	9	31	54	599	1244	2105	5.4	17.8	30.7
2026	34586	2698	130	0.19	24	150	147	143	139	181	663	1058	12	43	69	768	1864	3093	6.7	24.6	39.2
2027	35021	2732	125	0.18	23	147	144	138	132	226	857	1303	15	56	85	980	2664	4311	8.3	31.4	47.7
2028	35462	2766	120	0.18	22	144	140	132	124	283	1024	1555	19	67	102	1245	3622	5764	10.2	37.0	56.2
2029	35908	2801	115	0.18	21	142	137	126	117	354	1228	1812	23	80	119	1575	4769	7458	12.6	43.8	64.7
2030	36360	2836	110	0.18	20	139	133	119	108	465	1436	2076	30	94	136	2010	6111	9399	16.4	50.6	73.2
2031	36817	2872	105	0.18	18	137	129	112	100	580	1649	2347	38	108	154	2552	7652	11592	20.2	57.4	81.7
2032	37280	2908	100	0.17	17	134	124	105	91	697	1868	2434	46	122	159	3204	9398	13867	24.0	64.2	83.7
2033	37749	2944	95	0.17	16	132	120	97	82	817	2091	2524	53	137	165	3967	11352	16226	27.7	71.0	85.7
2034	38224	2981	90	0.17	15	130	115	89	74	940	2321	2615	61	152	171	4845	13521	18670	31.5	77.8	87.7
2035	38705	3019	85	0.17	14	127	110	81	65	1066	2555	2708	70	167	177	5841	15909	21201	35.3	84.6	89.7
2036	39192	3057	80	0.16	13	125	100	71	56	3057	3057	3057	200	200	200	8698	18766	24058	100.0	100.0	100.0
2037	39686	3095	75	0.16	12	123	90	62	48	3095	3095	3095	202	202	202	11591	21659	26951	100.0	100.0	100.0
2038	40185	3134	70	0.16	11	120	81	54	39	3134	3134	3134	205	205	205	14521	24588	29880	100.0	100.0	100.0
2039	40691	3174	65	0.16	10	118	72	45	31	3174	3174	3174	208	208	208	17487	27554	32846	100.0	100.0	100.0
2040	41203	3214	60	0.16	9	116	63	37	23	3214	3214	3214	210	210	210	20490	30558	35850	100.0	100.0	100.0
2041	41721	3254	55	0.15	8	114	54	29	16	3254	3254	3254	213	213	213	23531	33599	38891	100.0	100.0	100.0
2042	42246	3295	50	0.15	8	112	46	21	8	3295	3295	3295	216	216	216	26611	36679	42246	100.0	100.0	100.0
2043	42778	3337	45	0.15	7	110	38	14	7	3337	3337	3337	218	218	218	29729	39797	42778	100.0	100.0	100.0
2044	43316	3379	40	0.15	6	108	30	7	6	3379	3379	3379	221	221	221	32887	42955	43316	100.0	100.0	100.0
2045	43861	3421	35	0.15	5	106	23	5	5	3421	3421	3421	224	224	224	36084	43861	43861	100.0	100.0	100.0
2046	44413	3464	30	0.14	4	104	16	4	4	3464	3464	3464	227	227	227	39322	44413	44413	100.0	100.0	100.0
2047	44972	3508	25	0.14	4	102	4	4	4	3508	3508	3508	229	229	229	44972	44972	44972	100.0	100.0	100.0
2048	45537	3552	20	0.14	3	100	3	3	3	3552	3552	3552	232	232	232	45537	45537	45537	100.0	100.0	100.0
2049	46110	3597	15	0.14	2	99	2	2	2	3597	3597	3597	235	235	235	46110	46110	46110	100.0	100.0	100.0
2050	46691	3642	10	0.13	1	97	1	1	1	3642	3642	3642	238	238	238	46691	46691	46691	100.0	100.0	100.0

PATHWAYS - BASELINE

Mode	Population	Walk	Bicycle	Car / van driver	Car / van pass.	Motor-bike	Other private transport	Bus in London	Other local bus	Non-local bus	London Under.	Surface Rail	Taxi / minicab	Other public transport	Total distance
	Million	Average km/person/year													
Mayoral	1.04	344	87	3444	2029	10	88	2	333	73	13	781	172	99	7,475
Metro	3.15	344	87	3444	2029	10	88	2	333	73	13	781	172	99	7,475
Unitary + PSR	0.83	334	92	5229	2813	20	148	0	376	94	1	804	105	32	10,048
District + Unit Cheshire Urban	1.50	272	82	7147	3809	22	171	0	498	58	1	537	77	81	12,755
Rural	0.77	196	93	8662	4031	17	283	0	326	40	1	683	114	30	14,476

