Cross-Sector Policy Research:
Insights from the UK energy and transport sectors

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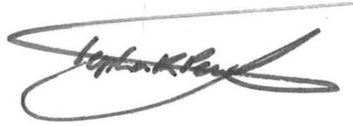
Dedication.

To Sarah and Charlie, for all their love and support.

Declaration.

I declare that except for commonly understood and accepted ideas, or where specific reference is made, the work reported in this dissertation is my own. It includes nothing which is the outcome of work done in collaboration. The work has not previously been submitted in part or in whole to any university for any degree, diploma or other qualification.



S R Peake

This dissertation has 250 pages including references, tabulated data and diagrams.

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List of Abbreviations.

AA	Automobile Association
ACC	Association of County Councils
ACEC	Advisory Council on Energy Conservation
AEA	Atomic Energy Authority
AGR	Advanced Gas Cooled Reactor
BAU	business as usual
BTC	British Transport Commission
btkme	billion tonne kilometres equivalent
BRS	British Road Services
CAA	Civil Aviation Authority
CEC	Commission of the European Communities
CEGB	Central Electricity Generating Board
CHP	Combined Heat and Power
ckm	carrier kilometre
CO	carbon monoxide
CO2	carbon dioxide
CPRE	Council for the Protection of Rural England and Wales
CPRS	Central Policy Review Staff
CSO	Central Statistical Office
DEn	Department of Energy
DoE	Department of the Environment
DTI	Department of Trade and Industry
DTp	Department of Transport
DWT	dead weight tonnage
E	total essential mass movement (passenger and freight, in tkme)
$E_{carrier}$	essential mass movement of a carrier (in tkme)
EC	European Commission
EEO	Energy Efficiency Office
ESI	Electricity Supply Industry
ETSU	Energy Technology Support Unit
$F_{carrier}$	net activity for a freight carrier in tkm
${}^{i}F_{b}$	elasticity of F to changes in an input i
${}^{i}F_{s}$	sensitivity of F to changes in an input i
FT	Financial Times
G	total gross mass movement (passenger and freight, in tkme)
$G_{carrier}$	gross mass movement of a carrier (in tkme)
GDP	Gross Domestic Product
GNP	Gross National Product
GST	General Systems Theory
gvm	gross vehicle mass
HC	hydrogen chloride
HGV	heavy goods vehicle
HMSO	Her Majesty's Stationery Office
IEA	International Energy Agency
IIED	International Institute for the Environment and Development
LDC	Less Developed Countries
LDT	light displacement tonnage

LGV	light goods vehicle
LVKM	loaded vehicle kilometres
$M_{carrier}$	maximum load of carrier (in tonnes or persons or tkme)
MJ	mega-joules
mtce	million tonnes of coal equivalent
N	total net mass movement (passenger and freight, in tkme)
NAO	National Audit Office
$N_{carrier}$	net activity of a carrier in tkme
NEDO	National Economic Development Office
NMHC	National Materials Handling Centre
NOx	nitrogen dioxides
NRTF	National Road Traffic Forecasts
NST/R	Nomeclature Statistique de Transport
NTS	National Travel Survey
$O_{carrier}$	implied occupancy of a carrier (in tonnes or persons)
OECD	Organisation for Economic Cooperation and Development
OPEC	Organisation of Petroleum Exporting Countries
$P_{carrier}$	passenger transport activity in pkm
PCUs	passenger car units
pkm	passenger kilometres
PSO	Public Service Obligation Grants
PTAs	Passenger Transport Authorities
R^i	estimate of range of uncertainty in true value of parameter i (in %)
RAC	Royal Automobile Cub
R&D	Research and Development
RTPI	Royal Town Planning Institute
SEC	specific energy consumption (in MJ per loaded ckm)
SM	sustainable mobility
SMMT	Society of Motor Manufacturers and Traders
SO2	sulphur dioxide
SSM	Soft Systems Methodology
tce	tonnes of coal equivalent
TEST	Transport and Environment Studies
TIOUT	transport industry own use of transport
tkm	tonne kilometres
tkme	tonne kilometre equivalents
$U_{carrier}$	unladen mass of carrier (in tonnes)
UK	United Kingdom
UKAEA	United Kingdom Atomic Energy Authority
ulm	unladen mass
US	United States of America
$V_{carrier}$	minimum distance travelled by a carrier to transport $N_{carrier}$ (in vkm)
vkm	vehicle kilometres
$W_{carrier}$	actual reported distance that a carrier travels (in vkm)
WAES	Workshop on Alternative Energy Strategies
WCED	World Commission on Environment and Development
$XRF_{carrier}$	extra running factor for a carrier

Summary.

Key words:

energy; transport; energy policy; transport policy; energy efficiency; transport efficiency; demand management; analogical reasoning.

Following established traditions in anthropology and sociology, where cross-border research helps to identify important themes which benefit from comparative study, this dissertation introduces cross-sector policy research as a new methodology for generating useful insights about public policy. The cross-sector method is applied to the study of the UK energy and transport sectors.

A range of generic policy developments in the energy sector are identified including: the development of efficiency indicators, scenario analysis, and the establishment of energy efficiency programmes. Such developments have not, as yet, occurred in the transport sector.

A structural analogy between energy and transport is developed which is used to generate a range of innovations for transport policy including: gross mass movements and intensities as indicators of the efficiency with which the economy uses transport; the projection of a quantitative scenario of sustainable mobility; and the outline of a transport efficiency programme.

The insights from the analogy are generalised to consider the benefits of a wider application of cross-sector policy research to other policy areas.

Chapter 1

Introduction

> It is proper to consider the similar....
> even in things far distant from each other.
>
> Aristotle, *Metaphysics*

1.1 Introduction.

The ability to make connections between previously unrelated ideas or to understand the new in terms of the old is an invaluable skill. Whether solving a problem, developing a theory or communicating with others, making full use of prior knowledge and previous experience improves learning through a series of matches and cross-comparisons between the familiar and the unfamiliar by avoiding duplication and inefficiency, and promoting order and consistency.

Such patterns of learning are present in natural science (e.g. Kuhn, 1962; Black, 1962; Hesse, 1970) and form the basis of all cross-border comparative research within the social sciences, where the borders of nations, regions, towns and even villages provide lines of discontinuity between one culture and the next.

Cross-border research has played a vital role in the formation of theory, acquisition of knowledge and spread of ideas throughout many fields within the social sciences such as anthropology, sociology, politics, economics and more recently the policy sciences and management studies (see for example Holy, 1987; Kohn, 1987; Heidenheimer et al., 1983; Janicke, 1990; Vogel, 1986; and Hamden-Turner, 1990).

Within the policy sciences, there has been much attention given to the idea of comparing particular sectors of policy between different countries so that the ways in which such policies are processed and the systems that deal with them can be understood.

In its effort to be scientific, the policy approach has developed a branch of research preoccupied with formulating and testing generalisations, which in turn necessitated a focus on empirical evidence via comparisons (as has happened throughout the positivistic period in other social science disciplines (see Holy, 1987; and Weiss,1991)). What are the differences and similarities between health policy in the UK and Germany, or transport policy in the UK and France, or regulatory style between the UK and the US ? Cross-border research has evolved to address such issues in a coherent and systematic way.

The standard comparative method attempts to understand, explain, or predict policy phenomena using data from more than one country. Cross-border research compares ideas, processes, policies and cultures between two or more countries and has become a popular research method. There are many examples of such studies between a number of different countries and across a wide range of policy sectors including: health (Leichter, 1979; Financial Times, 1993); education (Heidenheimer et al, 1983); transport (Barde and Button, 1990); energy (Baumgartner and Midtunn, 1987); social policies (Heclo, 1974); and Government-industry relationships (Wilks and Wright, 1987).

This dissertation explores what happens when the research question is modified slightly so that it asks, for example; what are the differences and similarities between energy and transport policy in the UK ? Instead of comparing a particular policy between two countries, two areas of policy are compared within the same country.

Thus, as an existing research methodology, the principles and rationale of cross-border policy research can themselves be used to substantiate a cross-comparison of policy sectors to study what influences and determines their comparative developments within a particular country

There is no clear definition of a policy sector. Just as the borders between neighbouring territories are a product of a whole range of influences including politics, culture, and natural relief, in a similar way the edges of policy sectors are influenced by particular policy processes, and the nature of the issues they deal with. Explicitly comparing policy across sectors involves taking into account the complex relationship between the nature of the issues contained within them and the way they are dealt with in the policy process. In any one sitting, the House of Commons or the House of Lords may consider a range of issues from criminal policy to defence, to agricultural policy, imbuing their development with whatever dominant political and social culture characterises them. Yet from another point of view, penal reform, arms technology development, and farmers' agricultural subsidies have very little in common. Each has its own special histories, languages, cultures and politics within the larger political system. As specialised issues they will inevitably be dealt with in different ways.

This perspective suggests that improvements in the policies which Government delivers can come in one of two ways, either by improving the general process across which most issues are dealt with (e.g. electing a new Government), or by improving the specific processes related to particular policies (e.g. forming new advisory or Select Committees). Cross-sector policy research is a method for improving specific processes related to particular policies. Instead of concentrating on how different political systems shape the development of various policies, it takes policy as the independent variable, examining the degree of convergence between sectors exploring the possibilities for cross-sector fertilisations.

Within various kinds of management processes, issues and tasks are normally allocated according to elementary categories defining particular areas of responsibility (or 'domains') and not by alternative types of process which these responsibilities may be seen to require. The individuals and organisations whose responsibilities are associated with a particular issue, regard themselves as specialists or experts, having experienced their own learning curves and founded their own wisdom. However, this specialisation and expertise occurs at a cost; it can mean that such specialists become isolated from other issues outside their own domains. The result is that the same skills and expertise may emerge in different areas of responsibility, and may even exist in one area when they could be applied in another. The great potential of cross-sector policy research is that it encourages the fertilisation of ideas between different sectors, which perhaps otherwise would not have occurred.

This dissertation demonstrates such cross-fertilisations with the case of the UK energy and transport sectors, where experiences from energy policy in the 1970s and 1980s are used to generate ideas which may help the 1990s transport problem. Experience of the past is often the best way of anticipating the future, and in this respect, ideas for tackling the transport problem may come just as much from remembering the great planning disasters of the 1960s, or the 1970s oil crisis, as they would from focusing on road transport informatics and automatic route guidance and parking information systems. A comparison between energy and transport may enable the wealth of experience that has accumulated in the energy sector to be translated and exported to the transport sector, providing a range of unique insights into the possible development of future transport policy.

Policy problems are, however, often messy. Understanding them frequently requires a combination of specialised 'cutting edge' knowledge as well as an immersion in earlier developments in the particular field. In comparing the developments in two broad areas of policy, energy and transport, each of which could sustain almost infinite study, this dissertation attempts a balance between exploring specific details within a sector and a comparison of those issues which are common to both.

1.2 Aims.

The dissertation has two aims. The first is to make a contribution to the understanding of the transport problem by comparing it with experiences in the energy sector. If insights can be gained from such a comparison, then this approach should be capable of contributing to improved learning in other policy contexts. The second aim is to use the lessons of the energy-transport case study to facilitate the development of further cross-sector research between other policy sectors. The second aim is partly linked to the achievement of the first in that it would be convenient if the case study provided useful insights for transport policy but it is also independent, in the sense that the true potential of cross-sector policy research will not be fully understood until further case work outside the scope of this dissertation has been carried out.

1.3 Method and Structure of Dissertation.

Work on the two main contributions occurred iteratively over the period of research. The aim was not to develop a theoretical framework and then apply it to some test case, but to investigate the implications of the similarities between energy and transport both at the policy and at the theoretical levels.

The dissertation begins with a literature review covering the background to the study of policy, the understanding of how policy is processed, cross border policy research and existing theories and evidence on policy sectors. A methodology for cross-sector research is subsequently outlined, based on the principles of conventional cross-border policy research. As it is derived by theoretical analogy, and not through some form of empiricism, the emerging cross-sector methodology is not a full and tested practical guide, ready to be used to inform other cross-sector comparisons, but represents a first attempt to develop cross-sector policy research as an innovative and potentially important new area of policy research.

A general overview of UK energy and transport policy is given in chapter 3 by analysing some of the main trends, issues and events that have shaped the development of the sectors over the last four decades. Chapter 4 then examines the pattern of similarity in the development of the two sectors and investigates a range of comparisons which led to the subsequent development of a more explicit structural analogy between the two sectors. Chapter 4 reflects the exploratory analysis which resulted in the identification of three specific comparative themes which are developed in chapters 5-7. Chapter 5 explores a range of statistical measures for the transport sector which can be related to economic activity and environmental quality. Three alternative views of the future development of transport form a scenario analysis of UK transport policy in chapter 6. Chapter 7 then explores specific programmes which could be used to guide the implementation of an innovative transport efficiency policy. The conclusions of the dissertation are drawn together in chapter 8, which assesses the extent to which the two aims of the research have been met, points to areas of further research and draws out the implications of the energy-transport case study for the development of cross-sector research in a wider context.

Chapter 2

Cross-Sector Policy Research: Context, Evidence and Theory.

> 'Whoever said that a journey of a thousand miles begins with a single step was wrong. It begins with an itch to move.'
>
> Hugh Heclo (1972) 'Policy Analysis'
> *British Journal of Political Science 2:108.*

2.1 Policy: A Research Perspective.

There are many uses of the term public 'policy', indeed so many, that in 1978 nearly three decades after what Brunner (1991) highlights as the original conception of the policy sciences by Lasswell and his collaborators in 1950, Elliot J. Feldman remarked that:

> 'no term in social science has suffered more ambiguity and abuse in the 1960s and 1970s than 'policy'' (Feldman, 1978: 288).

Feldman was expressing a view from the policy-*researching* community, rather than from the policy-*making* community. Indeed Drysek (1982) noted that there were almost as many definitions as there were policy analysts. In contrast Heclo (1972) found broad agreement amongst policy makers on some aspects of the definition. There have been several typologies or reviews of the uses of the term policy (e.g. Hogwood and Gunn, 1984; Manheim and Rich, 1986; Dye, 1981; Dunn, 1981).

Amongst these various typologies, the framework adopted by Hogwood and Gunn (1984) stands out in particular as being rigorous and comprehensive. They identified ten uses of the word 'policy' which can be illustrated with examples taken from the energy and transport sectors:

1. Policy as a label for a field of activity.

This view is implicitly associated with, for example, statements about a government's 'social', 'transport' or 'foreign' policy. Policy here, describes a 'field' of government activity or involvement such as 'environment', 'transport', and 'foreign affairs', as opposed to more specific issues within these fields that refer for example to housing, roads or trade sanctions.

An important concept, which is allied to the view of policy as a field, is that of 'policy space'. This is an abstract way of thinking about the connections between different fields, and how they compare with each other. Over time, government actions on specific issues can be viewed as leaving their mark on particular regions of policy space so that the space becomes occupied, perhaps even crowded (e.g. Wildavsky, 1979).

2. Policy as an expression of general purpose or desired state of affairs.

Expressions contained within political manifestos, or the mission statements of business organisations are regularly interpreted as policy. For example, the 1991 White Paper on the Environment contained the following:

> 'Transport should play a positive role in serving our towns and cities. To ensure this, the Government's aim is to civilise urban traffic - easing congestion, helping to improve the local environment and reducing air and noise pollution.' (HMSO, 1990: para 8.10).

3. Policy as specific proposals.

In attempting to set out how they might achieve a desired state of affairs, organisations sometimes spell out the means by which they hope to succeed. For example, a 1952 transport White Paper stated that:

> 'In order to allow road haulage to play its appropriate and expanding part in the transport system, provision will be made for greater latitude in the granting of new licences...' (HMSO, 1952: para 9).

4. Policy as decisions of government.

In 'moments of choice' governments embody certain 'decisions' in legislation. For example, the British Government's early policy for nuclear power is embodied in the White Paper 'A Programme for Nuclear Power' (HMSO, 1955), which announced the decision to build the first Magnox-type nuclear reactors.

5. Policy as formal authorisation.

Organisations are sometimes said to 'have a policy' on a particular issue. Usually this view of policy manifests itself in the knowledge that something is either allowed or forbidden (as distinct from preferred). The European Community, for example, has developed a policy to allow larger freight lorries on the roads. By 1994 to fall in line with E.C. legislation, the U.K. Government looks set to raise maximum axle weight limits for HGVs to 44 tonnes (DTp, 1993).

6. Policy as a programme.

A programme is a series of linked proposals or activities that collectively can be construed as policy. Frequently, in the 1970s and 1980s the government's plans and actions on energy conservation were referred to as a programme which included, amongst other things, energy audits, the Energy Efficiency Demonstration Scheme, the Energy Efficiency Survey Scheme, and the Industrial Energy Thrift Scheme.

7. Policy as output.

This view takes policy as what is actually delivered by organisations, as opposed to what is promised or authorised. This can take the form of goods, services or the enforcement of rules. For example, in the mid-1970s and 1980s government made available grants and loans within the energy sector for energy efficiency schemes, and produced standards for the energy efficiency of new buildings.

8. Policy as outcome.

Policy outcome is what is actually achieved, or the impacts of policy output. In terms of energy conservation, the policy outcome was a decrease in the U.K. primary energy intensity (see Bending and Eden, 1984).

9. Policy as a theory or model.

Policies contain assumptions about what organisations can do, and what the consequences of their actions will be. For instance the 1989 Transport White Paper 'Roads For Prosperity' contained the following theoretical argument:

> 'Good Transport is vital to the well being of our towns. Good transport links can help overcome the problem of urban decay, avoid isolating certain groups in society, such as the elderly or disabled people, and stimulate employment and business'. (HMSO, 1989b: para 8.10).

10. Policy as an historical, dynamic process.

The passing of an Act or Bill, or the making of a decision is the culmination of other activities and thoughts; it is not a discrete event. If the first nine views of policy are snapshots (with the partial exception of 6), then policy viewed as a process is analogous to moving film. Hogwood and Peters (1982) use this processual approach to policy-making. For instance, the introduction of lead-free petrol in the U.K. was a decision based on a long history of international Governmental activity. Before lead-free was eventually introduced in the UK in 1987 there had been a step-wise reduction in the lead content of petrol since the early 1970s (see Haigh, 1989).

The variety of definitions of the term 'policy' stem from people's differing experiences of the policy process or in policy research. Heclo (1972) noted that public policy is:

> '...an analytical category, the contents of which are identified by the analyst rather than by the policy maker or [by] pieces of legislation or administration. There is no unambiguous datum constituting policy and waiting to be discovered in the world. A policy may usefully be described as a course of action or inaction rather than specific decisions or actions, and such a course of action has to be perceived and identified by the analyst in question' (Heclo, 1972:85).

The above diversity in the range of uses of the term policy, implicitly defines an overall policy process encompassing the ways in which issues arise, and are dealt with. The various stages of the 'policy process' can be seen in the variety of the uses of the term policy. Many theories and descriptions of the policy process have been put forward (see for example Simon (1957); Lindblom (1979); Etzioni (1967); Dror (1989)), but two of the most influential have been the so-called rational model stemming for the field of decision theory (see Keeney and Raiffa, 1976:32-55; Watson and Buede, 1987:11) and the incremental model proposed by Charles Lindblom (1979). The rational model is characterised in a number of stages (Richardson and Jordan, 1979:19)[gender in the original]:

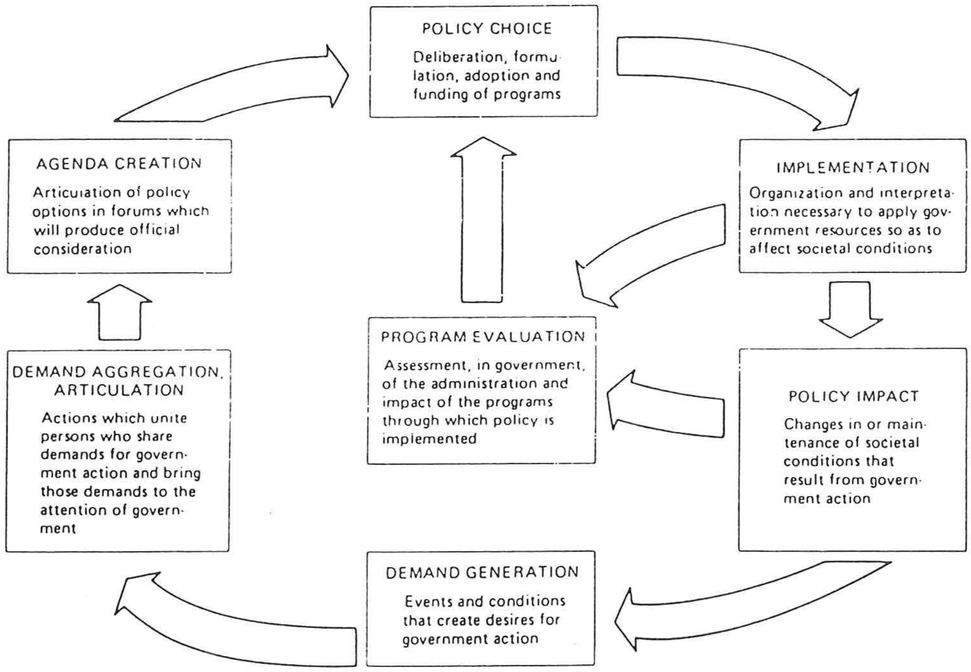
> *So-called rational model*
> 1. Faced with a given problem
> 2. a rational man first clarifies his goals, values, or objectives and then ranks or otherwise orders them in his mind;
> 3. he then list all the important possible ways of - policies for - achieving his goals,
> 4. and investigates all the important consequences that would follow from each of the alternative policies,
> 5. at which point he is in a position to compare consequences of each policy with goals,
> 6. and so choose the policy with consequences most closely matching his goals.

Richardson and Jordan (1979) noted that both Simon and Lindblom rejected the rational model as being impractical as it was a means-ends model, applied to situations where the ends do not always justify the means. Simon argued that the rational model was worth pursuing, and offered a model which recognised that rationality, in practice, is bounded by decision-makers' unconscious skills, habits and reflexes and is limited by their values and conceptions of purpose and by the extent of their prior knowledge, experience and access to information. Simon's preferred model of rational behaviour in decision-making rested upon the consideration of *available* alternatives and their consequences. Lindblom, on the other hand, argued that even to attempt to engage in this process would be a dangerous kind of 'pseudo-rationality'. Instead, Lindblom put forward an incremental model of policy making, which recognised that decision-makers examine options until something satisfactory (probably less than optimum) is discovered. In Lindblom's model, if nothing satisfactory is found, the level of aspiration is reduced, until eventually what is desired matches what is available in policy terms (Richardson and Jordan, 1979).

When the focus of behaviour is shifted from the concerns of the individual decision-maker to the goals, aspirations and behaviour of organizations, such as political parties or interest groups, and public opinion, theories of the policy process are dominated by group interests, litigation, coalition building and negotiation (see Lester, 1989). From this perspective, two models in particular have been influential: group theory and elite theory (see Dye, 1981: 26-30). Group theory predicts that individuals with common interests will group together to press their demands upon government. The policy process is then conceived in terms of group struggle and group equilibria. Elite theory assumes two main groups of people band together; those who have power and those who do not. Only a small number of people allocate values for society and these few are not typical of the masses whom they represent.

Elements of rationality, incrementalism, group theory and elite theory are usually involved in most overall conceptions of the policy process. Figure 2.1 below is a good example, showing a simplified diagram of the policy process, with seven stages arranged cyclically. Although this gives only a brief description of what in reality is a rich process, it is a good example of the way the various models of the policy making process are integrated (other examples include Hogwood and Gunn, 1984:24; Dye, 1981: 24; Jenkins, 1978: 22). The figure is highly simplified; any particular policy may be in more than one stage at one time, or may appear to 'jump' or iterate between stages. The cyclical nature indicates that policies usually have no clear beginning and end. Following the process round clockwise, starting at the bottom, the figure describes how certain conditions lead to organised demands for action which, if successful, lead to an issue getting on to the official agenda. Once on the agenda, the issue is dealt with in some bureaucratic manner, to produce a recommendation over the appropriate action to take. The policy is then implemented and its impacts are evaluated, to verify that the policy is having the intended effect. If it is not, the policy can be reformulated and re-implemented in its new form. Eventually, the outcomes of the policy will have some effect on the pressure for change in the original set of conditions that gave rise to the issue in the first instance. The cyclical nature of the process suggests that it is incremental with policy always being in some sense a variation on the past. The process also allows for a degree of rationality during the agenda creation and policy choice stages. Group theory emerges in the demand aggregation and articulation stage, whilst the responsibility for implementation of policy choices lies with the elites.

Figure 2.1 The Policy Process.



source: Manheim and Rich (1986)

Manheim and Rich (1986) state that at its broadest, the policy process is:

> 'That complex set of events that determine what actions governments will take and what effects those actions will have on societal conditions' (Manheim and Rich, 1986:324).

Policy research can be a formal part of the policy process, for instance in the policy choice or evaluation stages, or it can originate from 'outside' the process, for instance, from academic studies such as this dissertation. Due to the analytical evaluation and reflective elements of the policy process, the relationship between policy-making and studying policy is complex. Majone (1989) notes:

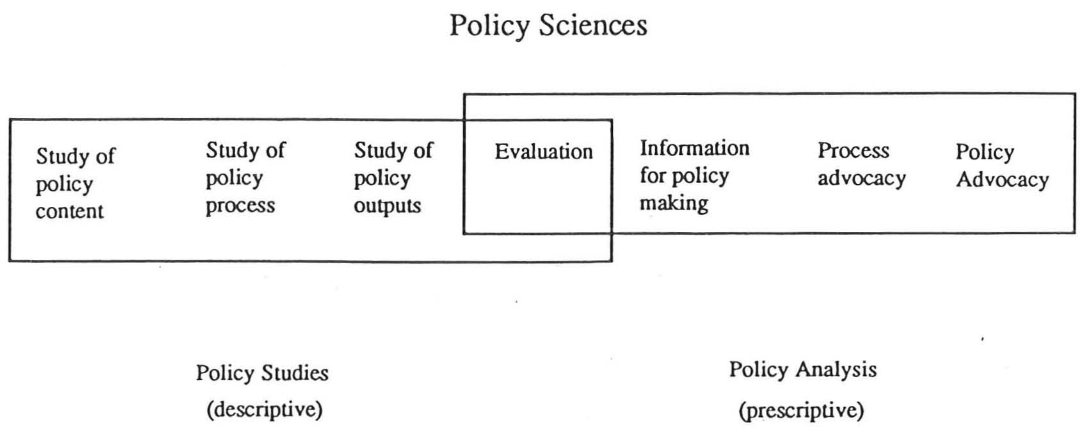
> '...there is a dialectic relationship between policy and meta-policy - the ideas, conceptualisations, and proposals advanced by policy actors, analysts, academics, and bureaucratic experts who share an active interest in that policy... Hence our understanding of a policy and its outcomes cannot be separated from the ideas, theories and criteria by which the policy is analysed and evaluated.' (Majone, 1989:147)

The subjectivity that Heclo (1972) attaches to the meaning of policy emerges in several different meanings of 'policy analysis' and 'policy studies', the terms most often used to describe what might otherwise be called policy-oriented research. Any approach taken to study policy will make implicit assumptions regarding the nature of policy itself. Hogwood and Gunn (1984) classify the variety of approaches to the analysis of public policy into eight categories:

> 1. Studies of policy content where the emphasis is on the origins, intentions and operation of specific policies;
> 2. Studies of policy process which are concerned with how policies are actually made in terms of the actions taken by various stake-holders at each stage;
> 3. Studies of policy outputs which aim to establish the determinants of the pattern of expenditure or other indicators of policy outputs;
> 4. Evaluation studies which attempt to assess the extent to which the outcomes have achieved the objectives of the policy;
> 5. Studies which involve the collection and analysis of information with the specific purpose of aiding a policy decision or advising on the implications of alternative policies;
> 6. Process advocacy - a type of analysis that is concerned with understanding the policy-making process with a view to changing it, usually to make it more 'rational';
> 7. Policy advocacy - the use of analysis in making an argument for a particular policy. The analyst may act politically or the politician may attempt to act analytically (both are controversial roles);
> 8. The analysis of policy analysis - critically appraises the assumptions, methodology, and validity of policy analysis.

Figure 2.2 shows the distinctions between the uses of the terms 'policy studies' (usually applied to descriptive activities), 'policy analysis' (usually applied to prescriptive activities) and 'policy sciences', an umbrella phrase to cover all types of public policy analysis.

Figure 2.2: Policy Studies, Policy Analysis and Policy Science.



source: Hogwood and Gunn (1984)

The classification identifies several different forms of policy studies and policy analysis, each of which may be usefully employed to explore a policy area, dependent on what emphasis is prioritised. Different studies of a particular area of policy in or between particular countries may address different issues e.g. output, content and process.

For each type of study or analysis there are several methods of investigation which the researcher may use. Manheim and Rich (1991) note three distinct methods of research: correlates analysis (which explores the relationship between policies and political, social and economic characteristics); behavioural analysis (which determines the role human factors play in policy formation); and decision analysis (a formal structuring of objectives and strategy). These methods can be theoretical (e.g. modelling) or empirical (e.g. interviewing, content analysis and survey research).

Wiess (1991) argues that in general there are three types of policy research products: data and findings, ideas and criticism, and arguments or beliefs for policy action. Within the post-positivist context, however, the distinctions between them are not always obvious. Wiess notes that policy analysts

> 'construct the world they study and that the values, priorities and conceptual models that they bring to their work influence the things they 'find'' (Wiess, 1991: 307).

Wiess also notes that research, basically, provides information which in turn is best seen as helping policy-makers decide which policies are best suited to the realisation of their ideologies and interests, and that in general, there are four intentions driving a policy researcher: to be a reputable and respected social scientist; to make a difference; to advance the cause of analytically based decision making; and to advocate a political or moral position.

2.2 Policy Space and Policy Sectors: Theories and Evidence.

Within the context of the policy sciences the complex relationships between issues and problems, politics, actions and beliefs, and policy can be thought of as the constituents of a 'policy world'. Majone (1980; 1991) has pointed out that these fundamental characteristics of policy development and evolution bear many resemblances with the interactions between Popper's worlds of reality (Popper, 1972a; 1972b). Popper distinguished three worlds or levels of reality: first, the level of physical objects and physical states; second, the world of mental states, subjective preferences and beliefs; and third, the world of objective structures that are produced by human minds but that, once produced, exist independently of them (such as theories, norms, artistic creations and styles, problem situations and critical arguments). These worlds are linked so that there can be interactions between the first and second, and between the second and third; problems and issues can influence actions and beliefs which in turn can influence theories and norms. The 'World 3' level also exhibits some autonomy from the other two, for example, in the sense in which one says that a work of art, once created takes on a life of its own (Majone, 1991).

Majone (1991) introduces three 'spaces' of the policy world analogous to Popper's distinction among three levels or worlds of reality: the 'problem space'; the 'actor space'; and the 'policy space'. The problem space can be described in terms of structural characteristics that determine the way in which policy communities and political actors perceive and handle different issues; for example, Majone (1991) contrasts the nature of inflation which sends out regular month-to-month signals (stimulating policy responses when some threshold of tolerance is reached) with natural calamities such as periodic droughts (often held to be inevitable or at least not caused by society). The actor space includes all the potential actors from the 'policy universe' (Wilks and Wright, 1987b; see also Kingdon, 1984 and Majone, 1991), whereas policy communities develop consisting of specialists with active interest in a given policy area such as: academics, analysts, policy planners, union or interest group experts, other professionals and politicians. Wilks and Wright (1987b) note that policy community is a metaphor for a sub-system consisting of political or social actors sharing certain qualities, values or interests. The policy community generates conceptual innovations in addition to sometimes becoming involved in political actions and selection processes. Majone (1980) describes the notion of a policy space as consisting of (actual and potential) 'policy problems, policy arguments, norms, constraints, tentative solutions and their institutional embodiments'. Majone (1991) suggests that policy space may be analysed in terms of generic structural characteristics such as:

> 1. *degree of fragmentation* (e.g. [as Majone has perceived them] highly fragmented such as transportation, energy, or education vs. less fragmented such as social security or health).
> 2. *level of maturity* (e.g. new areas such as environmental protection and risk management vs. old ones such as taxation or foreign policy);
> 3. *level of competition* from private or public sources (e.g. little competition in defence vs. a great deal of competition in health or education); and
> 4. *exposure to international influences* (e.g. highly exposed areas such as industry or agriculture vs. largely domestic such as social security or education).

The roles of technology, culture, and power could also be compared between different areas of policy space. There is a small literature on the sectorial or fragmented nature of policy consisting of a range of approaches from sociological (see Wright, 1988; Burstein, 1991), to political (see Freeman, 1985; Painter, 1980), to theoretical (see Majone, 1980) which is reviewed next, then related to Majone's three policy spaces.

There have been several attempts that describe and then use the idea that the policy world is itself split into a number of sub-spaces. These sub-spaces have been given names such as 'areas' 'sectors', 'communities', 'glens', 'domains', 'subsystems', 'dimensions', 'issue domains' and 'programmes' (Burstein, 1991; Wilks and Wright, 1987b; Dror, 1989; Hofferbert, 1974).

Hogwood and Gunn's (1984) image of policy as a label or field of activity fits into the notion of a policy world, within which, policy space typically tends to become 'crowded' over time, with more and more government interventions and increasingly complex interactions among them (see also Hogwood and Peters, 1983). Aaron Wildavsky (1979) described this phenomenon as an example of how 'policy can be its own cause' as the policy environment grows in its autonomy, and programmes come to depend less on external factors than on interactions with other existing and potential programmes.

Burstein (1991) considers three characteristics which determine the nature of 'policy domains'. A first way of defining a domain is by considering the 'substantive' nature of policy; issues that then define a particular domain are seen as sharing inherent substantive characteristics influencing, how they are framed and dealt with. Burstein writes,

> 'Domains such as energy, health, transportation, or agriculture, for example, arguably have a certain logic and coherence, and most specific issues fit relatively unambiguously into these or other domains' (Burstein, 1991:328).

The substantive differences between energy and transport are manifest in the division of policy-making in the UK between the Department of Transport and the Department of Energy (part of the Department of Trade and Industry since 1992), which each operate in their own policy networks and communities, in addition to their common governmental framework. Secondly, domains can be characterised as being socially constructed by those organisations that are active in politics. A policy domain then becomes the set of organisations concerned about a substantive set of problems, which take each other into account as they formulate policy options and work for their adoption. Thirdly, domains may be characterised as cultural constructs, around which organisations and individuals orient their actions.

Policy space has been thought to be divided in other ways. When policy is not perceived solely in terms of the actions and inactions of individuals or governments (Heclo, 1972), or perceived implicitly according to some analytical approach, what is left is its 'inherent' nature of policy (Freeman, 1985). Freeman reviews attempts to develop causal links between the nature of policy issues and the pattern of politics associated with them. For instance, the supposition could be that certain policy areas or sectors attract a higher degree of regulatory policies than others (e.g. agriculture may be perceived as heavily regulated compared with manufacturing industry). Or, in another instance, it could be thought that certain issues generate more political polarity than others (e.g. nuclear power debates have typically been more polarised than those concerning higher education). Lowi (1964) developed abstract analytical categories that combine a number of different policies or programmes which are thought to share theoretically significant characteristics. Hence policies may be grouped according to the abstract categories of 'regulatory', 'distributive' or 'redistributive' (see also Lowi, 1970). Freeman concludes that, since then, little progress has been made in developing alternative policy or issue typologies based on common inherent or substantive characteristics (see also Steinberger, 1980).

Padgett (1990) investigates the relationship between policy style and the 'issue environment' of electricity supply in West Germany. Padgett uses the term issue environment essentially as a way of describing the particular sub-system politics relevant to the issue which fits into Majone's actor space. He also recognises that the issue environment is related to two other elements: issue form and issue anatomy. Issue form is essentially a way of describing the nature of the problem and therefore fits into Majone's problem space, whilst issue anatomy abstracts the structure and form of the issue and in this sense is related to Majone's policy space. Padgett (1990) describes issue anatomy in terms of four abstract structures:

> i. the degree of relevance of the wider policy configuration (whether the issue constitutes a discrete policy area or a component in an interrelated issue complex);
> ii. whether the issue turns upon qualitative or quantitative consideration;
> iii. the frequency with which the issue occurs, whether it is a routinised or extra-ordinary issue;
> iv. the degree of politicisation of the issue.

Freeman (1985) notes that studies based on the 'sub-system politics' approach, which denies any single policy-making process but recognises several relatively narrow and self contained policy making systems,are more prevalent in the empirical policy literature than those which attempt to theoretically construct policy typologies. However, the sub-systems approach also results in the division of policy space into sub-spaces or sectors (Freeman, 1985). Unlike the Lowi scheme, the sub-system politics perspective does not rely on some abstract typology, but through more empirical grounding and description leads to a mapping out of a number of 'policy communities' or 'issue webs' (see also Wright, 1988). Within these communities the issues, actors and processes tend to be distinct, although there is significant overlap and they all operate within a single constitutional framework. Sub-systems emerge because of the natural division of labour and government activity into ministries or departments. Bureaucrats working within these organisations, then develop interests, expertise and commitments in specific policy areas. Painter (1980) describes the development of U.K. roads policy as an example of 'sectoral politics..the political and administrative politics of distinct policy fields' involving processes which revolve around 'subject matters defined through various necessary simplifications in 'self steering' policy sectors. Policy changes occur as readjustments of relationships within policy sectors or between them.

Wright (1988) suggests that the rather vague and general concept of 'policy' can be divided into two distinct components: process and level. The distinction of process is similar to the notion of 'sub-system' politics as described above. Wright usefully distinguishes between the level or 'arena' at which these sub-systems emerge. He notes that it is a relatively rare occurrence for policy to originate at the level of the whole sector as described by labels such as 'transport' or 'energy', which are merely abstractions. Instead, policy is carried out by government and non-government organisations at lower levels, sub-sectorially. For example, within the energy and transport sectors, policy is more likely to originate from, and be aimed at, sub-sectors such as nuclear power or roads, and within those sub-sub-sectors such as hazardous waste disposal or long distance freight haulage. An illustration of this is given by Painter (1980) who concludes that throughout the 1970s U.K. roads policy developed in isolation from the rest of transport policy. Table 2.1 shows Wilks and Wright's (1987b) conception of the relationship between policy levels and policy actors using an example from the chemical industry.

Freeman (1985) investigates whether policy-making methods (or 'politics') determine the nature of policies, or whether the direction of causality is in fact reversed, with the nature of policy issues determining the politics associated with them. There are two suppositions: firstly that policies of certain types including those sharing some abstract theoretical characteristics such as those described by Lowi

(1964, 1970) and those grouped by sector, produce particular kinds of politics or policy-making processes; and secondly, that different policy-making processes or political arenas produce different types of policy outcomes.

Table 2.1: The relationship between policy level and groups of policy actors.

Policy Level	Groups of Policy Actors
Policy Area (e.g. Industry)	Policy Universe (anyone with interest)
Policy Sector (e.g. Chemical Industry)	Policy Communities (Trade and Manufacturing Associations)
Policy Sub-Sector (e.g. Pharmaceuticals)	Policy Sub-Communities (Competitors in Pharmaceuticals)
Policy Issue (e.g. Health and Safety),	Policy Networks (any industrial sector with interests)

source: Wilks and Wright, 1987b

Freeman notes that the policy sector approach shifts our attention away from the political inputs to categories of issues and outputs of the political system; it suggests that policy determines politics (Freeman, 1985:469) and that, in sum, it predicts differentiation within individual countries across sectors and convergence across nations within sectors (Freeman, 1986:486).

Kingdon (1984) introduced the idea of policy communities composed of specialists in a given area - e.g. health, housing and environmental protection, noting that the relevant communities of specialists vary in their degree of fragmentation from one area to another. These communities of specialists develop out of their common interests and knowledge about a given issues or set of problems. Dror (1989) describes such knowledge pertinent to a set of specific policy issues as ‘policy issue knowledge’.

Kingdon also provides evidence of the sectorial nature of policy when he notes that national culture or dominant ideologies can affect different policy areas differently. His research suggested that health and transport policy in the U.S. were affected differently by ideological biases; within the health sector, the merits of private enterprise and distrust of government solutions were more significant than in the transport sector.

In 1979, Richardson and Jordan claimed that policy communities were the key to understanding the vast bulk of policy-making in settled western-type political systems:

> 'The main feature of the British System is that ongoing problems and constraints force successive governments into very similar policy positions. Problems are handled similarly irrespective of what government is in power. Agreement will be sought within the community of groups involved ...Our argument.. posits strong boundaries between subject matters and indistinct, merged relationships within individual policy areas....The central point is that policy-making is fragmented into sub-systems....The point is not only that many groups are involved in policy making, but that policy making is to a large extent made in 'issue communities'. Policy-making is segmented' (quoted in Jordan, 1990:471).

Further support to the idea of studying policy sectors is given by Richardson (1979), who argues for the value of studying individual policy areas as opposed to both individual decisions and entire political systems. He argues that this approach is appropriate since policy making *is* segmented in highly industrialised societies, where each area of policy develops in a semi-watertight compartment inhabited by its own 'policy elite' generating quite different policy styles within the same political system. A model or theory that adequately describes one area of policy may be inappropriate as a description of another.

This review has provided a range of evidence suggesting that the formation, adoption, implementation and outcomes of policy differ from one policy sector to another. Summarising this in terms of Majone's conception of three distinct policy spaces, this is due to differences in: (1) the nature of the policy itself (problem space); (2) the individuals and organizations it concerns (actor space); and (3) interactions with other existing policies (policy space).

There is also substantial evidence that there are divisions within Majone's problem, actor and policy spaces. Within the problem space, issues are categorised under the broad abstract headings such as 'education', 'health' or 'transport'. In turn, groups of specialists form in the actor space that are centred around these categories or sub-categories, such as 'primary education', 'dietetics' or 'public transport'. Within the policy space, different types of policy can be discerned as the nature of the problem and actor spaces produce policy sub-spaces that can share different characteristics such as 'market oriented', 'interventionist', or 'regulatory'.

Table 2.2 summarises the diverse range of perspectives on the theories and evidence for policy sectors and distinguishes three ways in which similarities and differences can occur from one sector to another; these are in the conceptions of a problem space, actor space, and policy space. Where some degree of similarity occurs, there is the potential that developments and experience in one sector may be useful in another. The framework also reveals why these developments and experiences do not naturally and automatically flow from one sector to another. Within each space, the literature that has been cited suggests that policy is divided yet further into a number of sub-spaces, sometimes resulting in the independent development of policy from one sub-space to another.

Table 2.2: The sectorial nature of policy and Majone's three worlds of policy.

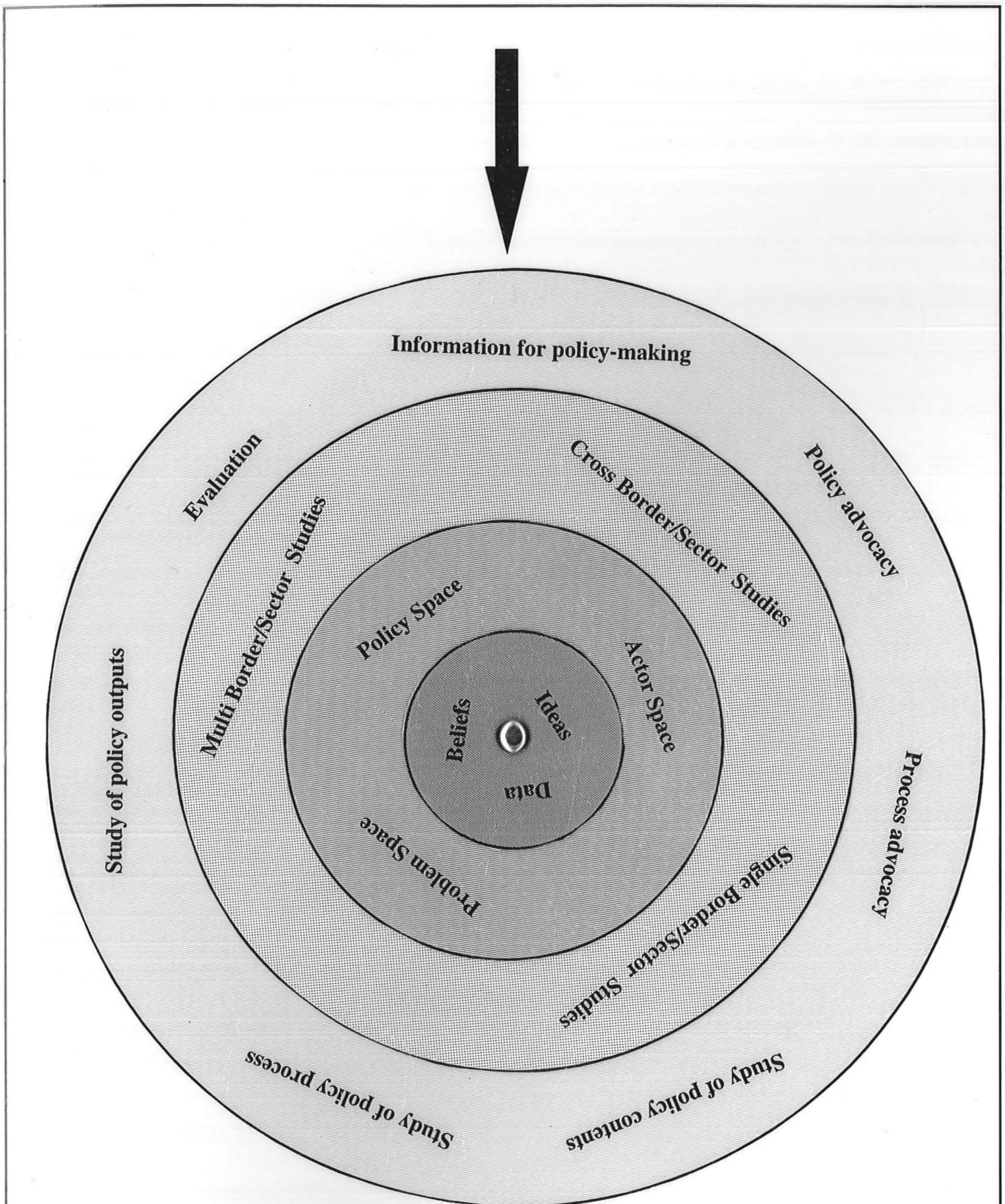
Problem Space	**Actor Space**	**Policy Space**
'Policy issue knowledge'[1]	'Socially constructed'[3]	'Policy as its own cause'[9]
'Labels for fields of activity'[2]	'Sub-systems politics'[6]	'Cultural Constructs'[3]
'Substantive nature of issues'[3]	'Policy communities'[5]	'Ideology'[5]
'Levels and Arenas'[4]	'Policy networks'[4]	'Structural characteristics'[10]
'Experts'[5]	'Self steering policy sectors'[8]	'Autonomous'[10]
'Inherent nature of issues'[6]	'Issue Environment'[7]	'Policy change as relationships within and between policy sectors'[8]
'Issue form'[7]	'Policy Universe'[11]	'Issue anatomy'[7]

[1]Dror; [2]Hogwood and Gunn; [3]Burstein; [4]Wright; [5]Kingdon; [6]Freeman; [7]Padgett; [8]Painter; [9]Wildavsky; [10]Majone; [11]Wilks and Wright.

Working bottom-up in table 2.2, a diverse and rich collection of perspectives and evidence on the sectorial nature of policy is condensed into Majone's three distinct categories. The table shows, that at present, the evidence can be related to Majone's theory; However, it should not be interpreted as suggesting that Majone's theory predicts the existence of such a rich collection of ideas (working top-down). The range of perspectives at the bottom of table 2.2 represent a comprehensive overview of many of the possible areas where cross-sector research would investigate similarities and differences between sectors. Since these perspectives are each distinguished as belonging to one of Majone's three spaces, a range of possible combinations of sectorial policy studies can be distinguished using the policy studies and analysis typology in figure 2.2. Figure 2.3 shows the theoretically possible range of combinations of types of policy sector (and border) studies (and analysis) in the form of a four dimensional graphic. The dimensions are represented by four concentric annuli, each of which can be rotated independently. The total number of possible combinations is large (189), each of which can be represented by a different combination of elements lining up with the reference arrow. Working inwards, any combination will consist of a type of policy study or analysis which is either comparative between borders or sectors (cross and multi) or is targeted within a particular border/sector (single). Multi-sector approaches are those which use various sectors as vehicles to investigate some generalised process or phenomena (e.g. the merits of privatisation within denationalised industries - see section 2.3.2). Such studies may in turn focus on one level within Majone's framework, leading eventually to one, or combinations, of Wiess's three basic research products.

Linking these ideas together in the form of presentation shown, demonstrates the diverse range of perspectives which this review of policy studies and analyses suggests theoretically exists, and it is hoped, encourages the reader to explore these. The graphic has the advantage of deliberately suppressing relationships between different combinations of such studies since they are not always distinct or quantifiable, ordinally or cardinally (as may be implied if different combinations were overlaid in the form of paths through a four-level flow chart).

Figure 2.3: Types of sectorial policy studies and analysis.



2.3 A Methodology for Cross-Sector Research.

Existing theory in policy analysis has not formally considered how two different areas of policy such as energy and transport can be compared. A first approximation to a more explicit description of a cross-sector policy research methodology, and an attempt to justify its validity, can be forged out of the methods of existing cross-border research, together with the theories and evidence of policy sectorisation described above.

An important component of any policy research is that it attempts to generalise the lessons that have been learned to the broadest possible level. Since no two policy contexts are identical, and most situations or circumstances carry their own idiosyncrasies and uniqueness, the challenge of this generalisation process is found in recognising the results and conclusions of the research which are common to other policy contexts.

There have been further studies across space (e.g. Feldman, 1978; and Heidenheimer et al., 1983; Hayworth and Watson, 1975; Dierkes and Meinolf, 1987) and studies over time (Kingdon, 1984), but, with the exception of this dissertation, I do not know of any studies which explicitly compare policy areas, even though its potential was recognised by Heclo in 1972:

> 'The scope for the comparative study of policy-making remains immense but largely unexplored, whether one thinks of policy comparisons across space, across time, or across subject areas.' (Heclo, 1972: 95).

2.3.1 Cross-Border Policy Research.

The broadest definition of cross-border research is any research that transcends national boundaries, but Kohn (1987) noted that it is better to restrict the term to:

> 'studies that utilise systematically comparable data from two or more nations'
> Kohn (1987:714).

It would otherwise be difficult to say what was not cross-national, since the objects of many research studies exist in many places. Bahry (1986) suggests that there are limitations when policy analysis is applied to a single country, and that the practice of cross-border research enables two important types of research insights to be gained. Firstly, each country (or region) has its own individual culture and character, which, if not compared with other countries' cultures, may bias any conclusions from the policy study. Comparisons with other countries highlight which results may be 'culture-bound' (see Antal et al., 1987). Secondly, there are certain types of study objectives which can only be satisfied by cross-border research. A study whose aim is to gain insight about attributes that describe a whole country (such as political or regulatory style) will require comparisons of equivalent attributes across different countries.

Cross-border research offers a broader range of information about issues which are to be studied, and increases the chances of the research reaching valid conclusions. It can put judgements about policy processes and outcomes into a broader and more refined perspective. It has been suggested that cross-national research is needed and conducted because it is the closest approximation to the controlled laboratory experiment of the natural sciences which is available to social scientists (Antal et al., 1987).