Mode	Population	%	All Travel	%	NTS Car	%	Other Car	Motorbike	%	Bus	%	Rail	%	Other LGV	HGV
	Million		Billion person km/year												
Mayoral	1.04	14%	7.79	11%	3.77	10%		0.01	10%	0.52	12%	0.93	16%		
Metro	3.15	43%	23.52	34%	11.38	31%		0.03	30%	1.56	37%	2.81	47%		
Unitary + PSR	0.83	11%	8.36	12%	4.44	12%		0.02	16%	0.51	12%	0.70	12%		
District + Unit Cheshire Urban	1.50	21%	19.19	27%	10.87	29%		0.03	32%	1.09	26%	0.93	16%		
Rural	0.77	11%	11.10	16%	6.73	18%		0.01	12%	0.50	12%	0.55	9%		
Total	7.29	100%	69.96	100%	37.18	100%	15.68	0.10	100%	4.18	100%	5.92	100%	6.10	3.10

Mode		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	**Billion vehicle km/year**		37.18	15.68	0.10	0.48	0.05	6.10	3.10
Emissions/km	**gCO_2/km**		173.40	173.40	112.17	833.33	5516.00	234.58	777.13
Total Emissions	**$MtCO_2$**	**13.68**	6.45	2.72	0.01	0.40	0.27	1.43	2.41
Percent	**%**	100.0%	47.1%	19.9%	0.1%	2.9%	2.0%	10.5%	17.6%

PATHWAY 1 – STEWARDSHIP

2025 Mode	Population	Walk	Bicycle	Car / van driver	Car / van pass.	Motor-bike	Other private	Bus in London	Other local bus	Non-local bus	London Under.	Rail	Taxi / minicab	Other public	Lever	Total
	Million	Average km/person/year														
Mayoral	1.04	344	87	3444	2029	10	88	2	333	73	13	781	172	99	2.7	7,478
Change	%	54%	54%	-20%	-20%	-20%	54%	54%	54%	54%	54%	54%	54%	54%		
Revised	km/person/year	530	134	2755	1623	8	136	3	513	112	20	1203	265	152		7,454
Metro	3.15	344	87	3444	2029	10	88	2	333	73	13	781	172	99	2.7	7,478
Change	%	41%	41%	-15%	-15%	-15%	41%	41%	41%	41%	41%	41%	41%	41%		
Revised	km/person/year	483	122	2927	1725	9	124	3	468	103	18	1097	242	139		7,459
Unitary + PSR	0.83	334	92	5229	2813	20	148	0	376	94	1	804	105	32	4.0	10,052
Change	%	40%	40%	-10%	-10%	-10%	40%	40%	40%	40%	40%	40%	40%	40%		
Revised	km/person/year	468	129	4706	2532	18	207	0	526	132	1	1126	147	45		10,036
District + Unit Cheshire Urban	1.50	272	82	7147	3809	22	171	0	498	58	1	537	77	81	6.1	12,761
Change	%	61%	61%	-10%	-10%	-10%	61%	61%	61%	61%	61%	61%	61%	61%		
Revised	km/person/year	438	132	6432	3428	20	275	0	802	93	2	865	124	130		12,741
Rural	0.77	196	93	8662	4031	17	283	0	326	40	1	683	114	30	7.1	14,483
Change	%	36%	36%	-5%	-5%	-5%	36%	36%	36%	36%	36%	36%	36%	36%		
Revised	km/person/year	266	126	8229	3829	16	383	0	442	54	1	925	154	41		14,467

Mode	Population	%	All Travel	%	NTS Car	%	Other Car	Motorbike	%	Bus	%	Rail	%	Other LGV	HGV
	Million		Billion person km/year												
Mayoral	1.04	14%	7.77	11%	3.15	9%	1.18	0.01	9%	0.80	13%	1.43	17%	0.70	Change
Metro	3.15	43%	23.47	34%	9.97	30%	3.97	0.03	29%	2.19	36%	3.95	46%	2.24	-2%
Unitary + PSR	0.83	11%	8.35	12%	4.04	12%	1.70	0.01	16%	0.72	12%	0.98	11%	0.63	
District + Unit Cheshire Urban	1.50	21%	19.17	27%	9.86	29%	4.16	0.03	32%	1.76	29%	1.50	17%	1.13	
Rural	0.77	11%	11.10	16%	6.43	19%	2.86	0.01	13%	0.67	11%	0.74	9%	0.61	
Total	7.29	100%	69.85	100%	33.45	100%	13.88	0.09	100%	6.14	100%	8.60	100%	5.30	3.04