The quality of results from cross-border research methods are, however, sensitive (see Bahry, 1986) depending upon four elements:

1. the ability of indicators that are used to evaluate research questions to 'travel'; for instance, Mclachlan and Itani (1991) conclude that the frequently used energy/GDP ratio is not, on its own, a good measure of comparative energy intensity due to a variety of qualitative differences between countries that are not taken into account in that particular measure (such as climate and economic structure);
2. the existence of equivalent measures of the same concept for each of the countries to be compared; for example a study that was aimed at assessing a group's success in terms of the frequency with which its members take employment in certain professions (e.g. medicine) should take into account the possibility that the same profession may not be respected equally in different countries;
3. the cultural biases that are contained in the sample of countries to be compared; given that it is nearly always impractical to include every country in any study, attempts need to be made to overcome cultural bias if the results are to be generalised beyond the countries in the sample;
4. the independence of an observation from one country to another; where one country, in some way, tangibly exerts influence on others, certain characteristic traits (e.g. military style) may not be independent.

Antal et al (1987) point out that structured comparisons provide a framework for determining those aspects of a situation which are due to unique circumstances and those which are more generally applicable, and that cross-national research can be seen as a hybrid between academic enquiry and policy-making information.

An important issue that has emerged from cross-border policy research is the development of the concept of policy 'convergence' within settled western-style democracies. This can be defined as the tendency of societies to grow more alike, and to develop similarities in structures, processes and performances (Bennett, 1991). Bennett identifies a four-fold framework of processes through which convergence might arise: emulation, where state officials copy action taken elsewhere; elite networking, where convergence results from trans-national policy communities; harmonization through international regimes; and penetration by external actors and interests. The question of convergence and other comparative issues can be addressed in a variety of ways. Kohn (1987) distinguishes four types of cross-border research, where:

> 1. the country is object of study; (e.g. how does America compare with Germany etc.);
> 2. the country is context of study; (e.g. how does energy policy in the UK compare with energy policy in the US);
> 3. the country is unit of analysis; (e.g. classification of countries along some dimension, say GDP/capita, or cars/1000 people);
> 4. it is trans-national in character (e.g. studies which investigate phenomena related to larger international systems, such as trade agreements, economic sanctions and international treaties and protocols).

Treating the country (or representative institution) as an object primarily entails a consideration of the nature of the countries (or institutions) themselves, whereas a contextual analysis is aimed more at establishing the generality of some findings or interpretation. Ultimately, in order to explain differences in contexts, research will focus on those aggregated variables that describe the macroscopic nature of a country itself such as GNP, educational attainment, employment etc. In these cases the countries are being treated as units. On the other hand, what at one level of analysis may seem to be a perplexing difference between some aspect of two countries developments, may be 'lawfully explained' at a higher level of analysis. In this case the country is perceived of as a component of some trans-national system (such as east-west trade, or capitalism).

2.3.2 Cross-Sector Policy Research.

The basic rationale of cross-border research can be translated directly to give a justification for comparisons between policy sectors. Whereas in cross-border research, the world is divided according to national boundaries, in policy terms, the limits (edges) of policy sectors form an amorphous structure in a three dimensional 'sector' space roughly divided into Majone's problem, actor and policy spaces.

The sensitivities of the results from cross-border research tell us that the results of cross-sector research will themselves be sensitive and dependent upon a range of analogous conditions being met. Providing research questions are capable of travelling across sectors, using equivalent measures of the same concept, and any biases or dependencies in the results are taken into account, it should be possible to distinguish four possible types of cross-sector research by analogy with Kohn's (1987) four strategies for comparing countries. Trying to understand the state of health or education in a country (or health and education management) would distinguish policy sectors (or elements of them) as objects; trying to understand the limitations or generalisations of management in health and education would treat the policy sector as context. A consideration of the cultural, strategic, economic and political importance of individual sectors would be treating the sectors as the unit of analysis, whilst discussions of national politics, industrial competitiveness or studies such as Porter's 'Competitive Advantage of Nations' (Porter, 1990) treat policy sectors as components of some larger system (i.e. 'Nation').

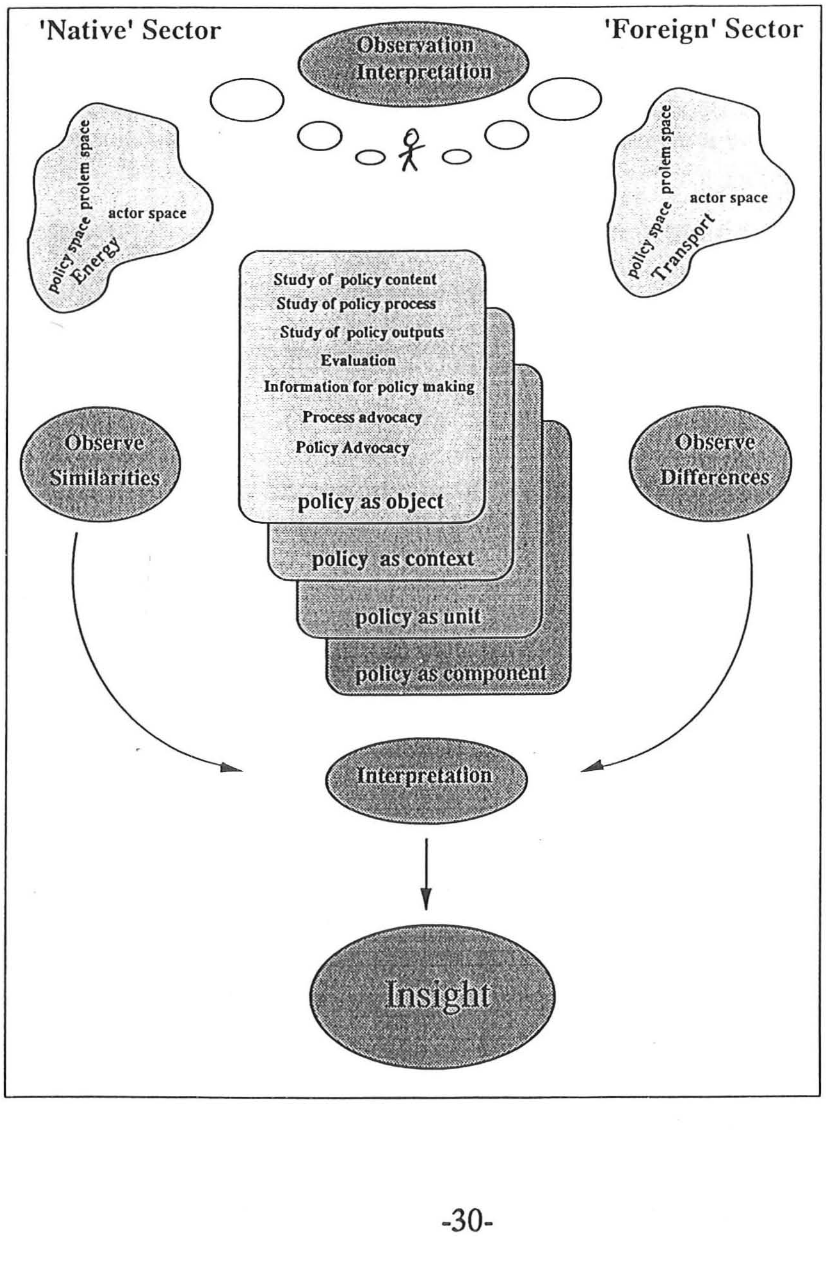
Since 1972, when Heclo recognised the absence of 'cross-area' (as Heclo referred to it) research, there has continued to be a dearth of cross-sector policy research. There have however been a number of studies with a 'multi-sector' orientation. The large literature concerning the theories and practices of privatisation and regulation in industry, for instance, has been predominantly 'multi-sector', with examples and applications taken from various economic sectors such as energy, telecommunications, transport etc. (e.g. Vickers and Yarrow, 1989; Veljanovski, 1989). Multi- sector analysis has also been a strong feature of work on comparative policy research for various sectors within different countries (see for example Heidenheimer et al., 1983; Feldman, 1978; and Wilks and Wright, 1987) and has also featured in many of the standard text books on public policy which categorise policy into distinct fields such as housing, social, and defense policy etc. (notably Dye, 1981; Dunn, 1981). Throughout these and other similar approaches, however, the sectors are being used as either 'contexts', within which to study certain general principles or processes (such as theories of regulation and styles of government-business relationships) or 'representative objects' of the various countries which enable the countries themselves to be compared directly (contrasting for example, management styles, styles of regulation or working practices).

What distinguishes the 'cross' from a 'multi' sector approach is that cross-sector research explicitly compares and maps out the relationships between the various sectors, rather than just using the sectors as a vehicle to draw out conclusions on some generalised process or phenomena. The focus of cross-sector research is the unique relationship determined by observing the similarities and differences between the two sectors from a variety of perspectives. These similarities and differences can be interpreted in terms of the concepts, systems, languages, and cultures pertinent to those sectors, rather than within some theoretical third party framework.

Figure 2.4 summarises a research method to develop insights between different policy areas. It depicts researchers as observing and comparing cultures in a 'foreign' policy sector in terms of patterns of learning developed in their 'native' sector (which can themselves be split into Majone's problem, actor and policy spaces). This process of observation and interpretation results in the researcher to some extent becoming immersed in the foreign sector's culture, allowing him/her to begin systematically comparing data, ideas and concepts, observing both similarities and differences between them.

A structure for the process of immersion and comparison is provided by the seven distinct types of policy study described in figures 2.2 and 2.3, and by the four types of cross-sector research through analogy with Kohn's typology for cross-border research (described in section 2.3.1). In practice, a research strategy may combine several approaches and it may be difficult to distinguish between the different typologies.

Figure 2.4: A comparative method for cross-sector research.



As Kohn (1987) has noted the distinction between country (or in this case policy sector) as object or context and country as context or unit is not always clear. The four categories are to be distinguished as extremes on a continuous spectrum rather than as step jumps from one to another.

That at some stage in the cross-sector method, the researcher is involved in observation, immersion and comparisons between sectors, bears a significant resemblance to the anthropologist or ethnologist trying to understand, interpret and communicate their experiences from a native perspective to the foreign culture. The notion of a native, or somehow familiar, perspective is very important. Even if anthropologists attempt to compare two cultures neither of which is familiar, it would be very difficult for them to control their interpretations in terms of their native culture. As MacIntyre suggests:

> '...there is no standing ground, no place for enquiry, no way to engage in the practices of advancing, evaluating, accepting, and rejecting reasoned arguments apart from that which is provided by some particular tradition or other.' (quoted in Throgmorton, 1991: 160)

As cross-sector research represents a new research methodology in the policy sciences, it has not yet developed its own 'native' culture in the same way that the cross-border policy community has done. Instead, initially it makes sense for attempts at cross-sector research to be rooted in one or more of the traditional sectors, from which researchers are drawn. Since the aim of this dissertation is to apply useful ideas from energy to transport, energy is playing the role of native sector, whilst transport is playing the role of foreign sector. Unlike conventional cross-border policy research, the cross-sector method explicitly avoids crossing national borders, as this would be too complicated; there is a need to control some of the variables.

The notion of fieldwork, in which the researcher observes life in the foreign culture (perhaps sometimes as a 'participant') is at the core of the comparative anthropological method. In this sense, anthropologists are neither full natives nor mere visitors as they attempt to employ both what Geertz (1983) has described as 'experience-near' and experience-distant' concepts to understand and eventually compare that understanding back with some home culture. Experience-near concepts are those that are so familiar that they are used and understood almost effortlessly (such as love or friendship), whilst experience-distant concepts typically include more abstract categories, including the products of research itself, such as 'culture' or 'religion'. Such distinctions may emerge in cross-sector research where familiar ideas are used as the basis to understand more abstract themes.

As cross-sector researchers toggle between the capacities to think and feel as a local (experience-near) and as a foreigner (experience-distant), their unique experiences are quite unlike that of either a native or a visitor. As Barnes (1987) noted, the tensions and stresses on ethnographers as participant observers result in valuable insights:

> '..those who have experienced fieldwork know the unpremeditated and painful lurches from one perspective to the other which often reveals more of value than carefully planned strategies of inquiry'. (Barnes, 1987:120)

So too, in the case of cross-sector research, it might be expected that the unique position of the researcher straddling two areas of policy, may reveal creative leaps and unplanned insight. Ultimately, the desired effect of any form of comparative research should be to expand awareness of appropriate comparative themes, rather than losing the researcher in a flood of particular experiences (Barnes, 1987:120). The comparative method develops this awareness through judgements concerning how events, processes and things are classified as either the 'same' or 'different' (Howe, 1987: 135).

Kohn (1987) noted that where similarities emerge from structured comparisons of the relationship between equivalent variables in two countries then:

> 'the unique historical experiences of each country, their distinctive cultures, and their particular political systems are not the focal point of interpreting the relationship' (Kohn, 1987:728).

Kohn argues that the most efficient strategy in searching for an explanation is to focus on what is actually similar. Moreover, Kohn (1987) notes that cross-national similarities lend themselves more readily to sociological interpretation than cross-national differences, which are more difficult to interpret. His argument is derived from the truism that if consistent findings have to be interpreted in terms of what is common to the countries (or sectors) then the inconsistent findings have to be interpreted in terms of how the countries (or sectors) differ. This, however, gives no clue as to which of the countries' (or sectors) idiosyncrasies lies at the heart of the observed differences. By focusing the cross-sector research in this dissertation on one country, the U.K., it will be easier to understand any cross-sectorial differences because the development of both sectors will share similar cultural, political and economic backdrops. This narrowing of the range of possible explanations of differences between the sectors (i.e. in some senses making them more 'similar'), makes the differences become more pertinent. As Evans-Pritchard noted:

> 'Institutions have to be similar in some respect before they can be different in others' (Evans-Pritchard quoted in Barnes, 1987:120)).

The cross-sector energy-transport case study described in this dissertation falls into two parts. The first is described in chapters 3 and 4, and represents an attempt to describe the main features of the historical and 'cultural' development of the two sectors, and identify patterns of similarity and differences between them. In doing this, changes in the demand and composition of energy and transport (a crude proxy for the changes in importance of the activities) are reviewed and collated , as are the events, processes and salient features which have been thought to be significant by the 'natives' of the sectors themselves. The relationship between the two sectors is then mapped and an appreciation of the similarities and differences is developed. In this way the ground is prepared for the second part of the cross-sector method which involves identifying three comparative themes which are then followed up in more detail in chapters 5,6 and 7. The energy-transport case study investigates a range of perspectives from the comparative nature of the sectors themselves (object) to more specific elements between them such as forecasting procedures and programme implementation (context).

Chapter 3

The Development of Energy and Transport in the UK

'Getting to see new problems, or to see old problems in one way rather than another, is a major conceptual and political accomplishment.'

John Kingdon (1984) *'Agendas, Alternatives and Public Policies*, page 121.

3.1 The Development of Energy.

3.1.1 Summary of the Evolution of Energy Policy: 1947-1991.

Studies of post-war energy history in the UK have tended to focus on the events, intentions or objectives leading up to a particular Government White Paper (e.g. Posner's (1973) study centred around the 1967 White Paper on 'Fuel Policy' (HMSO, 1967)), or the development of a particular strand of energy history such as the British Nuclear programme (see for instance Patterson, 1985 and Burn, 1967). In many instances, and particularly in the period before the mid-1960s, energy histories focused on the course of economic, social and political events surrounding the development of a particular fuel, mainly coal. In the immediate post-war period, and up until the mid 1960s, the country was critically dependent on coal. As Pearce (1982) wrote:

> 'in short the future of coal was from the standpoint of 1946, the very future of energy in the U.K. Energy policy was coal policy, a fact given explicit recognition when the coal industry was nationalised on January 1 1947' (Pearce, 1982:46).

Bending and Eden (1984) summarised the main trends in the development of post-war U.K. energy policy in terms of four major phases: (1) post-war recovery (1945- early 1950s); (2) steady growth, planning by consensus (up to early 1970s); (3) rising prices (up to early 1980s); (4) deepening recession, market forces (to present).

The first period was one of immediate post-war shortages of fuel and economic recovery lasting until the early 1950s. The Government's concern during this period was the restoration and reconstruction of pre-war levels of domestic and industrial heating and motive power. It was also a time when the newly elected Labour government established the major nationalised corporations responsible for coal, gas and electricity. The second period began in the mid 1950s and lasted for the next 15 years during which the economy grew fairly steadily and the major energy industries underwent major re-organisations aimed at co-ordinating and planning inter-fuel competition. Throughout this period, the coal industry was in decline (consumption had peaked in 1956, see figure 3.1) and imports of oil were rising steadily. By the end of the period, the development of the North Sea resources of oil and gas had begun. It was not until the discovery of North Sea oil and gas in the 1960s that the notion of an 'energy' policy (as distinct from 'coal' or 'solid fuel' policy) began to develop. These discoveries led to the publication of the 1965 and 1967 White papers on Fuel Policy (HMSO, 1965 and 1967) which for the first time actively considered a switch from a single to a multi-fuel economy.

The third phase began in the 1970s when oil and other energy prices rose rapidly, revealing the growing susceptibility of most western industrialised economies to changes in oil price and supply disruption due to war or political upheavals, particularly in the Middle East.

These uncertainties took place against a background of much slower economic growth. In response to these changes, coal once again came to be seen as central to UK energy policy along with other indigenous energy resources, and there was a new emphasis on energy efficiency and on energy conservation. The fourth phase began in the late 1980s and was characterised by deepening economic recession and energy surpluses, alongside a retreat from planning and consensus politics and the re-emergence of debate about the role of market forces and public versus private ownership of the energy industries.

With four successive Conservative governments since 1979, and the principles of energy planning formally abandoned in 1982 (as discussed later in this section), market forces backed by Government support have shaped the privatisation of the Electricity industry (except nuclear power) Gas industry, the selling of the Government's remaining shares in the oil industry, and the proposed privatisation of British Coal.

A more detailed review of the evolution of energy policy over the period 1952-1992 is given below. During the period 1947-1965 Britain had, basically, a two fuel economy with coal as the principal source of primary energy. Throughout this period the use of petroleum increased steadily from around 10 per cent of the total primary energy consumption in 1947 to around 35 per cent in 1965. Successive Governments throughout the 1950s and 1960s put great emphasis on economic recovery and stability through the macroeconomic objective of decreasing Britain's balance of payments deficit. Thus, exports of all kinds from raw materials and fuel (such as minerals and coal) to manufactured goods (such as cars) were seen as vital to the success of the economy. The decline in the consumption of coal in favour of consumption of imported oil was of great concern to the Government (Pearce, 1982).

In October 1950, the Windscale nuclear complex went critical, primarily to produce military grade plutonium, with two reactors producing plutonium and a chemical plant for separating the plutonium for bombs. After its initial successes, there were soon calls for a civilian programme, partly in response to the rising demand for electricity and partly as a way of diversifying Britain's dependence on coal and oil. The first civilian programme began in February 1955 as the Government published details of its nuclear power policy in the White Paper, 'A programme for

Nuclear Power' (HMSO, 1955). The initiative launched a 10 year civil nuclear plant programme - the 'first programme' as it is sometimes called. It envisaged around a dozen 'commercial' Magnox reactors operating by 1965.

Important events, were also occurring at the international level. In 1956, the British Government, together with Israel, embarked on an invasion of the Suez Canal, in an attempt to prevent its nationalisation by Egypt's President Nasser. When the canal was consequently closed, a major transport route along which oil travelled from the Middle East to Britain had been severed, and exposed the vulnerability of Britain's oil supplies. In response, the Government reconsidered the role that indigenous energy supplies should play in serving the economy's fuel needs, and in March 1957 announced a revised and expanded nuclear programme (Patterson, 1985:7).

In 1959 some of the most significant changes in the evolution of UK energy policy were set in motion by the discovery of natural gas at Groningen in the North Netherlands, which increased the perceived likelihood of the existence of substantial reserves of oil and gas throughout the North Sea region.

In 1964, dissatisfied with the projected lack of economic competitiveness of nuclear power from the Magnox stations, the Government published a White Paper announcing a second programme of nuclear power which would build a series of Advanced Gas Cooled Reactors (AGRs). The following year, in the light of its commitment to the nuclear programmes and changes in the pattern of primary energy consumption, the Government undertook and published a policy review entitled 'Fuel Policy' (HMSO, 1965). The White Paper coincided with a definitive change in the perception of fuel policy; a switch from a single to a multi-fuel economy was actively being considered; greater emphasis was given to the impact of energy availability on economic growth; and fuel policy was seen as an even more important means of assisting the balance of payments. Meanwhile the dramatic changes initiated by the discovery and exploitation of natural gas and oil on the United Kingdom Continental Shelf under the North Sea continued in 1967 with the first British landing of natural gas (North Sea oil would not start to flow until several years later in 1975).

Thus, in 1967, the Government promptly reassessed the balance between primary fuels in the light of the introduction of natural gas and the decision to go ahead with a major programme of second generation nuclear reactors (HMSO, 1967). Forecasts were central to the 1967 Fuel Policy; demand was forecast, and then the methods of meeting that demand were determined in the light of forecasts of costs. In line with the trends in other nationalised industries, the 1965 and 1967 White Papers were to be two of the last major analytical long- term planning exercises carried out by Government. For the following ten years various forecasting technologies consistently predicted high growth in energy consumption, a feature which came to dominate a predominantly supply-oriented energy policy (de Man, 1987).

Between 1967 and 1973 the natural gas conversion programme (involving the alteration of 35 million gas appliances) was implemented, more oil was discovered in the North Sea, and the consumption of coal continued to decline. In 1971, coal consumption was overtaken as the principal source of primary energy, by petroleum.

The exploration and development of the North Sea's gas and oil reserves were dramatically stepped up when between late 1973 and spring 1974, oil prices rose from around $2 to $12 a barrel. The 'oil crisis' as it became known, had an immense effect on a world economy which had become almost entirely oil dependent. The selective cuts in oil production imposed by OPEC had repercussions throughout most non-communist energy sectors. In Britain, they sparked off research into energy conservation and energy efficiency and searches for alternative sources of energy from technologies such as wind, wave, tidal and biomass. The crisis had the effect of internationalising UK energy policy, through new areas of co-operation among oil-consuming countries, in particular by the establishment in 1974 of the

International Energy Agency (IEA). Its principal purpose was to establish an international programme of co-operation in all forms of energy supply and use, but especially to deal with the risks of disruption to oil supplies.

In 1976 the first AGR, Hinkley Point B, came on line and during the same year, the Royal Commission on Environmental Pollution published its report on nuclear power and the environment (Cmnd, 6618) concluding that the abandonment of nuclear fission power would be neither wise nor justified, but expressing concern at the social, environmental and security problems which could arise from a major commitment to nuclear fission. In 1978, the Labour Government undertook what was to be the last major energy review in the UK up to present. The conclusions were published in a Green Paper, 'Energy Policy' (HMSO, 1978) intended as a consultative document that would invite further comments. It formed a broad review of the energy 'scene' at the time and concluded by listing a number of decisions that the Government thought needed to be addressed within two years including: concerns about the fast reactor programme (experimental Atomic Energy Authority (AEA) reactors had been running in the north of Scotland since the 1960s); power station ordering; energy conservation policies; research and development; and energy pricing.

The change of Government in 1979 came in the same year that the second major oil price shock took place and just at the time when great interest was aroused in a series of low energy forecasts (see Leach et al., 1979, de Man, 1987). Anxious to make the best use of its economic windfall, the Government then stepped up the relatively low production of North Sea oil. Conservative economic and ideological philosophies, characterised by a belief in the market place and retreat from any kind of central planning began to shape the energy sector. In 1982, Nigel Lawson, the then Secretary of State for energy, said in what was to be the death knell of official British energy forecasting:

> 'I do not see the Government's task as being to try and plan the future shape of energy production and consumption. It is not even to try and balance UK demand and supply for energy. Our task is rather to set a framework which will ensure that the market operates in the energy sector with the minimum of distortion, and that energy is produced and consumed efficiently' (DEn, 1982:3).

In 1982 the Oil and Gas (Enterprise) Act opened up the possibility of independent gas sales to large customers through use of the national gas grid. This was followed in 1983 by the opening, in principle, of the electricity grid for third party use. During the same year the Government re-organised responsibility for energy efficiency by abolishing the DEn's Energy Conservation Division to create an Energy Efficiency Office (EEO). The mid-1980s saw a year long miners' strike (with no power cuts), whilst the production of North Sea oil peaked and oil prices fell from around $30 to $15 a barrel.

In 1986 the Conservative Government continued its privatisation programme, with the sale of British Gas. In 1987 plans were approved to build the Sizewell B Pressurised Water Reactor (due to come on line in February 1995), and the announcement of the privatisation of the electricity supply industry (ESI) was made. In 1990, plans for the Hinkley C nuclear power station were approved and the twelve regional electricity boards were privatised. The Government completed the privatisation of the ESI in March 1991 with sale of the generating side of the electricity industry, in the form of two separate companies: National Power and PowerGen. Responsibilities for power transmission is now with the National Grid Company and responsibility for distribution and supply is with 12 Regional Electricity Companies. All nuclear power, however, remains under government control, in the form of Nuclear Electric and Scottish Nuclear which are responsible for generation, and British Nuclear Fuels which is responsible for reprocessing and all other fuel cycle services. The privatisation of the ESI involved major changes to the structure of the industry and the regulatory framework within which it operates; but is not expected to create major changes in the short to medium term demand for electricity.

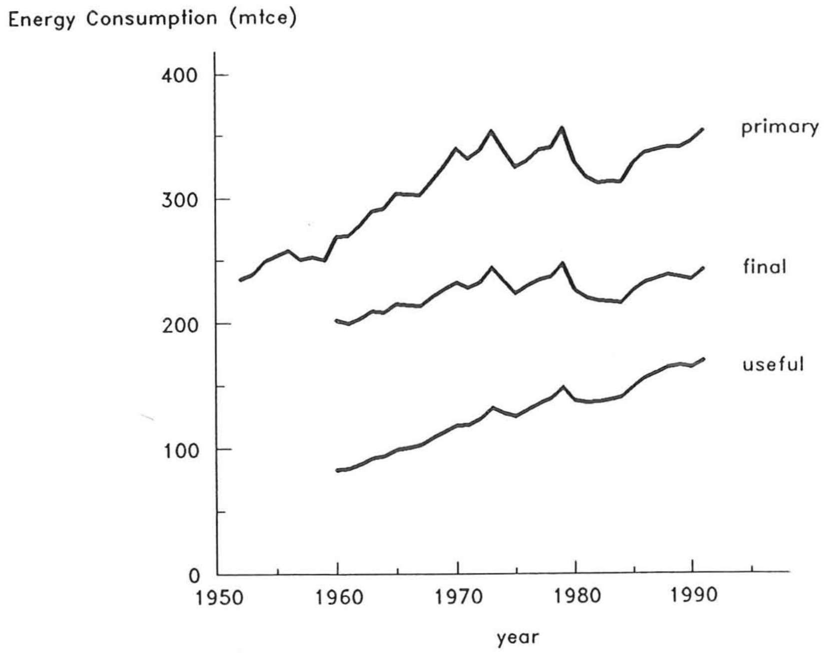
Within the last ten years primary energy consumption has risen by only 4 per cent in total, although, there continue to be changes in the primary fuel mix; there are continued trends to use less coal more petroleum, more natural gas and more primary electricity. Compared with the energy crises of 1973/74 and 1978/79, and with the introduction of natural gas in 1964, British energy policy is in a relatively smooth state of flux. The emergence of a new environmental awareness, the proposal and implementation of the privatisation of the Electricity Supply Industry, and the decommissioning plans for ageing nuclear facilities have been dominant features in energy policy over the last 5 years (Stern and Nichol, 1992). The impetus to continue developing and using reserves of fossil fuels, oil and gas in particular, is still strong. Even events such as the outbreak of the Gulf Crisis in August 1990, which ten years earlier may have had dramatic effects on oil prices do not today have the same effect, due to the protection and buffering systems that were established after the 1979 oil shock. Many oil consuming countries are now much better prepared to deal with such an event after learning the lessons of earlier crises.

Perhaps one of the most uncertain influences on the continued development of energy policy will be the results of further investigations of Global Warming due to the emission of greenhouse gasses, the greater proportion of which is due to the burning of fossil fuels (around 96 per cent of U.K. emissions of carbon dioxide [the main greenhouse gas] come from fossil fuels (DoE, 1992)). Further scientific research concerning the size of the effect, and the possible consequences of global temperature rise is underway. The outcome will have an immense influence on the introduction of policy measures to reduce emissions of carbon dioxide in particular, the carbon/energy taxes under consideration by the EC (Europe Environment, 1993).

3.1.2 Trends in Supply and Use of Energy.

The developments and trends in energy policy reflect and are reflected in changing patterns in the way that the country's energy is supplied and used. Changes in the two principal measures of energy consumption, primary and final energy consumption, are shown in figure 3.1 for the period 1952-1991 (data for final and useful consumption is only available from 1960 onwards). The primary measure of consumption includes all energy inputs to the economy, while final energy consumption is the actual amount of energy delivered to the energy user. The primary measure includes losses in power stations, refineries, transmission lines etc., whilst the final energy measure is the actual amount of energy used in factories, shops, vehicles and houses etc.

Figure 3.1: Primary, final and useful energy consumption: 1960-1991.



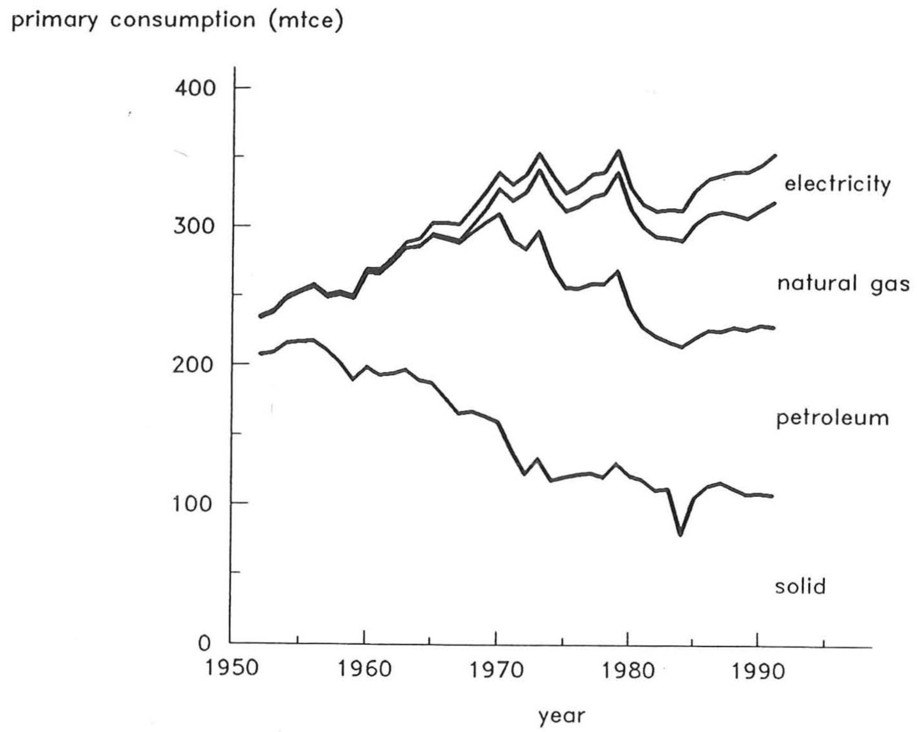
source: DTI, 1992

Figure 3.1 also gives the changes in useful energy consumption. Some of the energy delivered to the final users is lost as they use it in energy consuming devices. Useful energy, therefore, is the actual work that is derived from a particular fuel with a particular technology. In practice this measure is difficult to calculate, particularly at a high level of aggregation, but it is included here so that it can be contrasted with the more accurate final and primary use measures of consumption.

Figure 3.1 reveals that all three measures have risen over the period. The main trend in the relationships between the three measures can be seen in the way the three lines converge or diverge. Over the period, final energy consumption has remained at around two thirds of the primary measure varying slightly as indicated in a change in the ratio of final to primary consumption from 0.75 in 1960 to 0.68 in 1991. The useful measure of consumption was estimated by assuming an annual incremental increase in the ratio of useful to final consumption from around 0.4 in 1960 to 0.7 in 1991 (Eden, 1974). These changes are related to the changes in fuel mix and the ways fuels are used.

Changes in primary energy consumption by type of fuel for the period 1952-1991 are shown in figure 3.2.

Figure 3.2: UK Primary energy consumption by fuel: 1952-1991.



source: DTI, 1992

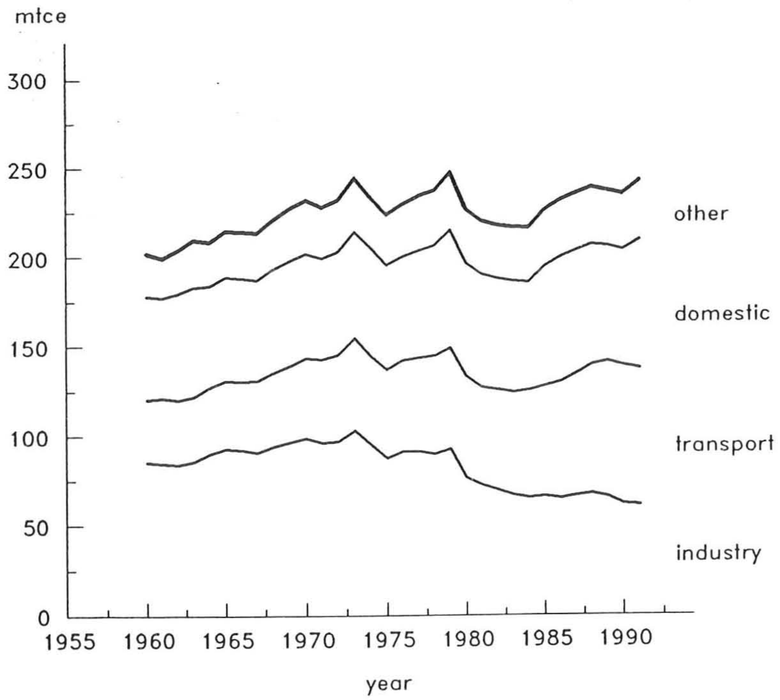
Overall, total primary energy consumption rose steadily throughout the first half of the period from 240 mtce in 1952 to a peak of around 350 mtce in 1973. Since the early 1970s total consumption has fluctuated, although the trend has been relatively flat, and in 1991 accounted for around 350 mtce (as it did in the early 1970s).

Of the four principle primary fuels (electricity, natural gas, petroleum and solid fuels [mainly coal]) the consumption of coal, in contrast with the other three, has decreased steadily over the period, peaking in 1956 and falling to an historic low during the miners' strike of 1984. In 1991, after 30 years of steady decline, coal consumption accounted for less than half the share of primary energy consumption than it did in the early 1950s. Coal now supplies Britain with around a third of its primary energy needs. In contrast, we have steadily increased our dependency on crude oil, primary electricity and natural gas. Over the period the contribution of petroleum to primary energy requirements rose by 10 % to its current share of around 35 %. The introduction and steady increase in the consumption of natural gas since the late 1960s meant that in 1991 it accounted for around a quarter of total primary energy needs.

Primary electricity is supplied in three forms: nuclear, hydro and imports. Net imports of primary electricity had been close to zero until the mid eighties, but since have risen to 2 % of the total primary energy consumption. In 1991 the production of hydro electricity accounted for just 1 % of total primary energy consumption, whereas the nuclear programmes of the late fifties and sixties, with their considerable construction times, have meant that the share of Britain's primary energy consumption derived from nuclear power rose from close to zero forty years ago, to 8 % in 1991.

Trends in the uses of primary energy once it has been delivered to final users are shown in figure 3.3. The consumption of energy by final users is usually classified into the four different categories shown. The 'Other Final Users', includes energy used for agriculture, commerce and public services.

Figure 3.3: Energy consumption by final users: 1960-1991.

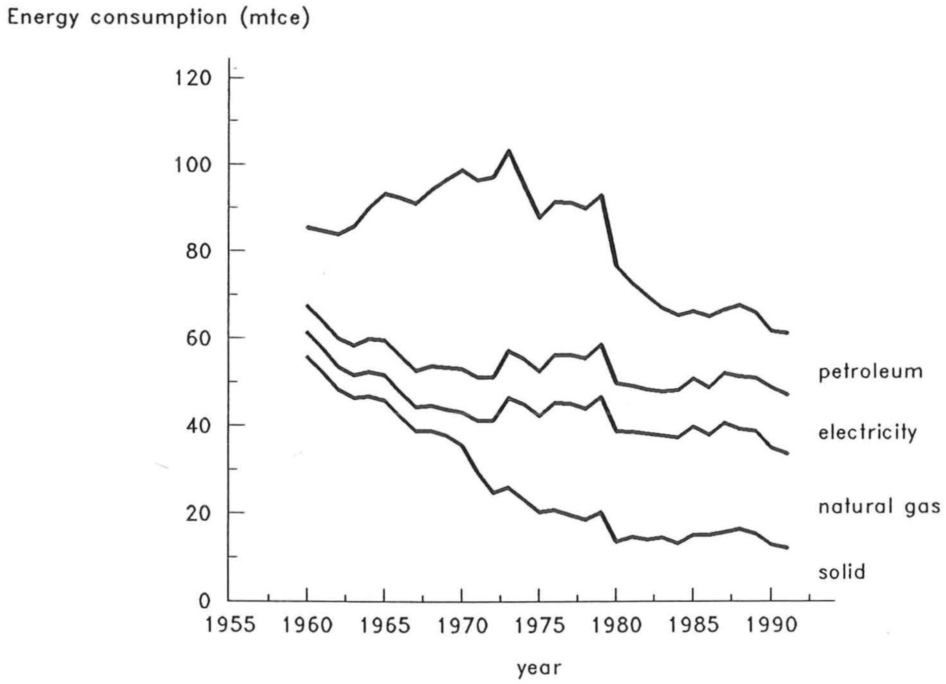


source: DTI, 1992

Since 1960 the final consumption of energy has increased steadily; in 1991, as final users, we consumed 17 % more energy, in total, than we did in 1960, largely due to increased transport activity. Figure 3.3 shows the proportion of final energy consumption used in each of the four sectors and how these proportions have changed over the three decade period. From 1960 to 1970, industry (including iron and steel production) was the greatest consumer of energy, accounting for 42 % of total final consumption in 1960, steadily falling to around a quarter of total consumption in 1991. Final energy use for domestic purpose has remained fairly constant in absolute terms throughout the period, falling slightly from a 29 % share of total consumption in 1960, to 24 % in 1973, and then rising back to retain the same share in 1991 as it did in 1960. Over the period the most significant change has been in the proportion of final consumption due to transport, which in 1960 accounted for 17 % of total consumption, which rose steadily to a level of 32 % in 1991 making it the single largest energy consuming sector. The share of total primary energy consumption used by other final users has risen only slightly by 2 % since 1960, to its current share of 14 % of total final energy consumption.

The suitability of a particular fuel for one purpose rather than another is reflected in the patterns of energy consumption of fuels in each of the four final use sectors. Figures 3.4-3.7 show changes in the use of each of the four main fuels within each of the four sectors for the period 1960-1991.

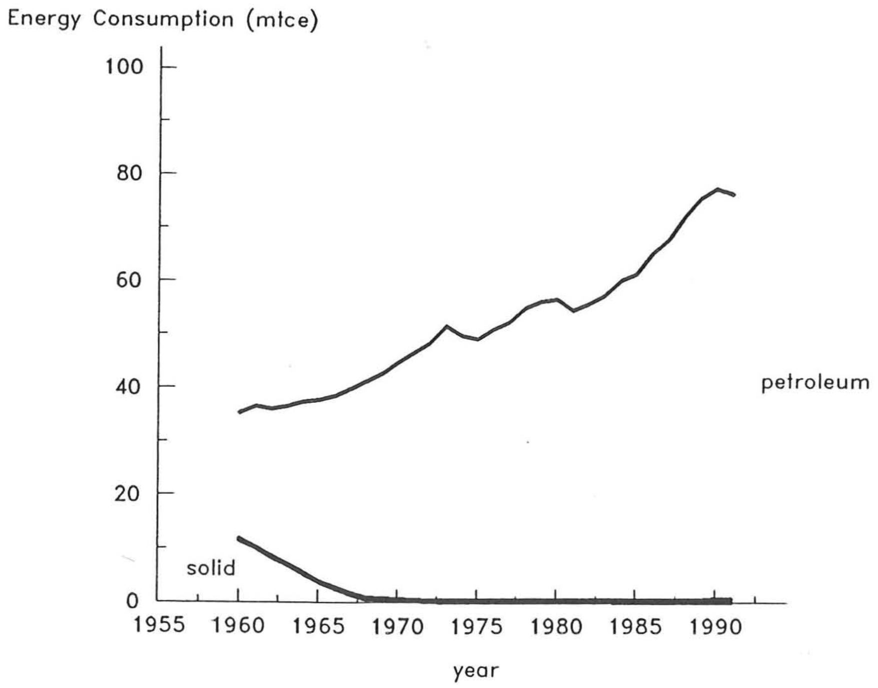
Figure 3.4: Industrial energy consumption by fuel: 1960-1991.



source: DTI, 1992

In contrast to the overall rises in domestic, transport and other final use sectors, in 1991, energy used for industrial purposes had declined to just over half what it was at its peak in 1974, and by 23 % since 1960. After initial increases in total energy used in this sector during the early part of the period, the downturn in industrial energy consumption after the mid-1970s was due to recession, structural changes and efficiency improvements, manifest in the decline in the uses of petroleum and coal. In 1991, petroleum provided industry with 22 % of its energy needs, a third less than it did in 1960. There has been a fourfold decline in the use of coal from around 42 % of industrial energy in 1960 (the figure in the graph shows all solid fuels) to 12 % in 1991. In contrast, the industrial use of electricity doubled over the period. As in the domestic and other final use sectors, the use of natural gas increased rapidly in the 1970s but then levelled off during the 1980s to a share of 35 % in 1991.

Figure 3.5: Transport energy consumption by fuel: 1960-1991.

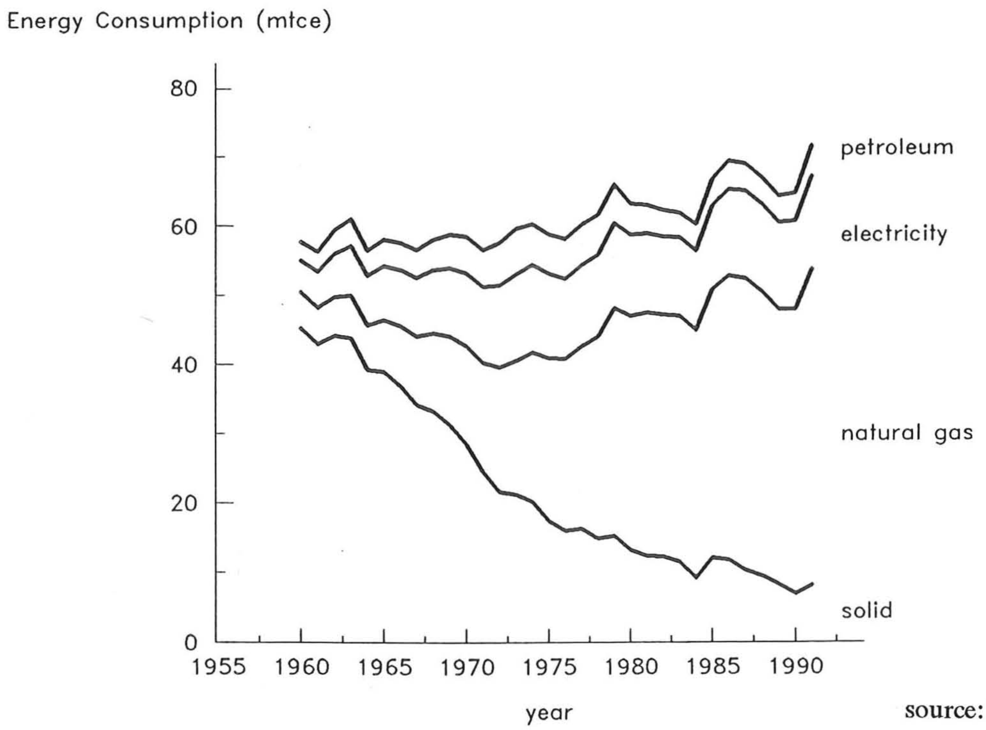


source: DTI, 1992

The overall steady doubling in the total amount of fuel used for transportation has nearly all been due to increased use of petroleum. Between 1960 and 1970, a considerable amount of coal was still being used on the railways; However this was declining, eventually ceasing in the late 1960s. The use of electricity for transport has remained minimal in comparison to the total used for transportation, accounting for just 1 % of the total in 1991 (its largest share over the period), not enough to be visible in the figure.

In the domestic sector, the most striking trend has been the steady and steep decline in the use of solid fuel coupled with an almost simultaneous increase in the use of gas (natural and other types of gas are shown here together, although from 1970 onwards the vast majority of gas used is natural). The uses of electricity and petroleum after an initial upward trend at the beginning of the period, have remained largely constant. The slight increase in the total amount of energy used for domestic purposes can be attributed to the increased use in natural gas. In 1991, 64 % of energy used in the home was derived from gas, 19 % was in the form of electricity, 11 % from solid fuels and 6 % from petroleum.

Figure 3.6: Domestic energy consumption by fuel: 1960-1991.

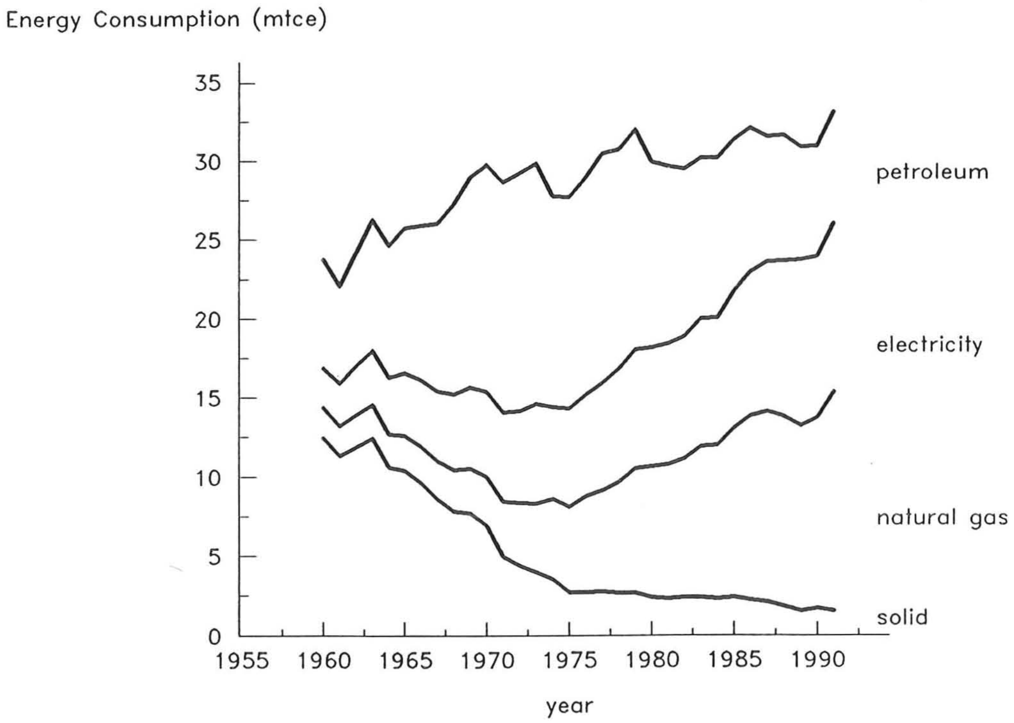


source: DTI, 1992

Over the period 1960-1975, the overall rise in energy consumption of other final users (figure 3.7), was due to a rapid and significant uptake of petroleum. During the early part of the period, the use of electricity, solids and gas (largely derived from fossil fuels at that time) were all in decline. From the mid-1970s onwards, the overall trend continued to rise but as a result of increased use of electricity and natural gas.

Since the mid-1970s there has been a steady decline in the use of petroleum within this sector. As in the domestic and transport sectors, the use of solid fuel declined steadily throughout the period. In 1991 42 % of fuel use in this sector was derived from natural gas, 32 % in the form of electricity, 21 % was derived from petroleum and 5 % from solid fuels.

Figure 3.7: Other final users energy consumption by fuel: 1960-1991.



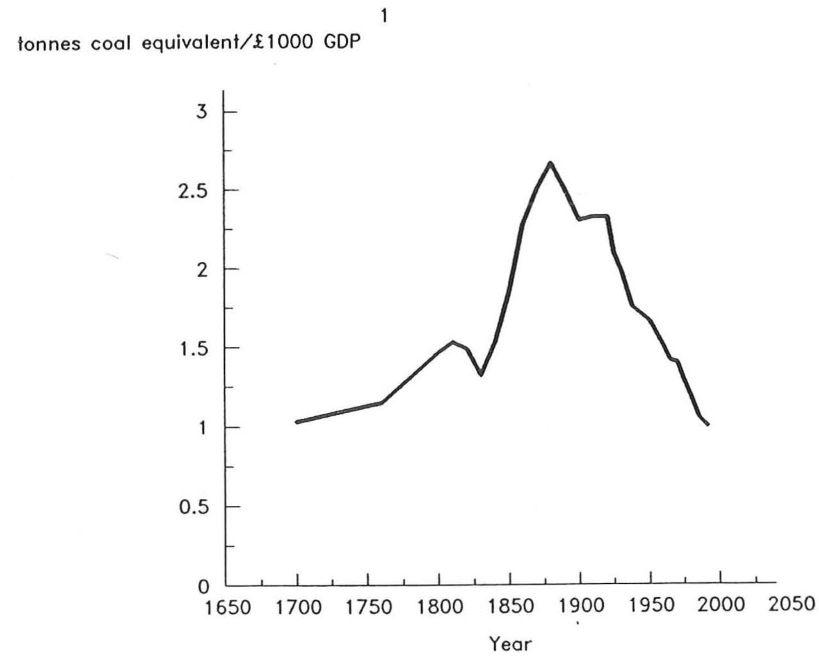
source: DTI, 1992

3.1.3 Features in the Patterns of Energy Use and Economic Activity.

Energy use is a natural result of economic activity. Individuals whose wealth is increased through economic growth use some of that wealth to keep warm, to replace their own labour by machinery (such as electrical tools, equipment), and to travel (Bending and Eden, 1984: 54). The link between economic growth and energy use has played a significant part in energy policy analysis (see chapter 7) and is normally evaluated in terms of the ratio between some measure of energy consumption and economic activity (measured in terms of GDP). This measure is referred to as an 'energy ratio' or 'energy intensity'. Each of the three main measures of energy consumption (primary, final and useful) may be used to produce a different intensity. Thus depending on how energy consumption is measured, different energy intensities are obtained.

Over a very long period, the process of economic development is usually associated with increasing energy intensity up to some maximum value, and then a gradual fall (Bending and Eden's interpretation of Humphrey and Stanislaw's (1979) work). The long run trend in the relationship between UK energy consumption and economic growth is shown in figure 3.8 which illustrates how the primary energy intensity has changed over the period 1700-1991.

Figure 3.8: UK primary energy intensity: 1700-1991.