Mode		All	NTS Car	Other Car	MBike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	**Billion vehicle km/year**		33.45	13.88	0.09	0.70	0.07	5.30	3.04
Emissions/km	**gCO_2/km**		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	**% Change**		0%	0%	0%	0%	0%	0%	0%
Revised	**gCO_2/km**		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Total Emissions	**$MtCO_2$**	**12.80**	5.80	2.41	0.01	0.59	0.39	1.24	2.36
Percent	**%**	100.0%	45.3%	18.8%	0.1%	4.6%	3.0%	9.7%	18.4%

PATHWAY 1 – STEWARDSHIP

2035 Mode	Population	Walk	Bicycle	Car / van driver	Car / van pass.	Motor-bike	Other private	Bus in London	Other local bus	Non-local bus	London Under.	Rail	Taxi / minicab	Other public	Lever	Total
	Million	Average km/person/year														
Mayoral	1.04	344	87	3444	2029	10	88	2	333	73	13	781	172	99	2.7	7,478
Change	%	135%	135%	-50%	-50%	-50%	135%	135%	135%	135%	135%	135%	135%	135%		
Revised	km/person/year	808	204	1722	1015	5	207	5	783	172	31	1835	404	233		7,423
Metro	3.15	344	87	3444	2029	10	88	2	333	73	13	781	172	99	2.7	7,478
Change	%	135%	135%	-50%	-50%	-50%	135%	135%	135%	135%	135%	135%	135%	135%		
Revised	km/person/year	808	204	1722	1015	5	207	5	783	172	31	1835	404	233		7,423
Unitary + PSR	0.83	334	92	5229	2813	20	148	0	376	94	1	804	105	32	4.0	10,052
Change	%	200%	200%	-50%	-50%	-50%	200%	200%	200%	200%	200%	200%	200%	200%		
Revised	km/person/year	1002	276	2615	1407	10	444	0	1128	282	3	2412	315	96		9,989
District + Unit Cheshire Urban	1.50	272	82	7147	3809	22	171	0	498	58	1	537	77	81	6.1	12,761
Change	%	305%	305%	-50%	-50%	-50%	305%	305%	305%	305%	305%	305%	305%	305%		
Revised	km/person/year	1102	332	3574	1905	11	693	0	2017	235	4	2175	312	328		12,686
Rural	0.77	196	93	8662	4031	17	283	0	326	40	1	683	114	30	7.1	14,483
Change	%	355%	355%	-50%	-50%	-50%	355%	355%	355%	355%	355%	355%	355%	355%		
Revised	km/person/year	892	423	4331	2016	9	1288	0	1483	182	5	3108	519	137		14,390

Mode	Population	%	All Travel	%	NTS Car	%	Other Car	Motorbike	%	Bus	%	Rail	%	Other LGV	HGV
	Million		Billion person km/year												
Mayoral	1.04	14%	7.74	11%	2.22	11%	0.83	0.01	10%	1.21	9%	2.19	13%	0.44	Change
Metro	3.15	43%	23.35	34%	6.69	32%	2.51	0.02	30%	3.67	28%	6.60	39%	1.32	-10%
Unitary + PSR	0.83	11%	8.31	12%	2.44	12%	0.91	0.01	16%	1.54	12%	2.09	12%	0.35	
District + Unit Cheshire Urban	1.50	21%	19.09	27%	5.85	28%	2.19	0.02	32%	4.43	34%	3.77	22%	0.63	
Rural	0.77	11%	11.04	16%	3.72	18%	1.39	0.01	12%	2.27	17%	2.49	15%	0.32	
Total	7.29	100%	69.53	100%	20.91	100%	7.84	0.05	100%	13.12	100%	17.14	100%	3.05	2.79

Mode		All	NTS Car	Other Car	Mbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	**Billion vehicle km/year**		20.91	7.84	0.05	1.50	0.14	3.05	2.79
Emissions/km	**gCO_2/km**		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	**% Change**		0%	0%	0%	0%	0%	0%	0%
Revised	**gCO_2/km**		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Total Emissions	**$MtCO_2$**	**9.90**	3.63	1.36	0.01	1.25	0.78	0.72	2.17
Percent	**%**	100.0%	36.6%	13.7%	0.1%	12.6%	7.8%	7.2%	21.9%

PATHWAY 1 – STEWARDSHIP

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	13.01	1.02	66.74
2030	11.71	1.03	128.54
2035	10.39	1.05	183.81
2040	10.56	1.07	236.19
2045	10.72	1.08	289.40
2050	10.89	1.10	343.43