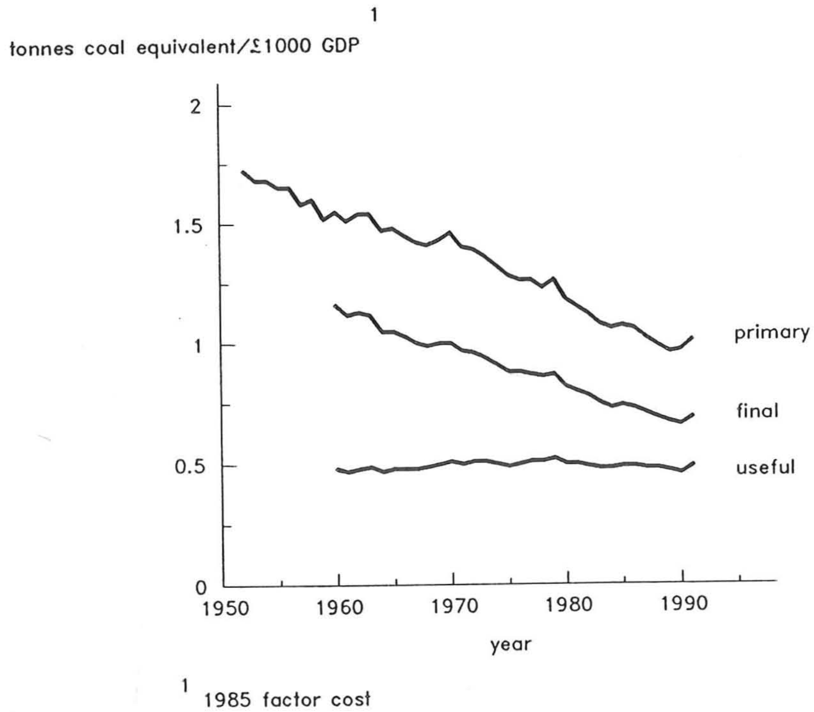


[1] 1985 factor cost

source: Humphrey and Stanislaw, 1979; DTI, 1992

By 1800 the dominant energy source was already coal which continued to fuel the expansion and rapid growth of iron and steel production, and construction. The decline in energy intensity in the UK after 1880 can be attributed to improvements in the efficiency with which fuels were used and a gradual shift in industrial production away from energy intensive industries (Eden et al., 1981). As a result, Britain built, climbed and then descended an 'energy hump' during its transition from a pre-industrial to a service economy (this transition is discussed in Gershuny and Miles, 1983). The figure reveals that the UK has been in a period of declining energy intensity since 1880. Variation in primary, final and useful energy intensities over the last four decades is shown in more detail in figure 3.9.

Figure 3.9: UK energy intensities: 1960-1991.



source: Peake and Hope 1991

In each case, a downward trend in energy intensity reflects an improvement in the efficiency with which we produce, supply or consume energy. As primary energy consumption is greater than final consumption which is in turn greater than useful energy consumption (by definition), the curves appear one on top of the other. Figure 3.9 reveals that in 1960, for every 1000 pounds GDP (at 1985 prices), Britain used around 1.5 tonnes of coal equivalent (tce) primary energy, of which 1.2 tce would be delivered to final users, and around 0.5 tce would eventually perform useful work. Over the last 40 years both primary and final energy intensities have decreased steadily; in 1991, for every 1000 pounds GDP, Britain used around 1.1 tce primary energy, of which 0.7 was delivered to final users, and around 0.5 tce was used to perform useful work. The decreases in primary and final energy intensities reflect significant changes in fuel supply and major reductions in energy-intensive industries but also major improvements in efficiency. Since the useful curve is an estimate, it must be stressed that it is only a tentative indication of the change in useful energy efficiency over the period. The other two curves are much firmer, being based on published statistics. The overall steady downward trends of primary and final energy intensities over the period, can be attributed to the following influences:

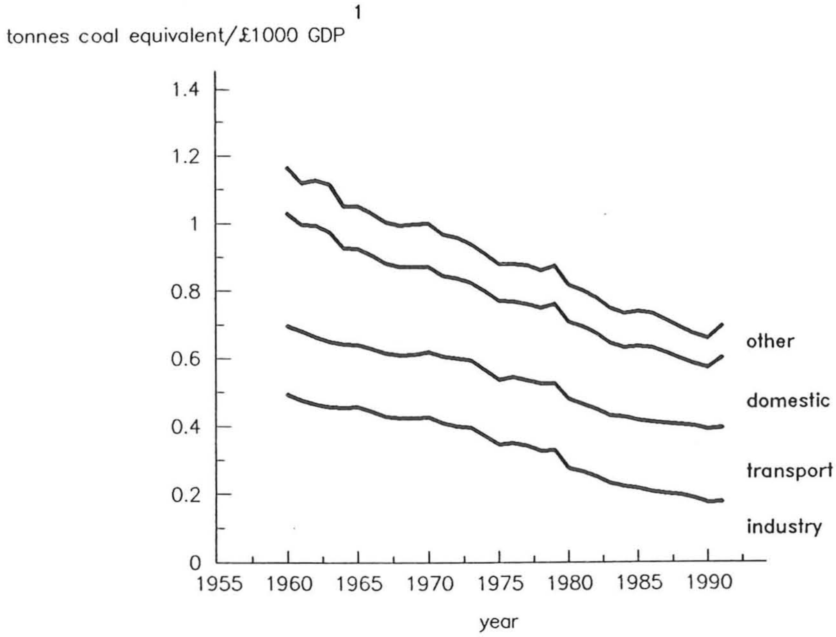
> 1. Technical changes (for example in manufacturing processes) which lead to increases in efficiency;
> 2. Changes in the mix of industrial products away from high-energy products such as steel;
> 3. Changes in the overall structure of the economy, in particular the growing role of service activities;
> 4. Changes in fuel mix. Some of these such as replacement of coal by oil or gas, often decrease energy intensity while others notably the growth of electricity's share in final consumption, tend to increase primary intensity;
> 5. Activities aimed specifically at energy conservation, in response to publicity or increased energy prices (Bending and Eden, 1984: 54).

The effects of these influences vary from sector to sector, and so it is useful to disaggregate the decline of final use energy intensity by sector to provide a more detailed picture of the changes that have taken place over the period.

Figure 3.10 shows changes in the UK's final energy intensity disaggregated by sector. The most significant trend is that whilst the industrial, domestic and other final use sectors have had declining energy intensities in line with the overall trend, the energy intensity of the transport sector has increased slightly.

The energy intensity of industry has fallen at the greatest rate of around 0.1 tce/ 1000 pounds GDP/ decade. This reflects significant structural changes in the economy away from energy intensive industries. Domestic intensity has fallen at around half the rate of the industrial decline, whilst the decline in the intensity of the other final use sector has been much less, at around a tenth of the rate of the decline in industry. The rate of increase of transport final use energy intensity has been similar to the rate of decrease in the 'other' use sector, about 0.03 tce/ 1000 pounds GDP/ decade.

Figure 3.10: Final energy intensity by sector: 1960-1991.



[1] 1985 factor cost

source: DTI, 1992

3.1.4 The Emergence of the Energy Problem.

Several factors contributed to the growth in awareness of an energy problem during the 1970s. In 1972, a working party, which became known as the 'Club of Rome' first published its influential report concerning the 'limits to growth' (Meadows et al, 1972). The report highlighted that in many instances, growth in the consumption of resources had been exponential, and that with appropriate action to dampen or compensate for this growth, the day when resources ultimately became scarce could be significantly delayed. Although many of the scenarios considered in the project have not come true and it has subsequently received much retrospective criticism in the futures literature as being part of the 'trendy pessimism' that characterised the era , it was nevertheless, influential on public and political thinking at the time (see Gershuny, 1992).

It was against this background that in 1973, over a period of just a few months, OPEC quadrupled the price of crude oil, from around $3 to $12 a barrel. These events made Governments of oil-importing countries realise what risks there were involved with the supply of the oil they needed. The shocks had a remarkable impact on energy trends. In the UK, fuel consumption in 1977 was lower than in 1970, despite an increase in gross domestic product of over 10 per cent, and was much lower than forecasts made in the early 1970s (Leach et al., 1979: 9). It was not, however, just fears over the security of oil supply that created a sense of an 'energy problem', there were at least two more factors; firstly it was not clear at all just how much oil and gas the world had in reserve, and secondly there was a great deal of uncertainty about future demand for energy. The combination of not being able to accurately predict world fuel supplies, future world energy demand, and the probable cost of fossil fuels (in particular oil), provided the basic ingredients of the energy problem. The scale of the perceived problem varied from country to country, depending upon how much energy that country required, and what supplies of indigenous fuel it commanded. In response to the oil crisis, many countries undertook research and development into alternative and nuclear energy strategy (IEA, 1987). Most research was aimed at providing for low cost future energy supplies that were abundant and secure. There was a notable absence in the formulation of the energy problem of an environmental perspective similar to that which exists today. There was, however, a brief period in the early 1970s when it was thought that increased global energy use beyond around 1 per cent of the solar influx, would eventually cause the whole earth to warm, through a direct heating mechanism that had been observed in built environments (see Chapman, 1975). The effect has been dismissed as negligible, although ironically those initial contemplations of a macroscopic global temperature increase have been echoed in the current concern over the greenhouse effect (DoE, 1992).

As well as establishing supply side research and development, many Governments, including the British, began to look more closely at the demand for energy. In the short term, particularly in the mid-1970s, any successful energy demand management projects would have to reduce energy costs, sometimes substantially. In the longer term, energy demand management would still mean lower energy costs, but would also help to preserve energy reserves. Britain introduced its own energy conservation programmes to reduce costs, reduce balance of payments problems, and ensure that energy was not being wasted (due to concerns over inter-generational equity - an early form of 'sustainable development')(see HMSO, 1978).

Britain has been described as an island of coal in a sea of oil and gas (quoted in Pearce, 1982: 48). This may be a little exaggerated but it does sum up part of the feeling that policymakers experienced when contemplating responses to the perceived mid 1970s energy problem. For some countries, the energy 'problem' meant increased oil revenues and for others it meant large balance of payments deficits. Britain was in a fortunate position as it attempted to deal with the events of 1973; it had discovered its own reserves of oil and gas and had a plentiful supply of indigenous coal. However it did import some oil in those days which meant that when the oil price rose sharply, Britain was not shielded from its effects. The existence of alternatives to importing expensive oil stimulated a good deal of research and debate into the best strategies for securing plentiful, cheap energy for the future. It was not clear which policies the Government should follow in the long term (e.g. DEn, 1976a).

After the 1967 White paper Fuel Policy energy forecasting played an increasingly important role in attempts to overcome the problems of dealing with long term energy policies (see de Man, 1987; Chesshire, 1986). Forecasting procedures began to directly influence the decisions of Government, although existing forecasting technology had great difficulty coping with the types uncertainty such as those surrounding the 1973 oil price hike. Hence, a shift away from straight energy forecasting (as those techniques were not good at incorporating uncertainty) towards scenario analysis occurred (a technique that considers a range of possible futures and that is better at dealing with uncertainty). There were several different views or scenarios about how energy policy might or could evolve. The study by Leach et al. (1979) was one of the most influential of such scenario analyses (see also WAES, 1977; UKAEA, 1980; Lovins, 1977). The Leach study identified a future based on a 'low energy strategy', which essentially challenged the widespread belief that energy and economic growth had to continue to be so strongly coupled. The election of a new Conservative Government in 1979 committed to an energy 'market' (see 3.1.1) coupled with the publication of a critical and dismissive response to the Leach study (UKAEA, 1980), signalled the end of a period which had taken energy policy to the very top of the UK political agenda and had forced Government to analyse the basic relationship between energy, the economy and society.

3.1.5 Energy Solutions.

The mid-1970s response to concerns about long-term energy futures provided a range of non-fossil based solutions to the energy problem. Two distinct types of solutions, in particular, were dominant and warrant a brief review here. The two approaches are to some extent polarised, one concentrating on conservation and efficiency, whilst the other concentrated on continuity of supply, although several scenarios have utilised them in tandem (see Jones et al, 1990; and Goodlad et al, 1986).

3.1.5.1 Energy Conservation and Energy Efficiency.

The promotion of energy conservation measures was a frequently suggested solution to the energy problem of the mid-1970s (see DEn, 1979c). Energy conservation involves the following interrelated sets of solutions (Eden et al, 1981):

> 1. The optimal choice of primary energy sources and assessment of their rates of depletion so as to conserve those resources whose scarcity could lead to adverse social or economic effects;
> 2. The avoidance of unnecessary waste of energy;
> 3. Technological or material changes leading to improvements in the efficiency with which energy is used;
> 4. Changes towards alternative products or alternative patterns of demand that reduce the rate of energy consumption.

Three aspects of the social response to energy conservation and efficiency may be distinguished:

> 1. Doing without, in the sense of lowering standards of comfort or convenience;

2. Using energy more efficiently so as to achieve the same standards for a lower consumption of energy;
3. Inter-fuel substitution to permit an alternative fuel to replace the scarce fuel with or without a loss of amenity or a gain in efficiency.

Chesshire (1986) points out that it is important to distinguish between the technical and the economic potential for energy efficiency. Estimates of the technical potential indicate how much energy could be saved by the widespread application of current best practice or readily identifiable future best-practice technology. The economic potential indicates how much could be saved within specific investment criteria (e.g. a rate of return or payback period).

3.1.5.2 Alternative and Renewable Energy Technologies.

Another important feature of energy policy after the mid-1970s was the emergence of interest in alternative and renewable energy technologies which were generally viewed as insurances against failure of the major sources to meet expanding requirements (Eden, 1981:185). Other viewpoints placed renewable energy resources, in particular, as potential major energy supply technologies deserving vigorous research and development (Chapman, 1975; Foley, 1981). Some renewable energy resources were also promoted as part of an argument in favour of small scale, simple technologies which promote diversification (Leach et al., 1979).

Alternative energy technologies include advanced coal-fired plants, combined heat and power (CHP), fast reactors and nuclear fusion. Although reserves of uranium, which were seen as the principal source of nuclear energy, have always been known to be limited, they were believed to be large enough to carry the world through to the next major technological energy achievement, (thought then, perhaps to be solar or fusion power). Nuclear power stations provide energy in the form of electricity, a high quality energy, which can be converted into many other forms. The large amounts of capital, high safety requirements, environmental risks and long lead times associated with nuclear technologies meant that they were limited to being funded by Governments. In the long term, it was realised that the success of nuclear fission technologies would depend upon the success of fast reactor technology. The wide-scale introduction of fusion power would seem likely only if the technology can be developed to reproducibly sustain fusion for long periods.

Unlike alternative technologies, the prospects for the introduction of renewable technologies such as wind, wave, tidal, geothermal and solar power are dependent upon improvements in economics and availability of suitable sites as well as advances in technology. The geographical dimension of renewable technologies makes them suitable in the short term for smaller decentralised power supply, whilst in the longer term, their wider use would entail major changes in land use patterns.

Overall, there is a large potential for alternative and renewable technologies to contribute to energy production, but in general their potential will not be fulfilled until they become economically viable or more money for R&D is found (e.g. DEn, 1989).

3.2 The Development of Transport.

3.2.1 Summary of Evolution of Transport Policy: 1947-1991.

A catalogue of intervention and regulation has characterised transport policy since Gladstone's Regulation of the Railways Act, 1844. Whereas regulation of the railways was reaching maturity in the late 1920s, it was not until 1930, that concern over the seemingly unlimited and increasing use of the road transport system led to the introduction of quantity licensing in road passenger transport through the Road Traffic Act, 1930, and in public road haulage through the Road and Rail Traffic Act, 1933. By the 1930s, the advances in road transportation began to substantially erode the monopoly of the railways. A three tier system of road haulage licensing (with 'A', 'B' and 'C' licences issued for hire or reward, for hire or reward subject to area of operation and for own account purposes respectively) was established which was to remain largely intact for 35 years.

Following the end of the Second World War the newly elected Labour government through the 1947 Transport Act brought a substantial part of the road and rail transport systems under Government control. The act established the British

Transport Commission (BTC) which was given the responsibility of co-ordinating the railways (British Railways), road haulage (the most successful part of which was later sold as British Road Services (BRS) in 1953), certain parts of public passenger transport, London Transport and the publicly owned ports and waterways.

The BTC had little time to develop the administration, accounting and working systems that were needed for what was a large and powerful organisation, before the Conservatives regained power in 1951. At the same time, the British motor car industry was continuing to regain its pre-war productivity, but Government policy emphasised the need to promote car exports as part of a strategy to reduce Britain's balance of payments deficit. The need to export combined with society's growing ambition to own a motor car meant that the supply of motor cars in the home market remained smaller than demand throughout the 1950s (Maxy and Silbertson, 1959).

In 1952, British Overseas Airways Corporation began the world's first regular jet airliner service from London to Johannesburg using Comet aircraft. A Ministry of Transport and Civil Aviation was established in 1953, in an Act which freed the railways from many of their long standing obligations under previous regulations (such as freeing them from having to publish standard freight rates, 40 or 50 million of which existed prior to the Act) and returned large sections of the nationalised road haulage industry to private ownership.

The late 1950s saw the beginnings of a new era in road transport that had its roots in an enthusiastic and powerful road lobby which, since 1943, had set about convincing the Government of the need for 1000 miles of motorway (Hamer, 1987). For fifteen years, the Society of Motor Manufacturers and Traders, the Automobile Association, the Royal Automobile Club and the County Surveyors's Society pressed for the development of a national motorway programme. British interest in a motorway programme had been enhanced by advances in Nazi Germany during the 1930s, resulting in the establishment of an ambitious roads programme in the late 1950s. In 1957, the 20 mph speed limit for HGVs was doubled and in the following year Britain's first motorway, the eight mile long Preston by-pass, was opened by Harold Macmillan. Shortly afterwards, in 1959, the M1 partly linking Birmingham and London was opened.

In 1962, the BTC was fully dissolved (including the remainder of BRS), replaced by separate administration for rail, road water and road freight activities and for transport in London from that of road haulage. At the request of the first Chairman of the new British Railways Board, Dr. Beeching, which was set up by the 1962 Act, detailed studies were carried out to determine the economic efficiency of specific rail links. In March of the next year, the Beeching report on 'Reshaping of British Railways' was published (HMSO, 1963b). It began a process of drastic closures of uneconomic stations, lines and services, reduced the rolling stock and modernised rail freight services. The need to support and sustain a strong public transport system, and the full social cost of Beeching's sweeping 'surgical' changes, (Barker and Savage, 1974: 233) were realised almost simultaneously, as increased car ownership and use began to fuel contemplation of the car's 'great destructiveness' (HMSO, 1963c). In the late 1960s the government undertook a series of detailed policy studies concentrating on controlling excessive competition between operators and modes, culminating in the passing of the 1968 Transport Act. The Act set up Passenger Transport Authorities (PTAs) to control and co-ordinate public transport, provided specific finance for socially necessary transport, initiated a national road building programme and revised the accounts and activities of the railways. The PTAs acted to control competition between public transport in urban areas (the inter-urban market was left to competitive forces with limited intervention to prevent dangerous haulage and service practices).

In 1968, British Rail's last steam train service ended and the QE2 was launched from Southampton. There was no halt in the growth of the numbers of motor cars and although road goods vehicles had become larger (the gross weight limit was raised from 24 to 32.5 tonnes in 1964), the total number of road traffic vehicle kilometres went on growing rapidly (see section 3.2.4). The period of the

Labour Government, 1974-1979, has been characterised as one dominated by the search for efficiency with central Government requiring local government to show that transport plans formed part of a coherent transport policy (Button, 1982). In 1977, a White Paper reassessed developments in transport policy in the light of changes brought about by the 1974 Local Government Finance Act, and the 1974 Railways Act. The Local Government Finance Act, in principle, gave local Government a much greater degree of discretion in determining how transport should be managed, operated, and financed. The Railways Act provided a global subsidy for individual rail services through a Public Service Obligation grant (PSO), which is still Government policy today. The 1977 White Paper emerged largely because of a realisation that it was becoming increasingly difficult to maintain the desired level of public transport service within acceptable public expenditure levels. The paper proposed a shift in investment trends away from roads to public transport in the form of subsidies.

The Conservative Government regained power in 1979 committed to privatisation through a belief in the efficient working of market forces. In 1980 the National Freight Corporation was sold and entry barriers to long distance coach services were abolished. In 1985, the National Bus Company was privatised and full deregulation of local bus services was implemented.

More recently, in 1989, roads policy once again became the centre of Government's attention, with the publication of the White Paper 'Roads For Prosperity'. It considered the current trends in car ownership and use, together with associated congestion and possible counter measures for this and announced a new expanded programme of road building, based on the 1989 national road traffic forecasts. These traffic forecasts form part of a continuing series (for an analysis of previous forecasts see Gershuny, 1979), produced by the DTp's forecasting model, which relies heavily on predicted economic growth. It has been widely observed that economic growth is coupled with the increased consumption of goods and services creating more passenger, service and freight traffic (ACC, 1991; HMSO, 1989b;

Cooper, 1990). In addition, the Government believes that the number of cars and their use will grow as society comes to rely on cars more and more (part of a general trend referred to by Carley (1992) as the 'crisis of automobility'). This belief is partly sustained through a comparison of Britain with other industrialised nations. In the White Paper, 'Roads For Prosperity', the Government notes:

> 'Both the number of cars and their use will grow. As people become more prosperous they choose to acquire cars and use them. There are still significantly fewer cars per head in this country than in the United States, France and the Federal Republic of Germany. Social factors are also at work, especially the increasing number of women driving cars'
> (HMSO, 1989b, para 22).

Hence, the Government has observed that growth in car ownership and use is linked to economic prosperity. Therefore to promote economic prosperity, it looks to providing for levels of car ownership, and use, that are found elsewhere.

The Government's attitude towards railway policy was also made clear in the 1989 White Paper; increased rail investment is not seen as an attractive method for satisfying all but a small proportion of inter-urban demand:

> 'Roads and rail by and large serve different markets, and for the most part, traffic on the one cannot be substituted for the other. Short freight movements are usually best suited to road; over 65% of loaded road freight journeys are 50 miles or less.
>
> The different scale of road and rail activity is also important. Road transport is responsible for twelve times more passenger travel and ten times more freight movement than rail. A 50% increase in rail traffic would reduce road traffic by less than 5%. Rail has an important contribution to make but it is not the panacea for congestion on inter - urban roads' (HMSO, 1989b:paras 12, 13).

Since the Government is committed to economic growth and increased prosperity, it believes there is every likelihood that car ownership and use will continue to rise and that demand for road transport will not saturate in the next 30 years. The Government is however aware of the difficulties in meeting this demand. Road space is a limited resource and is an integral part of our urban and rural environments.

The lack of belief in the transport research community in the capacity to continue to supply extra road space to accommodate the forecast levels of extra traffic is summed up by Goodwin and Jones (1990):

'For at least fifty years there have been two parallel streams of argument on what to do about the car and the infrastructure it uses. One view has been to control, moderate, or tailor car use so that it is in some way kept within bounds defined by broader objectives of traffic or social efficiency. The other has been to accept its growth as inevitable, and provide the road capacity necessary to accommodate it.

Since the publication of the revised road traffic forecasts in May 1989, there is now a radically new situation. The new feature is that, for the first time, there is universal recognition that there is no possibility of increasing road supply at a level which approaches the forecast increases in traffic' (Goodwin and Jones, 1990:11).

After considering the Roads For Prosperity White Paper (and also 'New Roads by New Means', a Green Paper on the private finance of roads) the House of Commons Transport Committee published a report, 'Roads for the Future', (HMSO, 1989a). The Committee's main recommendations included a thorough research exercise to be undertaken on the relationship between road infrastructure and economic growth. In particular, the objectives for trunk road developments were also reformulated to include: (1) assisting the national economy; (2) improving the environment; (3) enhancing road safety for all road users, including pedestrians; and (4) a Government review of plans for additional roads expenditure, to make sure it is putting the money to its best use.

The government has since reviewed its new transport programme and decided not to go ahead with some of the schemes, mainly in the west of London and to 'end' its roads policy based on demand (Independent, 15 January, 1990, page 7), although annual capital road expenditure (i.e. on new construction, improvements and reconstructions) is planned at around 2 Billion pounds per year (DTp, 1991a). A further statement of Government Policy is given in the environment White Paper, 'This Common Inheritance' (HMSO, 1990) in which the Government pledged to:

i. introduce 'red routes' in London;
ii. civilise traffic in towns;
iii. reduce congestion through better traffic management;
iv. improve public transport;
v. provide bus priority schemes;
vi. formulate sensible parking strategies;
vii. provide by-passes where needed to relieve towns of through traffic;
viii. study traffic management measures to maximise their benefits; and
ix. consider ways to improve the environmental assessment of new roads.

During Summer 1991, the Secretary of State for Transport announced a new and revitalised support for rail transport (see for example 'Tories switch Ideological Baggage to Railways' Guardian, 29 May 1991:1). The publicity was followed by great expectations from the transport community that this revised transport policy would mean greater Government investment in key areas of rail development such as the High Speed Rail Link to the Channel Tunnel, and inland freight hubs, new rolling stock and improved safety. The Conservative Government was re-elected in 1992 committed to the privatisation of British Rail (initial franchises of selected passenger services are due in early 1994 (DTp, 1992d) and has recently given support to the Channel tunnel rail link (FT, 1993). BR's privatisation will involve the creation of a nationalised Track Authority responsible for running and controlling track operations, and the creation of separate privatised passenger and rail freight services.

3.2.2 The Growth of Transport: 1952-1991.

Post-War Britain has enjoyed a steady and increasing rise in its standard of living measured by a 130 % change in the GDP per capita. The manner in which transport has developed over the period is closely related to economic growth (see for example ACC, 1991:22). Car ownership has increased by 670%, the population by 15% and the demand for personal travel per capita by 300% compared with forty years ago. Increases in car ownership have meant that people can live further away from their place of work, education or local facilities, and are capable of travelling large distances on a regular basis for personal and leisure trips; this has resulted in a 30 per cent increase in car use (kilometres per car) over the last four decades. With an increasingly mobile work force and the expansion of the motorway and trunk road systems, industry and commerce has been able to locate and relocate to sites away from existing towns and cities, and reduce overheads. Significant land use changes have occurred, especially around these motorway and trunk road networks, resulting in the now familiar 'corridor' effects (ACC, 1991:19).

Changes in the pattern of economic activity and regional planning policies have played a key role in the increase of road-based transport activity. Economic markets have extended beyond the old 'industrial revolution' growth areas, and have become nationally and internationally oriented. The new growth areas that have arisen due to these structural changes are often decentralised and rural with good physical environments (ACC, 1991:20).

Several studies have analysed the long-term nature and causes of the growth of transport. Adams (1981) reviews the nature of the 'mobility transition' from a 'Pre-Modern Traditional' society to the 'Advanced Society':

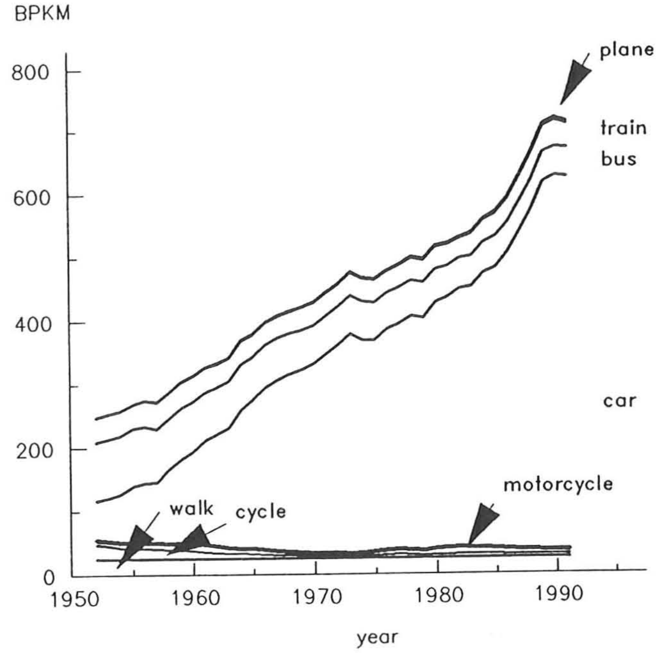
> 'Cheaper and faster transport for people and goods, and enhanced abilities to exchange and process information permit a continued increase in specialisation in production, and further centralization of the control of economic activity, while at the same time residential populations disperse outward from the focal points of specialisation and control' (Adams, 1981:35).

3.2.2.1 The Growth of Passenger Transport: 1952-1991.

The growth in passenger transport since the early 1950s is shown in figure 3.11 (complete data is only readily available from 1952 onwards); by 1991 it was over three times its 1952 level. Passenger transport is conventionally measured in terms of billion passenger kilometres (bpkm) with one passenger kilometre equivalent to one passenger travelling through one kilometre (drivers of cars are included as passengers, but drivers of buses, goods vehicles, trains or planes are not).

The absolute level of road passenger transport activity increased six fold over the period 1952-1991, with the proportion it contributed to total passenger transport activity rising from around half at the beginning of the period to nine tenths in 1991. The absolute level of rail passenger transport remained relatively constant over the period 1952-1991, showing a slight decrease in the 1960s and 1970s which was recovered in the 1980s. The proportion that rail passenger transport contributed to total passenger activity declined steadily over the period. In 1952 rail travel accounted for 16% of total activity; by 1991 this had fallen by two-thirds to 5%. Between 1952 and 1991 there was a steady increase in inland air passenger transport; in 1991 passengers travelled twenty five times as far by air as in 1952, although the proportion that this contributed to total passenger travel was still less than 1% in 1991 (making it difficult to see in the graph).

Figure 3.11: UK passenger transport: 1952-1991.

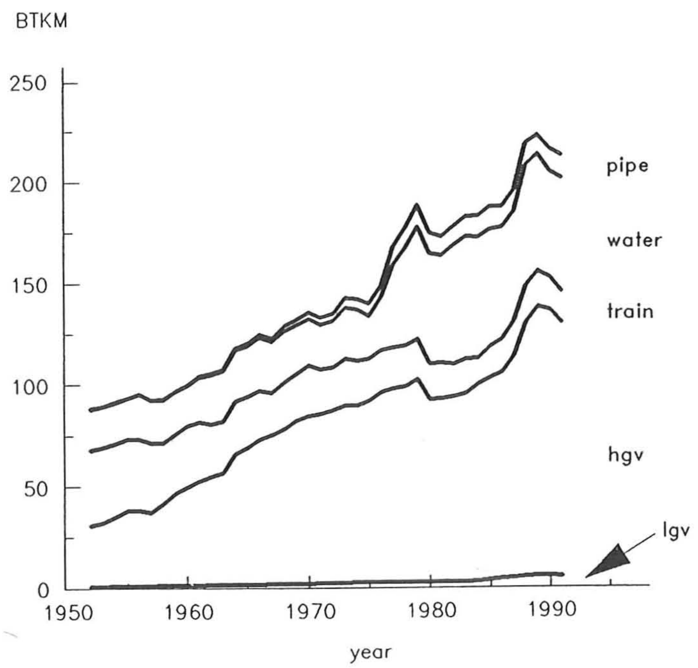


source: DTp, 1992b

3.2.2.2 The Growth of Freight Transport: 1952-1991.

Changes in freight transport activity over the same period are shown in figure 3.12. Freight activity is conventionally measured in units of billion tonne kilometres (btkm), with one tonne kilometre equivalent to one tonne of goods moving through one kilometre. Total activity doubled over the period. The absolute level of road freight activity rose fourfold between 1952 and 1991. In the early 1950s, around four tenths of freight activity was by road. This proportion rose steadily, until, in 1991, road freight accounted for six tenths of total freight activity. In contrast, the absolute level of rail freight decreased steadily over the period and in 1991 was under half its 1952 level. In 1952, three tenths of total freight activity went by rail; in 1991 this figure had dropped to around one tenth. Water freight rose steadily over the period; in 1991 there was nearly three times as much freight moved on water as in 1952 (a similar proportional increase to road freight), with the proportion that waterborne freight contributed to overall activity remaining near to a quarter (much of this consists of bulk fuel movements).

Figure 3.12: UK freight transport: 1952-1991.



source: DTp, 1992b

The amount of freight transferred through pipelines has increased steadily since the early 1950s; from very little in 1952 to around 5% of total freight moved in 1991.

3.2.3 Features of the Growth in Transport.

Figures 3.11 and 3.12 reveal that most of the growth in both passenger and freight transport has been taken up by increased road traffic activity. Even though there has been a relatively large increase in air passenger travel it still accounts for less than one per cent of total passenger activity, whilst the growth in waterborne freight is largely due to coast-wise petroleum shipments (DTp, 1992e).

Therefore, the main features behind the growth in transport are those that govern the growth in road traffic. The existence of alternative modes of passenger or freight transport has an effect on the demand for road transport, but a detailed analysis of the growth or decline in these modes will not explain the current importance of transport and its associated problems.

3.2.3.1 Growth in Personal Travel.

An aggregate, but crude, estimate of the growth in personal travel can be derived from DTp annual statistics. Personal travel rose from around 4000 km per person in 1952 to 12000 km per person in 1991 (DTp, 1991b; CSO, 1992). The increase in total passenger kilometreage was due almost entirely to increases in personal motoring. However, the DTp undertook a series of National Travel Surveys (NTS) in 1965, 1974, 1979 and 1985/6 which provide a more detailed picture of trends in personal travel from a series of selected samples of the population. The Travel Surveys analysed the weekly travel patterns of a representative cross-section of society in terms of variables such as journey purpose, transport mode, journey length and time, and the number of journey stages. This information was then coupled with a detailed analysis of travellers' socio-economic characteristics to provide a reasonably accurate and comprehensive study of travel patterns. An indication of changes in the distance travelled per person per week by journey purpose is shown in table 3.1.

Table 3.1 reveals that in 1985/6 the distance travelled per person per week for all purposes increased by over 40 % compared with 1965. The was due to increases in distance travelled in all three of the main journey purpose categories, with the largest increase for personal business. The table also shows the number of journeys per person per week to have increased for personal business and leisure but to have decreased for work and education. The average length of trip for all purposes has increased with the largest increase occurring in work and education (DTp, 1988).

Table 3.1: Distance travelled per person per week: by journey purpose.

United Kingdom

	1965	1985/86	% change
distance travelled per person per week (kilometres):			
work and education	43	56	*+29*
personal business	16	37	*+115*
leisure	53	68	*+29*
all purposes	113	160	*+42*
Journeys per person per week (numbers):			
work and education	5.2	4.3	*-17*
personal business	2.5	4.7	*+88*
leisure	3.5	4.2	*+20*
all journeys	11.2	13.2	*+18*
Average journey Length (kilometres)			
work and education	8.4	13.0	*+56*
personal Business	6.8	7.7	*+14*
leisure	15.0	16.1	*+8*
all journeys	10.1	12.1	*+20*

source: National Travel Survey, 1985/6

Another feature of the growth in personal travel is related to changes in the travel patterns of men and women. Men on average travel much further per week than women, although there is evidence that the difference is becoming less as women become more mobile as a result of social and economic trends. In particular, changes in the gender differences in the use of public transport and ownership of a driving licence play an important role in the convergence of male and female mobility patterns.

Table 3.2: Trends in driving licences and travel patterns: by sex.

United Kingdom

	Year		% change
Driving Licences:	**1975**	**1990**	
per cent of males	69	78	*+13*
per cent of females	29	48	*+65*
Weekly Distance Travelled[1] (km):	**1964[2]**	**1985**	
males	189	262	*+39*
females	103	161	*+58*

1 average of all men and women
2 adults aged 16-64. 1985 survey data was for adults aged 16-59 so is slightly biased towards younger more mobile groups than the 1965 survey.

source: NTS, 1964, 1985

Table 3.2 reveals that the proportion of women with licences has increased by 65 per cent over the period, compared with only one fifth of that increase for men. The table also shows that the distance women travel on average has increased by 58 per cent whereas there was only a 39 per cent increase in men's weekly kilometreage.

As well as having a high degree of correlation with gender, personal travel patterns are also correlated with income, age and environment. People earning less tend to travel less far to work , and as men generally earn more than women, they tend to travel further (NTS, 1985: 2.9). Middle aged groups and residents of suburban and rural areas tend to use public transport the least, whilst younger people and younger pensioners tend to use it most. Even though the population is relatively stable, demographic changes will mean that there may still be substantial increases in overall personal travel; certain groups are forecast to contract whilst others will expand. The contracting groups are those who at present use public transport most (especially buses) including: 15-19 year olds; younger pensioners (65-75); and residents of densely populated areas. The expanding groups are those who at present use public transport least including: those in middle and old age; and those in rural areas (Goodwin, 1990:85).

3.2.3.2 Growth in Freight Transport.

Over the period 1952-1991 total freight activity trebled; an increase largely due to increased water and road based transport. There are two main factors which drive the demand for freight transport: firstly there is the propensity of the UK population to spend money on products and services or possibly even develop life styles which aspire to consumption (increasing the demand for freight) rather than save money and consume less (which reduces the demand for freight); and secondly, there are transport intensive spatial patterns of production and consumption (Cooper, 1990).

There is a direct correlation between goods moved and GDP (ACC, 1991: 23). Generally as an economy grows there is some switch away from the consumption of goods into the purchase of services, but these services can also have large elements of goods consumption (e.g. Euro-Disney). Trends in the propensity to consume goods and services rather than save income look set to continue. The UK has shown a significant decline in savings as a proportion of GDP over the past twenty years, from around 11% in the mid 1960s to 6% in the mid 1980s (Cooper, 1990: 10). The spatial patterns of production relative to consumption are largely determined by the location of manufacturing, production and service industries. Traditionally these industries have been free to make their own decisions on where to locate facilities. These decisions often involve a number of criteria other than the transport. The price of land, the existence of a skilled labour force and the availability of Government subsidies all play a key role in influencing the location of industry (e.g. Porter, 1990).

The growth of road based freight transport in the UK has happened because of a variety of reasons (Cooper, 1990) including:

1. The UK's island location severing the extension of the continental through rail links for the international movement of goods;
2. Inbound goods arriving mainly by sea, a process which favours their onward journey by road;
3. The main centres of population and industry such as London, Leeds, Liverpool and Birmingham being relatively near to each other, providing few lengths of haul long enough for rail to gain a competitive advantage;
4. An extensive motorway system;
5. The deregulation and freeing from control of the road haulage sector in 1968 enabling it to plan to meet any expansion in demand.

Initiatives such as grants under Section 8 of the 1974 Railways Act, which made Government money available to encourage road freight onto rail have declined steadily, as the freight movements best suited to rail transit have already taken up the opportunity. Possibilities are emerging for a greater use of 'combined transport' a technique that uses various types of interchangeable technology to speed up the transfer times from road to rail and vice versa (see Sutcliffe and Plent, 1992). The collapse, however, of Britain's first privately owned rail freight company, Charterail which had extensively invested in this technology in August 1992, has meant a considerable setback for its wider use, although the DTp are still developing the idea (DTp, 1993). In general, rail freight is best suited to bulk commodities such as crude minerals, coal and liquids. Most other commodities are transported by road.

Since 1979, the DTp has carried out an annual survey of the transport of goods by road (e.g. DTp, 1989). Other surveys had been done as early as 1952 (Glover and Miller, 1954), but because of substantial changes in definitions, coverage and methods it is difficult to compare the results of earlier surveys with those carried out since 1979. A comparison of the changes in the composition of road freight in 1979 and 1989, broken down by a standard goods classification scheme, is shown in table 3.3. Also shown are the changes in the average lengths of haul associated with the goods over the decade. Between 1979 and 1989, the transport of all goods by road increased by a third, and the average length of haul associated with these movements rose by 10 per cent. Both these features are part of a trend that has been continuing since the 1950s. In general these changes were part of an overall trend across most categories of commodity. Goods moved increased across all categories apart from fertilisers, petroleum products and crude materials. The increase in average length of haul was also associated with an increase in haul lengths across most sectors with the exception of fertilisers, crude materials and miscellaneous transactions. The composition of road freight has remained fairly constant over the period. Most goods are picked up and set down within the same geographical region or within around 100 kilometres of their origin (DTp, 1991c).

Table 3.3 Commodities carried, goods moved and average length of haul: % change 1979-1989.

United Kingdom

Commodity	**1979** Goods Moved[1]	**1989** % change	**1979** Haul[2]	**1989** % change
Food and Drink	24.2	+32	85	+29
Wood and Timber	2.5	+28	120	+7
Fertiliser	1.6	-6	100	-6
Crude Minerals	10.3	+45	34	+11
Ores	1.1	+27	65	+4
Crude Materials	1.9	+0	110	-1
Coal and Coke	3.1	+29	42	+29
Petroleum Products	5.0	-10	56	+24
Chemicals	6.8	+22	140	+9
Building Materials	7.6	+49	51	+15
Iron and Steel	7.2	+12	110	+18
Other Metal Products	1.5	+60	100	+10
Machinery and Transport Equipment	6.0	+25	110	+14
Miscellaneous Manufactures	8.5	+49	130	+16
Miscellaneous Transactions	11.9	+55	60	-5
All Commodities	99.3	+33	70.1	+11

[1] billion tonne kilometres [2] kilometres *source: DTp, 1990*

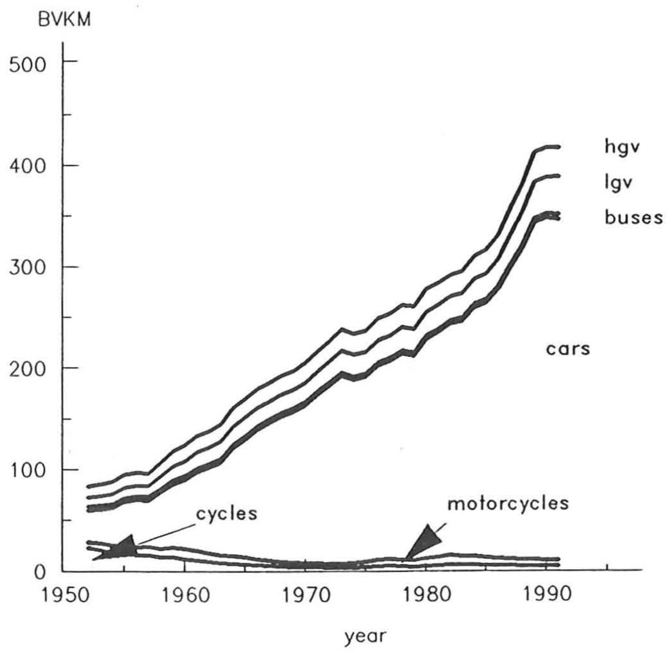
3.2.4 The Growth of Road Traffic.

The growth in the demand for personal and freight transport, and its uptake predominantly by road, has resulted in a growth of road traffic overall. Figure 3.13 shows the growth in road traffic over the period 1952-1991. The figure reveals that the vast majority of road traffic (measured by vehicle kilometres) over the period is attributable to the growth in car traffic. The absolute level of cycle and motorcycle traffic has declined over the period, partly attributable to increases in road users' perception of the risk of a serious accident, sometimes enhanced by Government Information Campaigns such as 'One False Move' (see Hillman et al, 1991a). The level of bus and coach activity has remained around the same, HGV traffic has trebled and LGV traffic has increased four-fold.

The growth in car traffic can be attributed to two factors: increased car ownership; and increased car use. Between 1952 and 1991, the number of cars registered in the UK increased by 650 per cent (there was a 400 per cent increase in the registration of all motor vehicles) and car use rose by 980 per cent (with an equivalent rise of 390 per cent across all motor vehicles). This means that over the period, annual kilometreage per car rose by 40 per cent whilst annual kilometres across all vehicles declined slightly by 2 per cent (note that 'vehicle' kilometreage includes cycling).

Increased car ownership has meant that the number of households without access to a car had fallen from around 86 per cent in 1951 (1952 figures not available) to 34 per cent in 1989 (DTp, 1992b).

Figure 3.13: Road traffic 1952-1991: by carrier.



source: DTp, 1991

3.2.5 The 1989 National Road Traffic Forecasts.

In April 1989, the Department of Transport produced the latest in a series known as the National Road Traffic Forecasts (NRTF) (DTp, 1989). The model which produces the forecasts predicts national traffic levels for all classes of vehicle on all roads by using assumptions about future economic growth. The forecasts for the 37 year period to 2025 are summarised in table 3.4. The predicted increases can perhaps be more easily understood by comparing them with the past, so the table also includes actual increases observed over the 37 year period to 1988.

Table 3.4: 1989 traffic growth forecasts: 2025 compared with 1988.

United Kingdom *per cent increase*

	2025 compared with 1988			1988 compared with 1951
	units	**low growth**	**high growth**	**actual**
GDP	pounds	101	215	154
Car ownership	cars/1000 people	60	84	670
Kilometres per car	km/car	8	22	30
Total car traffic	car km	82	134	1000
Heavy lorry traffic	lorry km	67	141	138
Light goods traffic	LGV km	101	215	293
Bus traffic	bus km	0	0	3
Total traffic	vehicle km	83	142	520

source: DTp, 1989

The 1989 NRTF are long term forecasts of growth rate (rather than actual levels which can be derived from the rates with the latest data - a technique known as rebasing). The main determinant of traffic growth is income or GDP, with fuel price exercising a lesser influence. The car traffic forecasts have two components, one based on car ownership and a second based on car use. The methods of forecasting these two components have attracted more attention than other modes and have been extensively covered in the literature (see Tanner, 1974; Mogridge, 1990; Gershuny, 1979). Car ownership is modelled on a household basis (the level at which most decisions about car ownership are made in the UK) taking into account factors such as numbers of adults, number of workers, family structure and licences per adult. The structure of the model provides estimates of the number of households owning zero, one and more than one car. Forecasts of car use are modelled independently of car ownership by assuming a use-income elasticity of 0.2 (a 5 per cent change in income will produce a 1 per cent change in car use).

Table 3.4 shows that the predicted changes represent only relatively modest increases in traffic activity compared with the actual increases over an equivalent period before 1988 (this is an important feature for the construction of future scenarios of the growth of transport - see section 6.6). The marginal effect of this increase in traffic will however be noticeable as the road system's capacity to accommodate more vehicles is neared.

3.2.6 The Costs of Traffic Growth.

The growth in passenger and freight movements has caused a steady increase in the stress put on the U.K.'s transportation system; for example, between 1952 and 1991 the overall length of the road network increased by only 21% (3032 miles of motorway were built between 1958 and 1991)(DTp, 1991b), whilst road traffic levels (vehicle kilometres) rose by 550 per cent over the same period. The absorption of this growth has resulted in the emergence of a number of problems, costs and unintentional side-effects associated with road transport in particular.

Goodwin et al (1991) consider that the growth in movement, whilst bringing about many advantages, has also brought about four main disadvantages or costs due to: congestion, decreased safety, poorer quality environment and changes in society.

3.2.6.1 Congestion.

There is widespread agreement that traffic congestion is getting worse (FTA, 1991; ACC, 1991). Congestion costs have been estimated at 1.5 billion pounds per year in London and at 10 and 15 billion pounds per year nationally (British Road Federation, 1989). Congestion costs are a contentious issue as they are measured from the difference in the value of journey time under 'ideal' conditions and in reality.

The concept of 'ideal' conditions implicitly assumes it is possible to build a road network on which everyone can travel as if there were no other driver travelling at the same time (Mogridge, 1989:279). However, as Mogridge points out the urban transport problem is that we do all want to travel to the same location at the same time. There are three components to the nature of congestion: (1) daily, weekly and seasonal fluctuations in the demand for transport to certain destinations; (2) random accidents and incidents; and (3) increased mean levels of traffic.

As traffic has increased, so too has the number of accidents and peak demand. The two are interlinked in the sense that as the utilisation of transport systems and infrastructures (be it road, air, sea or rail) increases towards its capacity to accommodate more traffic the effects of an accident or incident become more pronounced as backlogs and queues are formed. Since cars form the majority of road traffic they are involved in a substantial proportion of congestion. Larger goods vehicles and buses contribute disproportionately to congestion because of factors such as their length, lack of manoeuvrability and poor acceleration whilst public transport suffers from the congestion caused by cars and goods vehicles, as buses become caught up in the traffic queues. People who then consequently switch from buses to cars gain by slightly reducing their journey times, but impose more congestion on the other road users, resulting in an increase in overall journey times, setting up a vicious spiral.

Whatever technical differences there are between different types of road vehicle the dominance of cars as a proportion of traffic led Goodwin et al. (1991) to consider that 'congestion, essentially is cars' (Goodwin et al., 1991:44).

3.2.6.2 Safety.

In 1990, 5,217 people were killed, 65,658 seriously injured and 270,268 suffered some kind of injury on Britain's roads (DTp, 1992b). The numbers of people killed on the road has actually decreased slightly over the last four decades. Given the 650 per cent increase in road traffic volumes over the period this is a remarkable achievement. One explanation for the consequent dramatic reduction in deaths per road passenger or tonne kilometre involves changes in societal behaviour (for example increases in the escorting of children to and from school - see Hillman et al, 1991b) and the general retreat of street life (Adams, 1990)). Although road deaths are at their lowest level since 1948, the Secretary of State for Transport recently expressed dissatisfaction, particularly with the number of child pedestrian casualties (Independent 27 September, 1992: p7).

3.2.6.3 Environmental Problems.

There are local, regional and global environmental problems associated with transport activity. The local problems of transport activity include excess noise and vibration, nuisance parking, visual intrusion and pollution of the local air (see Button, 1990, and TEST, 1991:87; Transport 2000, 1992; ECMT, 1990; OECD, 1988). The most widespread environmental noise source is road traffic (DoE, 1991:65). Two thirds of the complaints not controlled by the 1974 Control of Pollution Act received by Environmental Health Officers are from road traffic and aircraft sources (DoE, 1990:61).

The regional environmental problems are essentially related to air pollution. Transport contributes to atmospheric pollution which in turn poses a health risk and causes acid rain. Table 3.5 shows the contribution of transport to various atmospheric pollutants. Transport is a major consumer of energy, particularly fossil fuels, taking 32% of total energy consumption by final users in Britain in 1989 (DEn, 1990). It is the burning of fossil fuels that creates these unwanted regional and global side effects.

The global problems of transport activity include global warming and the depletion of the ozone layer. Carbon dioxide and nitrous oxides are greenhouse gases whilst other nitrogen oxides and hydrocarbons are indirect greenhouse gases (reacting to form ground-level ozone).

Table 3.5: Transport's contribution to atmospheric pollution

United Kingdom	*per cent*
pollutant	contribution[1]
CO	88
NOx	48
Black Smoke	39
VOCs	37
CO2	19
SO2	2

[1] *proportion of total emissions derived from transport*

Source: DoE, 1990

3.2.6.4 Social Effects.

The immediate benefits that are brought to those who have access to a car, are associated with longer term disbenefits for everyone. For those without access to a car, the imbalance between benefits and disbenefits is even greater. Illich (1974) writes

> 'Past a certain threshold of energy consumption, the transportation industry dictates the configuration of social space. Motorways expand, driving wedges between neighbours and removing fields beyond the distance a farmer can walk. Ambulances take clinics beyond the few miles a sick child can be carried. The doctor will no longer come to the house, because vehicles have made the hospital into the right place to be sick. Once heavy lorries reach a village high in the Andes, part of the local market disappears. Later, when the high school arrives on the plaza along the highway, more and more of the young people move to the city, until not one family is left which does not long for a reunion with someone hundreds of miles away, down the coast' (Illich, 1974:35)

For Goodwin et al, the inequalities between those people who have access to cars and those who do not, is the key to the social problems associated with increasing car use and dependency (Goodwin et al, 1991).