PATHWAY 2 – REFERENCE 25

2030		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		37.18	15.68	0.10	0.48	0.05	6.10	3.10
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-20%	-20%	-32%	-18%	-28%	-27%	-8%
Revised	gCO_2/km		138.72	138.72	76.27	683.33	3971.53	171.24	714.96
Total Emissions	$MtCO_2$	11.12	5.16	2.18	0.01	0.33	0.19	1.04	2.22
Percent	%	100.0%	46.4%	19.6%	0.1%	2.9%	1.7%	9.4%	19.9%
2040		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		37.18	15.68	0.10	0.48	0.05	6.10	3.10
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-50%	-50%	-89%	-58%	-61%	-77%	-35%
Revised	gCO_2/km		86.70	86.70	12.34	350.00	2151.25	53.95	505.14
Total Emissions	$MtCO_2$	6.75	3.22	1.36	0.00	0.17	0.10	0.33	1.57
Percent	%	100.0%	47.8%	20.1%	0.0%	2.5%	1.5%	4.9%	23.2%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.42	1.00	
2025	12.67	1.02	65.24
2030	11.49	1.03	125.66
2035	9.66	1.05	178.53
2040	7.20	1.07	220.68
2045	4.32	1.08	249.50
2050	1.47	1.10	263.98

PATHWAY 2a – REFERENCE 25 + STEWARDSHIP

2030		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		27.26	10.89	0.07	1.10	0.11	4.19	2.91
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-20%	-20%	-32%	-18%	-28%	-27%	-8%
Revised	gCO_2/km		138.72	138.72	76.27	683.33	3971.53	171.24	714.96
Total Emissions	$MtCO_2$	9.27	3.78	1.51	0.01	0.75	0.42	0.72	2.08
Percent	%	100.0%	40.8%	16.3%	0.1%	8.1%	4.5%	7.7%	22.5%
2040		**All**	**NTS Car**	**Other Car**	**Motorbike**	**Bus**	**Rail**	**Other LGV**	**HGV**
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		20.91	7.84	0.05	1.50	0.14	3.05	2.79
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-50%	-50%	-89%	-58%	-61%	-77%	-35%
Revised	gCO_2/km		86.70	86.70	12.34	350.00	2151.25	53.95	505.14
Total Emissions	$MtCO_2$	4.89	1.81	0.68	0.00	0.52	0.30	0.16	1.41
Percent	%	100.0%	37.0%	13.9%	0.0%	10.7%	6.2%	3.4%	28.8%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	11.86	1.02	63.86
2030	9.57	1.03	117.45
2035	7.04	1.05	158.99
2040	5.22	1.07	189.64
2045	1.78	1.08	207.13
2050	0.21	1.10	212.11

PATHWAY 3 – REFERENCE 50

2030		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		37.18	15.68	0.10	0.48	0.05	6.10	3.10
Emissions/km	gCO$_2$/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-28%	-28%	-32%	-18%	-28%	-27%	-8%
Revised	gCO$_2$/km		124.85	124.85	76.27	683.33	3971.53	171.24	714.96
Total Emissions	MtCO$_2$	**10.39**	4.64	1.96	0.01	0.33	0.19	1.04	2.22
Percent	%	100.0%	44.7%	18.8%	0.1%	3.1%	1.9%	10.1%	21.3%
2040		**All**	**NTS Car**	**Other Car**	**Motorbike**	**Bus**	**Rail**	**Other LGV**	**HGV**
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		37.18	15.68	0.10	0.48	0.05	6.10	3.10
Emissions/km	gCO$_2$/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-75%	-75%	-89%	-58%	-61%	-77%	-35%
Revised	gCO$_2$/km		43.35	43.35	12.34	350.00	2151.25	53.95	505.14
Total Emissions	MtCO$_2$	**4.46**	1.61	0.68	0.00	0.17	0.10	0.33	1.57
Percent	%	100.0%	36.1%	15.2%	0.0%	3.8%	2.3%	7.4%	35.1%

Year	Annual Emissions MtCO$_2$	Population Change	Cumulative Emissions MtCO$_2$
2020	13.68	1.00	
2025	12.58	1.02	65.66
2030	10.73	1.03	123.95
2035	8.02	1.05	170.84
2040	4.76	1.07	202.79
2045	1.44	1.08	218.29
2050	0.26	1.10	222.55

PATHWAY 3a – REFERENCE 50 + STEWARDSHIP

2030		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		27.12	10.82	0.07	1.11	0.11	4.17	2.91
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-28%	-28%	-32%	-18%	-28%	-27%	-8%
Revised	gCO_2/km		124.85	124.85	76.27	683.33	3971.53	171.24	714.96
Total Emissions	$MtCO_2$	8.72	3.39	1.35	0.01	0.76	0.42	0.71	2.08
Percent	%	100.0%	38.8%	15.5%	0.1%	8.7%	4.8%	8.2%	23.9%
2040		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		20.91	7.84	0.05	1.50	0.14	3.05	2.79
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-75%	-75%	-89%	-58%	-61%	-77%	-35%
Revised	gCO_2/km		43.35	43.35	12.34	350.00	2151.25	53.95	505.14
Total Emissions	$MtCO_2$	3.65	0.91	0.34	0.00	0.52	0.30	0.16	1.41
Percent	%	100.0%	24.8%	9.3%	0.0%	14.4%	8.3%	4.5%	38.6%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	11.78	1.02	63.65
2030	9.01	1.03	115.61
2035	6.15	1.05	153.51
2040	3.89	1.07	178.61
2045	1.46	1.08	191.99
2050	0.21	1.10	196.17