Transport deprivation (or reduction in the quality of life associated with not having access to adequate mobility) is inversely related to household income in both urban and rural areas (see Goodwin et al, 1991 and Banister, 1980). However, people are capable of 'getting around' or 'putting up with' the problems of transport deprivation and this is perhaps why it is a most insidious problem.

Other social effects include: increased alienation from other people as personal interaction between motorists is limited; increased domestic isolation caused by parked cars and the reduction in the number of facilities accessible on foot; the retreat of street life and reduction of public transport (Adams, 1990; de Boer, 1986; Whitelegg, 1990); personal security implications for those who have no access to cars (because of cars, there are fewer people walking and using public transport, so it becomes more dangerous for the few, especially in the hours of darkness (Aitkens, 1990)); and community division and disturbance (see TEST, 1991:79).

A steady and basic trend has been occurring which has had important implications for the evolution of society over this century, particularly the latter half; this trend is the redistribution of homes, schools, public facilities, leisure activities and work places around access to the motor car (see RTPI, 1991:6-7).

3.2.7 Transport Solutions.

Bates and Dasgupta (1991) provide a useful categorisation of the appraches or 'policy levers' which have been suggested to help solve the transport problem. This is summarised in table 3.6.

Table 3.6: Transport solutions.

Supply Side Solutions		
Provision of Capacity:	Infrastructure:	Road (highways and parking); Rail
	Public Transport:	Route Density; Frequency; Vehicle Size
Demand Side Solutions		
Efficient Use of Existing Capacity:	Road: Traffic Management; Information. Public Transport: Co-ordination; Scheduling; Information.	
Allocation of Capacity:	Legal; Physical; Fiscal;	
Institutional Matters:	Deregulation; Private Capital for Roads.	
Non-transport measures:	Land-use; General taxation; Opening times; Working Conditions; General Behaviour Patterns; Telecommunications	

source: Adapted from Bates and Dasgupta (1991)

Efforts to control the main disadvantages of transportation have led to a variety of suggested solutions to transport problems. Recently there have been several comprehensive attempts to categorise the role of, and relationship between, different transport 'sub-solutions' (including: Goodwin et al., 1991; Buchanan, 1990; Freight Transport Association, 1991; RITP, 1991; OECD, 1989, 1990; TEST, 1991; Transport 2000, 1992)).

3.2.5.1 Provision of Capacity.

Particularly in the case of road transport, and as was the case with the canals and railways a century earlier, a strong tradition of supply-orientated policies has developed. As post-war reconstruction got underway, traffic levels began to rise helped by supply policies that were designed to encourage and accommodate them. Larger road building and improvement programmes were initiated throughout the 1950s and 1960s, and have continued up to the present day. The greater provision of parking is another type of supply-oriented policy, and was noted early on as being a key factor in car-oriented urban planning (HMSO, 1963c). The availability, quality and cost of parking plays a significant role in a motorist's decision to use the car, particularly in urban areas. Provision for parking can come from both private and public sources, and is generally a major feature of new out of town or urban regenerated shopping and leisure projects. Apart from encouraging greater car-usage, parking provision often gives local councils and land owners an easy method for generating income.

During the last forty years, the provision of extra road capacity has coincided with a steady decline in rail capacity. Between 1955 and 1991, the total track open to passengers reduced by 9500 kilometres or around 40% of 1955 capacity (DTp, 1992b). However, since the late 1980s, there has been a steady increase in the capacity of urban light rail and fixed track schemes (Goodwin et al., 1991:125).

In terms of the general provision of public transport, rail is usually regarded as superior to bus as it operates over protected rights of way and can achieve good service reliability, and unlike buses, trains are not impeded by rising road congestion. Buses can provide competitive services to cars when they are given priority and adopt service patterns that avoid excessive stopping. The standards for public transport are set relative to those of private car travel as people choose the optimum route and mode of transport (see Mogridge, 1990). This in turn means that the quality, flexibility and reliability of public transport competes with that of the car. Hence frequency, route and quality of service are major factors which determine the success of public transport schemes.

3.2.5.2 Efficient Use of Existing Capacity.

Many forms of transport operate regularly at much less than their maximum load factors; buses and train services typically operate at between 15 and 30 per cent of their maximum capacities. Average car occupancy is around 1.7 persons, around 40 per cent of its maximum (see section 5.3.3). This is a potentially fruitful area to improve efficiency, although past experience in the US and the UK suggests that there are many difficult barriers to be overcome (see Bonsall, 1979a,b). In the case of public transport, information is seen as a key determinant of travel patterns (Goodwin et al., 1991). The provision of general information on bus and rail services in the form of timetables, routes and maps can influence individuals' modal choices. Improved ticketing methods and information about transport services, timetables, and up-to-the-minute information about congestion and delays is seen as very important in helping public transport compete with the car. New technologies in the form of light rail systems and advanced bus designs (such as guided buses, buses running on two different fuels, trolley buses and buses with very low floors) can play a greater part in encouraging people to use public transport. The provision of facilities designed to promote interchange between different modes of transport can also influence the uptake of existing public transport capacity. 'Park and Ride' schemes with links to

'Rides' that have been awarded priority over other road users can help to make use of existing capacity, particularly in urban areas. In general, most traffic management procedures contribute towards the goals of stronger enforcement of traffic laws, priority status allocation for certain types of traffic, balanced parking provision in urban areas or traffic reduction by improving the efficiency of public transport (see for example Giannopoulus, 1989).

Better use of existing road capacity can be achieved in several ways through a package of traffic engineering techniques designed to increase the flow of traffic along roads. As a road network begins to operate near capacity, information technology can be used in the form of 'road transport informatics' to achieve the maximum possible use of capacity with the minimum of bottle necks.

3.2.5.3 Allocation of Capacity.

This is a combination of measures which are designed to influence modal split and vehicle usage, usually in a direction away from private car travel.

Legal measures in the form of parking prohibitions, vehicle bans, turning and entry regulations can help to discriminate in favour of moving traffic, residents and pedestrians. Legal measures however hinge on enforcement. Although they may have low implementation costs, they are likely to have high enforcement operating costs.

Physical allocation of existing capacity involves the conscious reduction of capacity in order to reduce traffic volumes. In this case, implementation costs may be higher than those of purely legal measures, but operating costs are lower. Area bans, both those such as pedestrianisation and general urban lorry bans, can redirect and in other cases restrain traffic helping to improve the local quality of street life and give preference to public transport. Another measure, purposefully not improving or providing extra road capacity, can also be considered to reduce congestion. Physical measures generally involve some sort of barrier and segregation strategy, which separates public transport from car congestion, or measures such as the introduction of high occupancy vehicle lanes. Bus priority schemes and park and ride schemes can help reduce congestion, particularly in urban areas. A concept allied to the use of physical planning measures as a disincentive to motorised travel is that of traffic calming, which aims to reduce speeds and accidents in urban areas. Typical measures include pedestrianisation, lowering speed limits, the introduction of cycle lanes, and the introduction of road constrictions and road ramps (see Haus-Klau, 1990).

The last category of policy levers that can allocate capacity more efficiently is fiscal. Road user charges in particular have received much attention over the last 5 years (see Hewitt, 1989; Newbery, 1988; Koopman, 1992). The introduction of road pricing means that road users pay more of the general costs that they impose on others. Benefits are achieved by the collection of revenues which can be used in turn to improve public transport. Public transport can be made more competitive if its fares can be reduced either by greater efficiency, the reallocation of road user revenues or the use of subsidies. Besides road user charges, fuel tax, road fund licence fees and other running costs can be manipulated to send price signals, and alter travel behaviour.

In the roads sector, the 1990 Government White Paper, 'New Roads by New Means' endorsed the use of private capital investment to fund road-building schemes and the issue has been seen as part of a wider strategy of introducing road-pricing in general (e.g NEDO, 1991). Road pricing would internalise more of the externalities associated with transport (see for example Hewitt, 1989 and Newbery, 1990) as users would pay for at least some of the costs their journeys impose on others and its success will be determined by the way in which the discrimination that the road pricing brings is tackled.

As transport activity is inextricably linked with many other social and economic processes, a wide variety of indirect or 'non-transport' measures have been highlighted as forming part of a strategy to reduce the costs imposed by transport (see for instance Arthur, 1992). Improved land use planning is seen as vital if the problems of congestion and energy use are to be solved. Planning could ensure that journeys become shorter, less frequent and that they are less frequently done in polluting and congesting modes of transport (e.g. Owens, 1991; Giuliano, 1989). Advances in information technology and telecommunications have the potential to reduce further the demand for personal travel by encouraging telecommuting (see for example Kitamura et al., 1991) but the scope for this may be limited (Giaoutzi and Nijkamp, 1989). If these are used in conjunction with flexible working conditions and practices they can have a significant effect on general travel behaviour patterns (e.g. Kitamura et al., 1991).

No single measure is likely to have a significant impact on demand management in transport. What is more likely to have a noticeable effect is a combination of all the various measures described in table 3.6, taking care that the unintended side-effects of one partial solution do not interfere with the efficacy of another. The demand for transport is inextricably linked with technical and economic advances. Significant changes can be made to a local environment where the problems caused by transportation are particularly bad, but reducing the overall demand for transport without reducing economic activity will require that demand management policies work together to reduce the elasticity between transport and economic growth. Previous trends suggest that this is unlikely to be achieved unless analogous structural changes and policy levers similar to those already observed in the energy sector emerge.

Chapter 4

The Analogy Between Energy and Transport.

> Analogy pervades all our thinking, our everyday speech and our trivial conclusions as well as our artistic ways of expression and the highest scientific achievements.
>
> Polya (1945) *'How to Solve It'*, page 37.

4.1 Similarities in the Development of Energy and Transport.

Energy and transport are directly linked in many ways. Firstly because transport is a major consumer of energy, and secondly because they both have strong impacts on the physical, social and economic environments. In particular, these similarities have meant that both areas of policy at one time or another have been afforded a strategic status in Government's long term economic, social and political plans. The debates about the best policy to respond to the 1989 road traffic forecasts were comprehensive and also quite polarised. This was reminiscent of the energy policy debates which occurred after the 1973/4 OPEC-inspired oil price increases which had stimulated a re-assessment of Government's energy policy strategy (see for example de Man, 1987). The realisation that these two events represent important watersheds in the way that policy in each sector was dealt with (at least by policy analysts and academics), suggests the existence of a much wider and significant pattern of resemblance in the development of the two policy sectors. Table 4.1 summarises this pattern and shows that there is a strong analogy in the development of energy and transport policy, leading up to the introduction and advocacy of demand-side management.

Table 4.1: Parallels in the development of UK transport and energy policy.

	Energy	**Transport**
Adverse policy conditions	caused by growth in dependence on oil, and projected growth in consumption as well as technological uncertainty.	Caused by concern over growth of transport and technological uncertainty.
led to supply side solutions	Production of North Sea oil and gas was stepped up, nuclear energy was seen as a way of securing cheap and plentiful quantities of electricity.	Prevailing philosophy has been that growth should be met with increased investment in extra road capacity.
but which conflicted with environmental objectives,	Fossil fuels are non-renewable and are a major source of air pollution, whilst nuclear power is risky and has proved costly.	Roads have become congested, transport has become the largest consuming energy sector and a major source of air pollution.
This in turn has led to demand side solutions including:	. improving the energy efficiency of devices and processes; . promoting energy conservation by influencing energy consuming behaviour.	Some initial responses include: . land use planning to reduce latent demand for transport . changes in working practices to reduce the need for transport.

The vital difference in the development of policy within the sectors is that the general shift towards demand management occurred earlier in energy. Until recently, developments in transport have distinctly lagged those in energy; the notion of an impending crisis in transport is relatively recent, whereas energy policy was exposed to shocks as early as the Suez crisis in 1956. At the same time, the current increase in environmental awareness which has permeated many areas of policy-making, has shrunk the gap between the development of ideas in energy and transport. Most importantly, however, energy policy has a rich history of demand-side management, strategic planning, forecasting and scenario analysis, which is absent in transport. The pattern of similarities in table 4.1 suggests that a further exploration of the nature, significance and meanings of the various similarities between the two sectors would provide a range of insights into the relationship that exists between them as well as the comparative nature of the areas themselves. Any parallels could provide a mechanism for relating the experiences of energy policy to those of present day transport policy, which in turn, may act as a valuable tool for generating and anticipating the success of various future transport policies.

4.2 Similarity and Analogical Reasoning in Comparative Analysis.

There is a large body of literature covering the theory of analogical reasoning applied to a diverse collection of studies, including: linguistics; artificial intelligence; logic; and philosophy (see for example Helman, 1988; Vosniadou and Ortony, 1989a; Lakoff and Johnson, 1979). The pattern of similarities between the development of energy and transport suggest a stronger analogy. Theories that logically analyse the relationship between similarity and analogy provide the basis for understanding the role of comparison in this type of cross-sector comparative analysis (see for example Gentner, 1989b; Vosniadou and Ortony, 1989; Turner, 1988; and Mazlish, 1965).

Analogy is usually dealt with as a form of primitive logic (Mazlish, 1965). Analogy has been defined as:

> 'a process of reasoning whereby we conclude, from the fact that all members of a group are known to have certain characteristics and that some members are known to have other characteristics, and therefore it is likely that the remaining members possess these additional characteristics as well' (quoted in Mazlish, 1965:5).

Within management studies, analogical reasoning has been recognised as a tool for problem solving described as a device of anticipation or as a guide to 'scientific' understanding (VanGundy, 1988; de Bono, 1970), whilst from other perspectives analogies have been described as beginning from a not-so-scientific 'unanalysed feeling of vague resemblance' (Mazlish, 1965). The similarities described in table 4.1 form part of a basic 'feeling of resemblance' between the energy and transport sectors. Particularly with historical analogies (for example when the French revolutionaires thought that they were merely doing what the virtuous republicans of Rome had done before them, or when the Nazi concentration camps were likened to the Southern treatment of Negroes) (Mazlish, 1965), analogies provide an original, an archetype, offering the secure feeling of familiar experience.

Analogical reasoning involves the transfer of a variety of types of information from a situation that is familiar (usually referred to as the 'source domain') to one which is to be explained or worked upon (referred to as the 'target domain'). The way the analogy is processed depends upon the extent of the learner's prior knowledge of the source and target domains. 'Pure matching' occurs when something is already known about both the source and the target domains; the analogy conveys that a relational system in the target domain matches one in the source domain. In such a case the analogy focuses attention on the matching system rather than conveying new knowledge. When little is known about the target domain the insights derived from analogical reasoning are determined from the object correspondences that are carried over from the source. Most analogies lie on a continuum between pure matching and pure carry over (Gentner, 1989). Apart from this distinction, relationships between source and target domains can be distinguished between those whose source and target are 'between-domain' and those where source and target are 'within-domain'. Between-domain analogies are drawn from conceptually different or remote domains (for example heat and water), whilst within-domain analogies are drawn from the same domain, or at least from conceptually very close domains (such as mug and cup).

Similarity plays a key role in some of the processes associated with analogical reasoning (see for example Vosniadou and Ortony, 1989b). The intensity of similarity between source and target can be divided along two basic dimensions: 'surface similarity' versus 'deep similarity' (see for example Vosniadou, 1989; Holyoak and Thagard, 1989); and 'object similarity' versus 'relational similarity' (see Gentner, 1989).

Surface similarities are characterised by simple, descriptive properties of the source and target (Vosniadou, 1989). These identities play a key role in determining how an analogical relationship is perceived in the first place. Deep or 'structural' (Holyoak and Thagard, 1989) similarities are identities that influence the transfer of information from the source to the target and determine whether or not the analogy is productive in the sense of providing new knowledge about the explanatory structure of the target. For example, an analogy between the Earth and the Moon used to discover if the moon has a day/night cycle or not, has surface similarities such as both bodies are spherical, solid, suspended and rotating, but also has deeper similarities in the sense that there is a causal relation between axis rotation and the existence of a day/night cycle on both the Earth and the Moon. Our initial observations which indicated a vague feeling of resemblance between the energy and transport sectors were examples of surface similarity. Later, through a purposeful analysis of the similarities between the two sectors, deeper similarities are observed; such as the idea that energy and transport are both derived demands.

For a particular comparison, the distinction between surface and deep similarities is not necessarily static in time. As an analogy is recognised and perceived, what was initially a deep similarity may eventually become a more familiar surface similarity. This dynamic process is at the heart of theory on knowledge acquisition, and demonstrates that even apparently obscure matches may become useful later on.

The second basis for distinguishing different kinds of similarity is proposed by Gentner (1989). Gentner makes a distinction between object attributes (one-place predicates) and relational attributes (two-or-more-place predicates). An example of object attributes related to the Earth could be 'solid' and 'spherical'. A good example where a common relational system holds is in the analogy between heat and water; pressure differences cause water flow, and temperature differences cause heat flow. Gentner (1989) gives an argument for the primacy of relational similarity:

> 'Thus an analogy is a way of focusing on relational commonalities independently of the objects in which those relations are embedded. In interpreting an analogy, people seek to put the objects of the base [source] in one to one correspondence with the objects in the target so as to obtain the maximum structural match. Objects are placed in correspondence by virtue of their like roles in the common relational structure; there does not need to be any resemblance between target objects and their corresponding base objects' (Gentner, 1989: 201).

It is possible to distinguish different types of similarity by considering the number of object and relational attributes that the source and target have in common. Table 4.2 lists five different kinds of domain comparisons.

Table 4.2 Kinds of domain comparisons.

	Object Attributes	**Relational Attributes**	**Example**
Literal similarity	Many	Many	Milk is like water
Analogy	Few	Many	Heat is like water
Anomaly	Few	Few	Coffee is like solar system
Mere appearance	Many	Few	The glass table top gleamed like water
Abstraction	Few	Many	Heat flow is a through-variable

source: Gentner, 1989

The table shows how there are 4 distinct ways of combining high and low numbers of object and relational attributes (the first four examples). A fifth category (abstraction) can be distinguished from an 'analogy' due to the absence of any concrete properties of objects in the source domain (in the example shown, 'through variables').

As with surface similarity, object attributes seem to play an important role in accessing an appropriate analogy, whilst relational systems have been found to be important in determining the subjective 'goodness' of an analogy (Gentner; 1989: 228). Hence a good analogy depends upon both the number and significance of relational attributes that are matched or carried over between the source and the target.

4.2.1 Relationship Between Source and Target.

When a vague resemblance was first perceived in the case of the energy-transport study, it was energy that was acting as the source and transport that played the role of the target. A comparison of the intrinsic properties of energy and transport is essentially comparing two conceptually distant domains; for instance, energy is usually defined as the potential to perform work and transport as the movement of goods and people. Hence at the level of intrinsic similarity, the source and target of the analogy are between-domain (like heat and water). In contrast, a comparison of the planning and decision-making processes, and the actions of organizations and individuals within the two sectors is a within-domain analogy (like mug and cup). The occurrence of these two different types of analogy can be understood by considering just what exactly is meant by the notion of 'an analogy between energy and transport'. Terms like 'energy' and 'transport' are abstractions, that when used in the context of policy can usually be 'unpacked' into sub-concepts or categories such as 'nuclear power' or 'public transport' which are then discussed at these different levels. Consequently, an analogy between energy and transport, can itself operate between different sub-categories and between different 'arenas' (Wright, 1988). Thus the general notion of an analogy between energy and transport is made up of both within-domain and between-domain comparisons.

4.2.2 Surface versus Deep Similarities.

The initial or 'surface' similarities between energy and transport were summarised in table 4.1. Further investigation of the similarities between the two sectors produced a range of deeper relationships which can be summarised in terms of Majone's three policy spaces (see section 2.2 and table 2.1).

4.2.2.1 Similarities in the Problem Space.

(a) Short term demand for mobility and fuel is highly inelastic. In the case of transport, freak weather conditions or any situation that disrupts transport supply reveal how important and inelastic our demand for mobility is. Similarly disruptions in the supply of oil, coal and electricity highlight the same effects;

(b) Transport and energy both have potentially high cross-elasticities between modes of travel and primary fuels respectively (Button 1982; Goodwin, 1988; Cook and Surrey, 1977). The mobility that is demanded can be supplied by a variety of means. Passengers can travel by private or public transport and easily change their travel patterns by swapping modes. Freight can in some cases be forwarded part of its journey by rail instead of wholly by road. Similarly industrial energy users can move from solid to liquid to gaseous fuels and back again. In the long term, distortion of demand for particular modes of transport can occur without coordination in the pricing of each mode;

(c) Transport and energy are both derived demands. That is, in both cases it is not, for example, the car journey or the electricity that is demanded per se, but the benefits that these bring;

(d) The transport debate, like the 1970s and 1980s energy debate is fuelled, in part, by prevailing uncertainties about future demand and supply, particularly with regard to technological uncertainty (Cook and Surrey, 1977; Ferrary, 1992);

(e) The cost of transportation, like the cost of energy, is an important item in the domestic budgets of lower income groups (see Donald and Pickup, 1989; Boardman, 1991). Transport deprivation seems analogous to fuel poverty (see also Dilnot and Helm, 1987);

(f) Energy and transport projects, both those concerned with infrastructure and those concerned with new system technologies, have long lead times and operating lives. Power stations and new roads typically have lead times of around 10 years, and last several decades;

(g) Both sectors have fringe technologies which can be perceived as insurance against future needs, rather than optimal solutions. In energy there are renewable energy resources which could be exploited. In transport, light rail, metabolic transport, and telecommunications might all, if needed, play a bigger role in any transport strategy. The potential for walking and cycling together with optimism that perhaps there may be new and significant developments in transport technology seem to be playing a similar role in transport policy to that played by renewable technologies and R & D in 1970s and 1980s energy policy;

(h) Energy and transport production and consumption have associated with them major environmental and social externalities such as atmospheric pollutants, noise, vibration and resource depletion.

4.2.2.2 Similarities in the Actor Space.

(a) Individual organisations with stakes in both the transport and the energy sectors can disclaim responsibility for the distant future and base their decisions on financial criteria. Since financial criteria do not capture all the concerns of society, government has a responsibility to coordinate any long term strategy;

(b) Both sectors have inspired polarised solutions to some of the problems they have faced. In energy the polarity was seen most clearly in the 'nuclear' versus 'anti-nuclear' lobbies, and within transport the polarity is manifest in the 'pro' and 'anti' roads lobbies;

(c) There is a growing consensus in the transport research community that there is a 'gap' about to occur, in that demand for road transport is going to outgrow our capacity to accommodate it. A similar consensus emerged in the energy research community in the mid 1970s with respect to the supply of, and demand for oil (compare WAES, 1977 with Goodwin, 1990);

(d) The evolution of policy in both areas has coincided with dramatic changes in society's perception of the strategic importance of that activity manifest in the notions of 'impending' energy (1973) and transport (1990) crises (see Chapman, 1975; and FTA, 1991).

4.2.2.3 Similarities in Policy Space.

(a) Planning exercises in both sectors traditionally used long term forecasts based on limited uncertainties. The Departments of Energy and Transport have had their own influential forecasting models which have been the basis of much policy (de Man, 1987; DTp, 1989);

(b) In both energy and transport, following the general acceptance that there was a problem, the all-pervading uncertainty made existing forecasting methods inappropriate. In energy they were replaced by a shift towards scenario analysis, but in transport this process is only just beginning (particularly in the UK; there are some studies in the Netherlands see van der Waard and Blom, 1992);

(c) In Britain, the energy sector has been linked with major government information campaigns on energy conservation to increase awareness (DEn, 1981). In the transport sector, information campaigns have been aimed at increasing child, pedestrian and cyclist safety awareness (see Adams, 1990:p34). This suggests there are similarities in the Government's perception of the relevance and effectiveness of information campaigns in the two sectors;

(d) The emergence of a set of traffic demand management measures (including improving public transport, purposely not relieving congested routes, road pricing, traffic management and land use planning) collectively form a policy direction that bears some similarities with the energy conservation developments of the mid-1970s, in that they have the same generic objectives of reducing overall demand and encouraging modal (fuel) substitution;

(e) Current traffic demand management programmes and past energy conservation projects operate within similar sets of constraints such as public co-operation and large capital investment requirements.

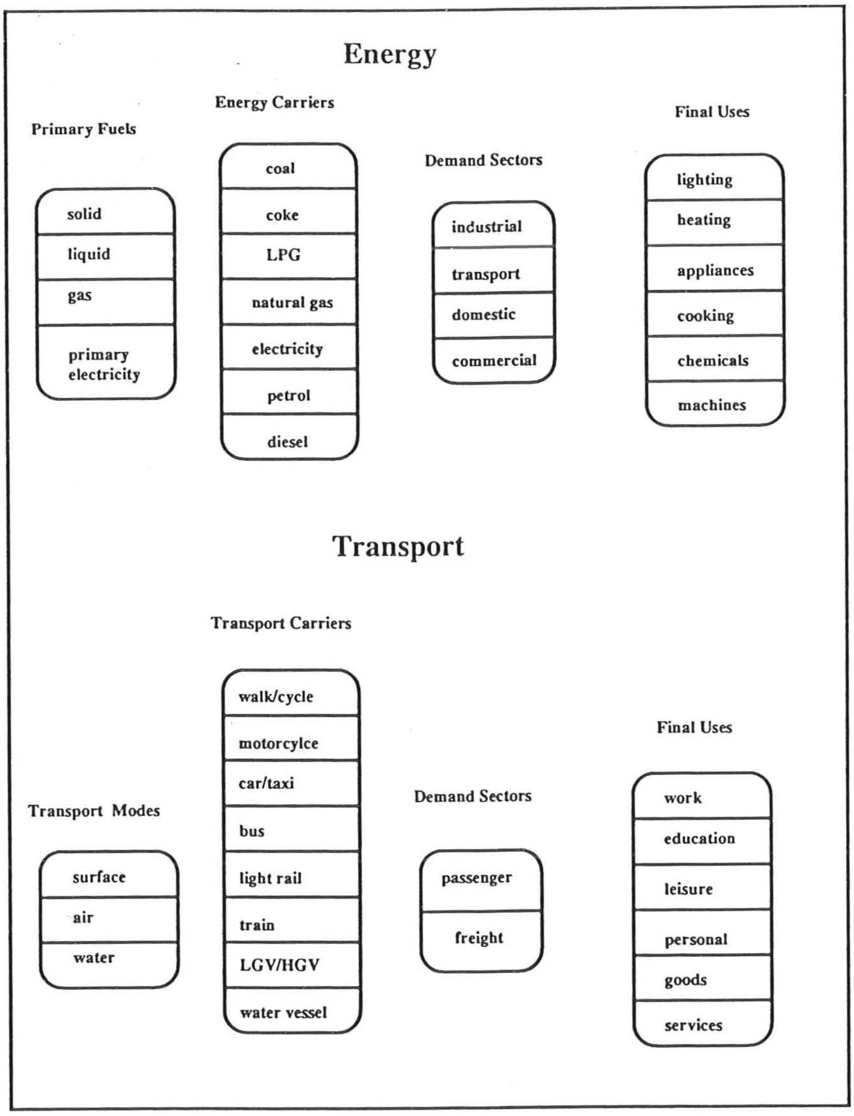
4.2.3 Object Versus Relational Similarities.

Transport and energy are themselves abstractions; they are higher-order system labels. A comparison of characteristics of these categories will itself be a form of abstract reasoning. Both these factors explain the absence of any true object similarities in the energy-transport analogy. Although the surface similarities highlighted in table 4.1 are not explicitly 'object attributes' (e.g. like 'round' or 'solid'), they are 'object relational abstractions' in that they are complex abstract relational attributes which are being matched one-to-one from one sector to another as if they were object attributes. Since the 'goodness' of an analogy is judged by the significance and the number of relational inferences which can be mapped between the source and target domains, the lack of object similarities is not worrying and the large number of significant relational attributes (deeper similarities) in the energy-transport analogy suggests that it is a good one.

4.3 Structural Similarities between the Energy and Transport Sectors.

In addition to the range of similarities identified in section 4.2, a structural analogy between the energy and transport sectors was identified through direct matching. The structures of the energy and transport sectors are each dominated by a number of specific supply elements (primary fuels and transport modes) and a set of demand elements (uses of energy and transport). Figure 4.1 maps out the relationship between some common energy and transport concepts.

Figure 4.1: The analogy between energy and transport: some structural similarities.



The columns on the left list what are probably the commonest perception of both sectors' structures; with energy there are the basic fuels, and in the case of transport there are the various transport modes. Fuel derivatives or 'energy carriers', such as petrol and diesel become analogous with different ways of travelling e.g. by car, walking or bus (the 'transport carriers'). The third column lists the areas that are conventionally associated with the different types of consumption (with energy there are the domestic, industrial, transport and other sectors, and in transport there are the passenger and freight sectors). Finally, the right-hand columns list the different 'end' uses that the demand for energy and transport is derived from in the first instance (in energy these are lighting and cooking etc., and in transport they are travel to, from and in course of work, education etc.).

The framework is useful because it can be used to interpret patterns in the relationship between structural elements in transport, in terms of past patterns between structural elements in the energy sector. For example, the post-war decline in coal consumption and steady rise in consumptions of petrol and natural gas (figure 3.1) can be likened to an analogous pattern in the transport sector, where there has been a decline in train, bicycle and bus transport, but a steady increase in the proportion and absolute amount of transport by car and taxi (figure 3.12).

Evidence in support of the structural analogy in figure 4.1, comes in both the energy and transport sectors, from the way that policy is dealt with at various stages in the policy process. The structure is implicit in the way energy and transport problems are defined, analysed and implemented; table 4.3 uses examples taken from the two sectors to summarise this.

Table 4.3 Evidence for the structural analogy.

Stage in Process	**Energy Sector e.g:**	**Transport Sector e.g:**
Problem Definition	Secondary Electricity vs Primary Electricity	Cars vs Heavy Goods Vehicles
Policy Evaluation	Split according to type of user e.g., domestic or industrial	Fundamental split between passenger and freight
Programme Implementation	Concentrate on lighting or heating requirements	Concentrate on journey to work or leisure journeys

The definition of energy and transport problems are characterised by uncertainty and confusion surrounding the nature of the problems themselves. For instance, there has been widespread confusion over the relative merits of fossil fuel derived electricity versus electricity generated from renewables and nuclear power (see Holman, 1992) and in the transport sector, the relative importance of cars and lorries as major source of congestion is disputed (see Goodwin, 1991:43).

The structures in figure 4.1 are also implicit in the way energy and transport policies are evaluated and monitored. In the energy sector, separate schemes for different types of energy user were developed ('Industrial Energy Thrift Schemes' and the largely domestic 'Save it' campaign), whilst transport policies are targeted to the needs of either passenger or freight movements, even though they often share the same networks and are both integral parts of economic activity. Finally, experience with the implementation of energy efficiency schemes demonstrates that policies are targeted on specific end uses such as space heating or water heating (see Bridger Robinson, 1991), whilst transport demand management has begun to identify and then target specific travel purposes such as travel to work or for leisure, or the irrational movement of products and raw material (see Short, 1992).

Hence, the case for the structural analogy is strong. It focuses attention on those elements in the energy and transport policy processes that are equivalent, promotes analytical consistency and increases the chances of discovering comparative themes, suitable for more detailed follow-up research.

4.4 Differences Between Energy and Transport: Limitations of the analogy.

Energy is not transport, and there are, of course, differences between the two sectors. One point in particular (1) sets energy apart from transport, and in turn is related to three others (2, 3 and 4):

1. The existence of international energy markets gave the energy problem a dimension that is largely missing from the transport problem (although there are international passenger and freight markets, these are not the principal source of most transport problems);

2. Energy policy had direct, proven, and accepted links with macroeconomic policy including implications for the balance of payments, employment and Government revenue. Transport policy is not held to be so strongly related to any of these. However, a recent Government paper did call for more research to be undertaken into the link between road infrastructure and economic growth (HMSO, 1989a-vol I);

3. There is no direct corollary in transport policy for the fears over the security of energy supply that existed post-1973 (HMSO, 1978). Perhaps the notions of a 'gridlock' jamming London as a result of a particular set of incidents or congestion strangling industrial competitiveness come nearest to the concept of fear or anxiety in transport; and

4. The environmental pressure which helps fuel today's transport problem did not receive much attention in the debate about energy policy (the concerns over the environment were largely confined to the side-effects of nuclear power). Since the mid 1970s, environment policy has gradually evolved into an influential area of public policy in its own right, giving an added dimension to the current problems of transport, particularly via concerns over the greenhouse effect and upper atmospheric ozone depletion.

4.5 Conclusions.

This chapter has compared energy and transport and explored the nature of the similarities between them, The analysis is not exhaustive and the emerging structural analogy is not intended to be presented as rigid and static. Good analogies are determined by the life they take on in the mind of the individual (de Bono, 1970). This subjectivity is an inherent feature of exploratory comparative analysis and although analogical reasoning has been defined as a form of reasoning that is peculiarly liable to yield false conclusions from true premises (Bullock et al., 1990), human logic is capable of processing analogies and disregarding ridiculous or non-sensible conclusions. This type of filtering process will differ from person to person, and as such could be described as a 'craft' (see Majone, 1980). Used in a sensible and meaningful way, the energy-transport analogy could be capable of delivering a great deal of insight.

The ultimate purpose of comparative research should be to identify suitable comparative themes which can then be studied in depth (Kohn, 1987). The next three chapters of this dissertation deal in more depth with topics derived from the three specific areas were the structural analogy was originally identified, and where transport may benefit from a rich history of energy policy analysis.

Chapter 5

New Indicators for Transport Policy Analysis.

5.1 Information and its Role in Policy Analysis.

There is a need for simple and effective communication of quantitative information throughout the policy process. In many areas of public policy, indicators are developed to give a simpler picture of what is happening; complex changes in the growth of the economy are boiled down to a single measure such as Gross Domestic Product or the Retail Price Index, and diverse information about vital changes in the environment are combined in a single environmental index (see Hope et al., 1991). However, there is a price to pay when simplifying data from a world which is complex and 'happily multivariate' (Tufte, 1990); the balance is between the disadvantages gained from using simple or crude information to promote effective action, and the problems of dealing with complex and confusing information which could have even greater disadvantages. The information which is collected, analysed and eventually presented within the policy process does not represent an objective and independent view of the world, because ultimately its flow depends on the actions and inactions of various actors and organisations who identify, collect and report the information. Selected criteria are panned out of the background flux of information and reported because of their perceived subjective relevance and importance. These subjectivities and preconceptions become important in determining any behaviour subsequently induced by such selective analysis, and so, the world as it is perceived is partly a human construct.

Rational evaluations of policy-making centre on the inputs and outputs of the policy process, with net output (defined as output minus input) as a criterion for evaluating the efficacy of various policies (Dror, 1989). However, such inputs and outputs range from specific and quantifiable attributes such as labour, capital and time, to fuzzy, ill defined attributes such as skills, values and knowledge. However, many of these outputs are intangible and cannot be quantitatively measured; some of them even defy qualitative formulation (Dror, 1989: 26).

The methodological problems of measuring changes in usually qualitative and broad primary output criteria (such as 'improvement of transport situation') lead to the use of more specific and quantifiable secondary criteria (such as traffic flow) (Dror, 1989). As indicators of the state of a problem, secondary criteria perform two main tasks; firstly they help decision makers assess the magnitude of the problem and secondly they help them to become aware of the scale of the changes following any policy actions (Kingdon, 1984: 95). Policy makers often consider a change in an indicator to be a change in the problem situation. The choice of secondary criteria are therefore related to changes in the problem situation through the actions they promote.

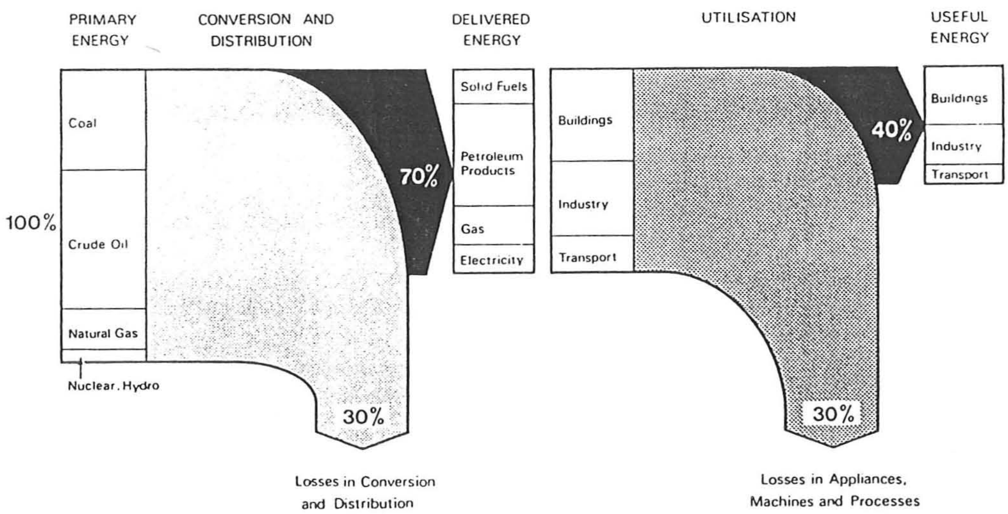
5.2 A New Unit in Transport Policy Analysis.

The key to the development of some new secondary criteria for analysing transport policy is held in an important development in the way information about the consumption of energy was handled. In April 1976, the OECD published, for the first time, energy statistics that used a common unit of energy (OECD, 1976). This method is still used and has become an established part of energy accounting. The introduction to the OECD report stated:

> Analysis of energy policy problems requires a comprehensive presentation of basic statistics in original units such as tons of coal and kilowatt hours of electricity. The usefulness of such basic data can be considerably improved by putting them in a single common unit suitable for uses such as estimation of total energy requirements, forecasting and the study of substitution and conservation (OECD, 1976:4).

The common unit (tonnes of oil equivalent with 1 tonne of coal = 0.7 tonnes of oil equivalent) has made it possible to combine energy consumption statistics for all sectors and fuels into one single measure. In this way it is possible to state, for example, that in 1989, the UK used 340 million tonnes coal equivalent of primary fuels. Using the common unit, figure 5.1 shows the three conventional measures of energy consumption within the economy.

Figure 5.1: The flow of energy in the economy.



source: DEn, 1990

Energy consumption measured on a primary fuel input basis assesses the total input to the economy of primary energy (left of figure 5.1). This measure includes energy used and lost in the conversion of primary fuels into secondary fuels (for example in power stations and oil refineries). The second measure, known as consumption by final users (or delivered energy), relates to inputs of fuels to houses, factories, vehicles and other users. This measure excludes fuel industry own use and conversion, transmission and distribution losses, but includes conversion losses by final users (for example waste heat and noise in car and lorry engines). The third measure, useful consumption by final users (on right of figure 5.1) represents the actual useful work derived from a particular fuel used in a particular way. It excludes losses when final users convert energy supplied to them into heat, motive power or light. These losses depend not only on the type and quality of the fuel, but also on the equipment used (e.g. modern gas boilers are more efficient than older models, and new car engines are significantly more efficient at using energy than they were some years ago). Without a common unit of energy consumption, it is clear that figure 5.1 could not be drawn, and the subsequent insights for energy accounting that it has led to could not be obtained.

An analogous framework for measuring transport activity within the economy which also requires a common unit and corollaries of the primary and final measures of energy consumption is developed in this chapter. Transport activity is conventionally measured in terms of goods and passengers moved; the nearest analog of this in the energy sector is the 'useful' measure of energy consumption. Transport use is estimated or measured from overall levels of observed activity without any attempt to disaggregate the different components of the activity (e.g. transport own use of transport). Seven out of the eight units conventionally used for measuring transport activity have drawbacks in this respect:

(i) converting the more fundamental unit of tonne kilometre into passenger kilometre does not seem appropriate;
(ii) goods lifted (tonnes) is related to the handling of freight (there is no clear analog for passengers);
(iii) users' expenditure is not commonly used in energy as a combined unit, and does not take into account distance travelled;
(iv) journeys and (v) journey stages are not appropriate as common units as they do not take into account distance travelled;

(vi) freight and passenger transport energy consumption is not only dependent on the overall level of activity but is also greatly dependent upon the efficiency of vehicles that use the energy. Transport energy consumption is dependent on mass, rolling and other resistances, and distance moved. Resistances can vary greatly, and as such energy consumption is not a reliable unit for measuring transport activity; and
(vii) vehicle kilometres are not appropriate as there are large differences between the size of vehicles (ships and trains are much larger than cars);

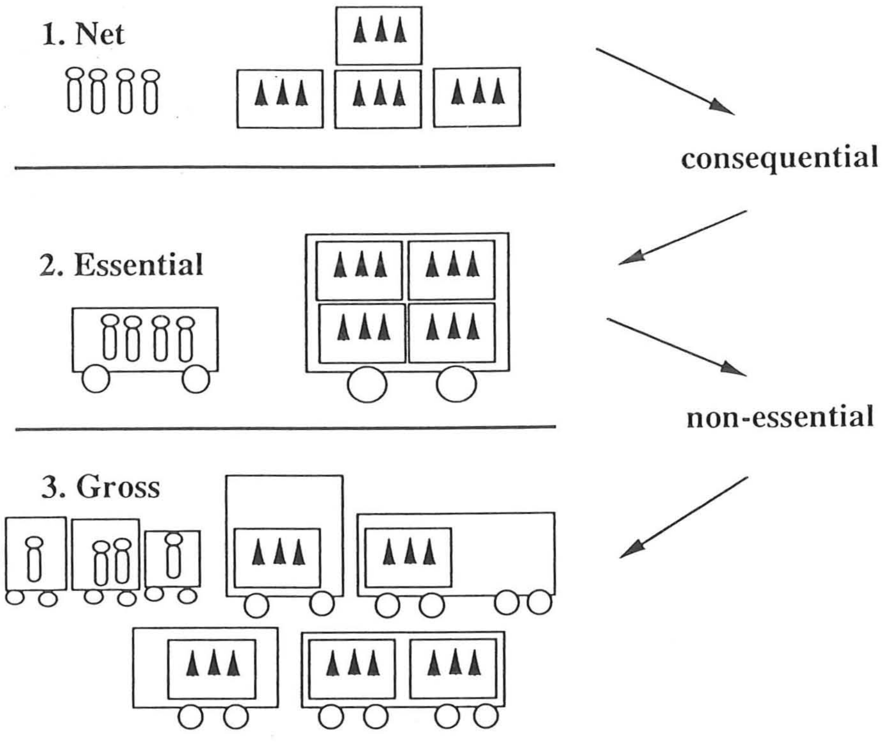
However, since freight activity is already measured in tonne kilometres, an aggregate mass movement measure of *total* transport activity can be achieved by transforming passenger kilometres into their 'tonne kilometre equivalents'. If, for example, the average passenger weighs 50 kgs, then 20 passenger kilometres will, in 'freight terms', be equivalent to 1 tonne kilometre. It could be argued that this conversion of passenger kilometres is flawed, as it appears to give equal importance to 20 passenger kilometres as it does to 1 freight tonne kilometre, although the work that follows shows that this criticism is misplaced: the extra importance of the 20 passengers is reflected in the much greater mass of transport carrier that they typically rely upon. In any case, existing measures of passenger and freight activity are not without their drawbacks; they make no distinction between the nature of the journey or the types of goods being transported (an emergency journey to hospital is very different from a shopping trip and a tonne of coal is very different from a tonne of electrical goods). Moreover, Hillman (1992) notes that travel distance is over-emphasised as a variable in analysis of transport policy, as it implicitly attaches more importance to longer journeys than shorter ones. The mass movement measures introduced here are designed to transcend the divide between passenger and freight transport and to be capable of aggregation to the extent that they incorporate the *whole* transport picture, representing an open and unbiased form in which transport statistics can be presented and interpreted.

The remainder of this chapter investigates how the idea of a common unit can be taken further and used in transport policy analysis. Three different measures of transport activity are suggested, which are in many ways analogous to the three measures of energy consumption described earlier, and the methods for constructing them over the period 1952-1991 are given. The methods rely on using existing data combined with a new set of parameters capable of transforming this data into the common unit. The results obtained by using these measures are therefore sensitive to the uncertainties in these new parameters. A set of initial results are used as a basis for a sensitivity analysis to find those parameters that have greatest effect on the initial results obtained. In this way, several key parameters are identified and investigated further to improve the accuracy of the new mass movement data. The chapter then goes on to consider the relationship between the mass movement measures and economic activity over the period, through the construction of a series of mass movement intensities. Finally, the chapter considers the relationship between the mass movement measures and other environmental data.

5.3 Three Measures of Transport Activity.

Transport analogues of the useful, final and primary measures of energy consumption are schematically represented in figure 5.2. The net mass movement measure takes account of how many or how much, and how far, passengers and freight are transported (this is currently the most common method of reporting transport statistics). Its nearest energy equivalent is the useful measure of energy consumption. The essential and gross measures of transport activity differ from net, by taking into account the additional mass movement of the carrier itself. Essential mass movement is the minimum movement of all carriers that is required to accommodate net mass movement with a given modal split. Thus, essential mass movement varies not only with the absolute level of net activity, but with the composition of the net mass movement (modal split) too. The difference between net and essential mass movement is termed 'consequential activity' as it is the minimum necessary extra mass movement needed to accommodate the net mass movement under the same modal split conditions.

Figure 5.2: Net, essential and gross measures of transport activity.



Gross mass movement is the reported movement of both passenger and freight vehicles and their contents plus, in some cases, corrections for extra movements not reported in published statistics. As most transport (i.e. mass movements) of whatever kind cause some degree of environmental problem, gross mass movement is the natural measure of transport activitiy to employ.

The difference between the gross and essential measures of activity is termed 'non-essential' mass movement, as it represents mass movement that theoretically could be avoided without changing net activity or modal split. The energy analogue of the essential measure is related to the maximum 'useful' activity from a particular level of gross, whilst the transport analogue of final energy consumption is the gross measure minus transport industry own use of transport (see section 6.5). The methods for calculating net, essential and gross mass activities are discussed next.

5.3.1 Net Mass Movement: Method.

The goods moved measure of freight transport is already a net mass movement measure. Passenger statistics, which are usually given in terms of passenger kilometres, have to be transposed to their equivalents in tonne kilometres. Passenger transport activity in passenger kilometres ($P_{carrier}$) is provided annually by the DTp for each type of carrier.

Passenger activity for a particular carrier can be transformed from passenger kilometres into its equivalent in tonne kilometres by using an estimate of the average mass of a person (parameter c in table 5.1). The net activity associated with any carrier, $N_{carrier}$, can therefore be calculated from $P_{carrier}$ using equation 5.1:

$$N_{carrier} = P_{carrier} * c \qquad (5.1)$$

For freight activity, the net activity associated with a particular carrier, $F_{carrier}$, is already measured in tonne kilometres, and so can therefore be written as in equation 5.2:

$$N_{carrrier} = F_{carrier} \qquad (5.2)$$

The DTp does not regularly publish statistics on walking as part of transport activity; this and the transformation of passenger kilometres into tonne kilometre equivalents are estimated using the parameters in table 5.1.

Total net transport mass movement, N, is then the sum of $N_{carrier}$ over all passenger and freight carriers:

$$N = \text{sum over carriers } [(P_{carrier} * c) + F_{carrier}] + (a * 52b * c) \qquad (5.3)$$

Table 5.1: Parameters employed in estimating net mass movement and walking activity

code	parameter	value	units	source
a	population	55	million	CSO, 1992
b	average distance walked per person per week	8.6	kilometres	DTp, 1988
c	mass of average person	0.05	tonnes	assumed

5.3.2 Essential Mass Movement: Method.

For a particular level of net activity, total essential mass movement is calculated by assuming all carrier movements occur at maximum occupancies or payloads, with no change in the modal split of net movement among the carriers.

Table 5.2 summarises the further parameters that are required to calculate an initial estimate of the trends in essential and gross mass movement measures over the period.

Table 5.2: Additional parameters used in essential and gross mass movement calculations.

Code	Parameter	Values	Units	Source
d	U_{cycle} [1]	0.02	tonnes	assumed
e	$U_{motorcycle}$	0.1	tonnes	assumed
f	U_{car}	1.0	tonnes	What Car, 1992
g	U_{bus}	7.0	tonnes	Transport Engineering, 1991
h	U_{ptrain}	250	tonnes	Marsden, 1987
i	U_{plane}	45	tonnes	Barrett, 1991
j	U_{LGV}	1.5	tonnes	Martin and Shock, 1989
k	U_{HGV}	4	tonnes	Transport Engineering
l	U_{ftrain}	350	tonnes	Marsden, 1984
m	U_{ship}	745	tonnes	Alderton, 1984
n	O_{ship} [2]	2000	tonnes	DTp, 1991b
o	XRF_{ptrain} [3]	0.3	no units	DTp, 1992b
p	XRF_{ftrain}	0.5	no units	DTp, 1992b
q	XRF_{ship}	0.7	no units	assumed
r	$M_{motorcycle}$ [4]	1	passengers per carrier	assumed
s	M_{car}	4.3	passengers per carrier	What Car, 1992
t	M_{bus}	60	passengers per carrier	DTp, 1992
u	M_{ptrain}	324	passengers per carrier	Marsden, 1987
v	M_{plane}	170	passengers per carrier	Barrett, 1992
w	M_{LGV}	1.75	tonnes per carrier	Martin and Shock, 1989
x	M_{HGV}	8	tonnes per carrier	DTp, 1991
y	M_{ftrain}	650	tonnes per carrier	Marsden, 1984
z	M_{ship}	2130	tonnes per carrier	Alderton, 1984

[1] U represents unladen carrier mass; [2] O represent implied carrier occupancy; [3] XRF represents an extra running factor which must be added for some carriers; [4] M represents maximum carrier occupancy.

The table also shows an initial estimate of their values and the sources from which they were estimated. The net movement that a carrier accounts for ($P_{carrier}$ or $F_{carrier}$) is divided by its maximum load, ($M_{carrier}$), from table 5.2 to give:

$V_{carrier} = P_{carrier}/M_{carrier}$, (passenger carriers) (5.4)

$V_{carrier} = F_{carrier}/M_{carrier}$, (freight carriers) (5.5)

where $V_{carrier}$ is the minimum number of vehicle kilometres needed to transport $N_{carrier}$ (with modal split remaining constant). Once $V_{carrier}$ has been calculated, essential mass movement for that carrier, $E_{carrier}$, can be calculated as the net movement plus the minimum number of vehicle kilometres times the unladen mass of the carrier ($U_{carrier}$):

$$E_{carrier} = N_{carrier} + (V_{carrier} * U_{carrier}) \quad (5.6)$$

Total essential mass movement is then the sum of $E_{carrier}$ over all carriers.

5.3.3 Gross Mass Movement: Method.

Instead of using the theoretical $V_{carrier}$, the minimum number of vehicle kilometres required, the gross mass movement is calculated using $W_{carrier}$ the actual reported distance that the carrier travels, which is typically much more than $V_{carrier}$. For some carriers (passenger train, freight train and ship), $W_{carrier}$ has to be adjusted by an extra running factor, $XRF_{carrier}$, which corrects for empty running not included in the DTp's statistics and which is actually undertaken. For a gross measure of transport activity, these components should be added and therefore estimates need to be made of the proportion of extra running for each of the three transport carriers (parameters o,p,q). An extra running factor of 0.3 means that for every kilometre given in the DTp's statistics, the carrier actually travels empty an extra 0.3 kilometres. Extra running factors for all other transport carriers are assumed zero. Gross mass movement for a carrier, $G_{carrier}$, is the sum of the net mass transported by the carrier, $N_{carrier}$, plus the product of the total distance travelled by that carrier (including any extra running) and the unladen mass of the carrier, given by;

$$G_{carrier} = N_{carrier} + (W_{carrier} * U_{carrier} * (1 + XRF_{carrier})) \quad (5.7)$$

Total gross mass movement is then the sum of $G_{carrier}$ over all the types of carrier.

For a particular carrier, with a total number of reported vehicle kilometres, $W_{carrier}$, the implied occupancy for that carrier, $O_{carrier}$, is given by:

$$O_{carrier} = P_{carrier} / W_{carrier} \text{ (passenger carriers)} \quad (5.8)$$

$$O_{carrier} = F_{carrier} / W_{carrier} \text{ (freight carriers)} \quad (5.9)$$

$W_{carrier}$ is readily available for all carriers except ships; O_{ship} has therefore been estimated to allow W_{ship} to be calculated (see appendix 9.1.3). Though not used further in the calculations of mass movement, it is worthwhile to calculate $O_{carrier}$ to see how close to maximum occupancy each carrier is in practice. Table 5.3 reveals that for many carriers the implied occupancies or loads are much less than the maximum occupancies or loads.

Table 5.3: Implied occupancies and maximum loads in 1991.

carrier:	$O_{carrier}$	$O_{carrier}/M_{carrier}$ (%)
Passenger[1]		
walking	1.0	100
bicycle	1.0	100
motorcycle	1.1	100
car	1.7	40
bus	9	15
train	120	40
plane	60	35
Freight[2]		
LGV	.15	9
HGV	4	50
freight train	450	70
ship	2000	94

[1] *passengers per carrier;* [2] *tonnes per carrier*

5.3.4 Initial Estimates for Net, Essential and Gross Mass Movements: 1952-1991.

By combining the constant parameter values from tables 5.1 and 5.2 with annual passenger, tonne and vehicle kilometre statistics published by the DTp, a spread sheet model was used to calculate an initial estimate of net, essential and gross mass movements in billion tonne kilometre equivalents over the period 1952-1991.

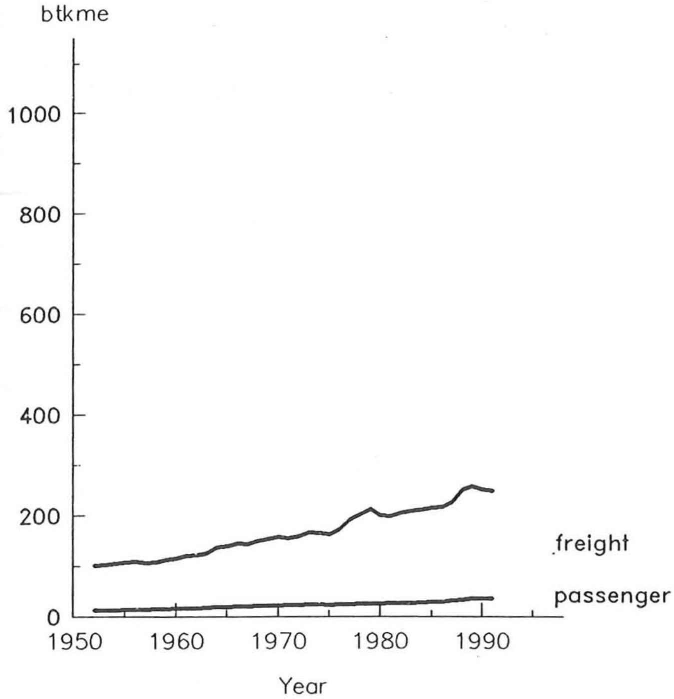
The results are shown in figure 5.3. The four graphs in figure 5.3 are all plotted using the same vertical and horizontal scales to aid cross-comparisons; the first three are cumulative graphs of net, essential and gross mass movement disaggregated into their passenger and freight components and the fourth graph (bottom right) compares the three measures (this is not a cumulative graph).

Total net mass movement doubled over the period, rising steadily from around 100 btkme in 1952 to 248 btkme in 1991. Freight transport accounts for the majority of mass movement by this measure, with the proportion of total mass movement due to passenger movements rising slightly from around 12% in 1952 to around 15% in 1991. Essential mass movement rose from around 200 btkme in 1952 to 515 btkme in 1991. This is approximately double net mass movement throughout the period. The definition of essential mass movement is such that it is linearly and directly dependent on net mass movement, providing the modal split, maximum loads and unladen masses do not change. In this calculation, $M_{carrier}$ and $U_{carrier}$ were held constant by assumption and the observed modal split varied slowly (see figures 3.11 and 3.12). This initial estimate of essential mass movement is therefore practically proportional to net mass movement.

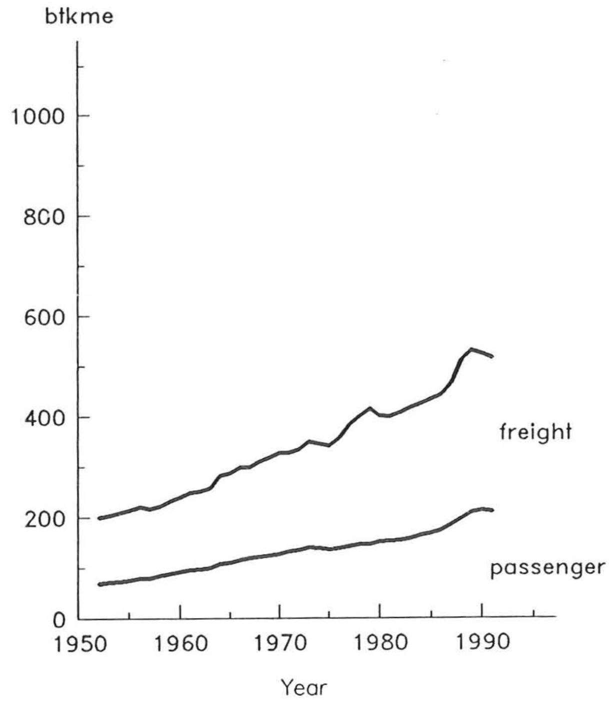
Gross mass movement is shown in the bottom left quadrant of figure 5.3. Total gross mass movement rose steadily over the period from 380 btkme in 1952 to 955 btkme in 1991. Using the gross mass measure, passenger mass movements account for slightly more than half the total mass movement (c.f. passenger component of total net mass movement which is around 15%). The change in the relative importance of passenger transport going from the net to the gross measures is due to differences in the nature of passenger and freight movements. Freight is generally moved more efficiently (in terms of the vehicle contents to the vehicle mass ratio), as it is capable of being transported in batches whereas passengers are less easily dictated to and demand a more spacious and safer environment to travel in.

Figure 5.3: Net, essential and gross mass movement 1952-1991: initial results.

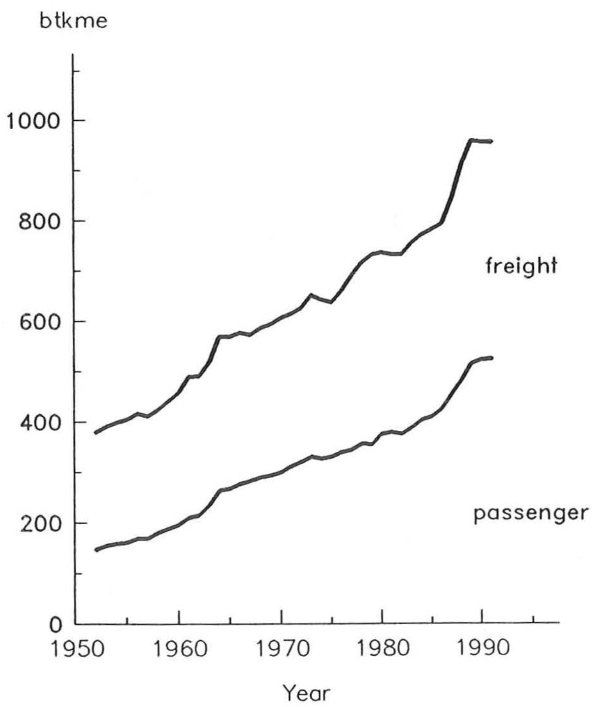
Net: passenger and freight



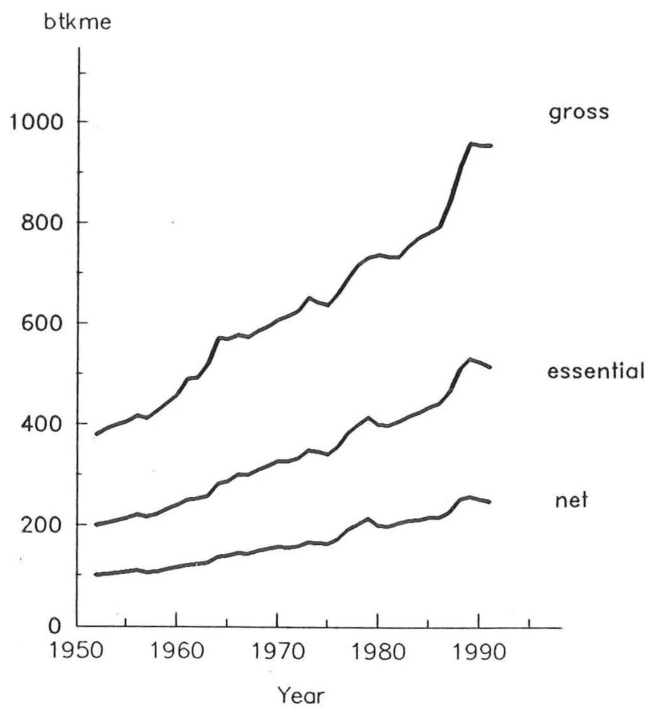
Essential: passenger and freight



Gross: passenger and freight



Total Mass Movement: net, essential and gross



5.4 Sensitivity Analysis of Parameters.

The initial estimates of mass movements in figure 5.3 were simplified by assuming that the parameters have held constant values over the period. There are two types of uncertainty surrounding the true values of these parameters which should be taken into account:

i. the values of some of the parameters may have varied significantly over the 40 year period. For example, as the law has permitted larger HGVs on the road, the unladen mass and payload of an average HGV ought to have increased; and

ii. values of certain parameters are not well known. For example, the average mass of an unladen ship (its light displacement tonnage) is extremely difficult to estimate or calculate.

The results of these initial mass movement calculations will be sensitive to changes in the values of the parameters listed in tables 5.1 and 5.2. A sensitivity analysis of the initial mass movement results to changes in the values of the various parameters will highlight and quantify the relative importance of the effect of changes in the value of each parameter.

In general, for a function F(i,j,k,...), the elasticity of F, ${}^{i}F_{b}$, to changes in an input, i, is given by:

$${}^{i}F_{b} = (dF/F)/(di/i) \qquad (5.10)$$

where dF and di represent small changes in the values of F and i. The sensitivity of F, ${}^{i}F_{s}$, to changes in the values of an input, i, can be defined as the product of the elasticity and the range of uncertainty in the value of i, R^{i}:

$${}^{i}F_{s} = {}^{i}F_{b} * R^{i} \qquad (5.11)$$

where R^{i} is an estimate of the uncertainty in the true value of 'i'. If R^{i} is expressed as a percentage, then ${}^{i}F_{s}$ will also be a percentage. Over the period, this is only an exact expression if the values of R^{i} are small and/or ${}^{i}F_{s}$ is constant (although R^{i} can be large and ${}^{i}F_{b}$ varies over the period, equation 5.11 is a good first approximation of ${}^{i}F_{s}$).

The results of the sensitivity analysis were used to identify those parameters whose associated uncertainties should be reduced by further investigation and analysis. It is important to take into account the uncertainty in the parameters as well as the elasticity of the mass movement measures because it will have a significant effect on the confidence with which the values of the net, essential and gross mass movement measures can be applied. The sensitivities of the net, essential and gross mass movement measures can therefore be written as:

$$^{i}N_{s} = (i/N)/(dN/di)*R^{i} \qquad (5.12)$$

$$^{i}E_{s} = (i/E)/(dE/di)*R^{i} \qquad (5.13)$$

$$^{i}G_{s} = (i/G)/(dG/di)*R^{i} \qquad (5.14)$$

The values of net (N), essential (E) and gross (G) mass movement for the initial calculation, which were used as a basis to calculate the sensitivities, were 248, 515 and 955 btkme respectively. Table 5.4 shows an assessment of the uncertainties associated with the individual parameters and tabulates the results of the sensitivity analysis, which are also shown graphically in figure 5.4.

Table 5.4: Parameters, estimated uncertainties, elasticities and sensitivities.

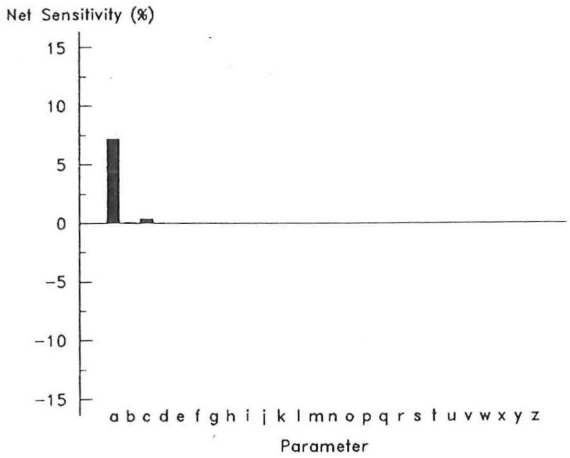
i	parameter	R^{i} (%)	$^{i}N_{b}$	$^{i}E_{b}$	$^{i}G_{b}$	$^{i}N_{s}$ (%)	$^{i}E_{s}$ (%)	$^{i}G_{s}$ (%)
a	average mass of a passenger	50	.14	.07	.04	7.20	3.47	1.87
b	population	10	.01	.00	.00	.05	.02	.01
c	average distance walked\pp\pw	75	.00	.00	.00	.37	.18	.10
d	average mass of unladen cycle	20	.00	.00	.00	.00	.00	.00
e	average mass of unladen m/c	30	.00	.00	.00	.00	.03	.02
f	average mass of unladen car	30	.00	.25	.35	.00	8.01	10.53
g	average mass of unladen bus	50	.00	.01	.04	.00	.52	1.75
h	average mass of unladen ptrain	30	.00	.06	.12	.00	1.84	3.61
i	average mass of unladen plane	20	.00	.00	.00	.00	.05	.09
j	average mass of unladen LGV	30	.00	.01	.06	.00	.27	1.75
k	average mass of unladen HGV	90	.00	.12	.12	.00	10.89	10.93
l	average mass of unladen ftrain	40	.00	.03	.02	.00	1.28	.70
m	average mass of unladen ship	90	.00	.04	.04	.00	2.96	3.34
n	average load on ship	30	.00	.00	-.04	.00	.00	-1.11
o	passenger train XRF	20	.00	.00	.03	.00	.00	.56
p	freight train XRF	20	.00	.12	.01	.00	2.34	.12
q	ship XRF	90	.00	.00	.02	.00	.00	1.37
r	max load per m/c	30	.00	-.00	.00	.00	-.03	.00
s	max load per car	10	.00	-.27	.00	.00	-2.67	.00
t	max load per bus/coach	50	.00	-.01	.00	.00	-.51	.00
u	max load per ptrain	30	.00	-.06	.00	.00	-1.71	.00
v	max load per plane	20	.00	-.00	.00	.00	-.05	.00
w	max load per LGV	30	.00	-.01	.00	.00	-.27	.00
x	max load per HGV	90	.00	-.12	.00	.00	-10.89	.00
y	max load per ftrain	40	.00	-.03	.00	.00	-1.28	.00
z	max load per ship	30	.00	-.04	.00	.00	-1.05	.00

The ranges of uncertainty, R^i, are an aggregation of two components: (i) a static component, which is an estimate of the uncertainty with which the figure accurately estimates the true value in 1991; and (ii) a dynamic component, which is an estimate of the uncertainty which should be attached to the parameter given that it may have changed over the period.

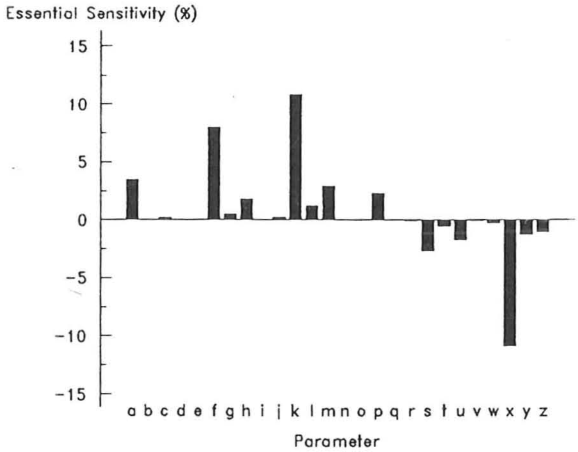
Table 5.4 shows the assumed values of R^i, the calculations for ${}^iF_b$ and the associated values of ${}^iF_s$ for each parameter. The values for R^i shown in table 5.4 are best prior intuitive assessments for the maximum possible error in the claimed value. For instance, the unladen mass of an average bus has a R^i of 50% which means that it is thought to lie somewhere between 50% and 150% of its value in table 5.2 throughout the period, i.e. between 3.5 and 10.5 tonnes. The values of ${}^iN_s$, ${}^iE_s$ and ${}^iG_s$ given in table 5.4 are plotted in figure 5.4. Only three parameters influence the net mass movement measure. Figure 5.4.1 shows that of these, parameter a, the mass of the 'average' person, has a much greater influence on the value of N than the other two. The figure reveals that a one percent uncertainty in the value of parameter 'a' giving ${}^aF_s$=0.14 leads to an associated net sensitivity of 7.2%. In contrast, uncertainties in the values of parameters b and c have a much lesser effect on net mass movement. Data which would help to reduce the uncertainty in R^a is not readily available, as most body weight surveys are carried out within specific groups of people or do not include a consideration of the full age range, 0-65 years, which was used in the sample frame for the National Travel Surveys. Figure 5.4.2 shows the sensitivity of the essential mass movement measure to changes in various parameters. The graph has both positive and negative components; for parameters 'r' to 'z', an increase in their value is associated with a consequent decrease in the essential mass movement. In particular, essential activity is most sensitive to changes in parameters 'f','k' and 'x': the unladen mass of a car, and the unladen mass and the maximum payload of an HGV respectively. Essential activity is proportional to increases in the values of 'f' and 'k' but is inversely proportional to increases in the value of 'x', so that 'x' has a negative sensitivity.

Figure 5.4: Net, essential and gross sensitivities by input parameter.

5.4.1 Net sensitivities by input parameter



5.4.2 Essential sensitivities by input parameter



5.4.3 Gross sensitivities by input parameter

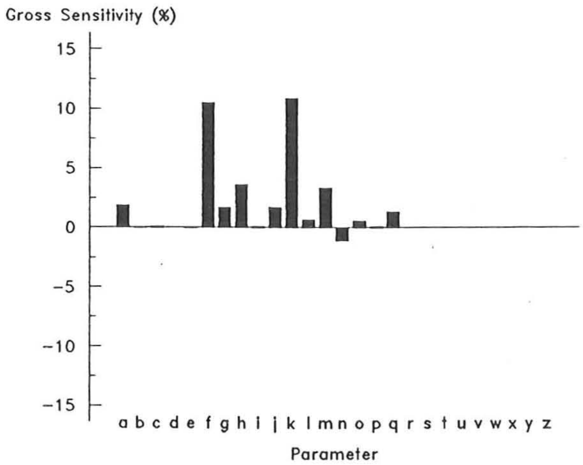


Figure 5.4.3 reveals that gross mass movement is around three times more sensitive to changes in parameters 'f' and 'k' (the average unladen masses of a car and an HGV) than it is to changes in any of the other parameters. An increase in parameter 'n', the assumed average load on a ship, decreases the value of gross mass movement and as such is represented by a negative bar. Parameter 'r' to 'x' are not used to calculate gross mass movement and so have no associated gross sensitivities.

5.5 Refinement of Parameters to Improve Accuracy of Mass Movement Measures.

It would be ideal if the uncertainty surrounding the values of the various parameters could be removed entirely. In practice, however, this is not possible nor may it be necessary, as the mass movement measures are more sensitive to changes in certain parameters than to changes in others, as the results of the sensitivity analysis have shown.

The uncertainty in the net mass movement measure originates almost entirely from parameter 'a', the average mass of a person. However, this uncertainty represents only a small contribution to the overall uncertainty in the absolute value of the essential and gross measures, and it is these measures which have most relevance for policy.

The results of the sensitivity analysis indicate that the greatest uncertainty in the essential mass movement measure is due to uncertainty in the average unladen mass and average maximum payload of an HGV, and the greatest uncertainties in the gross mass movement measure are due to uncertainty in the values of the unladen masses of cars and HGVs.

Therefore, a sensible approach to gaining a more accurate picture of the changes in essential and gross mass movement measures over the period 1952-1991 involves a further investigation of parameters 'f', 'k' and 'x', to reduce their associated uncertainties, rather than just using the values in table 5.2 and 5.3 unchanged over the whole period.

5.5.1 Estimation of Changes in Unladen Mass of Car: 1952-1991.

The purpose of this section is to estimate more accurately how the unladen mass of a car has changed over the period 1952-1991. In the previous calculations (table 5.2) it was assumed to be 1 tonne, held constant over the period. This is reasonable as a first approximation, but intuitively, it was felt that the value of this parameter could have varied by as much as +/- 30 per cent (table 5.4). There are two main reasons for this: (1) technology has improved, designs in the car market have converged on an optimal model which has, in turn, decreased the average unladen mass per unit engine size of a car; and (2) there have been changes in the engine size profile of the vehicle park (towards smaller engine sizes in the 1960s and towards larger engine sizes in the 1980s).

The unladen mass of a car differs from make to make and, within each make, from model to model (see for example What Car, 1991). A precise measure of the total essential or gross mass movement over the period due to cars would require: knowledge of unladen masses of all cars in use or previously in use; knowledge of the car occupancies for each trip; and knowledge of trip lengths for every trip. Clearly, data of this complexity is not available, but an estimate of essential and gross car activity over the period can be achieved using the existing statistics published annually by the DTp. Data on total passenger kilometres by car and total car kilometres are readily available. The high quality of these two statistics (both with 95 per cent confidence limits of around +/- 2 per cent) (DTp, 1991b) suggests that they should be incorporated into the calculation of essential and gross movements.

Using these statistics, essential and gross mass movements for cars may therefore be written:

$$E_{car} = N_{car} + (V_{car} * U_{car}) \qquad (5.14)$$

$$G_{car} = N_{car} + (W_{car} * U_{car}) \qquad (5.15)$$

where N_{car} and W_{car} are derived directly from the reported passenger and vehicle kilometre statistics, and where V_{car} is derived from a combination of these and parameter 's'. The DTp estimates W_{car} by surveying all car traffic movements on a sampling grid which covers all classes of roads (DTp, 1991). W_{car} therefore represents the estimate of total movements of all types of car observed on the road and so the parameter U_{car} should be an estimate of the unladen mass of the 'average' car encountered on the road.

Bearing in mind the heterogeneities in the availability and quality of data over the period, an overall method for estimating the trend in unladen masses was devised which itself consisted of two main sub-methods. The method involves estimating the unladen mass of the average car in four sample years, and then using a linear interpolation across the whole period to refine the unladen car mass parameter in the calculation of the mass movement measures. The chosen sample years were 1952, 1963, 1981 and 1991. A further sample point around mid-way between 1963 and 1981 would have meant that the samples would be fairly evenly spaced over the period, but as described below, data for such a point was not readily available.

The unladen mass of the average car can be determined by considering: (1) the distribution of vehicles in the car park by make and model; and (2) manufacturers' specifications of the unladen masses of all vehicles in the car park.

The SMMT has been the Government's primary source of motor industry statistics throughout the period 1952-1991. Due to the fragmented nature of the motor industry pre-1960, the SMMT does not have reliable estimates for the distribution of cars in the car park throughout the whole of the period. However, high quality data on car sales over the period as a function of engine size are available (Mogridge, 1983:93). The first two sample points are constructed by combining data from Times Motor Industry Surveys and data on new registrations by engine size from the Society of Motor Manufactures and Traders (SMMT) in the years 1952 and 1963.

Perhaps because of its crucial role in defining tax and insurance brackets, and the social and cultural importance of the size of a car's engine, engine size has a history of being one of the most important car specifications. Since the mid-1970s the SMMT have collected and published new car registrations according to make and model. Prior to the mid-1970s, however, reliable statistics on new car registrations according to anything other than engine size were not available. From the mid-1970s onwards, the SMMT have reliable data for the exact composition of the vehicle park, stored in their database 'Motorparc' which, since 1981, has been used by SMMT to provide data on the 'Top Twenty' best selling car models. In 1981 the top twenty most popular cars accounted for 66 per cent of all new car registrations and in 1991, 65 per cent of all new car registrations (SMMT, 1982, 1992). Whilst the top twenty best selling cars will consistently not include some of the less common or higher priced new cars, it is nevertheless reasonably comprehensive (in that it does include a range of inexpensive to medium priced cars whose unladen masses vary considerably) and it seems reasonable to assume that systematic changes in this sample of cars will accurately reflect systematic changes in the total vehicle park.

Accurate specifications of the cars produced in any one year over the period are available from two sources. Between 1952 and 1963, the Times newspaper published an 'Annual Survey of the British Motor Industry' (Times Newspapers, 1952-1963). The surveys contained a comprehensive list of all contemporary car specifications, including their unladen masses. Between the last Times survey in 1963 and a change in editorial policy of 'What Car' magazine in 1981, there were no complete surveys of new car specifications. What surveys there were often included only a handful of cars and, of those, unladen mass was sometimes not listed in the specifications. Starting in 1981, What Car magazine has published a comprehensive monthly guide to new car specifications, including unladen masses.

5.5.2 Estimation of unladen masses of average car 1952 and 1963.

The full lists of cars included in the 1952 and 1963 Times Surveys of the British Motor Industry together with engine size and unladen masses is given in table A3 (appendix 9.2). The survey includes only British-made cars since only a small proportion of the total of new cars registered in any year over the period 1952-1963 were imported; car imports did not account for more than 6 per cent of the total new car market in any year before 1965 (Thoms and Donnelly, 1985:162). The number of model variations offered by manufacturers rose over the period in line with a number of other significant production changes which were occurring in the motor industry between 1952 and 1963 (see Maxy and Silberston, 1959: 22-23). Given that the measure of 'average' that is required in this study is related to car use, the cars of the small, independent manufacturers which between 1952 and 1963 accounted for only around 7 % of the total new car market (table 5.5) can be ignored, leaving only those cars made by the 'Big Five' manufacturers (Thoms and Donnelly, 1985).

Table 5.5: The big five car manufacturers: average market share 1952-1963.

United Kingdom

Manufacturer	Market Share (%)
BMC	39
Ford	25
Rootes	11
Vauxhall	10
Standard	8
Small Independents	7
Total	100

source: Thoms and Donnelly, 1985:161

Reliable data on which particular models made by the Big Five were most popular is not available and so all models made by the big five were considered in the sample. Although some of these models were produced in small numbers (e.g. the Humber Super Snipe (see Robson, 1990)), they were not excluded from the analysis.

Figures 5.5 and 5.6 show the relationship between unladen mass and engine size of all the cars produced by the Big Five in 1952 and 1963.

For any particular engine size there were a number of models available, the heaviest sometimes weighing twice as much as the lightest. Some of the points in both figures have been labelled with the corresponding car to help bring the data to life. In both 1952 and 1963, distinct clusters of car models with different unladen masses occur at particular engine sizes. The reason for this is the existence of car tax brackets which favoured the maximisation of engine size within any particular bracket. As there is a large variation in the production numbers of car models within the sample, certain points are clearly more important than others, however accurate data for this is not available.

Figure 5.5: Unladen mass versus engine size: cars of the big five 1952.

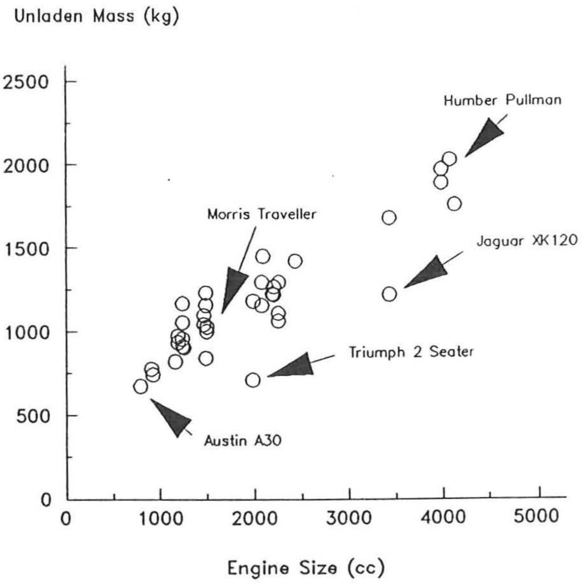
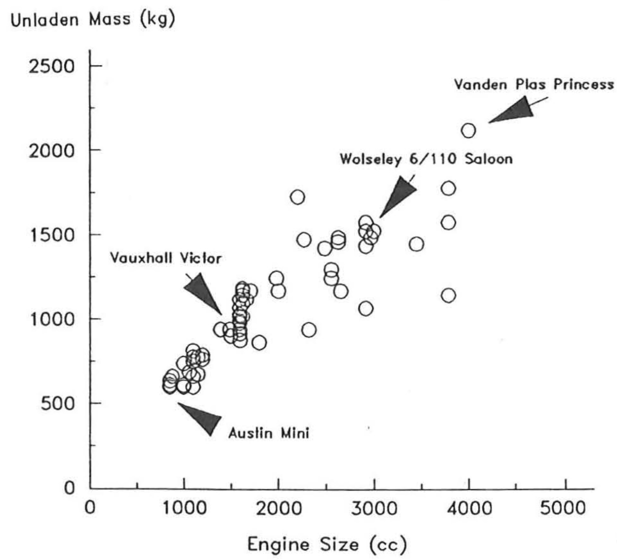


Figure 5.6: Unladen mass versus engine size: cars of the big five 1963.



The change in the unladen mass of the average car between 1952 and 1963 can be estimated by combining the average unladen mass of cars within a given engine size range for a particular year with data on the number of cars sold in that engine size range for the same year. Table 5.6 gives the results of averaging the unladen masses of the cars produced by the big five manufacturers in 1952 and 1963 according to engine size, giving equal weight to each model.

Table 5.6: Average unladen mass by engine capacity, 1952 and 1963.

United Kingdom *kilos*

engine size (cc)	1952	1963
up to 1000	741	629
1001 to 1600	1008	870
1601 to 2200	1170	1170
2201 to 3000	1239	1364
over 3000	1755	1613
all sizes	1229	1100

source: Times Newspapers, 1952 and 1963

The results of the 1952 and 1963 samples can now be coupled with SMMT data on the number of new car registrations by engine size. Table 5.7 gives a breakdown of new car registrations in 1952 and 1963 by engine capacity.

Table 5.7: New car registrations by engine capacity, 1952 and 1963.

United Kingdom *number/per cent*

engine size (cc)	1952	%	1963	%
up to 1000	24211	14	230884	24
1001 to 1600	81895	48	532746	56
1601 to 2200	29287	17	100923	11
2201 to 3000	23656	14	73756	8
over 3000	10006	6	14456	2
Total	169055	100	952759	100

source: SMMT, 1952, 1963

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over 3000	10006	6	14456	2
Total	169055	100	952759	100

source: SMMT, 1952, 1963

The estimate of the average unladen mass of cars in different engine size brackets can now be weighted by the proportion of cars sold in each engine size bracket in both the sample years (i.e. combining tables 5.6 and 5.7). This gives the unladen mass of the average new car to be 1074 kilos in 1952 and 893 kilos in 1963.

The change in average unladen mass is influenced by two factors: (1) a shift towards cars with smaller engines (80 per cent of new cars in 1963 were under 1600 cc compared with only 62 per cent in 1952); and (2) technological changes which improved the power to weight ratio of cars.

5.5.3 Estimation of unladen mass of average car 1981 and 1991.

Since the late 1960s, imports of new cars into Britain have risen steadily. In 1991, 56% of new cars originated from overseas (SMMT, 1992). The internationalisation of car markets, and the many combinations of car makes and models has meant a large increase in the diversity of the cars in the car park. Since 1981, however, What Car magazine has regularly published a comprehensive survey of new car specifications. Since the range of new cars in the 1980s was so much greater than during the rest of the period it would be impracticable to correlate the registrations rates of every make and model with manufacturers specifications. Instead, a method was chosen that used the top 20 'Best Sellers' of 1981 and 1991 which themselves accounted for over 65% of all new car registrations in those years. The top twenty best sellers together with their unladen masses and sales figures are listed in table A4 in appendix 9.2.

Table A4 weights the unladen mass for each engine size by the proportion of new car sales in those categories. The weighted average unladen mass of the top twenty best selling cars rose by around 7 per cent from 907 kilos in 1981 to 1004 kilos in 1991. Although technological improvements continued to reduce the weight of many car components such as engine blocks, wheels and chassis, falling real fuel prices (encouraging larger and heavier engines) and safety-oriented marketing (increasing the weight of the car) have more than offset these reductions over the period 1980-1991.

5.5.4 Estimating Trend in Unladen Mass of Average Car Over Period 1952-1991 Using the Sample Points.

A linear interpolation between the four sample points is plotted in figure 5.7. In comparison with the previous estimate of the uncertainty in the parameter 'f' in table 5.4 (1000 kilos +/- 30 % for the maximum change in the unladen mass of cars over the period 1952-1963), the range indicated by the sample points is 1000 kilos +/- 10 per cent. The remaining uncertainty in each of the four sample points is estimated to be 5 per cent which takes into account the fact that not all cars have been included in the analysis, and certain types of cars are used more than others. A linear interpolation between the points (rather than some form of regression analysis) therefore gives an accurate estimation of the trend in unladen masses over the period.

Figure 5.7: Estimation of trend in car unladen masses 1952-1991.

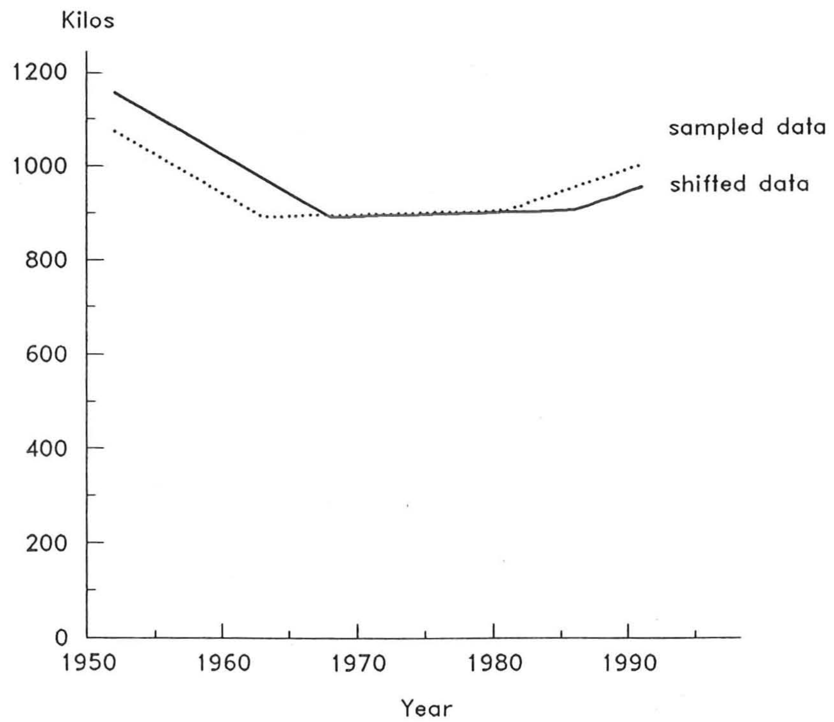

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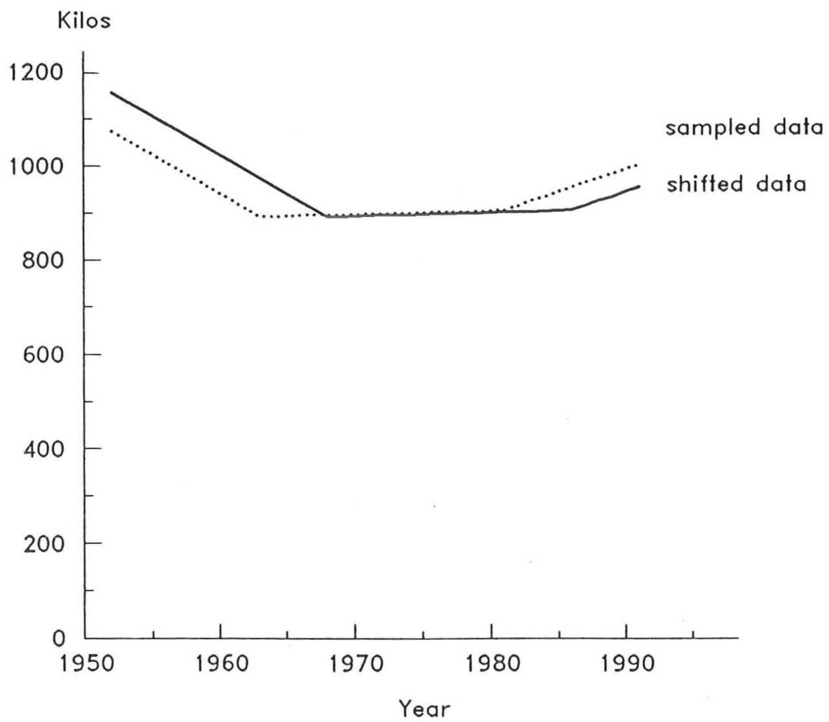
Figure 5.7: Estimation of trend in car unladen masses 1952-1991.



The interpolation forms a broad 'U' shaped trend for the change in unladen masses over the full period. Although a literature survey (involving the Transport Research Laboratory, England) did not reveal any other studies which have specifically estimated the trend in car unladen masses, the shape in figure 5.7 does seem plausible for the reasons described above (Sorrell (1992) uses a similar methodology to that which produced it). Figure 5.7 also shows the interpolated curve systematically shifted 5 years to the right (with a linear extrapolation for the period 1952-1957). Since the four data points were calculated using data solely on new car registrations, the shifted curve is thought to be a better representation of the change in unladen masses over the period of the typical car in the car park. Table A7 in appendix 9.2 shows the age profile of the cars in the car park at the end of 1991. The mean age of all cars is 5.14 years. Since the interpolations between the sample points are linear, the average of new cars in any particular year is a good approximation of the average unladen mass of all the cars in the car park 5 years later on. There is some evidence that car survivor rates have decreased slightly over the period 1952-1991 (Mogridge, 1983: 91-95), (i.e. that the mean life of a car is becoming shorter); the calculation for the 1974 car park revealed the mean age then to be 5.81 years (table A6, appendix 9.2). This effect and possibly others prior to 1974 is small in comparison with the uncertainties already in the sample points and is not incorporated into the calculations; hence the mean age of a car is assumed to be 5 years throughout the period 1952-1991. This shifted curve is the one which will be used for unladen car mass in the refined mass movement calculations in section 5.6.

5.5.5 Estimation of Unladen mass and Payload of Average HGV: 1952-1991.

This section describes the method which was used to estimate more accurately the changes in the average unladen mass and payload (the maximum mass of goods that can be carried) of HGVs over the period 1952-1991. Initially, a value of 4 tonnes was chosen for the unladen mass and 8 tonnes for the average payload, which were held constant over the period (table 5.3). The uncertainty in these parameters was initially estimated to be between 10 and 190 per cent of their initial values, i.e. between 0.4 and 7.6 tonnes for the average unladen mass and between 0.8 and 15.2 tonnes for the average payload. Clearly, the accuracy of the mass movement measures would be improved if the uncertainty in the values of these parameters over the period were reduced, particularly as there has been a well-documented shift towards larger vehicles over the period (Hamer, 1987; DTp, 1992b).

The unladen mass and payloads of HGVs differ from make to make and within each make, from model to model (see for example Transport Engineer, 1991:15). A precise measure of the total essential or gross mass movement over the period due to HGV activity would require: knowledge of unladen masses and payloads of all HGVs in use or previously in use; knowledge of the HGV load factors for each trip; and knowledge of trip lengths. Data of this complexity is not available. However, data on total net tonne kilometres moved by HGVs and total HGV vehicle kilometres are readily available. The high quality of these two statistics suggests that they should be employed in the estimation of essential and gross mass movement.

Using these statistics and from equation 5.5, gross mass and essential mass movement of HGVs may therefore be written: $E_{hgv} = F_{hgv} + V_{hgv}*U_{hgv}$ (5.17), $G_{hgv} = F_{hgv} + W_{hgv}*U_{hgv}$ (5.18), where F_{hgv}, and W_{hgv} are derived directly from the available net mass movement and vehicle kilometre statistics, and U_{hgv} represents the unladen mass of the 'average' HGV. The DTp estimates W_{hgv} for all types of vehicle from an annual survey of the transport of goods by road. Since $V_{hgv} = F_{hgv} \backslash M_{hgv}$, the parameters U_{hgv} and V_{hgv} therefore need to be estimates of the unladen mass and payload of the 'average' HGV observed in the DTp's surveys (i.e. according to the number of vehicle kilometres driven on the road).

There are two distinct and important components in defining the 'average' HGV. The first is related to aggregate characteristics of all the HGVs in the 'HGV park', which includes all those that currently hold a vehicle registration document. Secondly an estimation of the average HGV should take into account differences in the road usages of particular makes and models of vehicle. As a result of existing legal, financial and logistical constraints, the transport of goods by road is highly stratified by type of vehicle according to the nature of the goods transported, length of haul and geographical location. For example, in 1991, 78 per cent of all goods transported by road were moved in vehicles with gross vehicle weights over 25 tonnes (DTp, 1992b:124).

Within the transport sector, the system of accounting for the transport of goods by road has had two main phases. The first phase which lasted throughout the post war period until 1968, was based on the unladen masses of vehicles. For taxation and insurance reasons this became an important parameter for the manufacturers and owners of heavy goods vehicles. The then Ministry of Transport used unladen masses as the classification scheme for most accounting procedures when considering goods vehicles (see for example Glover and Miller, 1954). In 1968, amid growing resentment of the damage to road surfaces thought to be caused by goods vehicles, the government produced a report on Road Track Costs (Ministry of Transport, 1968). This was the beginning of the second phase of accounting procedures which switched over to maximum gross vehicle mass and is still used today (see DTp, 1992b). The change from unladen masses to gross vehicle mass has important consequences for any scheme which attempts to estimate trends in unladen masses and average payloads over the whole period 1952-1991. The earliest survey of goods vehicle activity was done between 1952 and 1953. It was not published as an official government publication but in the form of an academic paper (Glover and Miller, 1954). The survey method was refined and subsequent surveys occurred in 1958, 1962 and in annual surveys since 1974. However, the annual surveys between 1974 and 1979 did not give correlations between vehicle kilometreage and both unladen and gross vehicle weights; within the series, data for the above relationships is available only from 1980 onwards. Therefore, in order to produce four sample points for the trends in unladen vehicle weight and payloads over the period, the results of the surveys in 1952, 1962, 1980 and 1990 were chosen as the sample years, the overall trend is estimated by linear interpolation between them. It is coincidental that the gap in the 1970s parallels the gap for data on unladen car masses in section 5.5.1.

5.5.6 Goods Vehicle Survey 1952.

Table 5.8 has been constructed using data from Glover and Miller's (1954) paper on the outlines of the road goods transport industry.

Table 5.8: 1952 survey of unladen masses, payloads and vehicle kilometres.

United Kingdom

ULM[1,2]	mean ULM[2]	Payload[2]	Vehicle Kilometres (%)
<.61	0.5	0.3	5
.61-1.16	0.9	0.5	21
1.16-2.32	1.7	1.4	17
2.32-2.54	2.4	3.4	17
2.54-3.05	2.8	5.0	24
3.05-5.08	4.1	6.8	11
>5.08	6.0	11.5	5
weighted average	2.3	3.5	

source: Glover and Miller (1954), converted from tons to tonnes; [1]unladen mass; [2]*tonnes*

Weighting the unladen masses and payloads by the proportion of total vehicle kilometres in each category gives the weighted average results of 2.3 tonnes for average unladen mass and 3.5 tonnes for average payload.

5.5.7 Survey of Road Goods Transportation 1962.

Table 5.9 gives the results of an analysis of the Survey of Road Goods Transportation 1962 (Ministry of Transport, 1964). As in table 5.8, average unladen masses and payloads are calculated using the proportion of vehicle kilometres in each unladen mass category to weight their contribution.

Table 5.9: Unladen mass, payload and vehicle kilometres: 1962

United Kingdom

ULM[1,2]	mean ULM[2]	Payload[2]	Vehicle Kilometres (%)
0-1	1.0	0.8	23
1-2	1.5	1.0	18
2-2.5	2.3	2.5	05
2.5-3	2.8	3.8	12
3-5	4.0	6.2	30
>5	7.2	11.2	12
weighted average	3.1	4.2	

source: HMSO, 1963a [1]unladen mass; [2]tonnes

5.5.8 Survey of Road Goods Transportation 1980.

In 1981, the DTp published data on the transport of goods by road which included the correlation between vehicle kilometreage and both unladen and gross vehicle masses (DTp, 1981). Table 5.10 gives details of the unladen masses and payloads and the average unladen mass and payload using a weighted average according to vehicle kilometreage for 1980.

Table 5.10: Unladen mass, payload and vehicle kilometres: 1980.

United Kingdom

ULM[1,2]	mean ULM[2]	Payload[2]	Vehicle Kilometres (%)
0-4	1.50	4	12
4-5	4.50	6	11
5-6	5.50	8.50	14
6-7	6.50	11	8
7-8	7.50	13	5
8-9	8.50	15	5
9-10	9.50	17	9
10-12	11	19	27
>12	13	20	10
weighted average	7.8	13.1	

source: DTp, 1982; [1]unladen mass; [2]tonnes

5.5.9 Survey of Road Goods Transport 1990.

The most recent figures on road goods transport are given in DTp, 1991b. The survey no longer uses unladen masses or carrying capacities and so in order to estimate these, the relationship between unladen mass and payload was estimated and is shown in table 5.11 below, together with the weighted averages for the unladen mass and payload.

Table 5.11: Unladen mass, payload and vehicle kilometres: 1990

United Kingdom

GVM[1]	mean ULM[1,2]	Payload[1]	Vehicle Kilometes (%)
Rigids[3]			
0-7.5	3.60	3.90	21
7.5-17	5.80	8.70	26
17-25	8.50	15.96	6
>25	10.40	20.10	6
Artics[3]			
0-33	12.30	20.20	15
>33	13.50	23.75	26
weighted average	8.8	14.5	

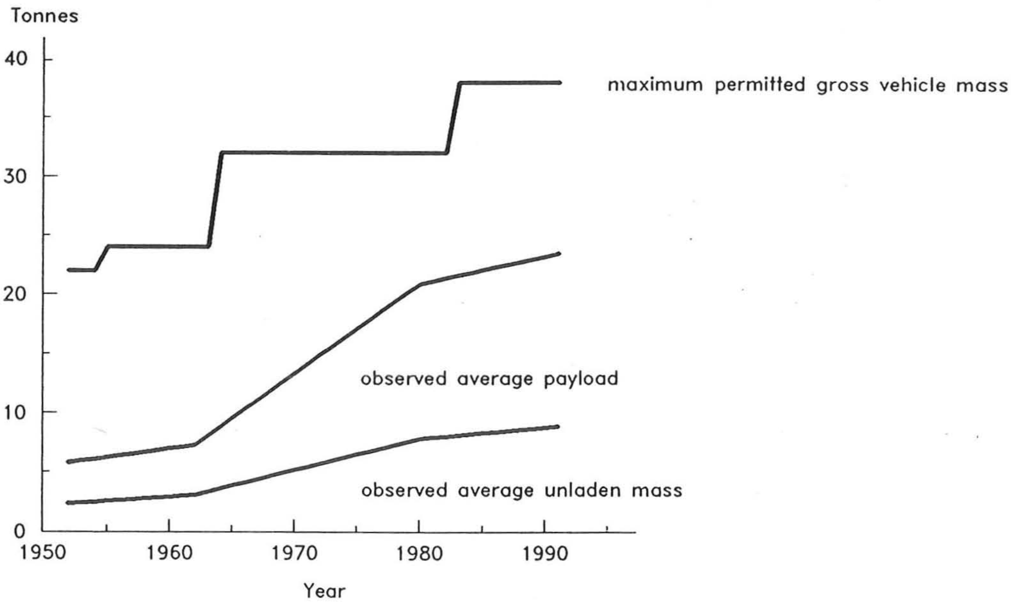
source: DTp, 1991b

[1] Data is given in terms of Gross Vehicle Mass (unladen plus payload); [2] derived from data table in Transport Engineer (1992:15); [3]The 1990 data use a different accounting system in terms of gross vehicle weights than was used in earlier parts of the continuing survey. Two categories of goods vehicle are distinguished; rigid and articulated vehicles.

5.5.10 Estimating Changes in Unladen Mass and Payload of HGVs: 1952-1991.

The figures obtained for the unladen mass and payload in the four sample years are plotted in figure 5.8 with a linear interpolation between them. The figure also shows the major policy changes surrounding the maximum gross vehicle mass (sum of unladen mass and payload) which have taken place over the period. The upper curve represents policy, while the middle curve is the sum of unladen mass and payload. Although the upper curve suggests an approximately linear increase in maximum permissible payload over the pericd, a least square regression was not applied to estimate the changes in average unladen mass and payload. This is because the residual uncertainty in each of the points is estimated to be 5 % (due to the assumptions about vehicle designs), small enough for a linear interpolation to be a better approximation of changes over the period.

Figure 5.8: Estimation of trends in average unladen masses and payloads of HGVs and major policy changes: 1952-1991.



This analysis has shown that both the unladen mass and the payload rise steadily over the period; there was a fourfold increase in unladen mass and a fivefold increase in payload over the period and the average gross vehicle mass as a proportion of the maximum permissible has increased. In 1952, 95 per cent of heavy goods vehicle kilometreage was due to vehicles equal to or less than 5 tonnes unladen mass. By 1991 the proportion of vehicle kilometres attributed to vehicles of unladen mass equal to or less than 5 tonnes had fallen to 23 per cent.

The original estimate of the uncertainty for the unladen masses (table 5.4) was not high enough; this calculation has revealed the 1991 estimate to be 120 per cent greater than the original estimate, 30 per cent greater than was thought possible. The results of the HGV payload survey (the 1991 value being 80 per cent higher than the initial estimate) are however within the original estimate of 90 per cent uncertainty, following Tupule's (1972) study for the earlier part of the period. In both cases the improved accuracy of the estimates of changes in unladen masses and payloads of HGVs over the period greatly enhance the overall accuracy of the revised mass movement measures calculated below.