PATHWAY 4 – REFERENCE 75

2030	All		NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		37.18	15.68	0.10	0.48	0.05	6.10	3.10
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-35%	-35%	-32%	-18%	-28%	-27%	-8%
Revised	gCO_2/km		112.71	112.71	76.27	683.33	3971.53	171.24	714.96
Total Emissions	$MtCO_2$	9.75	4.19	1.77	0.01	0.33	0.19	1.04	2.22
Percent	%	100.0%	43.0%	18.1%	0.1%	3.4%	2.0%	10.7%	22.7%
2040	**All**		**NTS Car**	**Other Car**	**Motorbike**	**Bus**	**Rail**	**Other LGV**	**HGV**
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		37.18	15.68	0.10	0.48	0.05	6.10	3.10
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-85%	-85%	-89%	-58%	-61%	-77%	-35%
Revised	gCO_2/km		26.01	26.01	12.34	350.00	2151.25	53.95	505.14
Total Emissions	$MtCO_2$	3.54	0.97	0.41	0.00	0.17	0.10	0.33	1.57
Percent	%	100.0%	27.3%	11.5%	0.0%	4.7%	2.9%	9.3%	44.2%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	9.91	1.02	58.98
2030	10.07	1.03	108.94
2035	7.06	1.05	151.76
2040	3.78	1.07	178.86
2045	1.37	1.08	191.74
2050	0.26	1.10	195.82

PATHWAY 4a – REFERENCE 75 + STEWARDSHIP

2030		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		27.12	10.82	0.07	1.11	0.11	4.17	2.91
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-35%	-35%	-32%	-18%	-28%	-27%	-8%
Revised	gCO_2/km		112.71	112.71	76.27	683.33	3971.53	171.24	714.96
Total Emissions	$MtCO_2$	8.26	3.06	1.22	0.01	0.76	0.42	0.71	2.08
Percent	%	100.0%	37.0%	14.8%	0.1%	9.1%	5.1%	8.7%	25.2%
2040		**All**	**NTS Car**	**Other Car**	**Motorbike**	**Bus**	**Rail**	**Other LGV**	**HGV**
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		20.91	7.84	0.05	1.50	0.14	3.05	2.79
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-85%	-85%	-89%	-58%	-61%	-77%	-35%
Revised	gCO_2/km		26.01	26.01	12.34	350.00	2151.25	53.95	505.14
Total Emissions	$MtCO_2$	3.15	0.54	0.20	0.00	0.52	0.30	0.16	1.41
Percent	%	100.0%	17.3%	6.5%	0.0%	16.7%	9.6%	5.2%	44.7%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	11.61	1.02	63.24
2030	8.53	1.03	113.59
2035	5.63	1.05	148.98
2040	3.36	1.07	171.45
2045	1.46	1.08	183.50
2050	0.21	1.10	187.68

PATHWAY 5 – INTERVENE 25

2030		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		37.18	15.68	0.10	0.48	0.05	6.10	3.10
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-48%	-48%	-32%	-18%	-28%	-27%	-8%
Revised	gCO_2/km		90.17	90.17	76.27	683.33	3971.53	171.24	714.96
Total Emissions	$MtCO_2$	8.55	3.35	1.41	0.01	0.33	0.19	1.04	2.22
Percent	%	100.0%	39.2%	16.5%	0.1%	3.8%	2.3%	12.2%	25.9%
2040		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		37.18	15.68	0.10	0.48	0.05	6.10	3.10
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-94%	-94%	-89%	-58%	-61%	-77%	-35%
Revised	gCO_2/km		10.40	10.40	12.34	350.00	2151.25	53.95	505.14
Total Emissions	$MtCO_2$	2.72	0.39	0.16	0.00	0.17	0.10	0.33	1.57
Percent	%	100.0%	14.2%	6.0%	0.0%	6.2%	3.8%	12.1%	57.6%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	12.11	1.02	64.50
2030	8.84	1.03	116.88
2035	5.62	1.05	153.02
2040	2.90	1.07	174.31
2045	1.44	1.08	185.17
2050	0.26	1.10	189.43

PATHWAY 5a – INTERVENE 25 + STEWARDSHIP

2030	All		NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		27.20	10.86	0.07	1.10	0.11	4.19	2.91
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-48%	-48%	-32%	-18%	-28%	-27%	-8%
Revised	gCO_2/km		90.17	90.17	76.27	683.33	3971.53	171.24	714.96
Total Emissions	$MtCO_2$	7.41	2.45	0.98	0.01	0.75	0.42	0.72	2.08
Percent	%	100.0%	33.1%	13.2%	0.1%	10.2%	5.6%	9.7%	28.1%
2040	**All**		**NTS Car**	**Other Car**	**Motorbike**	**Bus**	**Rail**	**Other LGV**	**HGV**
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		20.91	7.84	0.05	1.50	0.14	3.05	2.79
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-94%	-94%	-89%	-58%	-61%	-77%	-35%
Revised	gCO_2/km		10.40	10.40	12.34	350.00	2151.25	53.95	505.14
Total Emissions	$MtCO_2$	2.70	0.22	0.08	0.00	0.52	0.30	0.16	1.41
Percent	%	100.0%	8.1%	3.0%	0.0%	19.4%	11.2%	6.1%	52.2%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	11.36	1.02	62.61
2030	7.65	1.03	110.15
2035	4.84	1.05	141.39
2040	2.88	1.07	160.70
2045	1.46	1.08	171.55
2050	0.21	1.10	175.74

PATHWAY 6 – INTERVENE 30

2030	All		NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		37.18	15.68	0.10	0.48	0.05	6.10	3.10
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-31%	-31%	-32%	-18%	-28%	-27%	-8%
Revised	gCO_2/km		119.65	119.65	76.27	683.33	3971.53	171.24	714.96
Total Emissions	$MtCO_2$	10.11	4.45	1.88	0.01	0.33	0.19	1.04	2.22
Percent	%	100.0%	44.0%	18.6%	0.1%	3.2%	1.9%	10.3%	21.9%
2040	**All**		**NTS Car**	**Other Car**	**Motorbike**	**Bus**	**Rail**	**Other LGV**	**HGV**
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		37.18	15.68	0.10	0.48	0.05	6.10	3.10
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-86%	-86%	-89%	-57%	-61%	-77%	-35%
Revised	gCO_2/km		24.28	24.28	12.34	358.33	2151.25	53.95	505.14
Total Emissions	$MtCO_2$	3.46	0.90	0.38	0.00	0.17	0.10	0.33	1.57
Percent	%	100.0%	26.1%	11.0%	0.0%	5.0%	3.0%	9.5%	45.3%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	12.58	1.02	65.66
2030	10.45	1.03	123.24
2035	7.06	1.05	167.01
2040	3.69	1.07	193.88
2045	1.44	1.08	206.70
2050	0.26	1.10	210.96

PATHWAY 6a – INTERVENE 30 + STEWARDSHIP

2030		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		27.20	10.86	0.07	1.10	0.11	4.19	2.91
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-31%	-31%	-32%	-18%	-28%	-27%	-8%
Revised	gCO_2/km		119.65	119.65	76.27	683.33	3971.53	171.24	714.96
Total Emissions	$MtCO_2$	8.53	3.25	1.30	0.01	0.75	0.42	0.72	2.08
Percent	%	100.0%	38.1%	15.2%	0.1%	8.8%	4.9%	8.4%	24.4%
2040		**All**	**NTS Car**	**Other Car**	**Motorbike**	**Bus**	**Rail**	**Other LGV**	**HGV**
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		20.91	7.84	0.05	1.50	0.14	3.05	2.79
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-86%	-86%	-89%	-58%	-61%	-77%	-35%
Revised	gCO_2/km		24.28	24.28	12.34	350.00	2151.25	53.95	505.14
Total Emissions	$MtCO_2$	3.10	0.51	0.19	0.00	0.52	0.30	0.16	1.41
Percent	%	100.0%	16.4%	6.1%	0.0%	16.9%	9.8%	5.3%	45.5%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	11.78	1.02	63.65
2030	8.81	1.03	115.13
2035	5.63	1.05	151.24
2040	3.31	1.07	173.57
2045	1.46	1.08	185.49
2050	0.21	1.10	189.67

PATHWAY 7 – INTERVENE 35

2030	All		NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		37.18	15.68	0.10	0.48	0.05	6.10	3.10
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-28%	-28%	-32%	-18%	-28%	-27%	-8%
Revised	gCO_2/km		124.85	124.85	76.27	683.33	3971.53	171.24	714.96
Total Emissions	$MtCO_2$	**10.39**	4.64	1.96	0.01	0.33	0.19	1.04	2.22
Percent	%	100.0%	44.7%	18.8%	0.1%	3.1%	1.9%	10.1%	21.3%
2040	**All**		**NTS Car**	**Other Car**	**Motorbike**	**Bus**	**Rail**	**Other LGV**	**HGV**
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		37.18	15.68	0.10	0.48	0.05	6.10	3.10
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-78%	-78%	-89%	-58%	-61%	-77%	-35%
Revised	gCO_2/km		38.15	38.15	12.34	350.00	2151.25	53.95	505.14
Total Emissions	$MtCO_2$	**4.18**	1.42	0.60	0.00	0.17	0.10	0.33	1.57
Percent	%	100.0%	33.9%	14.3%	0.0%	4.0%	2.5%	7.9%	37.4%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	12.58	1.02	65.66
2030	10.73	1.03	123.95
2035	8.02	1.05	170.84
2040	4.46	1.07	202.06
2045	1.44	1.08	216.83
2050	0.26	1.10	221.09