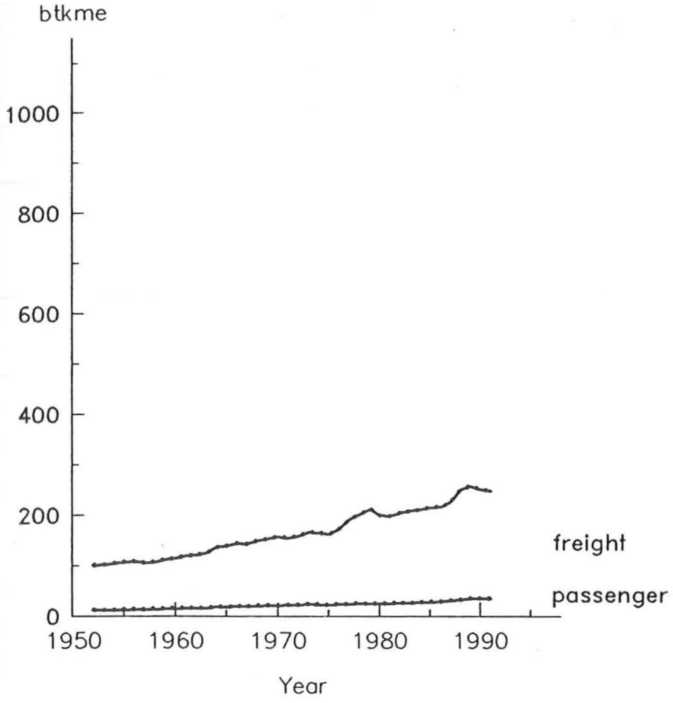
In summary, the car and HGV sensitivity analyses have removed much of the uncertainty associated with those parameters which had the greatest effect on the essential and gross measures of mass movement. In the case of cars, the original estimate of unladen mass was very close to that obtained from a more detailed study, whereas significantly different results emerged from the HGV study.

5.6 Revised Estimates of Net, Essential and Gross Mass Movements: 1952-1991.

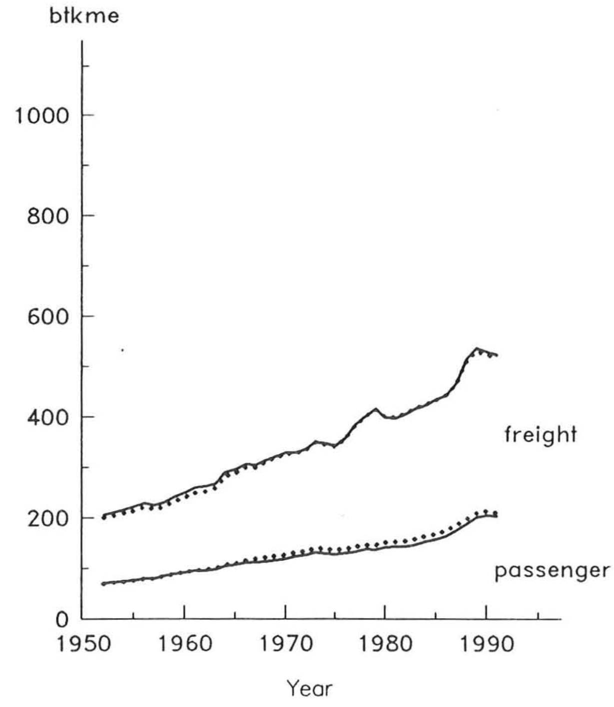
The calculation of mass movements can now be repeated using the time series results of the unladen car mass analysis (as a substitute for parameter f - table 5.3) and the HGV unladen mass and payload analysis (parameters k and x - table 5.3) with all other data held constant, as before. There is still uncertainty in the values of some of the variables used to construct the mass movement measures, but by reducing the uncertainty attached to those parameters to which the mass measures were most sensitive, the accuracy of the estimates of mass movements over the period have been significantly improved. The actual values of the changes in net, essential and gross mass movements for the whole of the period are given in table A6 (appendix 9.3), disagregated by type of carrier. Figure 5.9 shows the overall changes in net, essential and gross mass movements for the revised estimates and compares these with the initial results (dotted lines) from figure 5.3.

Figure 5.9: Net, essential and gross mass movements 1952-1991: revised results.

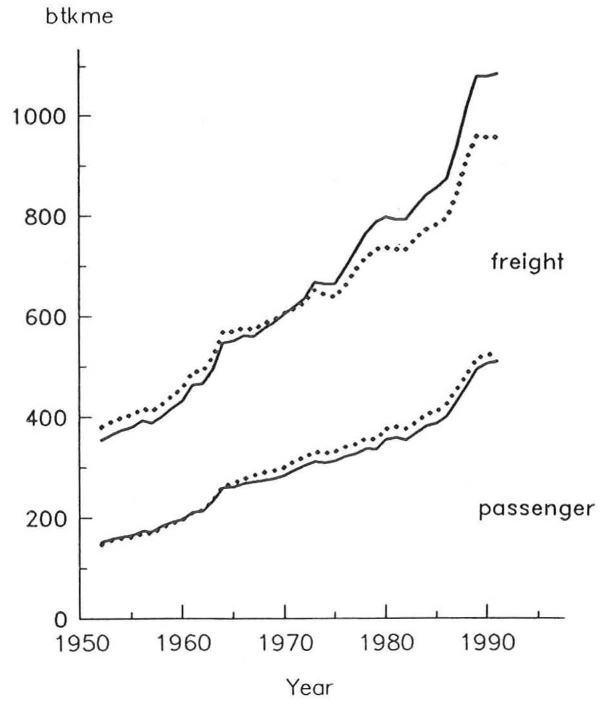
Net: passenger and freight



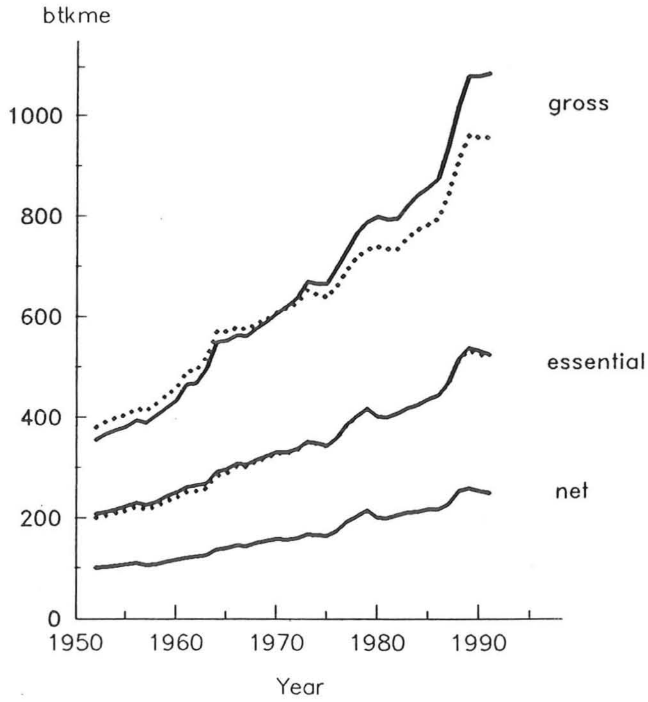
Essential: passenger and freight



Gross: passenger and freight



Total Mass Movement: net, essential and gross



Overall the shapes of the initial and revised curves are very similar. Since it is not dependent on any of the revised parameters, the estimate of net mass activity is not affected by the analysis and remains the same. The revised estimates of essential and gross mass movements are slightly lower for the beginning of the period and higher for the latter part of the period compared with the initial estimates. The combination of revised changes to the car and HGV parameters in section 5.4 had only a small effect on essential mass movement over the period compared with the original estimate. However, these changes had a greater effect on the gross mass measure, particularly its freight component (because of the absence of the payload counterbalancing effect present in the essential measure).

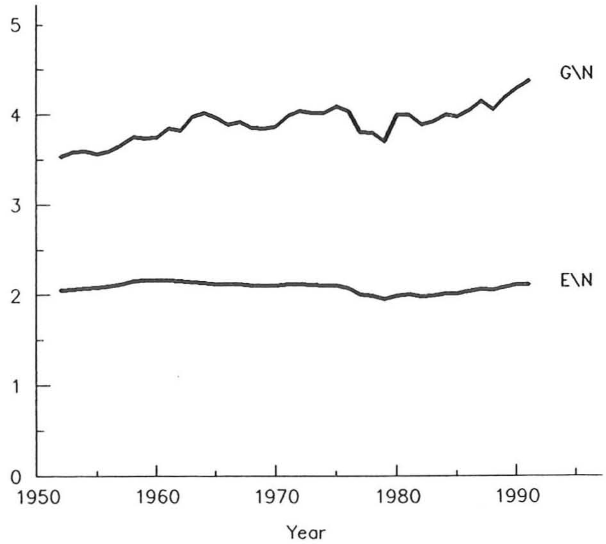
Total net mass movement more than doubled over the period rising from 99 btkme in 1952 to 240 btkme in 1991. There has been a steady growth in net passenger mass movement from 11 btkme in 1952 to 34 btkme in 1991, representing an annual increase of around 0.6 btkme, due entirely to increases in car travel. In 1952, car travel accounted for just over 2 btkme, rising to 28 btkme in 1991 (the absolute level of all other modes decreasing from around 9 btkme in 1952 to 6 btkme in 1991).

There has been a significant growth of net freight mass movement, but in contrast to the trend in net passenger mass movement, this growth has fluctuated more in the short term. Of the 88 btkme freight mass movement in 1952, 37 (42%) was by rail, 31 (35%) by road and 20 (22%) by waterborne transport. By 1991, road freight mass movement had risen to 136 btkme (63% share), waterborne transport held its share at 24% and net rail freight mass movement had fallen to 15 btkme (7%). The effects of the various economic downturns in 1973, 1979 and 1989 (see figure 5.11 below) on the movement of raw materials and manufactured goods, particularly by road can be seen. The peak in freight mass movement in the late 1970s corresponds almost entirely to a drop of around 10 per cent in road freight mass movement from 99 btmke in 1979 to 90 btkme in 1980.

Total essential mass movement increased by 150% over the period from 202 to 500 btkme. Essential passenger movement rose steadily over the period from 64 to 196 btkme, representing a small increase in the proportion of total essential mass movement of 6 per cent. In 1952, car travel accounted for 16 btkme (21% share) and train travel accounted for 32 btkme (50%). By 1991, this relationship had more than reversed with car travel now accounting for 77% and train travel declining to 22% of essential passenger mass movement. Essential freight mass movement grew over the period from 138 to 324 btkme. The majority of this growth has occurred in road and waterborne transport (the latter almost entirely due to increased shipments of petroleum). In 1952, 54 btkme of essential freight mass movement was by road (39%) and 26 btkme by water (18%). By 1991, essential road freight mass movement was 210 btkme (65%) and essential water mass movement was 70 btkme (22%). In contrast to the growth of road and waterborne essential freight mass movement, essential rail mass movement declined steadily from 57 btkme (41%) in 1952 to 24 btkme (7%) in 1991. Total gross mass movement rose steadily over the period from 355 btkme in 1952 to 1077 btkme in 1991. The proportion of gross passenger mass movement rose slightly from 43 to 46 per cent. The growth in gross passenger mass movement was due mainly to increases in travel by car (38 btkme (25%) in 1952 to 340 btkme (69%) in 1990) and partly due to a lesser degree by train (74 btkme (49%) in 1952 to 114 btkme (23%) in 1991). The increase in gross passenger train mass movement has occurred at the same time as a slight decrease in the level of net passenger mass movement. Similar to the trends that emerge in essential freight mass movement, changes in gross freight mass movement are characterised by a steady growth overall, which is due mainly to growth of road and waterborne gross freight mass movement. In 1952, 67 btkme of gross freight mass movement was by road (33%) and 32 btkme by water (16%). In 1991, gross road freight mass movement was 457 btkme (79%) and gross water mass movement was 86 btkme (15%). As with essential rail mass movement, gross rail mass movement declined steadily from 106 btkme (52%) in 1952 to 28 btkme (5%) in 1991. The bottom right hand graph in figure 5.9 reveals that gross mass movement rose at a faster rate than essential over the period, resulting in a widening of the gap between the two curves.

Differences in the growth of gross and essential mass movements relative to net mass movement over the period are shown in figure 5.10

Figure 5.10: Changes in gross and essential relative to net mass movements: 1952-1991.



The figure reveals that the ratio of E\N has remained near constant over the period, i.e. net and essential mass movements have been growing at the same rate. In contrast, gross mass movement has been growing at a faster rate than net movement with the ratio G\N rising from 3.5 in 1952 to 4.3 in 1991. The higher growth rate for gross mass movement implies that the economy is becoming more wasteful, if waste is measured by (G-N)/N, with implications for changes in the social and natural environments.

5.7 Transport Intensities.

5.7.1 Transport and the Economy: Lessons from the energy sector.

The relationship between economic and transport activity has long been recognised from the establishment of the earliest surface and water trade routes to present day road and air traffic forecasting. At some levels the relationship is perhaps obvious; most goods and commodities are made of raw materials which travel to a manufacturing plant, and finished goods are then transported to their places of consumption. At other levels, the relationship is less obvious with car ownership, for instance, itself reinforcing dependence on car travel; the drop in public transport usage leads to reduced services which in turn leads to greater car dependence, and annual car road tax and insurance payments make subsequent marginal car usage more attractive.

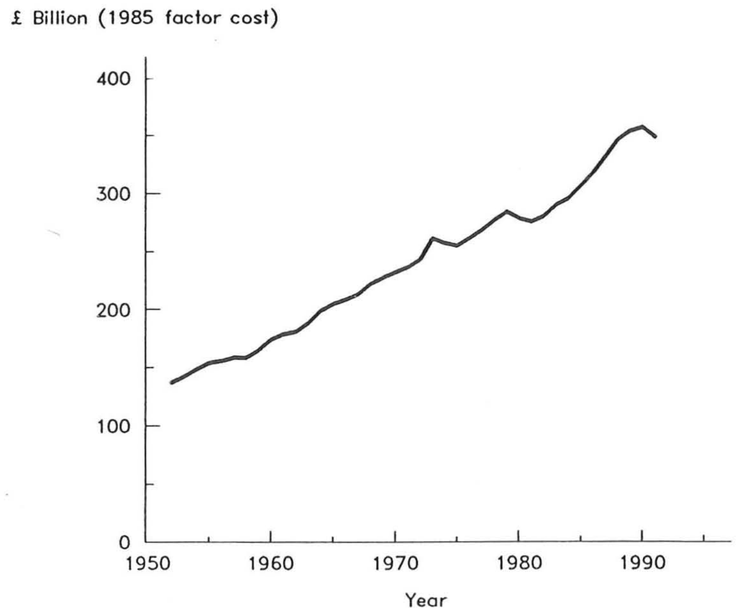
Traditionally, the relationship between transport and the economy comes under most scrutiny where large capital investments projects are being considered such as London's Third Airport, or the construction of a new motorway or tunnel (see CAA, 1990; DTp, 1989). For these individual projects, it is often important that they provide an adequate rate of return on the initial investment, and so the microeconomics of demand for transport in that particular geographical area is tested in the project's planning process. Recently however, a new context has arisen which has given impetus to consider the relationship at a more macroscopic level. The concern over transport's negative impacts on the environment, particularly in the light of forecast increases in road traffic, suggests that the relationship between transport and the economy needs to be considered as a whole (Goodwin et al, 1991); a way of measuring overall transport efficiency is needed.

National energy efficiency is normally measured by changes in the ratios of energy consumption to gross domestic product (known as 'energy intensities'). The three measures of energy consumption, (useful, final and primary) provide three measures of energy efficiency (the use of energy intensities to measure energy efficiency is discussed in detail in chapter 7). Three analogous 'transport intensities' can be constructed by calculating the ratios of net, essential and gross measures of mass movement to gross domestic product.

5.7.2 Transport Intensities: 1952-1991.

Economic growth over the period 1952-1991, as measured by changes in GDP at 1985 factor cost, is shown in figure 5.11. Overall, there has been a steady rise in the level of GDP between 1952 and 1991 of around 6 billion pounds per year. The figure shows some noticeable exceptions to this trend for the years 1956, 1973, 1979 and 1989-90.

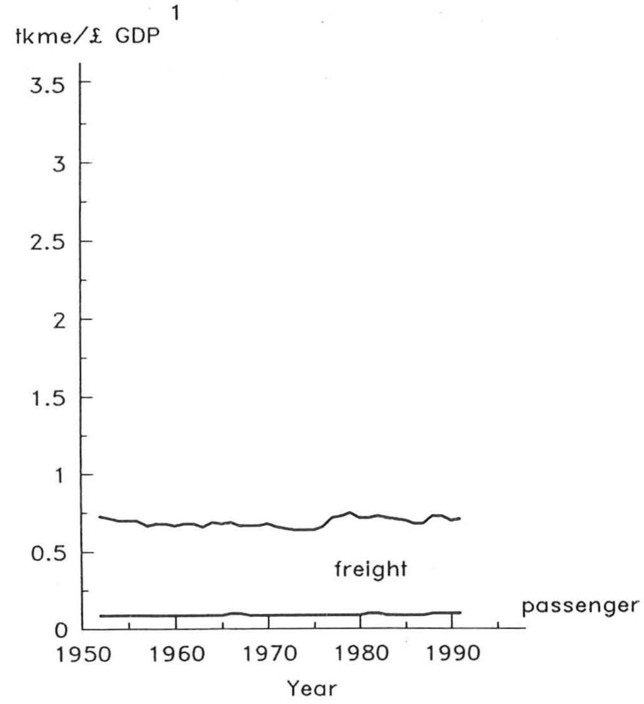
Figure 5.11: UK gross domestic product: 1952-1991



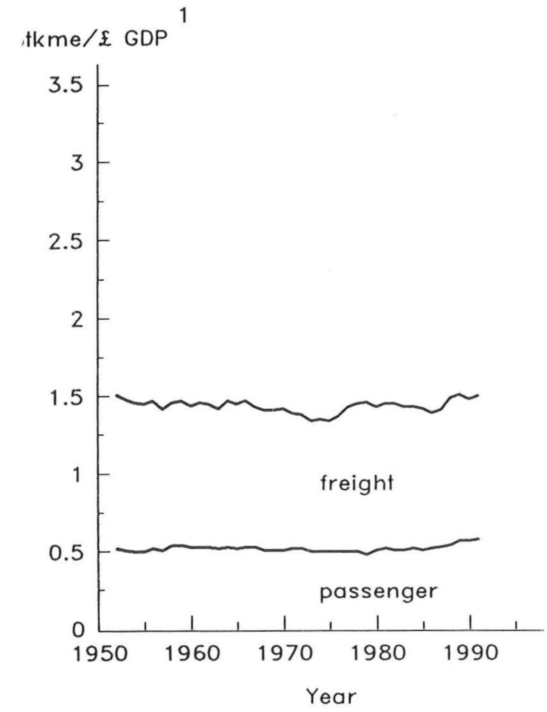
Changes in the ratios of GDP to mass movement are shown in figure 5.12, disaggregated by their cumulative passenger and freight components. Total net transport intensity (top left) is fairly constant at around 0.7 tkme per pound GDP (85% of which is due to freight movement). Total essential transport intensity (top right) is also nearly constant at around 1.4 tkme per pound GDP, around two-thirds of which is due to freight.

Figure 5.12 Net, essential and gross transport intensities: 1952-1991.

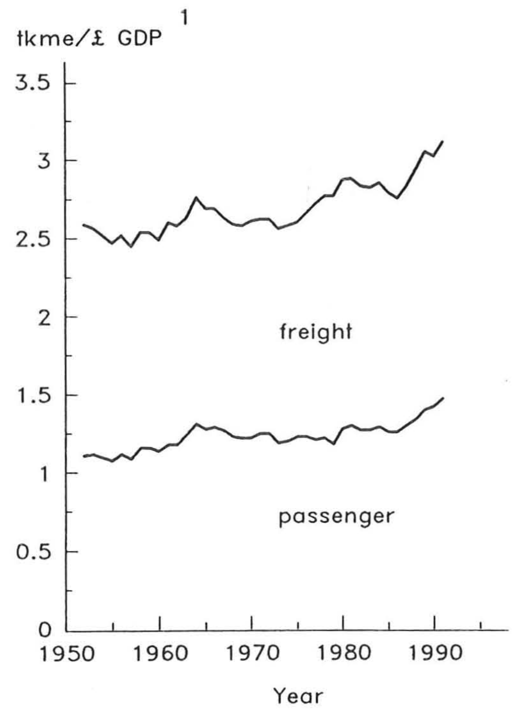
Net: passenger and freight



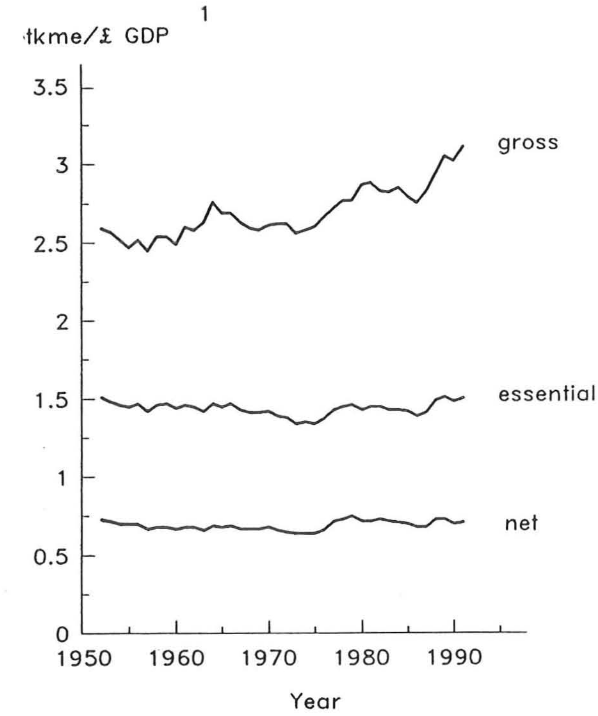
Essential: passenger and freight



Gross: passenger and freight



Total Mass Movement: net, essential and gross



[1] 1985 factor cost

With the exception of HGVs, the average maximum payload or occupancy of transport carriers was held constant over the period which means that the fluctuations in net intensity will be carried over to essential intensity (modal splits by definition unchanged, and changing slowly from year to year), but will be relatively smaller. Essential passenger intensity has remained steady at around 0.5 tkme per pound GDP. In contrast, gross transport intensity has steadily increased from 2.5 tkme per pound GDP in 1952 to 3.1 tkme per pound GDP in 1991. The bottom left hand graph in figure 5.12 shows that passenger mass movement accounts for nearly half of gross transport intensity, and that both gross passenger and freight intensities have been rising at a similar rate. The bottom right hand graph in figure 5.12 (not cumulative) shows the three measures of transport intensity. The contrast between the relatively constant essential and net mass intensities and the increasing gross intensity can be clearly seen. Figure 5.12 is very important in demonstrating the *overall* problem that transport is facing. It shows the continual increase of all mass movements per unit GDP - the essence of the relationships between transport, the environment and economic growth. The continuation of the trends shown in figure 5.12 would result in further disproportionate increases in gross mass movement per unit GDP which, in a growing economy, would result in further increases in many of the problems associated with transport activity. If transport intensity were to begin to decline in a similar way that energy intensity has declined over the last four decades (figure 3.9), then higher levels of economic growth could be sustained without placing yet more pressure on the social and physical environments.

5.8 Relationships between Mass Movement and Environmental Problems.

Having developed a new common unit of transport activity, it is instructive to consider the relationship between tonne-kilometres equivalent of mass movement and other variables which are related to transport and the environment. From an environmental quality perspective, gross mass movement is the measure of transport activity which has the most significance. Energy consumption, emissions, and congestion are not just functions of the net contents of a particular transport carrier, they are features associated with the movement of any masses. In a complex policy world, where one initiative often has ramifications for another, it would be important if, for instance, a 10 per cent reduction in gross transport intensity were set as a policy target (see energy equivalents in section 7.2.2), to consider what implications this would have for environmental objectives and policies.

The situation with gross mass movement is no different to that with the existing measures of transport activity (see section 5.2). If a reduction in the ratio of passenger or tonne kilometres to GDP were adopted as the aim of an environmental transport policy, then it would matter how that reduction was achieved. For instance, a policy which had the effect of shifting travel from cars to trains, may under certain conditions, have the side effect of increasing energy consumption and emissions. This, in turn, may conflict with other policy objectives. Indeed, within the energy sector, policy analysis (in common units across the various fuels and uses) had to take into account the relationships between energy intensity and variables linked to other policy objectives such as emissions or dependency on fuel imports (see chapter 7). Primary energy intensity may be reduced by following a policy which, for instance, substituted the demand for coal with petroleum and nuclear electricity, but such a policy would involve increases in radioactive emissions and have implications for the security and diversity of energy supply. Nevertheless, used wisely, common units and aggregate measures of activity and intensity have proved to be valuable tools to analyse and present information for public policy in the energy sector (IEA, 1987; DTi, 1992). The energy-transport analogy suggests they may make an important contribution in the transport sector.

The technical data which is available on relative energy consumption and emissions usually arises from analyses of different carriers' relative efficiencies (CEC, 1992; TEST, 1991; Barret, 1991; Potter and Hughes, 1990; Martin and Shock, 1989). This in turn leads to a natural focus on relative efficiencies when carriers are operating at their full capacities, i.e. when they are most energy or emissions efficient congestion are not just functions of the net contents of a particular transport carrier, they are features associated with the movement of any masses. In a complex policy world, where one initiative often has ramifications for another, it would be important if, for instance, a 10 per cent reduction in gross transport intensity were set as a policy target (see energy equivalents in section 7.2.2), to consider what implications this would have for environmental objectives and policies.

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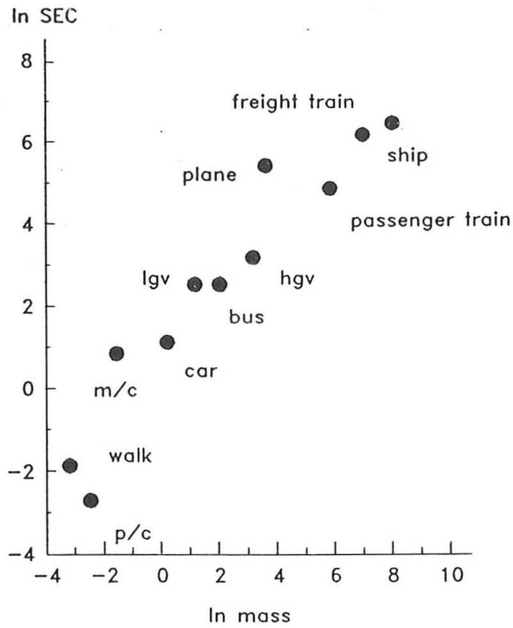
The technical data which is available on relative energy consumption and emissions usually arises from analyses of different carriers' relative efficiencies (CEC, 1992; TEST, 1991; Barret, 1991; Potter and Hughes, 1990; Martin and Shock, 1989). This in turn leads to a natural focus on relative efficiencies when carriers are operating at their full capacities, i.e. when they are most energy or emissions efficient in terms of their net productivity. The data used in this section give, at best, only an indication of the relationships between gross mass carrier movements and energy consumption or emissions, since carriers typically operate at much less than their maximum loads (see table 5.3). Such data on gross carrier mass movements at maximum occupancies are therefore taken as a proxy for those relating to actual gross mass movement characteristics.

5.8.1 Gross Mass Movement and Energy Consumption of Carriers.

Several studies have detailed the energy consumption of different types of passenger and freight transport (CEC, 1992; TEST, 1991; Barrett, 1991; Howard, 1990; Potter and Hughes, 1990). The variety in terms of size and/or types of technology associated with any particular class of carrier (e.g. HGV) is very large. Consequently, the results of the studies do not have a high degree of correlation for any particular carrier, since energy consumption between makes and models can vary considerably (a conclusion also reached by Banister, 1981). Table A7 (appendix 9.4) shows some relationships between carrier mass, occupancy or payload and energy consumption. The correlation between gross carrier mass (defined as unladen mass plus the mass corresponding to maximum occupancy or payload) and specific energy consumption (SEC) (the energy consumed for a carrier at maximum occupancy or payload over a distance of 1km) is shown in figure 5.13.

Because of the wide range of masses and energy consumptions, the data has been plotted in a ln-ln form. If gross mass is a good indicator of energy consumption, we would expect the relationship between them to be approximately linear (of the form $Y = mX^b$, where b is the slope on a ln-ln plot and should be close to unity). A least squares linear regression gives the slope in figure 5.13 to be 0.78, which indicates that the relationship is approximately linear, but that the SEC increases at a lower rate than mass.

Figure 5.13: Gross mass (maximum occupancy or payload) and SEC.



5.8.2 Gross Mass Movement, Atmospheric Emissions and Congestion.

The relationships between gross mass movement, various atmospheric emissions and congestion is shown in figure 5.14. Tabulated data for these relationships are given in tables A8/A9 (appendix 9.4). The data for each of the emissions in table A8 is plotted in a ln-ln form in figure 5.14. Figure 5.14 indicates a slightly flatter relationship between gross mass and CO2 than with energy consumption, but with a regression coefficient of 0.68, this relationship is approximately linear, but that CO2 emissions increase at a lower rate than mass (and than SEC). Clearly, HC emissions are not correlated with gross mass, but rather are related to the types and qualities of fuels used for particular carriers (see Watkins, 1991). With a regression coefficient of 0.96, the correlation between NOx emissions and gross mass is very close to linear. The pattern for carbon monoxide emissions reveals that they are not correlated with gross mass movment, but instead are more dependent upon the qualities of fuel and types of technology used in the carriers (Watkins, 1991). There is a near linear relationship between SO2 emissions and gross mass, with SO2 emissions increasing at a slightly higher rate than mass with a slope of regression slope of 1.17.

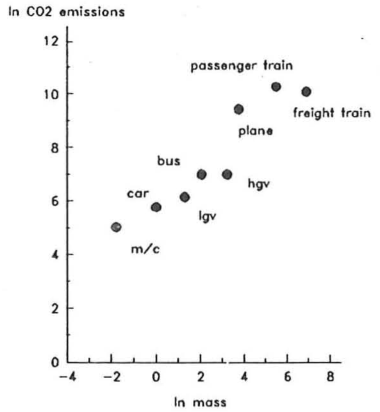
Passenger car units (PCUs) are traditionally used to represent the effects of changes in traffic composition on the saturation flows at traffic signal junctions. The values of PCU for carriers are usually derived empirically, through traffic surveys. A recent survey (see Kimber et al., 1986), derived the values given in table A9 and which are plotted in the bottom right of figure 5.14.

Figure 5.14 reveals that the PCU of a carrier goes up as the mass of the carrier increases (with regression slope of 0.97). This is as we would intuitively expect. Whereas empirical technical data constraints constrain the analysis of energy consumption and emissions to relative efficiencies at maximum occupancies or payloads, since the PCU of a carrier is independent of its mass, the relationship between PCU and average occupancies is used. In practice, we would expect the PCU of a carrier to vary slightly as a function of its gross mass (as carriers' performance and handling characteristics are related to their load factors). The PCU equivalent of a carrier is derived empirically from observing the vehicles with a range of occupancies, i.e. derived assuming average occupancies. Figure 5.14 indicates that if for a particular level of net mass movement, gross mass movement is reduced then so too are the possibilities of road congestion.

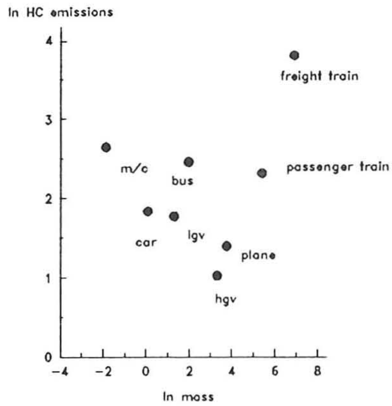
This analysis has shown that in general, reductions in total gross mass movement for the same net mass movement would result in reductions in energy consumption, carbon dioxide, nitrogen dioxide, and sulphur dioxide emissions and likely reductions in congestion. HC and CO emissions may be reduced if particular attention is paid to gross mass movements of the most HC and CO inefficient carriers. The situation is very similar to that which exists with secondary criteria in the energy sector, where care has to be taken that policies which seek to reduce overall energy consumption do not inadvertently create other problems, such as more atmospheric pollution or greater environmental risks.

Figure 5.14: Gross mass movement, atmospheric emissions and congestion: by carrier.

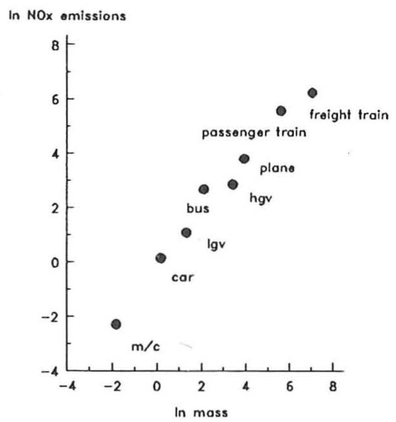
Gross Mass Movement and CO2 Emissions



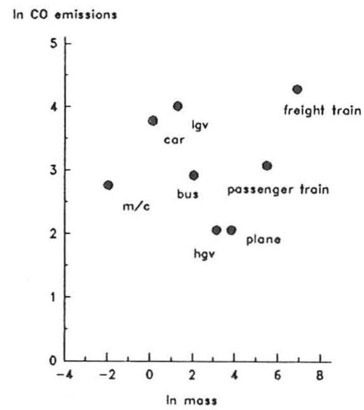
Gross Mass Movement and HC Emissions



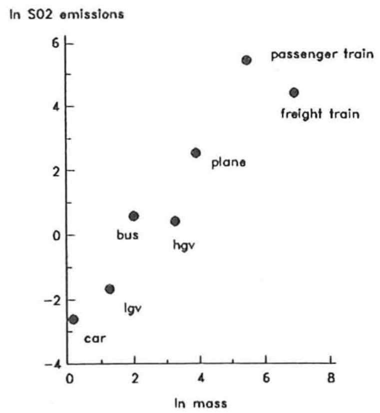
Gross Mass Movment and NOx Emissions



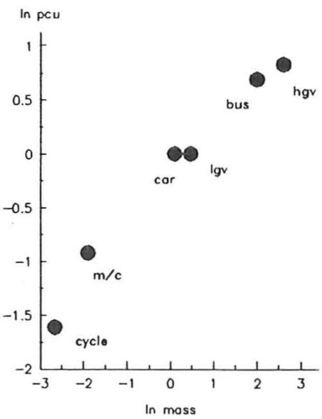
Gross Mass Movement and CO Emissions.



Gross Mass Movement and SO2 Emissions



Gross Mass Movement and Carrier PCUs



Chapter 6

Transport Policy Analysis: lessons from scenario analysis in the energy sector.

'It is necessary to devise systems of managing demand which are economically efficient, provide attractive possibilities for travel for both car owners and non-car owners and give priority to 'essential' traffic (including emergency services, freight, buses and limited categories of need)'.

P.B. Goodwin and P.M. Jones 'Towards a Consensus in UK Transport Policy' Proceeding of Seminar C, PTRC Summer Annual Meeting, 1990, University of Sussex.

6.1 Forecasts, Backcasts and Scenario Analysis.

Planning, evaluation and analysis are usually born out of concern about the risks and consequences associated with future patterns of development. Formalised planning procedures of whatever type often provide the means for organisations to demonstrate their commitment or professionalism over a particular issue or problem. In addition to their formal role as a rational technique, models are a way of legitimating decisions, shifting the emphasis away from emotional or seemingly irrational thought processes (de Bono, 1970). Forecasts, models and scenarios do not exist independently in some perfectly rational or theoretical world; they are the products of their designers and as such are sensitive to concerns about the actual and proper role of intuition, judgement, and usage passed on by their creators (Wynne, 1983). These problems are important when dealing with the types of uncertainty which have surrounded the energy crisis of 1973, or estimates of future transport demand into the next century.

Although scenario analysis has been used to describe detailed planning and policy design techniques within the decision making, operational research and management science disciplines, within energy policy it has been predominantly used in a holistic sense to identify particular patterns of future development (Chapman, 1975; Lovins, 1977). As particular scenarios became a familiar and accepted part of policy debates, they were referred to by particular names such as 'low' or 'technical fix' and as such were an extremely effective analytical device and method of communication (see Jones et al 1990).

Pearman (1988) focuses on the difference between forecast and scenario in his understanding of the latter:

> 'Scenarios do not constitute a forecast, either collectively or individually. Rather, as a set their aim is in some sense to span the range of futures which might reasonably be expected to occur, and hence to provide a broad-ranging background against which policy assessment can be undertaken' (Pearman, 1988:74)

Scenario analysis has also been used as a method for expressing values, or a desired future (see Leach et al, 1979). Used in this way, scenario analysis becomes a way of 'backcasting' rather than forecasting (see Lovins, 1977; Bridger Robinson, 1982b). Backcasting is explicitly normative and involves working backwards from a particular desired future end-point to the present, to determine what policy measures would be required to reach that future. Whereas good forecasts would presumably converge upon the most likely future, good backcasts can be expected to diverge, to reveal the relative policy implications of alternative futures.

This chapter considers how the style of energy scenario analyses developed to aid energy planning in the 1970s may be effectively applied to the construction of a series of aggregated transport scenarios up to 2025.

6.2 Scenario Analysis and Energy Policy.

In the mid-1970s, several factors stimulated much energy policy analysis including: forecasts of large increases in energy demand; uncertainty about future supplies of fossil fuels; the unknown potential of alternative and renewable energy technologies; and the 1973 oil crisis. Prior to 1973, a large number of policy stakeholders including the Ministry of Fuel, the CEGB, the Government and the financial markets were not able to anticipate the series of events which led to the quadrupling of oil prices (de Man, 1987). The shock of the oil price increases led to a critical appraisal of the importance of low energy prices and secure energy supplies. In turn, a demand for complex forecasting models, which attempted to reduce financial and policy uncertainties, was created (see DEn, 1978). However, a combination of confusion between different forecasts and the realisation that conventional forecasting procedures had great difficulty in dealing with 'oil crisis types' of uncertainty resulted in a shift away from forecasting towards scenario analysis as a way of examining the future (de Man, 1987). In the wake of the post-1973 forecasting crisis, scenario analysis, and backcasting in particular, became an important tool in the evaluation of energy policy (see Chapman, 1975; Bridger Robinson, 1982b).

There have been several important uses of scenarios and backcasts in national and international energy planning (see for example: WAES, 1977; Lovins, 1977; Leach et al., 1979; Hankinson, 1986; DEn, 1986; Goldfarb and Huss, 1988).

Some qualitative examples of energy scenarios for the U.K. are listed in Jones et al (1988). They are:

1. a scenario in which a free market in energy exists and the government provides no forecast of future energy consumption or supply;
2. a scenario which emphasises nuclear power and other supply options as the main policy measures to meet the energy needs of the UK (DEn scenario YU from the Sizewell B Public Enquiry (DEn, 1986);
3. a scenario which represents a mixture of coal and nuclear supply options and some energy conservation to meet the energy needs of the UK (DEn scenario BL from the Sizewell B Public Enquiry (DEn, 1986);
4. a scenario that places emphasis on energy conservation measures, and fossil fuel supply to meet the energy needs of the UK (IIED Low Case from Leach et al (1979) A Low Energy Strategy for the UK);
5. a scenario which emphasises renewable energy technologies and improved energy efficiency to meet energy needs (Earth Resources Research Technical Fix Scenario A2).

The representation of such energy scenarios has occurred in a variety of different ways, ranging from explicitly qualitative (often value laden) statements such as 'a future society based entirely upon renewable energy resources or soft energy technologies' (Bridger Robinson, 1982b) to graphs revealing changes in fuel mixes and to more detailed quantitative 'pictures' of the future using energy balance tables (see for example WAES, 1976).

6.3 Scenario Analysis in Transport Planning.

Like the energy sector in the 1970s, the transport sector in the 1990s is characterised by a range of uncertainties about forecast levels of demand and technological capabilities. Goodwin and Jones (1990) noted that for the first time in transport, the situation had been reached where transport demand will have to be tailored to meet the available supply and that in future, traffic levels will be chosen, not forecast. A regime in which traffic levels are chosen will in turn require analytical and evaluative techniques to guide the planning and implementation of demand-management policies requiring the targeting and evaluation of wasteful (NMHC, 1991), irrational (Short, 1992) and inefficient (ACC, 1991) transport movements.

In adopting scenario analysis as a tool for transport planning, the comfort of having a single forecast would be lost (as it was when scenarios were adopted in energy), but so too would the scepticism surrounding the accuracy of the NRTFs (see for example Hallett, 1990; NAO, 1988; Transport 2000, 1989).

Gershuny (1979) reviewed the development of forecasting techniques within the transport sector, observing a steady stream of unconditional forecasts both of road and air transport which had the effect of 'fixing the future' by encouraging actions that would necessarily fulfil the forecast predictions. In the U.K., the present form of the National Road Traffic Forecasts (NRTF) began in 1974, since when there have been several forecasts, the most recent in 1989 (DTp, 1989). For Goodwin et al (1991) these latest forecasts are seen as the catalyst for the proposition that there is no possibility of increasing road supply at a level which matches the growth rates in demand. According to Goodwin et al (1991), this leads to the logical suppositions that: (a) whatever road construction policy is followed, congestion will get worse; and (b) demand management will therefore become the centre of transport policy. The NRTF are generally used as the main focus for U.K. transport policy debates and have been extremely influential in persuading government to allocate resources (see HMSO, 1989a).

Pearman (1988) argued that the types of uncertainty that have the most serious consequences for transport planning are not captured by conventional modelling techniques (such as the DTp's NRTF) and recommended scenario based analyses for improving long term transport planning. Applications of transport scenario analysis (which began in the mid-1970s) have been less influential than in the energy sector. From around 1976, examples of scenario use in transport planning began to emerge (Pearman, 1988), mostly at low levels of spatial aggregation (e.g. scenario analyses for cities such as Chigaco), with very few highly aggregated scenarios analyses such as Allport's (1982) European study (Allport, 1982; Nash, 1991).

Grubler and Nakicenovic (1991) investigate the evolution of transport systems using a series of scenarios for railways, roads and air transport systems. Their OECD study is reminiscent of energy policy analyses in the late 1970s, a feature which has more to do with the background to their study, rather than coincidence (the International Institute for Applied Systems Analysis specialised in energy policy analysis). Ironically, the closest their study comes to an aggregate scenario of overall passenger, freight and intermodal demand is a calculation of the overall changes in energy demand. The ideas contained in Grubler and Nakicenovic's study are close to those contained within this chapter.

Prior to the introduction of scenario-based planning, energy policy was polarised to the extent that debate had become ritualised (see for example Bridger Robinson, 1982a; Thompson, 1984; and Frost, 1982). The use of scenarios in energy policy had some success in bringing together the various stakeholders, defusing arguments and creating a level playing field for debate (Baumgartner and Midttun, 1987; Jones, 1990). The ongoing and continually polarised transport debate might also benefit from the introduction of scenario-based planning.

6.4 Energy Balance Tables.

An indication of the widespread use and acceptance of energy balance tables since they were introduced by the OECD in 1976 (OECD, 1976) as a way of providing a holistic view of energy policy, is given by Eden et al. (1981):

> The simplest definition of an energy policy assumes a target energy balance table for some set of future years, either single-valued or, in more sophisticated analysis with a statistical distribution to take account of risk and uncertainty. Policy is then defined as the set of actions necessary to bring about this outcome (Eden et al; 1981:387).

In this way, Eden et al indicate the use of a target energy balance table for the future to 'backcast' to the present, highlighting the policies which need to be adopted to achieve that particular future scenario.

Using a common accounting unit for all forms and uses of fuels, energy balance tables present a more detailed quantitative picture of each fuel within a single sector of energy supply or consumption, and how a fuel is transformed and split between different uses. Energy balance tables may be constructed in a whole host of different ways. No one format is right and others wrong. Different formats may be useful for different purposes. Prior to the OECD's adoption of a common unit in its energy accounting practices, the organisation produced an energy account sheet for each individual fuel. The common accounting unit enabled, for the first time, relationships between different fuels and different consuming sectors to be mapped more effectively on a single page as a consolidated inter-fuel, multi-sector balance table. As an analytical tool for policy analysis, and a means of communication, the energy balance tables were a significant improvement upon previous accounting practices (DEn, 1979b).

Table 6.1 shows the DTI's energy balance table for 1991. Across the top of the table, the various primary and secondary fuels are listed. Listed vertically down the left of the table are some of the many stages through which primary energy passes as it is supplied, delivered and eventually used. Each row of the table (e.g. energy used by industry), gives information about how much of the range of primary and secondary fuels are utilised for that purpose. Thus the relative importance of different fuels is shown in each row for that stage, whilst the importance of the various stages for any particular fuel is shown in the column below that fuel. The DTI's energy balance table uses thermal content as the common unit.

Table 6.1: DTi's energy balance table, 1991.

Million therms

	Primary fuels: Coal	Primary fuels: Crude petroleum	Primary fuels: Natural gas	Electricity: Nuclear	Electricity: Natural flow hydro	Electricity: Foreign trade	Total primary fuels	Secondary fuels, Petroleum products: Motor spirit	Secondary fuels, Petroleum products: Gas/diesel oil
Fuel supplies									
Production of primary fuels	23,363	37,993[2]	20,086	5,932[3]	535[3]	-	87,909	-	-
Arrivals	5,459	24,741	2,457	-	-	1,676[3]	34,333	545	431
Shipments	-451	-23,894	-	-	-	-	-24,345	-2,227	-2,777
Marine bunkers	-	-	-	-	-	-	-	-	-515
Stock changes [5]	-1,505	-94	-102	-	-	-	-1,701	+59	+2
Statistical differences[6]	-419	+1,127	-	-	-	-	+708	-56	-68
Available supply (before conversion)	26,447	39,873	22,441	5,932	535	1,676	96,904	-1,679	-2,927
Fuel uses									
Inputs for conversion									
Petroleum refineries	-	39,873	-	-	-	-	39,873	-	-
Electricity generators	19,744	-	467	5,932	535	1,676	28,354	-	-
Gas supply industry	-	-	-	-	-	-	-	-	-
Coke ovens	2,996	-	-	-	-	-	2,996	-	-
Other manufactured fuel plants	413	-	-	-	-	-	413	-	-
Total inputs	23,153	39,873	467	5,932	535	1,676	71,636	-	-
Outputs from conversion									
Petroleum refineries	-	-	-	-	-	-	-	12,368	11,231
Electricity generators	-	-	-	-	-	-	-	-	-
Gas supply industry	-	-	-	-	-	-	-	-	-
Coke ovens	-	-	-	-	-	-	-	-	-
Other manufactured fuel plants	-	-	-	-	-	-	-	-	-
Total outputs	-	-	-	-	-	-	-	12,368	11,231
Net input for conversion	+23,153	+39,873	+467	+5,932	+535	+1,676	+71,636	-12,368	-11,231
Used by energy industries									
Primary fuel producers	30	-	1,226	-	-	-	1,256	-	-
Secondary fuel producers	6	-	163	-	-	-	169	-	-
Total used by energy industries	36	-	1,389	-	-	-	1,425	-	-
Losses in distribution	-	-	649	-	-	-	649	-	-
Final energy consumption									
Iron and steel industry	2	-	404	-	-	-	406	-	60
Other industries	1,311	-	4,687	-	-	-	5,998	-	1,160
Total industry	1,313	-	5,091	-	-	-	6,404	-	1,219
Transport	-	-	-	-	-	-	-	10,689	5,394
Domestic	1,646	-	11,395	-	-	-	13,041	-	112
Other final consumers	299	-	3,450	-	-	-	3,749	-	1,321
Total final energy consumption	3,258	-	19,936	-	-	-	23,194	10,689	8,046
Total inland energy consumption of primary fuels & equivalents [10]	26,447	39,873	22,441	5,932	535	1,676	96,904	-1,679	-3,185
Non-energy uses:									
Petrochemical feedstocks			-	-	-	-		-	258
Other		-	-	-	-	-		-	-
Total non-energy uses	-	-	-	-	-	-	-	-	258
Gross inland consumption	26,447	39,873	22,441	5,932	535	1,676	96,904	-1,679	-2,927

(1) Including Orimulsion
(2) Crude petroleum (37,634 million therms) and condensate (360 million therms) for distillation by refineries
(3) Fossil fuel input required had primary electricity been produced at conventional U.K. power stations. Data for natural flow hydro includes wind generation
(4) Petroleum gases and condensate extracted at gas separation plants for direct supply to consumers
(5) Stock fall (+), stock rise (-). Includes stocks held by secondary fuel producers
(6) Supply greater than recorded demand (-)

	Secondary fuels (continued), Petroleum products: Fuel oil[1]	Petroleum products: Other products	Petroleum products: Total petroleum products	Coke & breeze	Other solid fuel	Coke oven gas	Electricity	Total secondary fuels	Total fuel
Fuel supplies									
Production of primary fuels	-	1,739[4]	1,739	-	-	-	-	1,739	89,648
Arrivals	1,969	1,320	4,265	71	39	-	-	4,375	38,708
Shipments	-1,887	-1,403	-8,294	-60	-27	-	-	-8,381	-32,726
Marine bunkers	-524	-	-1,039	-	-	-	-	-1,039	-1,039
Stock changes [5]	-136	+91	+16	+39	-11		-	+44	-1,657
Statistical differences[6]	+1,128	-2,217	-1,213	-43	-	-	-	-1,256	-548
Available supply (before conversion)	550	-470	-4,526	6	1	-	-	-4,518	92,386
Fuel uses									
Inputs for conversion									
Petroleum refineries	-	-	-	-	-	-	-	-	39,873
Electricity generators	2,872	153	3,025	-	-	-	-	3,025	31,379
Gas supply industry	-	1[7]	1	-	-	-	-	1	1
Coke ovens	-	-	-	-	-	-	-	-	2,996
Other manufactured fuel plants	-	-	-	-	-	-	-	-	413
Total inputs	2,872	154	3,026	-	-	-	-	3,026	74,662
Outputs from conversion									
Petroleum refineries	5,361	10,711	39,671	-	-	-		39,671	39,671
Electricity generators	-	-	-	-	-	-	10,940	10,940	10,940
Gas supply industry	-	-	-	-	-	-	-	-	-
Coke ovens	-	-	-	1,901	-	527	-	2,428	2,428
Other manufactured fuel plants	-	-	-	-	316	-	-	316	316
Total outputs	5,361	10,711	39,671	1,901	316	527	10,940	53,355	53,355
Net input for conversion	-2,489	-10,557	-36,645	-1,901	-316	-527	-10,940	-50,329	21,307
Used by energy industries									
Primary fuel producers	-	-	-	-	-	-	155	155	1,411
Secondary fuel producers	900	1,646	2,546	66[8]	-	238	903[9]	3,753	3,922
Total used by energy industries	900	1,646	2,546	66		238	1,058	3,908	5,333
Losses in distribution	-	-	-	-	-	17	292	307	958
Final energy consumption									
Iron and steel industry	225	11	296	1,634	-	253	306	2,489	2,895
Other industries	1,423	632	3,215	48	-	19	3,091	6,373	12,371
Total industry	1,648	643	3,510	1,681	-	272	3,397	8,860	15,266
Transport	48	2,733	18,864	-	-	-	180	19,044	19,044
Domestic	6	974	1,092	84	312	-	3,347	4,835	17,876
Other final consumers	438	11	1,769	76	5	-	2,665	4,515	8,265
Total final energy consumption	2,139	4,362	25,235	1,841	317	272	9,590	37,255	60,451
Total inland energy consumption of primary fuels & equivalents [10]	550	-4,549	-8,863	6	1	-	-	-8,855	88,049
Non-energy uses:									
Petrochemical feedstocks	-	2,450	2,708	-	-	-	-	2,708	2,708
Other	-	1,629[11]	1,629	-	-	-	-	1,629	1,629
Total non-energy uses	-	4,079	4,337	-	-	-	-	4,337	4,337
Gross inland consumption	550	-470	-4,526	6	1	-	-	-4,518	92,386

(7) Petroleum gases
(8) Including blast furnace gas used at coke ovens (36 million therms)
(9) Including electricity used for pumping at pumped storage stations less the quantity of electricity generated by them
(10) Including non-energy use of natural gas
(11) Industrial and white spirits, lubricants, bitumen and wax. Also includes miscellaneous products mainly for inland consumption but excludes small quantities derived from coal

source: DTI, 1992

Balance tables can range from the simple and aggregated to the large and disaggregated ones used by the DTI. Larger and more disaggregated tables are useful for detailed analysis of energy consumption and use, with more compact and aggregated tables best suited to showing the basic energy supplies and how they are used. A more aggregated form of the DTI's balance table is shown in Table 6.2 to explain the concept.

Table 6.2: The DTI's energy balance table in an aggregated form.

United Kingdom: 1991 *Billion Therms*

		Primary Fuels	Secondary Fuels	Total
(g)	**Fuel Supplies**	97.0	-4.5	92.5
(a)	**Net Conversion Inputs**	71.5	-50.0	21.5
(b)	**Industry Own Uses**	1.5	4.0	5.0
(c)	**Distribution losses**	0.5	0.3	1.0
	Industry	6.0	9.0	15.0
	Transport	0	19.0	19.0
	Domestic	13.0	5.0	18.0
	Other	4.0	4.5	8.0
(d)	**Total Final Consumption**	23.0	37.0	60.0
(e)	**Non Energy Uses**	0	4.3	4.3
(f)	**Total Gross Consumption**	97.0	-4.5	92.0
		(p)	(s)	(t)

In each column of the table, the sum of conversion inputs (a), industry own uses (b), distribution losses (c), final consumption (d) and non-energy uses (e) adds up to the total gross consumption (f), which in turn is equal to the total fuel supply (g). In each row the sum of primary and secondary fuels (p) and (s) equals the total (t) (the sums may not be exact due to rounding errors). The negative figures for secondary fuel supplies show that the U.K. was a net exporter of these in 1991, and the negative value for the net conversion inputs shows a net output of secondary fuels from conversion processes. The fuels have been grouped as primary and secondary for convenience, and the sections of the table have been compacted (the disagregation of final use by sector in table 6.1 has been kept in table 6.2). In theory, the balance table could be made to include useful energy statistics (as described in section 3.1.2), but these vary as a percentage of final energy from fuel to fuel and are dependent upon energy conversion technology. Although the DEn in 1979, did sponsor an extensive study that published useful energy statistics (DEn, 1979a) it did not regularly tabulate them, as the information required is difficult and expensive to gather and assimilate.

6.5 Transport Balance Tables.

The three measures of passenger and freight transport mass movement, (net, essential and gross) enable something similar to the DTI's energy balance table to be constructed for transport. A table of the various transport uses and activities can be drawn up that is disaggregated and made to balance (i.e. the disaggregation is complete - there are no unknown sources or sinks of transport consumption). Such a transport balance table is shown in table 6.3 below.

The table is analogous to the aggregated DTI energy balance (table 6.2) and units of billion tonne kilometres equivalent (btkme) are used throughout. Similarities include: (1) the distribution losses that are detailed in the energy balance table are the analogue of the non-essential mass movement in the transport balance table; (2) final consumption in the energy balance table is analogous to gross mass movement minus transport industry own use of transport (not shown in this transport balance table, but discussed in section 6.6 below); (3) the bottom row of the transport balance table details the total gross transport activity (for both passenger and freight) by transport carrier, in the same way that the energy balance table gives details of total energy consumption by type of fuel.

for convenience, and the sections of the table have been compacted (the disagregation of final use by sector in table 6.1 has been kept in table 6.2). In theory, the balance table could be made to include useful energy statistics (as described in section 3.1.2), but these vary as a percentage of final energy from fuel to fuel and are dependent upon energy conversion technology. Although the DEn in 1979, did sponsor an extensive study that published useful energy statistics (DEn, 1979a) it did not regularly tabulate them, as the information required is difficult and expensive to gather and assimilate.

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There are three notable differences between the tables 6.2 and 6.3: (1) the DTI's balance table does not contain useful consumption statistics (analogous to net transport mass movement); (2) there is no analogue in transport for non-energy uses of fuels; and (3) there are no conversion activities.

Table 6.3: Transport balance table, 1991.

United Kingdom:1991 *Billion Tonne Kilometres Equivalent*

	Metabolic[1]	Road[2]	Rail	Water	Air	Pipe	Total
net passenger	2	32	2	-	- [5]	-	36
net freight	-	130	15	56	- [5]	11	212
Total Net	2	162	17	56	- [5]	11	248
consequential passenger	- [5]	137	29	-	2	-	168
consequential freight	-	80	8	18	-	-	106
Total Consequential	- [5]	217	38	18	2	-	274
essential[3] passenger	2	169	31	-	2	-	203
essential freight	-	210	24	74	-	11	319
Total Essential	2	379	55	74	2	11	522
non essential passenger	-	218	86	-	4	-	307
non essential freight	-	232	3	17	-	-	253
Total Non Essential	-	450	89	17	4	-	560
gross passenger	2	386	117	-	6	-	510
gross freight	-	442	27	91	-	11	571
Total Gross[4]	2	829	143	91	6	11	1082

[1] Cycling and Walking; [2] Motorcycles, Cars/Taxis, Buses, LGVs, HGVs; [3] net + consequential = essential
[4] Gross = net + consequential + non-essential; [5] less than 0.5 btkme

For each mode, the column shows the relationship between net, essential and gross mass movement for that carrier. The right hand column reveals that overall, gross mass movement could in theory have been under half what it actually was in 1991 (i.e. if all non-essential mass movement had been zero).

The ratio of net to gross mass movement can be used as a rough measure of productive efficiency (with larger ratios indicating more efficiency in terms of mass movements). The ratio varies greatly between carriers: for rail it is around 0.1; for motorised carriers it is 0.2; for water the ratio is around 0.3; and for metabolic carriers and pipe it is around 1.0.

The table also shows net, consequential and essential, non-essential and gross mass movement divided into passenger and freight components. Essential freight mass movement was a little more than half total essential mass movement. There was little or no essential passenger mass movement for water carriers or pipe, and little or no essential freight mass movement for metabolic and air carriers. For both road and rail carriers, essential passenger mass movement was slightly more than essential freight mass movement.

Non-essential mass movements for road, rail, and air transport carriers were roughly four thirds of their respective essential activities, whilst the non-essential mass movement for water carriers was only around one third of its essential mass movement. Metabolic and pipe transport were very efficient; their non-essential activities were both zero.

Energy balance tables are able to accurately depict the total 'gross' amount of primary energy that is used, and then to distinguish within that, a component that is demanded by the fuel processing and transmitting industries themselves, whereas, beyond final use (see figure 5.1), it would be a relatively difficult task to give an estimate of useful energy consumption. Transport statistics are in some sense the other way round, in that they are normally given in terms of accurate measures of productive net transport consumption (i.e. in terms of passenger or tonne kilometres). Just as it is difficult to estimate useful energy consumption since the collection of energy statistics is geared to primary consumption, so too it is more difficult to estimate gross transport mass movement since the collection of transport statistics is geared to net mass movement.

Unlike its energy equivalent, the transport balance table does not distinguish the component of the total demand for transport that is a secondary effect of the demand for transportation in the first instance (the analogue of energy industry own use). Intuitively, since about 10 per cent of all people employed work in transport related industries (Department of Employment, 1991), and expenditure on transport accounts for one sixth of household income (DTp, 1992b), the demand for transport itself can be expected to be an important economic activity. There are two reasons why it may be important to estimate transport industry own use of transport. Firstly, it will give a better indication of the non-transport economy's demand for transport, and secondly as transport industry own use will be a function of modal split (with more motorised mass movement demanding more industrial support), it may be important in the consideration of alternative transport futures to calculate transport industry own use of transport associated with various different modal splits. The next section estimates transport industry own use of transport for 1991.

6.6 Transport Industry Own Use of Transport.

Since energy production, transformation and transmission require a significant proportion of total energy consumption, (5 billion therms or 6% of total consumption in 1991 - see table 6.2) it is important in energy policy analysis to explicitly distinguish between energy industry own use of energy and all other energy use.

A similar situation exists in transport, where demand is partly generated by transport-related industries themselves. The energy analogy suggests that a first estimate of transport industry own use of transport would give greater insight into the nature of the current demand for transport and the likely incremental industrial demands of any future transport scenarios.

6.6.1 Transport Industry Own Use of Passenger Transport.

Table 6.4 gives details of the number of employees who are directly involved in developing, maintaining, and staffing various transport-related activities. In a complex economy like the UK's, where output from one industry or sector can be the input to another, it is difficult to evaluate exactly all those jobs which are related to transport. The list in table 6.4 can be regarded as a first approximation, the actual number (incorporating further secondary and tertiary feeder industries e.g. driving instruction) will be greater. In 1991, the DTp estimated that just over 1.6 million people were employed in all transport-related industries and services (DTp, 1992b) .

Table 6.4 updates this estimate, and also modifies it by taking into account: walking as a form of transport; the domestic proportion of U.K. air and sea transport; and wholesale distribution of fuels, vehicles, parts and materials. The table reveals that in 1991, the number of employees (male and female, full and part time) in transport-related industries was just over 2 million or 9 per cent of the total work force.

Table 6.4: Employees in transport-related industries, 1991 [1].

Table 6.4: Employees in Transport-Related Activities, 1989 [1]

Great Britain

brief description (SIC code)	number of employees 000s	per cent female[2] %	weekly travel[3] male	weekly travel[3] female	average weekly[6] distance per person
			kilometres		
manufacture of motor vehicle and parts (35)	253	12	157	84	148.4
manufacture of construction equipment (3254)	14	9	157	84	150.6
manufacture of other transport (36 - but not 364)	77	47	157	84	122.9
manufacture of footwear (451)	45	52	159	56	105.4
manufacture of tyres and inners (4811/482)	22	59	159	56	98.5
construction - civil engineering (502)	194	11	159	56	147.6
wholesale distribution of fuel(612)	90	25	216	51	173.7
wholesale distribution vehicles/parts (6148)	47	28	216	51	169.1
retail distribution of footwear (6450)	71	84	216	51	77.6
retail distribution of vehicles/parts (651)	210	23	216	51	177.1
retail distribution of fuel (652)	59	49	216	51	134.5
repair of motor vehicles (671)	193	20	216	51	183.4
railways (71)	129	8	161	49	151.8
inland transport (72)	425	14	161	49	145.2
domestic sea transport (74)	23 [2]	18	161	49	140.6
domestic air transport (75)	15 [3]	38	161	49	118.3
support to inland transport (761)	19	14	161	49	145.0
transport-related insurance (82)	100 [4]	48	130	74	103.2
transport hire (848)	30	33	130	74	111.2
Department of Transport (9111)	15	54	241	101	165.9
local government transport (9112)	30 [5]	56	241	101	162.2
transport police (9130)	20 [5]	28	241	101	201.6
total of all transport-related classifications	**2081**				
total of all SIC classifications	22300				

[1] 1989 is the latest year for which data that disagregates employment statistics down to four figures of the SIC is available; [2] Source: Department of Employment, 1991; [3] Source: DTp (1992a);
[2] defined as G.B. 'seafarers' in DTp, 1992: table 6.21; [3] in 1991, out of 56 million passengers uplifted, 12 million were domestic (21%) so that of the total 72000 employees of UK airlines, 15000 for domestic;
[4] estimated from net premium incomes from Association of British Insurers Statistics (ABI, 1992)
[5] estimate; [6] weighted average of males and females.

sources: DTp, 1992b; Department of Employment, 1991

6.6.1.1 Female Employees.

Table 6.4 shows that the proportion of women employed varies significantly across the different industries, from 8 per cent in railways to 84 per cent in retail distribution of footwear. Overall, there were 498 000 women working in transport-related industries, approximately one quarter of the total.

6.6.2 Average Work Distance Travelled.

Results from the National Travel Survey (NTS), indicate a significant difference between work distance travelled by males and females (age 16-59); working males travel an average of 164 work km per week, whereas working females travel around 62 work km per week. These figures are solely for the travel undertaken by employed males and females to and from work and in the course of work. Table 6.4 shows disaggregated data taken from the NTS across the main industrial classifications (by first digits) and by sex. There are no estimates of work travel beyond this stage of classification, by sex or by mode. Hence, a gross mass movement measure of transport industry own use of passenger transport can be estimated by first calculating the implied total annual work travel of all transport related employees, and then combining this with the results of the 1985/6 travel survey for work travel modal splits.

An estimate of total annual work travel of employees in transport-related industries is given by:

total travel = travel distance per person per week$*$ weeks worked$*$number of employees

For a particular industry classification, 'i', the total weekly work travel 'd_i' of all employees 'n' in that industry can be calculated by taking into account the proportion of males 'p' and females (1-p) working in that industry, and the average weekly work travel for males, 'm' and females, 'f', in that industry:

$d_i = n * (p*m+((1-p)*f))$ (6.2), which is the same as

$d_i = n *$ (last column of table 6.4) (6.3)

Total weekly work travel for employees of all transport-related industries is then the sum of d_i over all relevant industries.

The result of this calculation and summation, using the data in table 6.4, provides an initial estimate of the total transport industry own use of passenger transport of 15 billion passenger kilometres over 48 weeks in 1991 (allowing four weeks for holidays). This is around 2 per cent of the total passenger activity in 1991 of 669 billion passenger kilometres.

6.6.3 Gross Mass Movement.

A first approximation of the gross mass movement associated with the transport industry own use of passenger transport assumes that the modal split for transport industry work travel will not differ from the modal split estimated across all work travel as observed in the 1984/85 NTS. Table 6.5 shows the patterns in work distance travelled for men and women (age 16-59) by main mode. The slight difference in modal split between men and women can be combined to form an aggregated modal split. The number of transport industry own use passenger kilometres associated with each mode is calculated by allocating the total 15 billion passenger kilometres to each mode using the modal split as shown in table 6.5 (third column from left). Average carrier occupancies and unladen carrier masses for 1991 (see tables 5.2 and 5.3) can be used to estimate gross mass movement for each type of carrier, assuming that occupancies for these journeys are the same as for travel in general. The gross mass movement of a particular carrier, G_c, can be calculated using:

$$G_c = (N_c*0.05) + N_c/O_c*U_c \qquad (6.4)$$

where N_c is the number of passenger kilometres for a particular carrier.

Table 6.5 compares transport industry own use gross passenger mass movements with total gross passenger mass movements for each of the carriers. Overall, transport industry own use of passenger transport accounted for 2 per cent of total passenger gross mass movements in 1991.

Table 6.5: Work distance travelled and gross mass movement: by main mode and sex

Great Britain *1991*

mode[6]	men[1] *km*	women[1] *km*	weighted average[2] *%*	Net TIOUT[3] *bpkm*[4]	Unladen mass *tonnes*	Average Occupancy *persons*	Gross TIOUT *btkme*[5]
car	129	39	75	11.25	0.95	1.07	6.85
train	18	11	12	1.8	250	119	3.87
bus	11	11	10	1.5	7	8.7	1.28
walking	2	1	1	0.15	0	1	0.01
cycle	2	0	1	0.15	0.02	1	0.01
motorcycle	2	0	1	0.15	0.1	1.09	0.02
all modes	164	62	100	15	-	-	12.04

[1] results of national travel survey - (DTp, 1988); [2] according to male/female ratio derived in section 6.5.2; [3] Transport Industry Own Use of Transport; [4] billion passenger kilometres; [5] billion tonne kilometres equivalent; [6] assuming that average modal splits for transport-related employees are the same as those for all employees.

6.6.4 Transport Industry Own Use of Freight Transport.

The nearest freight equivalent to the NTS is the Survey of Road Goods Transportation (DTp, 1991b). This survey provides a limited breakdown of estimates for the transportation of various type of goods by road according to an international goods classification scheme. Unlike the NTS, where all modes of passenger transport are included, detailed statistics for the transport of goods by road, rail, water, air, and pipe are published separately. Detailed disaggregated data on goods transport in any mode is not readily available, nor does it seem that it can be made available, short of designing and conducting new surveys. The standard goods classification scheme for Transport Statistics in Europe (Nomeclature Statistique de Transport - NST/R) classifies goods into 176 headings, 52 main Groups, and 10 chapters. In practice, data is only available at the level of the 10 chapters and a few groups. Table 6.6 gives details of the three main commodity groups that are directly related to transport industry own use of freight transport: petroleum products; crude minerals; and transport equipment. The figures given in the table have been estimated from the data available in some cases only at the chapter level. A first approximation of transport industry own use of transport measured on a gross mass movement is achieved by assuming that, for instance, as 62% of all petroleum is used in transport, 62 per cent of petroleum transported by each mode is transport industry own use of transport. Table 6.6 reveals that, in 1991, 55 billion tonne kilometres (out of a total of 212 btkme of all goods moved) were transport industry own use of transport, amounting to just over one quarter of all net productive freight movements in the U.K. The accuracy of this figure is determined by the three main inputs that determine net mass movement. Two of these (table 6.6: footnotes 1 and 3) are accurate to within 5%, whilst a third (footnote 2) has an unknown accuracy. If the uncertainty in the CPRE's estimate were put at 50% (an extreme suggestion) the change in the overall net estimate would be 10%. Hence, an estimate of the overall uncertainty in the net figure can be identified by weighting the uncertainties in the three parameters by their respective contributions to total net mass movement. This gives a final estimate of 13% uncertainty in the net mass movement figure ($0.82 * 5\% + (0.18 * 50\%)$). Apart from the three main categories of goods in table 6.6, there will be other categories of goods transported by transport-related manufacturing and support services which at this stage have not been taken into account. It seems reasonable to assume that if all such movements (across the 176 NST/R headings) were taken into account, the original estimate of 55 btkme may rise by as much as 20 per cent or a level of goods movement equivalent to that of total transport industry own use of crude minerals transport. Further research is needed, although the lessons of energy analysis about the difficulties of drawing system boundaries should be borne in mind when dealing with the ultimate limits to the accuracy of this calculation (see Leach, 1975; Jones, 1989).

In table 6.6, the unladen masses and average payloads of the four types of carrier are used to transform net mass movement to an estimate of gross mass movement in the same way as for passengers (table 6.5). On a gross mass movement basis, transport industry own use of freight transport accounts for around 100 btkme or around 20 per cent of total gross freight mass movement (a slightly smaller proportion than that in net terms, due to the bulk commodity nature of petroleum and crushed stone etc., which makes them more efficient to transport than other goods).

Table 6.6: Transport-related freight transport, 1991: by type of goods.

United Kingdom *1991*

Description	NST/R		Mode	Net goods moved (*btkme*)	Unladen mass (*tonnes*)	Average occupancy payload (*tonnes*)	Gross TIOUT (*btkme*)
petroleum	3	1	road	3.0	9	4.41	9.12
products			rail	1.2	350	449	2.14
			water	28.2	745	2000	38.7
			pipe	6.9	0	0	6.9
Crude Minerals/Building Materials	6	2	road	6.9	9	4.41	21.0
(crushed stone; macadam)	631		rail	1.0	350	449	1.78
			water	1.9	745	2000	2.61
Machinery/Manufactures	9	3	road	5.7	9	4.41	17.3
(transport	91-93		rail	0.2	350	449	0.36
equipment)			water	0.2	745	2000	0.27
total transport-related freight				**55**			**100**
all freight transport				**212**			**582**

Sources: DTp, 1992b: tables 4.1 and 1.10

[1] in 1991 62 % of total petroleum consumed was used for transportation (DTi, 1992). It is assumed that this proportion also applies to petroleum transported; [2] One third of all aggregates are used in road construction (CPRE, 1991), so this figure is 1/3 of total movement of aggregates corresponding to NST/R 631; [3] only categories NST/R 91-93 are included, these figures represent the 12 % of all category 9 goods which in 1991 for road transport were in these classifications (DTp, 1992b)

In contrast to the relatively accurate picture that can be drawn for transport industry own use of freight transport measured on a net mass movement basis, the assumptions about carrier unladen masses (see table 5.3), average occupancies and distribution of goods moved by mode within each category create much more uncertainty in the gross mass movement estimate of transport industry own use of freight transport. An estimate of the maximum uncertainty in the gross mass measurement, can be made by considering the extremes where all goods are transported via the most and the least efficient means in terms of occupancy/unladen mass ratios. Using the data in table 6.6, these ratios are 2 for road, 0.8 for rail and 0.4 for water (pipe is not considered). Using in equations 5.7 and 5.9 (with N_c = 55 btkme), the maximum possible value of gross mass movement was equal to 167 btkme (if all were transported by road) and a minimum equal value to 75 btkme (all transported by water). This sets an upper bound for the maximum possible uncertainty in the value of 100 btkme given in table 6.6.

6.6.5 Transport Industry Own Use of Transport: 1991.

Table 6.7 summarises the calculations of transport industry own use of transport.

Table 6.7: Transport industry own use of transport, 1991.

United Kingdom *1991*

	Transport Industry Own Use of Transport	All Uses	Units
Net Passenger	15	669	bpkm
Net Freight	55	212	btkm
Gross Passenger	12	508	btkme
Gross Freight	100	582	btkme
Total Gross (passenger and freight)	**112**	**1090**	**btkme**

Two per cent of net passenger movements and 26 per cent of net freight movements were transport industry own use of transport. Measured on a gross mass movement basis, this is equivalent to two per cent of gross passenger transport movement and 20 per cent of gross freight transport movement. Overall, in 1991 therefore, 10 per cent of all transport movements were transport industry own use of transport. This represents a higher proportion than the energy industries own use of energy. The result is broadly in line with the importance of transport relative to other important economic indicators: 16 per cent of household income is spent on transport and travel (DTp, 1992b); 9.3 per cent of the total work force are employed in transport-related activities (see section 6.5.1); and 6.4 per cent of total business expenditure is on transport (DTp, 1992b).

The calculation of transport industry own use of transport has shown that transport is important for the transport industry as well as for the economy and industry as a whole. The pursuit of some of the solutions to the transport problem given in table 3.6, may themselves generate extra transport industry own use. The efficient targeting of demand management schemes in general, and within industry, will therefore require significant further research in order that any demand reductions are seen to have been allocated fairly and economically with the minimum risk to employment and competitiveness. Even though there may be much more research needed into the allocation of transport demand reductions by industry or personal usage, reductions for a particular level of economic growth may be investigated in terms of changes in overall levels of transport mass movement and modal splits. The remainder of this chapter deals with three alternative views of the future development of transport along these lines.

6.7 Three Transport Scenarios for the UK.

6.7.1 Origin of Scenarios.

Since the World Commission on Environment and Development published its influential report in 1987 (WCED, 1987) there has been a series of calls for a shift towards a 'sustainable' transport policy (see ACC, 1991; Short, 1992). Whilst the broad notion of sustainability is well defined (e.g. meeting the needs of the present without compromising possibilities for the future), when translated down from that broad level, the transport implications of sustainability have not been quantified and are even qualitatively unclear; an EC green paper on transport and the environment (CEC, 1992) has been criticised for failing qualitatively or quantitatively to interpret sustainable mobility (Short, 1992).

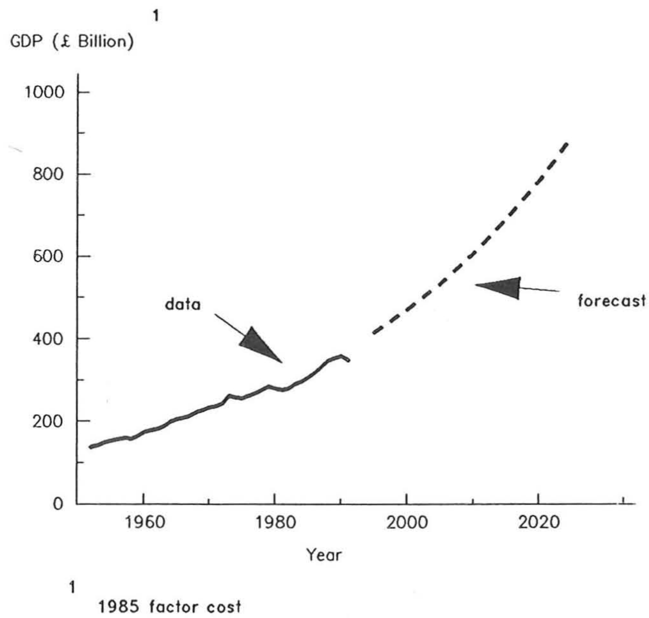
Although there is no obvious way of identifying a sustainable level for gross transport intensity, a scenario involving a path towards it can be constructed from the analogy with energy. The long term reduction in primary energy intensity since the late nineteenth century (figure 3.8) is an example of the level of reductions that can be achieved in another sector of economic activity. Although absolute levels of energy consumption in the UK have not yet been significantly reduced (see figure 3.1), this is due to economic activity and not to low efficiency. As such, the history of reductions in primary energy intensity indicate that a less transport intensive and more sustainable economy can be achieved. If an equivalent (or better) rate of reduction could be achieved for transport intensity as has happened with energy intensity, then this would represent a significant move towards sustainable mobility.

Two other possible UK futures have been the subject of much research and debate. These can be described firstly in terms of a continuation in the long term trends that have been observed over the post-war period, and secondly in terms of the DTp's 1989 NRTF (see table 3.4). The contrast between these two different views of the future is made by Goodwin et al (1990) who note that the NRTF increases are relatively modest compared with the increases that would occur if post-war trends continued. Two scenarios of the overall growth in gross transport mass movement may therefore be constructed from extrapolations of past trends (business as usual - 'BAU') and the 1989 National Road Traffic Forecasts (NRTF).

Three distinct scenarios of the development of transport up to 2025 (the NRTF's horizon) can therefore be identified: *(1) Business as Usual (BAU).* This scenario represents a continuation of observed trends in traffic levels and economic growth up to the year 2025; *(2) National Road Traffic Forecasts (NRTF)*. The basis of this scenario is the 1989 National Road Traffic Forecasts. The forecasts estimate economic growth and then predict estimated traffic levels. Corresponding assumptions about the growth of traffic on other modes have to be made; *and (3) Sustainable Mobility (SM)*. The basic characteristic of a sustainable transport policy would be its emphasis on decoupling economic growth from transport growth. The stimulus for this scenario is observed trends in the energy sector over the period 1880-1992.

The methods of transport policy analysis developed in chapter 5 can be used to transform the three qualitative scenarios into more detailed quantitative pictures of the future. Gross transport intensity is an appropriate indicator to monitor the total extent of transport in the economy, in the same way as primary energy intensity is used as an indicator of total energy consumption. A system which for the same level of GDP generates less gross mass movement than another, will tend to be less congesting, less energy intensive, less polluting, less costly and more efficient. The midpoint of forecast GDP contained in the NRTF's analysis can be used as an exogenous variable, which can be combined with the different gross mass movements of the three scenarios to give a series of gross mass movement intensities. Figure 6.1 shows the forecast growth of GDP over the period which is used throughout the analysis.

Figure 6.1: NRTF median forecast of GDP 1991-2025.



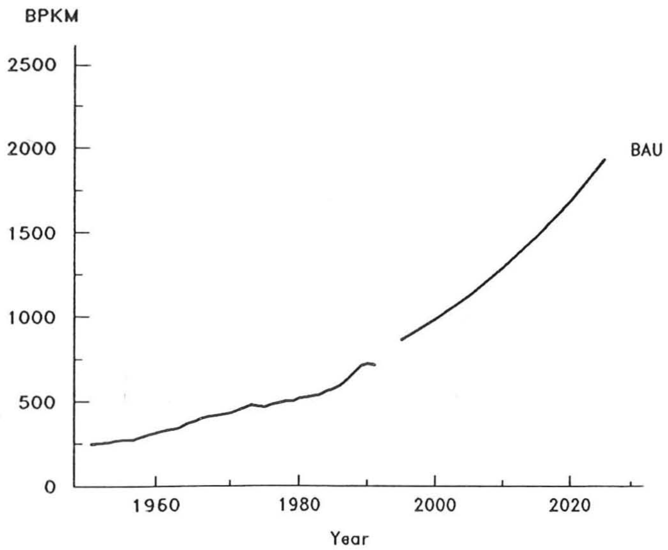
source: DTp, 1989

6.7.2 Transport Policy Scenario Analysis: Method.

6.7.2.1 Business as Usual Scenario.

The continuation of net passenger and freight mass movement trends are used as the key variables determining the nature of the business as usual scenario. There is a strong, nearly linear correlation between both the growth of passenger and freight movements and GDP; a ln-ln (natural) regression of passenger kilometres on GDP gives an elasticity of 1.09 (R^2 = 0.99), and a ln-ln (natural) regression of tonne kilometres on GDP gives an elasticity of 1.02 (R^2 = 0.97). The overall growth of passenger and freight transport for the BAU scenario can be developed by assuming that these long term elasticities will continue to hold in the future and that they can be combined with forecast GDP levels from the NRTF. The results are shown in figures 6.2 and 6.3

Figure 6.2: Passenger transport, 1955-2025: BAU scenario.



Having used these GDP levels to grow total passenger and freight mass movement up to 2025 at the same rate as observed between 1952 and 1991, trends in the occupancies, modal shares, and unladen masses of passenger and freight modes then have to be taken into account.

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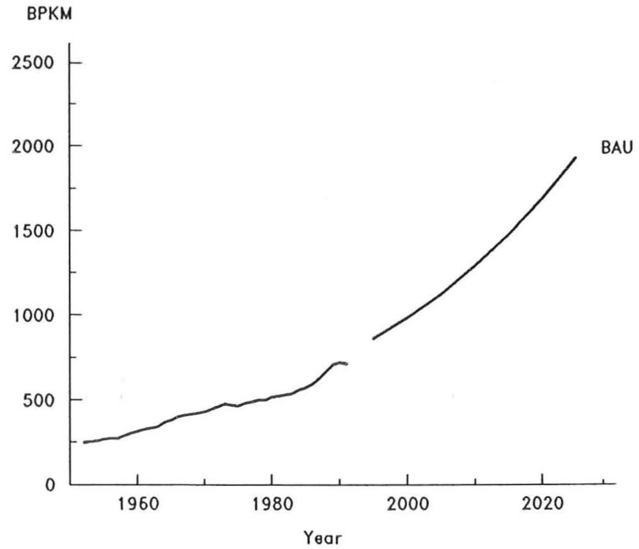


Having used these GDP levels to grow total passenger and freight mass movement up to 2025 at the same rate as observed between 1952 and 1991, trends in the occupancies, modal shares, and unladen masses of passenger and freight modes then have to be taken into account.

Figure 6.3: Freight transport, 1955-2025: BAU scenario.

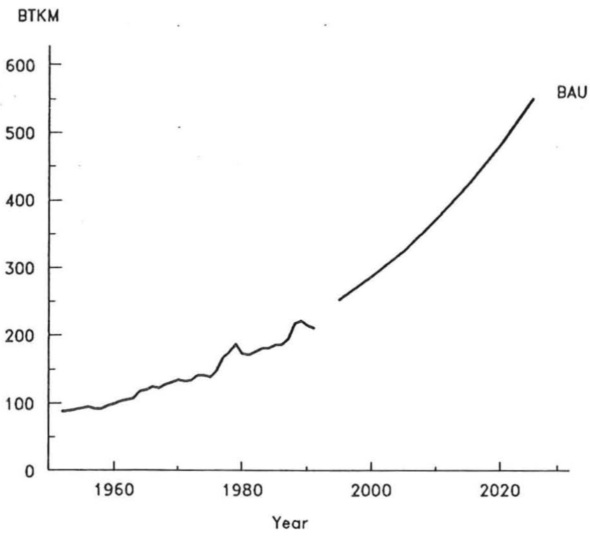


Table 6.8 summarises the changes in these variables which were incorporated to arrive at a more detailed picture of the BAU scenario, comparing 1991 with 2025. The average occupancy levels for cars, buses, LGVs and HGVs have been allowed to continue changing at their previous rates (the rest have remained constant over the period). Under BAU, the absolute levels of net walking, cycles, motorcycles and passenger train transport were held constant. The absolute level of net mass movement for all other carriers (apart from cars and HGVs) were then allowed to continue changing at their previous long-term rates. The overall growth in passenger and tonne kilometres under BAU was then taken up, in passenger transport by car, and in freight by HGV. The modal split of cars and HGVs is therefore left to increase at the expense of the other modes. The calculation of the gross mass movements for the scenarios takes into account the long-term trends in the unladen masses of cars and HGVs.

Also shown in table 6.8 are the implied changes in net transport activity for a particular mode, and implied changes in the number of carrier kilometres travelled by carriers in each mode under BAU. Figures 6.4 and 6.5 show the evolution of modal split for passenger and freight transport under the BAU scenario for the period 1955-2025. Over the period, as the absolute level of passenger travel increases, mainly due to increased car travel, there is a steady increase in the proportion of travel by car and accompanying decreases in the proportion of travel by all other modes. A change in the definition of waterborne transport (in 1976) dominates what otherwise would have been a steady increase in the proportion of HGV freight compared with all other freight modes (which in this scenario is projected to resume in the future).

Table 6.8: BAU Scenario: % changes in key variables 2025 compared with 1991.

per cent increase

Mode	Average Occupancy	Modal Split[1]	Net Mass Movement	Unladen Mass	Carrier km
Passenger					
walk	0	-2	0	0	0
cycle	0	0	0	0	0
m/c	0	-1	0	0	0
car	-15	+12	+209	+16	+262
bus	-36	-5	-50	0	-22
train	0	-3	0	0	
plane	0	-3	+100	0	+100
all passenger modes			+170		
LGV	+33	+1	+294	0	+195
HGV	+40	+19	+241	+37	+144
train	0	-6	-50	0	-50
plane	0	-13	+33	0	+33
pipe	0	-1	+100	0	0
all freight modes			+160		

[1] *sum total of changes not equal to zero because of rounding errors*

Figure 6.4: Passenger transport by mode, 1955-2025: BAU scenario.

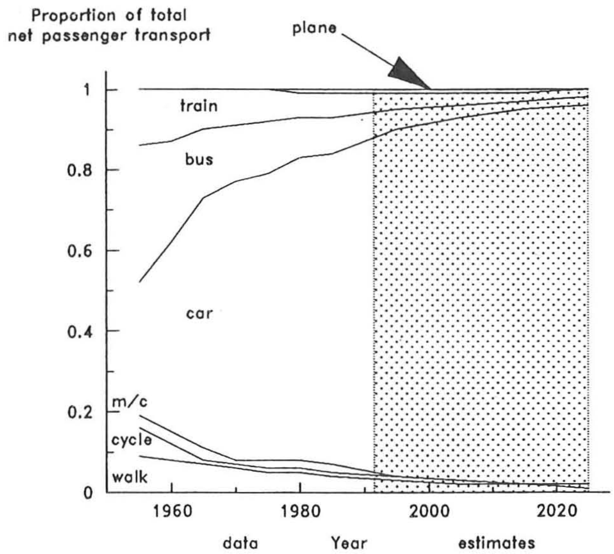
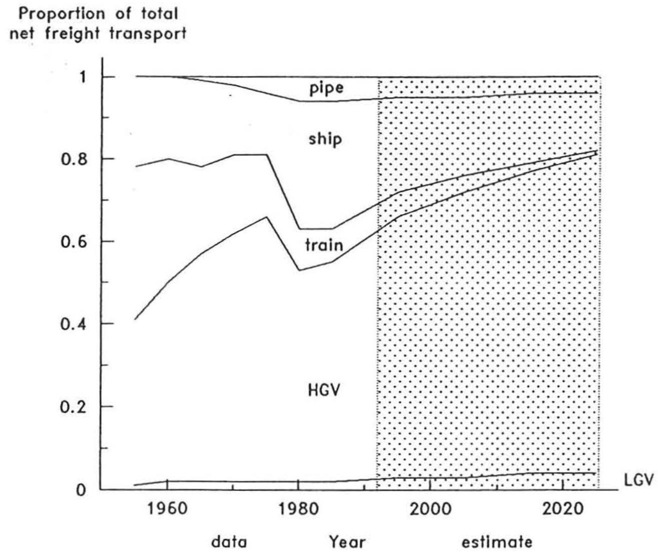


Figure 6.5: Freight transport by mode, 1955-2025: BAU scenario.



6.7.2.2 National Road Traffic Forecasts Scenario.

The DTp's NRTF model specifically forecasts vehicle kilometres for all types of motorised road transport with the exception of motorcycles. These traffic levels are themselves derived from data concerning GDP, fuel price, car ownership levels and car use. The model does not however go as far as predicting the net associated amount of passenger or freight transport (DTp, 1989), but this can be done by taking occupancies used in the BAU scenario into account. An estimate of net road based passenger and freight movements implied in the NRTF is shown in table 6.9 in the form of changes relative to 1991.

The NRTF makes no attempt to forecast transport by other modes such as rail, water, air and pipeline, and does not take possible changes in these modes into account in its forecasting procedure. As a result, although there is a majority of road-based transport, the full picture of total passenger and freight movements can only be achieved by extending the implications of the NRTF forecast to non-road-based modes. As a first approximation, the interaction between the road traffic forecasts and trends in other modes can be assumed to be negligible.

Table 6.9: NRTF scenario: % changes in key variables 2025 compared with 1991.

per cent increase

Mode	Average Occupancy	Modal Split[1]	Net Mass Movement	Unladen Mass	Carrier km
walk	0	-1	0	0	0
cycle	0	0	0	0	0
m/c	0	0	0	0	0
car	-15	+7	+62	+16	+90
bus	-36	-4	-43	0	-10
train	0	-2	0	0	0
plane	0	0	+100	0	+90
all passenger modes			+49		
LGV	+33	+1	+196	0	+122
HGV	+40	+15	+174	+37	+96
train	0	-6	-50	0	-50
plane	0	-10	+33	0	+33
pipe	0	0	+100	0	0
all freight modes			+117		

1 sum total of changes not equal to zero because of rounding errors

Overall passenger and freight transport levels (shown in figures 6.6 and 6.7) for the NRTF scenario can be constructed from the BAU scenario by modifying only those components which are directly forecast from the DTp's model.

Figure 6.6: Passenger transport, 1955-2025: NRTF scenario.

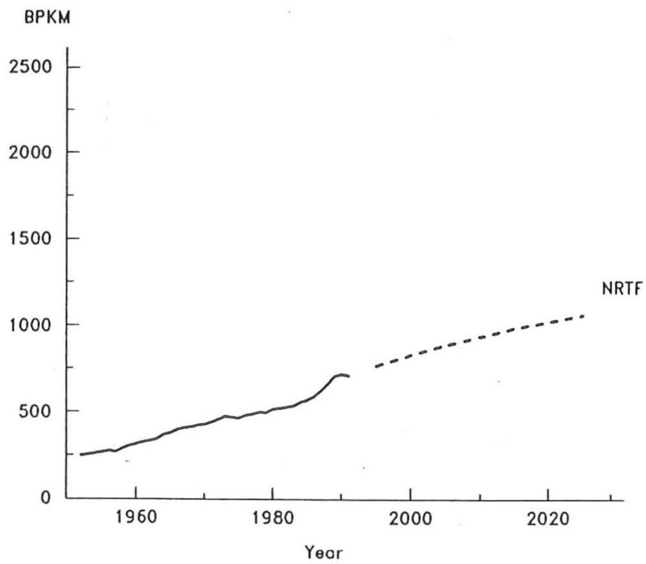
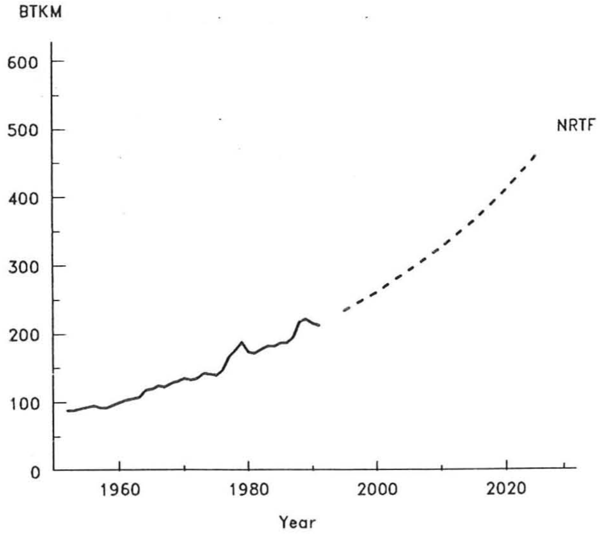
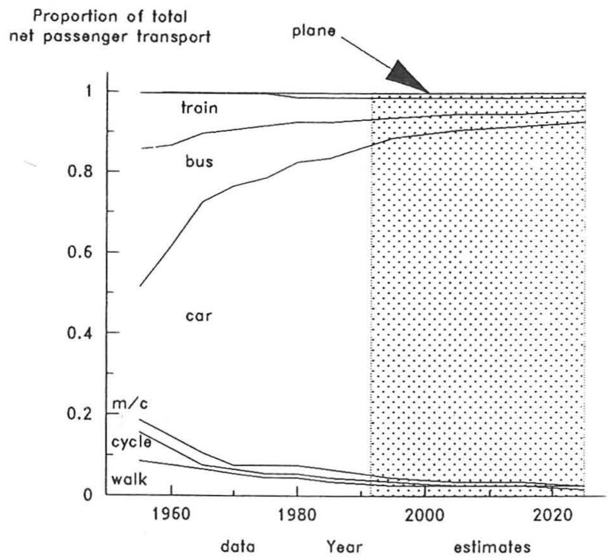


Figure 6.7: Freight transport, 1955-2025: NRTF scenario.



Figures 6.8 and 6.9 show the evolution of modal split for passenger and freight transport under the NRTF scenario for the period 1955-2025.

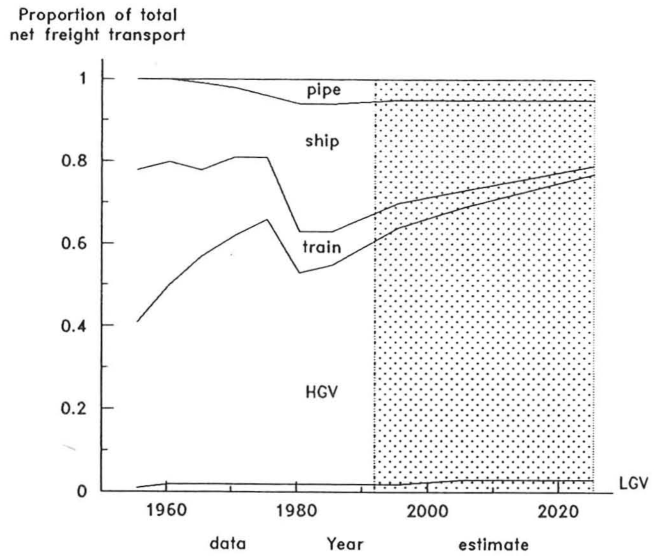
Figure 6.8: Passenger transport by mode, 1955-2025: NRTF scenario.



Changes in modal shares of passenger and freight transport under the NRTF scenario are very similar to those under the business as usual scenario, but with the modal share of both road-based passenger and freight transport evolving slightly less rapidly.

The most significant difference between the BAU and NRTF scenarios is in their implied elasticities. Total passenger transport elasticity drops from 1.05 in the BAU scenario to 0.42 for the NRTF case, whilst total freight transport elasticity drops from 1.01 in the business as usual scenario to 0.88 in the NRTF case. These drops in total passenger and freight elasticities are entirely a result of the failure of the NRTF to take into account their relationships with the demand for transport by non-road based modes.

Figure 6.9: Freight transport by mode, 1955-2025: NRTF scenario.



Since within the NRTF scenario, it is business as usual for all modes other than those directly specified by the NRTF forecasts, these reductions are brought about by the NRTF forecasts themselves. The DTp have accepted that their forecasts of traffic levels are relatively modest compared with forecasts of GDP based on previous experiences (Spackman, 1992). There are some reasons to support this, such as car ownership saturation levels, although these aspects were not clearly addressed within the DTp's 1989 report.

6.7.2.3 Sustainable Mobility Scenarios.

It is generally thought that the consequences of the traffic increases implied in the National Road Traffic Forecasts would be severe. A scenario for sustainable mobility must therefore imply a sharper decrease in the rate of traffic growth. In turn this implies that if economic growth is not to be compromised, there must be a significant decoupling of traffic levels from economic activity. Implicit in the distinction between 'sustainable' and 'unsustainable' mobility is concern over transport's growing imposition on the social, economic and physical environment. Notions of inter-generational equity, quality of supply, economic competitiveness, social and welfare objectives, and environmental awareness are driving a search for sustainable mobility, just as they led to what, in retrospect, might be called a sustainable energy policy during the 1970s. Defining exactly what levels of transport are sustainable is a difficult and subjective issue. It is not clear what is a sustainable relationship between GDP and transport activity. Whatever the nature of this relationship, in a world that places high priority on economic growth, it is recognised that sustainability will only be achieved if economic growth can be decoupled from transport growth. This implies that a transport scenario with a lower gross mass intensity represents a more sustainable future.

The energy-transport analogy provides one way of overcoming the problems of envisioning sustainable transport. The changes in primary energy intensity shown in figure 3.8 (reproduced below as figure 6.10) represent significant changes in the economy's dependency on energy.

For the last 130 years energy intensity has fallen steadily to around 1/3 of its peak value in 1880 and it is still dropping although there are signs that the rate of decrease is slowing down. A guide to a feasible path for reductions in transport intensity can be estimated by analogy with the long term shift in energy intensity. Here, the decoupling of the relationship between economic growth and energy consumption has meant that absolute levels of energy consumption are around two thirds lower in the 1990s than they would have been had energy intensity remained at late-Victorian levels. Reductions in energy intensity therefore, have occurred at the same time as increases in economic growth. The sustainable mobility scenario is based on a combination of the changes shown in table 6.10 which are with respect to 2025 NRTF scenario.

Figure 6.10: UK primary energy intensity: 1700-1991.

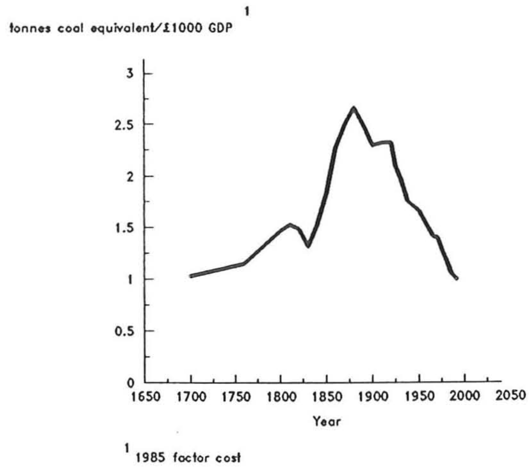


Table 6.10: Key changes in SM scenario relative to NRTF 2025.

	Changes Relative to NRTF 2025	% reduction in Gross Transport Intensity
a	10 % shift from cars to 3 % walk, 7 % cycle	3.1
b	10 % shift from cars to buses (O_{bus}=12, U_{bus}=5t)	2.2
d	20 % shift from HGV to 2% pipe, 2% ship, 16% rail	4.2
e	20 % increase in O_{ptrain}, 17% decrease in VKM	1.0
f	10 % increase in O_{cars}, 9% decrease in VKM	3.1
h	60 % increase in O_{lgv}, 37% decrease in VKM	3.3
i	10 % increase in O_{hgv}, 9% decrease in VKM	3.1
m	10 % reduction in U_{car}	3.1
q	10 % reduction in U_{hgv}	3.1
u	5 % reduction in elasticity of passenger movements	2.0
v	5 % reduction in elasticity of freight movements	3.0
total theoretical reduction[1]		31.2
observed reduction		29.26

[1] *the estimates of the effects of the individual changes in parameters a-v do not take into account the effects of combining measures into a series of changes. As a result the cumulative effect of the changes produces a slightly different observed reduction.*

The sustainable mobility scenario is designed by targeting a trend in transport intensity, analogous to the long term trend in energy intensity, and then working with this to backcast modal shares, traffic levels etc. A target value for gross transport intensity of 1.85 btkme/pound GDP for the year 2025 was chosen because it represents a rate of reduction in gross transport intensity equivalent to that experienced in the reduction of primary energy intensity. Reductions in gross transport intensity can be achieved by a number of combinations of changes in the occupancies, modal splits, unladen masses and absolute levels of transport for each carrier. The SM scenario was specified by taking into account the effects on gross mass movement intensity of changing various input parameters (the full list is shown in table A8 in appendix 9.5). To ensure the scenario's credibility, only those changes that were thought to be feasible within the time period where considered. It was assumed that the relative ease of small changes in the four main groups of parameters followed the following order from most feasible to most difficult: changes in occupancies are easier than changes in modal splits which are easier than changes in unladen carrier masses which are easier than changes in elasticities.

Table 6.11 summarises the changes in carrier occupancies, modal shares, unladen masses and carrier kilometres that are produced by the changes in table 6.10.

Table 6.11: SM scenario: % changes in key variables 2025 compared with 1991.

per cent increase

Mode	Average Occupancy	Modal Split[1]	Net Mass Movement	Unladen Mass	Carrier km
walk	0	+2	+103	0	0
cycle	0	+6	+1217	0	+1217
m/c	0	+4	+747	0	+747
car	-6	-15	+15	+5	+23
bus	-27	+5	-155	-29	-100
train	+25	-2	-5	0	-24
plane	0	0	+90	0	+80
all passenger modes			+41		
LGV	+113	+1	+181	0	+32
HGV	+54	0	+108	+23	+36
train	0	+6	287	0	+287
plane	0	-9	+38	0	+38
pipe	0	+1	+148	0	0
all freight modes			+107		

[1] *sum total of changes not equal to zero because of rounding errors*

Starting in 1991, the target intensity was reached by allowing the transition to the above configuration to be a succession of linear changes in each variable. In other words the rate of advancement towards the target intensity was constant. The overall effects of these changes in terms of total freight and passenger movements are shown in figures 6.11 and 6.12.

Figure 6.11 Passenger transport, 1955-2025: SM scenario.

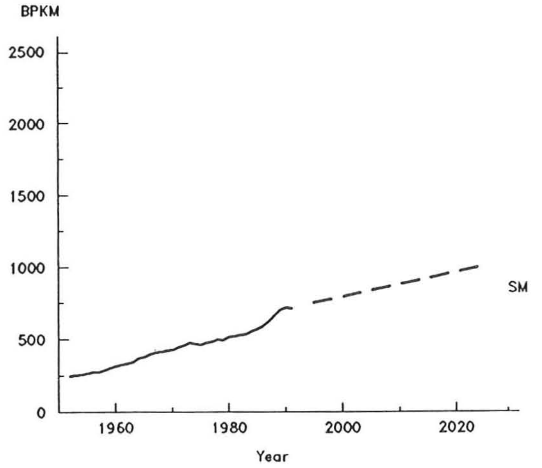
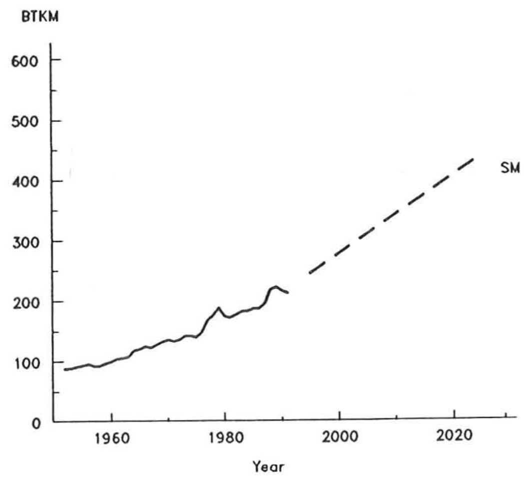


Figure 6.12 Freight transport, 1955-2025: SM scenario.