PATHWAY 7a – INTERVENE 35 + STEWARDSHIP

2030	All		NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		27.20	10.86	0.07	1.10	0.11	4.19	2.91
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-28%	-28%	-32%	-18%	-28%	-27%	-8%
Revised	gCO_2/km		124.85	124.85	76.27	683.33	3971.53	171.24	714.96
Total Emissions	$MtCO_2$	8.73	3.40	1.36	0.01	0.75	0.42	0.72	2.08
Percent	%	100.0%	38.9%	15.5%	0.1%	8.6%	4.8%	8.2%	23.9%
2040	**All**		**NTS Car**	**Other Car**	**Motorbike**	**Bus**	**Rail**	**Other LGV**	**HGV**
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		20.91	7.84	0.05	1.50	0.14	3.05	2.79
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-78%	-78%	-89%	-58%	-61%	-77%	-35%
Revised	gCO_2/km		38.15	38.15	12.34	350.00	2151.25	53.95	505.14
Total Emissions	$MtCO_2$	3.50	0.80	0.30	0.00	0.52	0.30	0.16	1.41
Percent	%	100.0%	22.8%	8.5%	0.0%	15.0%	8.6%	4.7%	40.3%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	11.78	1.02	63.65
2030	9.02	1.03	115.64
2035	6.15	1.05	153.57
2040	3.73	1.07	178.27
2045	1.46	1.08	191.25
2050	0.21	1.10	195.44

PATHWAY 8 – SPECULATIVE CAR

2030		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.30	1.30	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		20.92	10.86	0.07	1.10	0.11	4.19	2.91
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-31%	-31%	-32%	-18%	-28%	-27%	-8%
Revised	gCO_2/km		119.65	119.65	76.27	683.33	3971.53	171.24	714.96
Total Emissions	$MtCO_2$	7.78	2.50	1.30	0.01	0.75	0.42	0.72	2.08
Percent	%	100.0%	32.2%	16.7%	0.1%	9.7%	5.4%	9.2%	26.8%
2040		**All**	**NTS Car**	**Other Car**	**Motorbike**	**Bus**	**Rail**	**Other LGV**	**HGV**
Occupancy			1.50	1.50	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		13.94	7.84	0.05	1.50	0.14	3.05	2.79
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-86%	-86%	-89%	-58%	-61%	-77%	-35%
Revised	gCO_2/km		24.28	24.28	12.34	350.00	2151.25	53.95	505.14
Total Emissions	$MtCO_2$	2.93	0.34	0.19	0.00	0.52	0.30	0.16	1.41
Percent	%	100.0%	11.5%	6.5%	0.0%	17.9%	10.3%	5.6%	48.1%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	11.30	1.02	62.46
2030	8.04	1.03	110.81
2035	5.13	1.05	143.73
2040	3.13	1.07	164.38
2045	1.42	1.08	175.75
2050	0.20	1.10	179.80

PATHWAY 9 – SPECULATIVE FREIGHT

2030		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		27.20	10.86	0.07	1.10	0.11	4.19	2.64
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-31%	-31%	-32%	-18%	-28%	-31%	-31%
Revised	gCO_2/km		119.65	119.65	76.27	683.33	3971.53	161.86	536.22
Total Emissions	$MtCO_2$	7.82	3.25	1.30	0.01	0.75	0.42	0.68	1.41
Percent	%	100.0%	41.6%	16.6%	0.1%	9.6%	5.4%	8.7%	18.1%
2040		**All**	**NTS Car**	**Other Car**	**Motorbike**	**Bus**	**Rail**	**Other LGV**	**HGV**
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		20.91	7.84	0.05	1.50	0.14	3.05	2.33
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-86%	-86%	-89%	-58%	-61%	-86%	-86%
Revised	gCO_2/km		24.28	24.28	12.34	350.00	2151.25	32.84	108.80
Total Emissions	$MtCO_2$	1.88	0.51	0.19	0.00	0.52	0.30	0.10	0.25
Percent	%	100.0%	27.0%	10.1%	0.0%	27.9%	16.1%	5.3%	13.5%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	11.53	1.02	63.04
2030	8.08	1.03	112.06
2035	4.37	1.05	143.19
2040	2.00	1.07	159.13
2045	0.65	1.08	165.77
2050	0.11	1.10	167.68

PATHWAY 10 – SPECULATIVE BUS

2030		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	20.00	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		27.20	10.86	0.07	0.48	0.11	4.19	2.91
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-31%	-31%	-32%	-18%	-28%	-27%	-8%
Revised	gCO_2/km		119.65	119.65	76.27	683.33	3971.53	171.24	714.96
Total Emissions	$MtCO_2$	8.11	3.25	1.30	0.01	0.33	0.42	0.72	2.08
Percent	%	100.0%	40.1%	16.0%	0.1%	4.1%	5.2%	8.8%	25.7%
2040		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	20.00	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		20.91	7.84	0.05	0.66	0.14	3.05	2.79
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-86%	-86%	-89%	-58%	-61%	-77%	-35%
Revised	gCO_2/km		24.28	24.28	12.34	350.00	2151.25	53.95	505.14
Total Emissions	$MtCO_2$	2.80	0.51	0.19	0.00	0.23	0.30	0.16	1.41
Percent	%	100.0%	18.1%	6.8%	0.0%	8.2%	10.8%	5.9%	50.3%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	11.46	1.02	62.87
2030	8.38	1.03	112.47
2035	5.15	1.05	146.30
2040	2.99	1.07	166.66
2045	1.33	1.08	177.47
2050	0.21	1.10	181.31

PATHWAY 11 – SPECULATIVE STEWARDSHIP

2030		All	NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		20.91	7.84	0.05	1.50	0.14	3.05	2.91
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-31%	-31%	-32%	-18%	-28%	-27%	-8%
Revised	gCO_2/km		119.65	119.65	76.27	683.33	3971.53	171.24	714.96
Total Emissions	$MtCO_2$	**7.63**	2.50	0.94	0.00	1.02	0.56	0.52	2.08
Percent	%	100.0%	32.8%	12.3%	0.1%	13.4%	7.3%	6.8%	27.3%
2040		**All**	**NTS Car**	**Other Car**	**Motorbike**	**Bus**	**Rail**	**Other LGV**	**HGV**
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		20.91	7.84	0.05	1.50	0.14	3.05	2.79
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-86%	-86%	-89%	-57%	-61%	-77%	-35%
Revised	gCO_2/km		24.28	24.28	12.34	358.33	2151.25	53.95	505.14
Total Emissions	$MtCO_2$	**3.11**	0.51	0.19	0.00	0.54	0.30	0.16	1.41
Percent	%	100.0%	16.3%	6.1%	0.0%	17.3%	9.7%	5.3%	45.3%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	11.03	1.02	61.79
2030	7.89	1.03	109.09
2035	5.63	1.05	142.87
2040	3.32	1.07	165.24
2045	1.46	1.08	177.19
2050	0.21	1.10	181.37

PATHWAY 12 – SPECULATIVE EMISSIONS

2030	All		NTS Car	Other Car	Motorbike	Bus	Rail	Other LGV	HGV
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		27.20	10.86	0.07	1.10	0.11	4.19	2.91
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-33%	-33%	-32%	-18%	-28%	-27%	-8%
Revised	gCO_2/km		116.18	116.18	76.27	683.33	3971.53	171.24	714.96
Total Emissions	$MtCO_2$	8.40	3.16	1.26	0.01	0.75	0.42	0.72	2.08
Percent	%	100.0%	37.6%	15.0%	0.1%	9.0%	5.0%	8.5%	24.8%
2040	**All**		**NTS Car**	**Other Car**	**Motorbike**	**Bus**	**Rail**	**Other LGV**	**HGV**
Occupancy			1.00	1.00	1.00	8.75	122.00	1.00	1.00
Vehicle Movements	Billion vehicle km/year		20.91	7.84	0.05	1.50	0.14	3.05	2.79
Emissions/km	gCO_2/km		173.40	173.40	112.17	833.33	5516.01	234.58	777.13
Technological	% Change		-99%	-99%	-89%	-64%	-61%	-77%	-35%
Revised	gCO_2/km		1.73	1.73	12.34	300.00	2151.25	53.95	505.14
Total Emissions	$MtCO_2$	2.38	0.04	0.01	0.00	0.45	0.30	0.16	1.41
Percent	%	100.0%	1.5%	0.6%	0.0%	18.9%	12.7%	6.9%	59.3%

Year	Annual Emissions $MtCO_2$	Population Change	Cumulative Emissions $MtCO_2$
2020	13.68	1.00	
2025	11.78	1.02	63.65
2030	8.68	1.03	114.79
2035	5.05	1.05	149.11
2040	2.53	1.07	168.08
2045	0.72	1.08	176.21
2050	-0.28	1.10	177.31