Figures 6.13 and 6.14 show the evolution of modal shares for the various passenger and freight modes under the SM scenario over the period 1955-2025.

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Figure 6.11 Passenger transport, 1955-2025: SM scenario.

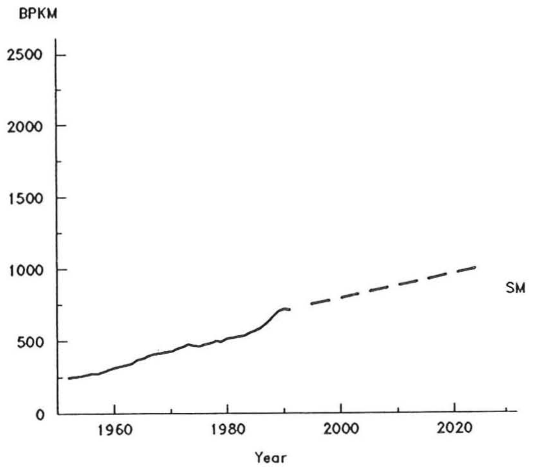
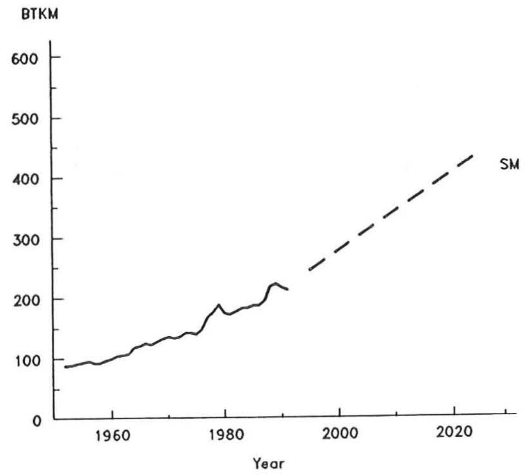


Figure 6.12 Freight transport, 1955-2025: SM scenario.



Figures 6.13 and 6.14 show the evolution of modal shares for the various passenger and freight modes under the SM scenario over the period 1955-2025.

Figure 6.13: Passenger transport by mode, 1955-2025: SM scenario.

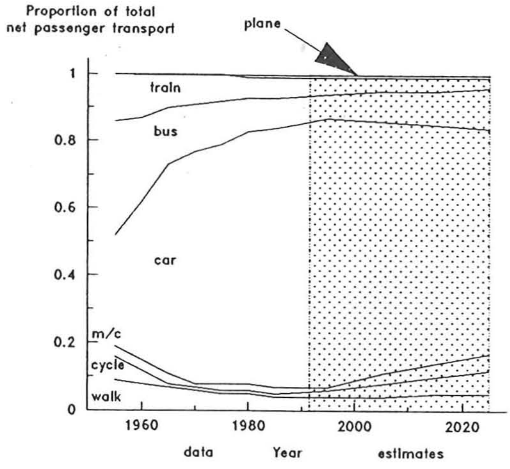
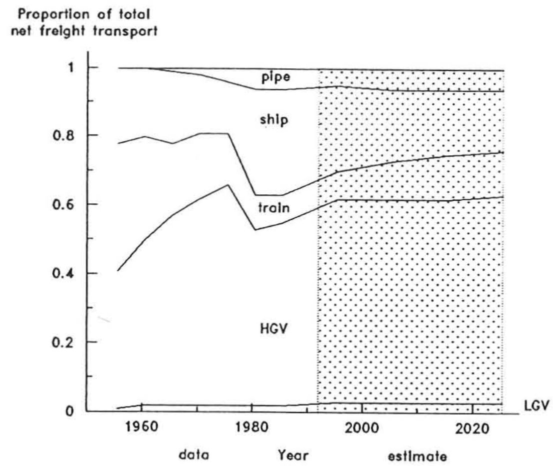


Figure 6.14: Freight transport by mode, 1955-2025: SM scenario.



In contrast to the BAU and NRTF scenarios, under the SM scenario, modal shares for non-car-based passenger transport begin to increase steadily. The result is a gradual squeezing of the car's share of passenger transport and an increase in both metabolic and public transport. Whereas road freight movements continued to increase their overall share of all freight transport under BAU and NRTF, the SM scenario suppresses this trend by increasing the modal shares of non-road freight. The result is a 15% decrease in the modal share of LGV and HGV freight compared to the BAU scenario and a 10% decrease compared with the NRTF scenario.

6.7.4 Overall Net Movements and Gross Mass Movement Intensities.

A comparison of the changes in passenger and freight transport movements for the three scenarios are shown in figures 6.15 and 6.16. For both passenger and freight mass movements, if observed trends are to continue then, in the absence of any significant policy changes, growth will continue at a roughly constant rate over the period resulting in exponential increases in both passenger and freight movements.

Figure 6.15 Passenger transport, 1955-2025: BAU, NRTF and SM senarios.

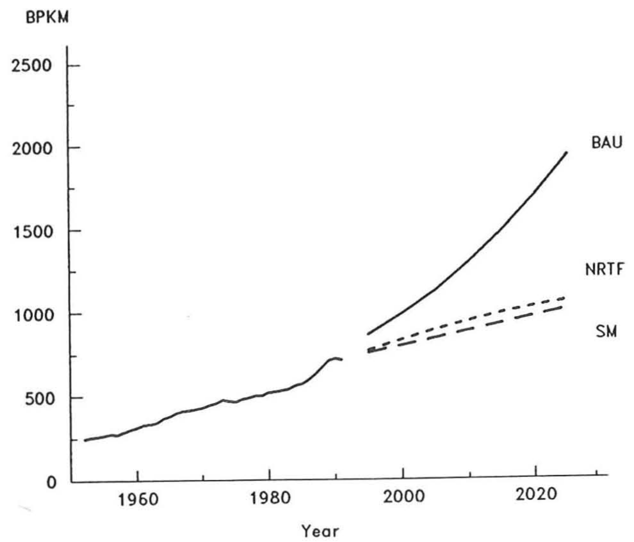
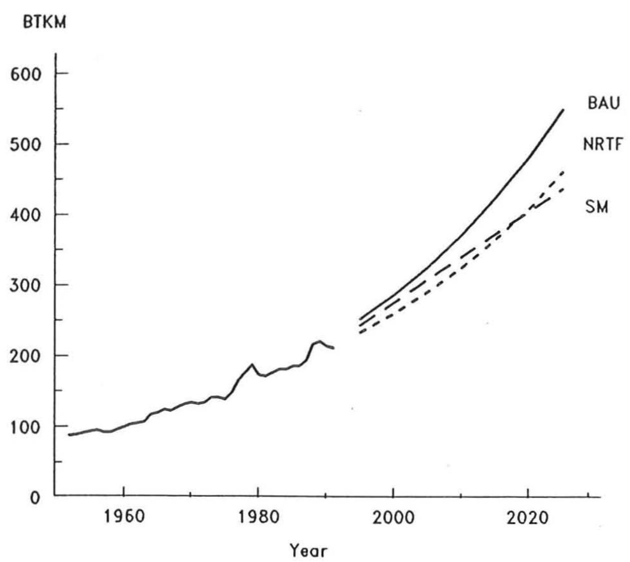


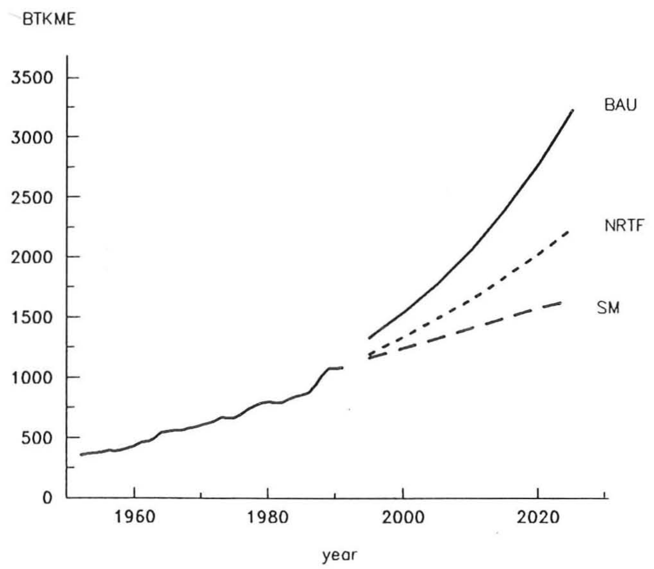
Figure 6.16: Freight transport, 1955-2025: BAU, NRTF and SM scenarios.



In the case of passenger movements, the difference between trends continued and either the NRTF or the SM scenarios is significant. Trends in passenger and freight movements under the SM scenario have been designed to closely follow those in NRTF with a slackening of passenger and freight elasticities of only around 5 % compared with those of the NRTF scenario. Under the NRTF scenario, increases in both passenger and freight movements are predicted to be less that the trend for BAU (indeed, as figure 6.16 shows, less than SM for some of the period).

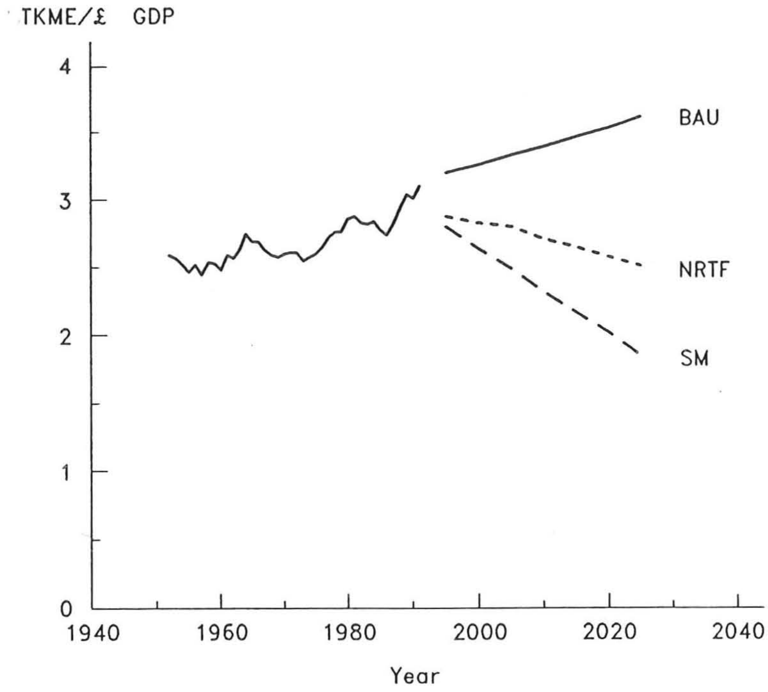
The gross mass movements resulting from the three scenarios are shown in figure 6.17. The figure shows that there is a factor of two difference between the gross mass movements of the three scenarios in 2025. The NRTF scenario lies around mid-way between the other two, representing a considerably larger increase than SM, but considerably less than BAU. Even the SM scenario has a significant growth in gross mass movement of around 50 per cent compared with 1991.

Figure 6.17: Gross mass movement: BAU; NRTF and SM scenarios.



A combination of the above changes in gross mass movements and the forecast changes in GDP (figure 6.1) gives rise to the three scenarios for transport intensity shown in figure 6.18. The continued growth of transport at its previously observed rate (BAU) is clearly unsustainable. Even the Government's forecasts imply a significant downturn in the growth of transport intensity.

Figure 6.18: Transport intensities 1952-2025: BAU; NRTF and SM scenarios.

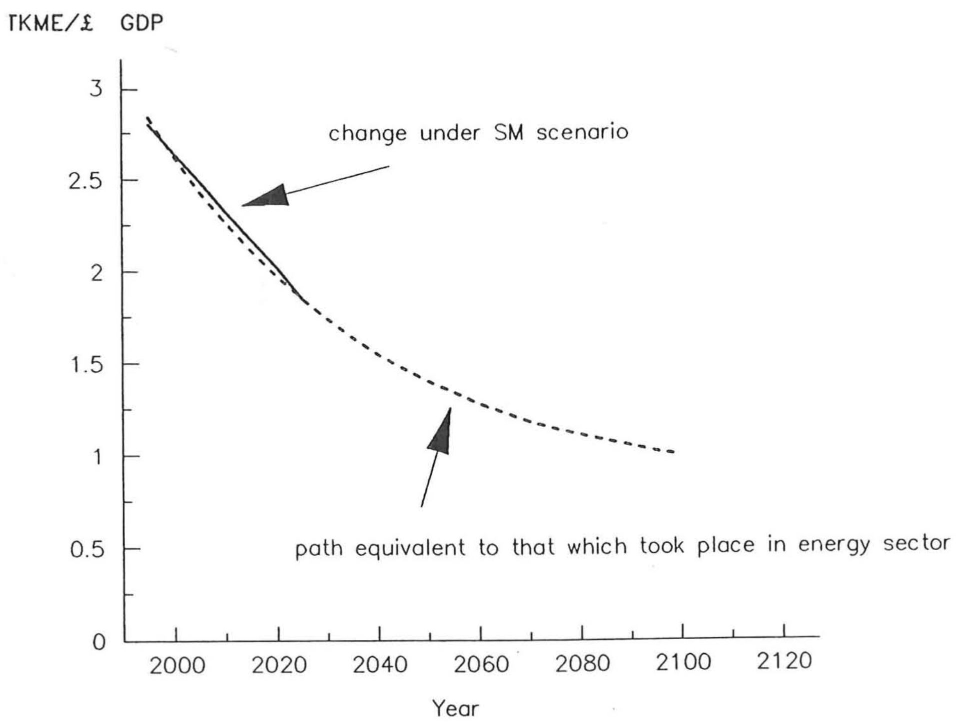


The next chapter deals in more detail with the types of policies and programmes which may be adopted to help achieve a more sustainable relationship between transport and the economy. Like their energy counter-parts, transport efficiency programmes may be judged according to the rate at which gross transport intensity is reduced. As time passes, marginal reductions in intensity may become successively harder and harder to achieve (as has been predicted with energy intensity), and ultimately there will be a limit to the possibilities for further significant decreases in transport intensity.

Figure 6.19 shows an exponential extrapolation to 2100 (dotted line) of the trend towards sustainable mobility under the SM scenario (solid line). The reduction in transport intensity from 3 tkme/pound GDP in 1991 to 1 tkme/pound GDP in 2100 corresponds to an equivalent rate of reduction in transport intensity as was experienced with energy intensity over the 110 year period 1880 to 1990 (the exponential curve in figure 6.19 corresponds to a residual asymptotic value of 0.8 tonne kilometres/pound GDP).

The SM scenario which has been developed is capable of being changed or refined in numerous ways to reflect different emphases or priorities. Alternative scenarios may be generated in a series of incremental changes from familiar qualitative and quantitative pictures of the transport future. The analogy with energy, therefore, has provided a workable interpretation of sustainable mobility, whilst the scenario analysis and backcasting have allowed a quantitative expression of it.

Figure 6.19: Sustainable mobility scenario in context.



Chapter 7

Transport Efficiency: Lessons From The Energy Sector.

> 'We suggest that copying, borrowing and pinching are widespread in the actual [policy] design process and that there are styles of policy analysis that could produce useful information for it'
>
> Schnieder and Ingram (1988) 'Systematically Pinching Ideas: A Comparative Approach to Policy Design' *Journal of Public Policy* 8(1):79.

7.1 The Need For Transport Efficiency.

The scenario analysis in chapter 6 concluded that the continued growth of transport at its current and previous rates (business as usual) is clearly unsustainable. Although the DTp's 1989 NRTF do imply a downturn in the growth of transport intensity (which may or may not be observed), there is a widespread consensus that the levels of traffic increase implied in the NRTF would be difficult to accommodate without major social, environmental and economic damage. This suggests that for the longer term, sustainable mobility will only be achieved by even greater reductions in gross transport intensity.

Experience in energy efficiency has demonstrated that even with the application of specific demand management-oriented policy, considerable barriers will still need to be overcome if sustainable mobility is to be achieved. Since there is no robust evidence that gross transport intensity will drop naturally, transport efficiency policies must take up the challenge. This chapter reviews developments in energy efficiency, both from the point of view of the process through which energy efficiency evolved and from an analysis of associated policy outputs (see chapter 2) in order to design a programme for transport efficiency.

7.2 Energy Efficiency in the U.K.

7.2.1 Development and Background: Analysis of Process.

As far back as 1945, the Minister for Fuel and Power had the responsibility to promote economy and efficiency in the supply, distribution, use and consumption of fuel and power. The development of energy efficiency policy, however, can be traced back to the formation in 1954 of the National Industrial Fuel Efficiency Service, a non-profit making company sponsored by the fuel and power industries to promote fuel saving in industry (HMSO, 1968). In addition to consultancy work, it provided advice and services to all non-domestic fuel users in a variety of forms, from 'spot' inspection to full-scale heat and power surveys and regular visits on a contract basis. The period 1955 to 1970 was one of abundant supplies of cheap energy causing demand to grow rapidly at an annual average rate of 5% (CPRS, 1974: para 28). This was sustained primarily by growth in oil and to a lesser extent natural gas consumption (see chapter 3). The 1973 oil crisis played a key role in focusing attention on the search for energy savings. In 1974 the Central Policy Review Staff (CPRS, 1974) concluded that there was wide scope for energy savings in transportation, electricity generation, domestic energy use and industrial energy use. In the same year a second report on energy conservation made further recommendations to Government (NEDO, 1974) who responded with a twelve point interim programme for energy conservation which included: the appointment of the Advisory Council on Energy Conservation (ACEC)(see DEn, 1975); the establishment of the Energy Technology Support Unit (ETSU); and the creation of the Energy Audit and Thrift schemes.

After rejecting calls from the House of Commons Select Committee on Science and Technology, for a special 'Task Force' of ministers to deal with energy conservation, the Government in 1977 announced a ten year programme to reduce future growth in energy demand in all sectors of the UK economy. An Energy Conservation division was established within the Department of Energy, and the 'Save It' campaign that had been introduced in 1974 was extended for another three years (HMSO, 1978; DEn, 1976b).

The 1982 review of how the Government handled energy conservation (the 'Rayner Scrutiny'; DEn, 1982) led to the establishment in 1983 of the Energy Efficiency Office (EEO) within the DEn. The Government's stated aim was to concentrate efforts to improve energy efficiency where they would have greatest impact and to ensure that the EEO had adequate resources to support its role as the central and strategic arm of the Government's efforts to improve energy efficiency throughout the economy (NAO, 1989:1). Current responsibility for energy efficiency is taken up by the EEO (part of the Department of the Environment since April 1992) which advises and instructs other individual Departments such as the Department of Health on how to increase their energy efficiency. The EEO also has the overall objective of 'devising, administering and promoting programme activities to assist the removal of barriers impeding the proper operation of market forces for securing energy efficiency' (NAO, 1989: para 1.7). Essentially, it promotes energy efficiency via publicity which, in turn, is aimed at increasing consumer awareness; through schemes providing practical assistance and in some cases funding; through research and development; and through the demonstration of improved methods and technology (NAO, 1989).

The DEn promoted energy efficiency as cost-effective energy saving (NAO, 1989), emphasising that improved energy efficiency reduced energy bills. Improvements can be made with or without any direct expenditure; energy savings that can be achieved without direct expenditure include staff motivation and the targeting and monitoring of energy use; even where investment is required it can have payback periods of less than two years (e.g. for example, draught proofing and loft insulation of dwellings, and the insulation of hot water storage cylinders, (NAO, 1989:9)). The EEO is currently implementing a new programme called 'Best Practice' aimed at advancing the spread of best practice energy efficiency in industry, commerce, housing and the public sector (having discontinued two older schemes: the Energy Efficiency Demonstration Scheme and the Energy Efficiency Survey Scheme).

Since 1983, direct Government expenditure on energy efficiency programmes has decreased slightly, although the Government's latest expenditure plans suggest that it may begin to increase again from 1993-96. The DEn planned to spend around 50 million pounds per year between 1993-96 on promoting energy efficiency (HMSO, 1991a). In addition to this, the European Community provides the UK with some 22 million pounds per year for technological demonstration schemes, and for the period 1985 to 1988 it provided some 18 million pounds for research and development projects (NAO, 1989).

In 1989 the NAO concluded that as well as saving money, there are wider benefits to the nation as a whole from the continued promotion of energy efficiency. These include (NAO, 1989:9):

(i) *Resource Depletion* - stocks of non-renewable fossil fuel resources are depleted at slower rates, promoting fuel diversity;
(ii) *Supply Security* - the nation's vulnerability to interruptions of fuel supply is reduced;
(iii) *Economic Competitiveness* - industrial competitiveness is increased with consequential benefits to investment, exports, employment and taxation revenues. Efficiency projects are also able to contribute to training and employment objectives;
(iv) *Social and Welfare policy* - low income families are helped by increasing home heating comfort and increasing disposable incomes. The main problem is the inability of the poor to pay for energy to heat their homes adequately. Fuel subsidies rose in the UK from 11 million pounds in 1973 to 443 million in 1985, a tenfold increase in real terms (see Boardman, 1991);
(v) *Environmental* - impacts on the environment due to energy production and use are reduced.

There is still much scope for improved energy efficiency (put at as much as 30% if all the measures which were currently viable were implemented (IEA; 1987)) and therefore the continued development of energy efficiency policy. Chesshire (1992) points out that there are strategic and macro-economic justifications for a far more vigourous energy efficiency policy including: benefits for industry; technology; employment; and social policy (see also Chesshire, 1986). It has been noted that the means to promote energy efficiency are - with very few exceptions - practically free of environmental disadvantages and the environmental problems associated with energy production and consumption are therefore reduced if less energy is used (IEA, 1987:87), whilst other studies have revealed a small net gain in employment if conservation measures are achieved (IEA, 1987:89).

Even though the process was in reality not well understood, the whole culture of energy efficiency programme design and implementation was centred on the notion of end-use matching; the acknowledgement that it was not energy itself that was demanded but the heat, light and motive force that it supplied (see for instance Bejan, 1982; Lovins, 1977; HMSO, 1978). The pivotal argument in the development of an acceptable energy efficiency policy was therefore the notion of targeting end-use benefits. If the same feeling of warmth could be achieved, or type of work could be done, by fuel switching or behavioural/investment changes in a cheaper and probably more environmentally friendly way, then there was a reason to promote efficiency. The existence of alternative ways of supplying the same needs is a fundamental characteristic of the energy sector and has been frequently exploited as a strategy for improving energy efficiency.

7.2.2 Evaluation of Energy Efficiency Programmes: Analysis of Policy Output.

The long run trend in the relationship between U.K. energy consumption and economic growth (figure 3.8, reproduced as figure 7.1 below) illustrates how energy intensity peaked and then declined over the period 1700-1991.

Within the last four decades the continued decrease in primary and final energy intensities (figure 3.9, reproduced as figure 7.2 below) reflect significant changes in fuel supply and major changes in energy-intensive industries but, also major improvements in energy efficiency (see Bending and Eden, 1984:56).

Figure 7.1: UK primary energy intensity: 1700-1991.

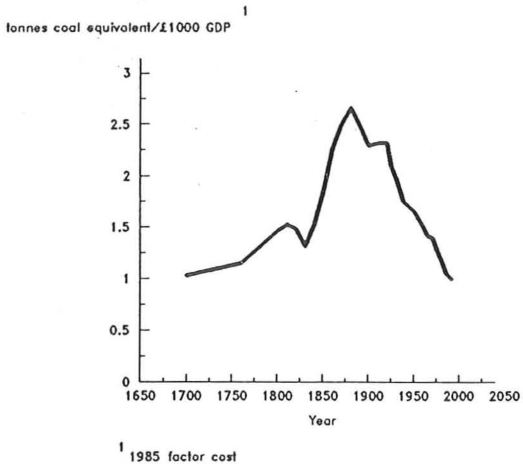
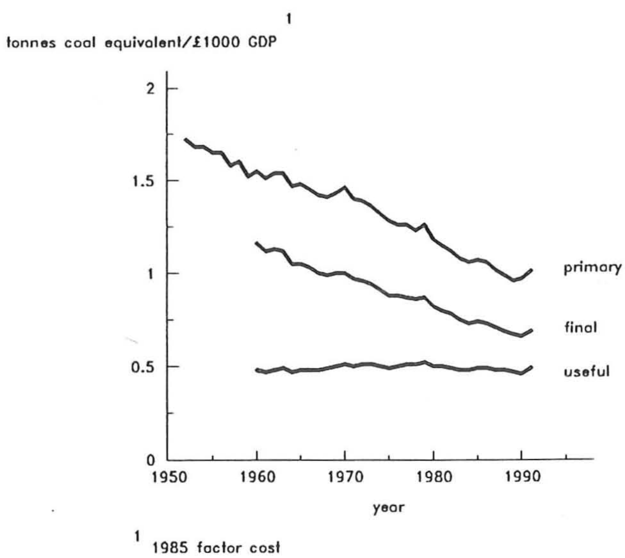


Figure 7.2: UK energy intensities: 1960-1991.



Although there are some difficulties in measuring the effects of the Government's energy efficiency policies, they are thought to have had some influence on the continued downward trend in energy intensity (Jenne and Cattell, 1983). In other words there is evidence that had Government not acted, intensity would not have continued to decrease at the rate it has done. In 1987, the International Energy Agency concluded that:

> The increase in energy prices and long standing trends towards increased productivity were the driving forces in bringing about these [energy efficiency] improvements but it was supplemented by government policies and programmes to promote energy conservation (IEA, 1987: 8).

An important step in the development of energy efficiency policy was the adoption by the Secretary of State for Energy in 1983 of a national target to improve energy efficiency by 20 per cent within 10 to 15 years (which would save 7000 million pounds a year at 1983 prices). In March 1989, based on changes in the U.K.'s primary energy intensity, the EEO calculated that the UK was on target and had improved its energy efficiency over the period 1983 to December 1987 by 8 per cent and had saved some 2,290 million pounds a year inclusive of taxes at 1983 prices (although low energy prices could make it more difficult for this target to be achieved) (HMSO, 1991b:paras 24/18; NAO, 1989: p7). In addition to the 1983 target, the U.K. became party to a European target in 1986 of a 20 per cent improvement in energy efficiency by 1995, although this looks very unlikely to be reached (Owens and Hope, 1989).

While the overall progress towards specific energy efficiency targets can be measured by reductions in national primary energy intensity it is much more difficult to measure the success of particular energy efficiency projects or schemes. Roberts (1979) noted that quantifying the effects of energy savings is fraught with difficulty and that the potential energy savings from specific conservation measures are difficult to calculate.

The three main types of energy efficiency programmes which have emerged are summarised below:

(i) Government information programmes which included:
. General campaigns informing energy users of the need for, and advantages of, saving energy and reducing energy costs;
. Energy Audits - these were done to increase awareness of the conservation opportunities;
. Energy labels and guides for appliances and engines - these increased market transparency and avoided national schemes which would have created trade barriers;
. Technical handbooks - which detailed how to set up energy management systems;
. Advisory services - which provided a point of contact for information;
. Training and Education programmes - that attempted to firmly install the concepts of energy conservation for present and future energy consumers.

(ii) Financial Investment Incentives including:
. Grants - which stimulated energy conservation, principally by improving the rate of return on an investment;
. Loans - less attractive for the consumer but still a possible incentive. Governments sometimes preferred loans as they were able to reach more consumers with the same amount of capital.
. Tax Incentives - fitted in with the generally large array of tax incentives for consumers. Tax reductions and exemptions, particularly credits were appropriate.

(iii) The introduction of Regulations and Standards.
. For example, in the domestic sector, building regulations for new properties were established which set a minimum thickness for loft insulation.
. a 20% target for improving national energy efficiency was adopted in 1983

It is hard to generalise about the information component of programmes alone, as they are often carried out in conjunction with grants/loans etc. Bridger Robinson (1991) notes that in general, they are thought to have been unsuccessful, pointing our that their success is dependent upon the information being vivid, personalised, concrete and targeted to specific energy users and energy end-uses (criteria not often achieved). There is also evidence that casting the efficiency message in terms of avoidable losses is likely to be more effective than describing it in terms of expected savings (the largely unsuccessful UK 'Save it' campaign is remembered by people as having to do without (DoE, 1991;p114)). Another study observed that the best way to sell energy efficient services was via health and comfort, and not through the benefits of energy efficiency per se (see Katzev and Johnson, 1982).

The problems of implementing effective energy information programmes are due to the substantive nature of energy issues themselves; in an investigation into attitudes to energy conservation in the home, the DoE (1991) found that the concepts of energy and energy efficiency were not generally well understood. The woolly interpretation of these issues stems from their abstract nature. People don't perceive that they buy energy, but that they buy warmth, petrol and heat for example. It was found that home dwellers attach significant importance in terms of their perceived standard of living to being able to live comfortably. In this respect, shops and other public buildings which, in general, appear to use energy freely do not set a good example (DoE, 1991).

Other barriers to domestic energy efficiency arise because for many dwellers, energy used in private households can seem negligible compared to images of that used by countries, governments industries and massive organisations. Further confusion about energy efficiency (and therefore the likely success of any programmes) arises because links between domestic energy use and environment are not well established. The DoE (1991) found, for instance, that it was not clear to home dwellers that electricity contributes disproportionately to carbon dioxide emissions. Industrial energy consumers have little understanding of energy flows within their industries. Energy consumption is effectively invisible, since most energy consuming systems and services do not directly report energy consumption on a frequent enough basis (for most people the fuel gauge in the car and the price sensitivity of petrol are the most obvious exceptions to the invisibility of energy consumption and prices). The bill for energy use is in many cases received weeks, even months, after the event making it hard therefore to relate energy costs to specific use. Feedback is important in encouraging energy consumers to conserve. Another problem is the lack of consumer confidence in new technologies or processes with certain new energy efficiency products and services having problems. For instance, the introduction of urea formaldehyde insulation in housing was subsequently banned in some countries, eroding consumer confidence in energy efficiency products and services in general (IEA, 1987).

As far as financial incentive programmes have been effective, there has been no clear indication that grants are more effective than loans, but where incentives are concerned, the institutional context has been viewed as critical . In this respect, integrated energy service programmes (packages of local authority administered programmes and incentives from all the various actors and organisations involved) have been found to overcome many of the institutional and organisational barriers that would otherwise exist (Bridger Robinson, 1991). In general, financial incentives have been found to be best used selectively to support the operations of the market (IEA, 1987).

In contrast, regulations and standards in many ways represent the most reliable and easiest methods of increasing energy efficiency. Their conceptual significance, likely large impacts and relative ease of implementation mean that their use entails the minimum of effort in achieving improved energy efficiency (IEA, 1987). It is, however, difficult to design them so that they receive a wide acceptance from the typically large number of interests affected (Bridger Robinson, 1991).

7.2.3 Barriers to Energy Efficiency.

Experience with the implementation of energy efficiency programmes and other related research (see Schipper and Meyers, 1992; DoE, 1991; Stern and Aronson, 1984) has suggested that a rational-economic model of energy consuming behaviour does not, on its own, adequately describe actual energy-using activities and investments (Bridger Robinson, 1991). In addition, there is little evidence of any direct link between attitudes towards energy use and energy policy and actual energy using behaviour. Bridger Robinson (1991) notes that a number of studies based upon ethnographic analyses of consumer behaviour have suggested that energy-using decisions depend strongly on such considerations as social status, convenience, feelings of competence, interest in new technologies, health and safety concerns.

The failure of attitudinal based models (which assume that energy consuming behaviour is a function of attitudes towards energy use and energy policy) explains the generally poor record of information based energy efficiency programmes to date (Bridger Robinson, 1991). Another reason for the failure of some early programmes was their tendency to focus upon behavioural conservation (e.g. turning down thermostats) rather than increased energy efficiency (e.g. investment in double glazing).

There is, therefore, evidence that well-designed energy efficiency policies can lead to energy savings, although attention should be given to ensure the best means of achieving them. This, in turn, indicates a general shift in energy efficiency culture, away from substantiation, towards strategy (Sioshansi, 1991).

It seems that society operates at a less than optimal level of energy efficiency through under investment in it. In the UK the causes of this under investment include:

1. Consumers sometimes face wrong prices - energy forms can be implicitly subsidised and/or do not reflect the full costs of energy use to the individual consumers;
2. Lack of utility incentives. Under existing legislation, utilities have little or no compelling economic incentives to invest in energy conservation;
3. Consumers' ignorance when making energy investment decisions;
4. Consumers have fast payback requirements, between 6 months and three years whereas utilities work on payback periods of around 5-10 years or so. 'consumers and utilities live in totally different economic worlds when it comes to energy investments' (Marritz, quoted in Sioshansi, 1991);
5 Forced purchase decisions. The landlord or builder provides a flat or house with low standards of insulation;
6. Energy efficiency is not aggressively marketed. For example, salespeople have other pressures to sell anything but the best energy efficient device;
7. Externalities. One of the problems in resolving these is that there are no markets for trading environmental damages; and
8. Other reasons include: a lack of skills necessary to conserve energy, the invisibility of energy use, lack of confidence in new conservation services and products and separation of responsibilities for energy expenditures and conservation actions.

In summary, three main sets of barriers to energy efficiency have been highlighted (HMSO, 1991b:p xv). These are:

1. Lack of Information and Expertise Among Energy Consumers.

Energy consumers tend to lack both a general awareness of the economics of their use of energy and the specific knowledge of how they could save money by using energy more efficiently. A recent report concluded that the concepts of energy and energy efficiency were not well understood by energy consumers (DoE, 1991).

2. Economic Barriers.

Energy costs are only a small proportion of total costs in many businesses and higher income households, and therefore energy management is not high on the management agenda. The initial investment of time and effort into improving energy efficiency is often considerable and this deters people from acting.

Consumers of energy expect energy efficiency investments to pay for themselves in lower running costs very quickly, often requiring a payback period of one or two years. The energy supply industries seek lower real rates of return, usually below 20 per cent, and their investments (notably nuclear power stations) provide no return at all for some years after construction begins.

There is often a lack of capital for energy efficiency investment, especially in parts of the public sector and among low income households. Until recently, taxation to some extent distorted the market by including VAT on energy efficiency goods and services but not on domestic fuel and power. Also the pricing policies for larger consumers can distort the market; large step tariffs have proved a disincentive to energy efficiency. Prices do not reflect the full costs of energy consumption, and unstable prices make it difficult to assess payback periods.

3. Structural or Institutional Barriers.

The Department of Energy was originally set up to manage the supply industries. Energy supply is concentrated in a few large companies, whereas a great many small companies provide energy efficiency products and services. The market is therefore dominated by supply companies, with interests in increased sales (and only rarely an interest in promoting energy efficiency). In contrast to thinking about the individual much less literature is available on the relationship between energy efficiency and organisational behaviour (Bridger Robinson, 1991). On the energy supply side, the Energy Select Committee (HMSO, 1991) proposes that energy suppliers should see themselves as providers of heat, light and motive power at the least possible cost rather than units of electricity. Despite this, some energy efficiency products are not readily available.

Sometimes those who incur energy efficiency costs do not get the benefits, as with the landlord-tenant relationship. Capital expenditure in the public sector is more tightly controlled than running costs. Energy users can sometimes be shielded from the full cost of energy, e.g. when energy costs are included in rent and when company cars are provided.

The barriers to efficiency are therefore diverse. They differ from sector to sector and no one single measure (e.g. higher taxes) is universally appropriate. The close relationship between energy and transport means that the lessons from this evaluation of energy efficiency can be used to begin formulating efficiency policies in the transport sector.

7.3 Developing Transport Efficiency.

7.3.1 Objectives and Justification.

The energy efficiency experience indicates that transport efficiency policies can be justified not solely in terms of a microeconomic context (e.g. marginal improvements in household disposable income or company profitability) but with the full force of macroeconomic arguments normally reserved for strategic supply-side decisions such as industrial markets, technology policy, employment and social policy. The appropriate objectives and justifications for the formulation of a transport efficiency program for the 1990s are analogous to those which have sustained UK energy efficiency policy over the last 20 years (Chesshire, 1986;1992) (see section 7.2.1):

(i) *Urban and Rural Space Depletion* - once a road has been built it is rarely turned back into a green field site, but instead tends to encourage subsequent neighbouring developments;
(ii) *Supply Security* - in 1990, over 99 per cent of fuel for UK transportation was derived from petroleum. The transport sector should be shielded from short-term supply disruptions and destabilising fuel price hikes;
(iii) *Economic Competitiveness* - to ensure that use of transport, as with the use of energy, capital, labour and other raw materials, is minimised subject to broad cost-effectiveness criteria as a means of boosting international economic competitiveness;
(iv) *Social and Welfare policy* - to enhance standards of living perhaps by increasing accessibility, reducing road accidents and avoiding community severance, and by minimising unnecessary consumers' expenditure on transport, particularly those on low incomes; and
(v) *Environmental* - to assist, together with a wide range of other measures (within and without the transport sector), in curbing deleterious impacts upon the local, regional and global environment.

The whole focus of the UK's energy efficiency programme was meeting energy targets, not environmental targets. Whilst the contribution of primary, final and useful energy to the generation of environmental pollution was acknowledged, objectives for energy efficiency were not expressed as environmental improvements, but were put forward simply as efficiency targets in energy production, supply and use. This has important consequences for the development of transport efficiency. It tells us that objectives should be expressed as simple efficiency targets which, if achieved sensibly, would imply gains for the environment and less congestion. Despite its roughness (Mclachlan and Itani, 1991), the widespread use of primary energy intensity as a measure of energy efficiency, suggests that gross transport intensity is a sensible measure of transport efficiency.

As time goes on, these principles and possibly others could form a sound basis from which to defend the rationale of a transport efficiency programme and, as general principles, have the added quality that they have been tested already in the energy sector.

7.3.2 Barriers to Transport Efficiency.

This new notion of transport efficiency may take some time to be accepted. The benefits that accrue to society from aggressive transport efficiency policies are likely to be the same as those which accrue from analogous energy efficiency policies. By analogy with the energy efficiency experience described in section 7.2.3, if these benefits exist, then society is currently operating at a less than optimal level of transport efficiency. Reasons for this include:

1. Consumers facing wrong prices - many transport modes are implicitly or explicitly subsidised and/or do not reflect the full costs of transport use to the individual consumers (for example, the Government views expenditure on the railways as subsidy, but expenditure on road building as capital expenditure and investment) (Chesshire, 1992);
2. Lack of commercial incentives: car manufacturers, bus and rail companies have little or no compelling economic incentives to invest in transport efficiency which may reduce their markets;
3. Consumers lack of knowledge and ignorance when making transport investment decisions (for example when buying a house or car or taking a new job);
4. Consumers have fast payback requirements, between 6 months and three years (e.g. season tickets) whereas privatised public service operators work on payback periods of around 10 years or so (e.g. bus companies manage their vehicle stocks with ten year business plans and new technology replacement schemes);

5 Forced purchase decisions - cheap houses out of town with low standards of transport efficiency (the transport content of goods and services is invisible);
6. Transport efficiency is not aggressively marketed (e.g. shoes and bicycles are not as labour and technologically intensive per unit produced, and therefore profitable, as cars);
7. Externalities - the price that consumers face does not reflect the full costs of their activities, particularly those incurred by the environment.

7.3.3 Towards a Programme of Transport Efficiency.

The basic characteristic of a sustainable transport policy would be its emphasis on decoupling economic growth from transport growth. A system which for the same level of GDP generates less gross mass movement than another will tend to be less congesting, less energy intensive, less polluting, less costly and more efficient. The measures which formed part of the SM scenario in chapter 6 are examples of how gross transport intensity could be reduced in three generic ways:

1. a reduction in net intensity

This would involve a reduction in transport movements without compromising GDP levels. Strategies to achieve this could include the implementation of best-practice land use planning techniques and more emphasis on trip degeneration techniques (Owens, 1991);

2. a reduction in essential intensity (net intensity remaining constant)

There are two basic strategies for reducing essential transport intensity. The first involves a redistribution of previous modal splits towards those modes that can transport goods or people more efficiently. An example of this would be encouraging passengers to use public transport instead of private cars, and forwarding more goods by pipe, ship or train instead of by road goods vehicles. A second strategy for reducing essential mass movements could be improvements in passenger and goods vehicle technologies, so that passengers and goods could be transported using proportionately less vehicle mass per tonne of passenger or freight;

3. a reduction in gross intensity (essential and net intensities remaining constant);

The most obvious way in which gross intensity could be reduced is by improving the occupancies of passenger and freight carriers. This could be achieved by ensuring that vehicles are more often operating near their maximum load capacities. Reducing the proportion of empty journeys that freight transport carriers undertake would also have the effect of reducing gross mass intensity (see also section 6.7.2.3).

The three components for reducing transport intensities that are outlined above are complementary and could, in general, be used in combination to achieve lower levels of gross mass movements for the same or higher GDP. Although energy efficiency policy has been criticised, transport efficiency policy, as yet, does not exist. By analogy with energy efficiency (section, 7.2.2) transport efficiency programmes might usefully include the following features:

(i) Government information programmes which could include:

. General campaigns, aimed at large audiences, informing travellers and freight managers of the need to transport themselves and their goods efficiently;

. Transport Audits - these could be done to increase awareness of the opportunities for greater efficiency both in the freight and passenger sectors. Audits could be done by private sector consultants with the government providing grants to meet all or part of the costs (as it did with the Energy Efficiency Survey Scheme and the Industrial Heat Recovery Consultancy Service). Beneficiaries might include business, industry and other groups such as small communities;
. Transport labels and guides for the different modes of transport and vehicles - which would increase market transparency and avoid national schemes which would otherwise create trade barriers. The labels and guides might give information about how efficient a particular method of transport is, in terms of mass, energy and pollution (fuel consumption figures for various makes and models of cars are already produced);
. Technical handbooks - For the public the handbooks could be fairly simple and could show the consumer how to service a bicycle and perhaps how to add on devices for carrying loads, what protection is needed against the possibility of an accident, what types of shoes are most suitable for walking long distances, and the correct way, and best devices for carrying loads. For the transport or general company manager, handbooks could detail how to set up and account for group transport schemes and how to use available information technology to reduce the need for inefficient transport;
. Advisory services - would provide a point of contact for transport efficiency information;
. Training and Education programmes - would firmly install the concepts of transport efficiency for present and future transport users. Governments could promote transport management initiatives in the form of workshops, seminars, conferences and research projects (c.f. Institute of Directors, 1975).

(ii) Financial Incentives (to stimulate action and reduce perceived investment risks).

. Grants - which would stimulate transport efficiency investment, principally by improving the rate of return on an investment (e.g. to purchase mini buses for transporting company employees to and from work, or provide money for employees to work from home);
. Loans - less attractive for the transport consumer but still a possible incentive (e.g. loans to meet the costs of company relocation to a more accessible site). Governments may prefer loans as they would be able to reach more consumers with the same amount of capital;
. Tax Incentives (both reductions and increases) - would fit in the generally large array of tax incentives for consumers. Tax reductions and exemptions, particularly credits might be most appropriate (e.g. raising car or fuel taxes or reducing tax on companies providing public transport services). Road pricing and increasing car taxes are further alternatives.

(iii) The introduction of Regulations and Standards.

. A target for improving gross transport intensity could be set (similar to the 1983 energy efficiency target), which could help focus transport demand management strategies and policy. There are many different strategies that could help reduce transport intensity; for example a rise in average car occupancies from their current level of 1.7 to 2.4 would reduce gross transport intensity by around 10 per cent. If it proved too optimistic to expect car occupancies to rise above 2, a ten per cent reduction in gross transport intensity by 2000 could be achieved by increasing passenger and goods vehicle occupancies across several modes, each by only a relatively small amount;
. Regulations and standards would probably vary considerably between transport modes. The government could establish standard efficiency levels for industry, commerce and communities. Mandatory regulations could be introduced; for example, in California, Regulation XV (the Commuter Program) requires employers to offer incentives to reduce commuting by car (Chatfield, 1991).

The efficacy of any transport efficiency policies can be judged according to the speed with which gross transport intensity declines. Experience in the energy sector suggests that a dedicated transport efficiency program, perhaps coordinated through an independent Transport Efficiency Agency, might expedite a reduction in gross transport intensity and achieve the first steps towards a more sustainable future (see Peake and Hope, 1992a).

Chapter 8

Conclusions: Towards a Greater Understanding of Cross-Sector Policy Research.

'An analogy does not prove anything.
It merely suggests a possibility.'

Bruce Mazlish (1965) 'Historical Analogy', page 6, in Mazlish B. (1965) *'The Railroad and the Space Program: An exercise in historical analogy'*, MIT Press, Boston.

There is no doubt that viewing transport issues in the 1990s as analogous to energy issues in the 1970s and 1980s, has generated useful ideas and knowledge, that would otherwise have conceivably not emerged at this time. The energy-transport analogy has given a new, dynamic perspective to the transport problem, the full implications of which are not yet fully understood; the life of the ideas that have emerged has only just begun.

8.1 Insights for Energy and Transport.

8.1.1 Insights into the comparative nature of energy and transport.

In advanced industrialised societies, people seem to be more aware of transport than they are of energy (the invisibility of energy consumption was noted by the Energy Select Committee (HMSO, 1991b)). Commuters express strong views about the state of transport and its associated policies, whilst domestic energy users do not have the same level of knowledge or opinion about the state of the energy sector and its associated policies. There are many transport users groups such as the Railway Development Society, the RAC and the AA; the analogous energy groups do not exist. Many people travel somewhere every day, gaining exposure to other transport users, other transport modes and obtaining a general overview of what the nature of transport activity is. In contrast, although each of us uses energy every day (when we travel for instance), most of us only ever *use* it; we rarely come into contact with the production and transmission sides of energy supply, as we do with their analogues in transport. The problem of transport and its solutions certainly do have their technical aspects (such as the MAGLEV train, or the electric car), but from the Government's point of view (and with the possible exception of the Anglo-French Concorde project) transport has not been as closely associated with the 'white heat of technology' as has energy; it is now coming up to half a century ago that Governments first started to discuss the issues of nuclear fission, nuclear fusion, renewable and natural gas technologies. In contrast to research efforts in energy, (which have concentrated on discovering and realising new and viable technologies) research efforts in transport have been directed at improving cars, trains, planes buses and ships, but not at providing significant new transport solutions.

There are other notable differences between the two sectors. Energy and transport are both derived demands, but the relationship between what is actually demanded and how, and by what method this demand is satisfied is different. In the case of energy, heat or motive force is what is actually demanded and comes bundled up in the form of a gallon of petrol or a log of wood, neither of which are inherently attractive commodities to energy users.

With transport, what is ostensibly being demanded is access, which in turn requires mobility, which in turn requires us to move ourselves with our own energy or use an energy consuming machine to move us. But the types of machines that transport us such as trams, trains, planes and cars are, at least for some people, attractive and if they are not themselves desirable then, as advertisers well know, the cachet of being associated with them is. This in turn may explain our tendency to have transport-related opinions and not to have equivalent energy-related ones.

Since transport intensities, transport scenario analysis, and transport efficiency programmes have not been developed before this dissertation, the case study does not give firm insights about their associated contextual properties or the general principles that govern them. In a sense, whatever specific issue one highlights can always be framed in some contextual manner, and therefore from that moment on, can if studied at the general level stimulate contextual analysis of the general ideas. Hence the 1973 energy crisis, a peculiar and never-to-be repeated set of events becomes 'the beginning of the shift towards demand management' or 'the shift towards policy adversity'. The cognitive aspects of policy problems are often founded upon a complex mesh of factors and can be difficult to measure or ascertain (see Pearman and Hopkinson, 1989). Part of the case study, particularly the notion of an analogy (table 4.1) is based on such contextual themes (which may be seen as a partly cognitive construction) whilst the specific comparative themes which were developed, in many ways exist independently in their own right, regardless of the other parallels that may or may not exist.

Although some aspects of energy and transport policy are influenced at the international level, the specific UK-oriented nature of the case study simplifies the interpretation of the research findings. In principle though, cross-border-cross-sector studies could develop in the future, particularly for those issues that have a large inter-national component (e.g. macro-economic policy).

The primary energy intensities of many advanced industrialised nations were reduced as energy intensive industries moved to other countries (such as the shift in steel production from Europe to China and the Far East). Experience from the energy sector suggests it may be difficult to reduce the demand for transport uniformly at the global level. The primary energy intensities of advanced industrialised nations were reduced at the expense of an increase in the energy intensities of other less developed countries (LDCs) (Eden et al, 1981). The energy experience, therefore, has implications for the development of LDC economies. If certain patterns of employment and production have high associated demands for transport, Governments in their desire to achieve transport efficiency targets may discourage these industries from developing 'at home', in favour of them being taken up in LDCs. This in turn means that the transition to advanced industrialisation for LDCs may require a greater emphasis on, what advanced nations have started to see as, self-defeating transport-intensive development. In effect, what may happen is that the transition to the post-motor age for LDCs will involve copious dependency on motor vehicles.

8.1.2 Insights for the Development of Policy Indicators in Transport Policy Analysis.

Most importantly perhaps, further research needs to be undertaken on the uses of the mass movement measures for transport policy analysis, in particular concerning their links with environmental and economic indicators. At best, changes in gross mass movement and intensity, broadly indicate the impact of transport on the economy and the environment. At worst, because there is still some underlying uncertainty in the mass movement input data, the technique could be misleading. As qualitative information resulting from research, it has a considerable way to go before it becomes established through peer acceptance and colleague consensus (see Funtowicz and Ravetz's (1990) ideas on 'pedigree' of information). Care needs to be taken that policies to minimise gross transport intensity and promote transport efficiency are implemented sensibly, so that they do not create more problems than they address. For example, in the energy sector, throughout the 1970s and 1980s, there has been a trend to switch from coal and oil to gas on the grounds that gas was cheaper, more efficient and a higher quality energy resource (it also has the lowest carbon content). However, such a switch conflicts with the need to preserve a diversified energy resource base, and other important objective of energy policy such as industrial competitiveness (via related innovations and technologies) and employment.

If gross mass movement analyses are to become effective tools for assessing the possibilities of improved transport efficiency, then they will need to be carried out at more targeted and disaggregated levels. With passenger movements, for example, the relationship between gross mass movement and length/purpose and frequency of journeys needs to be researched further. In addition, a more detailed understanding of gross freight mass movement characteristics by commodity may mean that more effective policies for reducing transport intensities are designed.

Ultimately, a cross-national comparison of gross transport intensities would provide valuable data on the possible relationships between transport and economic growth, but would have to take into account national characteristics such as physical geography, climate, economic activity, culture and urban density. This parallels the conclusion of McLachlan and Itani's (1991) study on interpreting primary energy intensities. Such trends have already begun in the transport sector, although only at the net level of mass movement (see Greenpeace, 1992).

8.1.3 Insights for the Development of Planning and Scenario Analysis.

There is clearly a need for a more integrated approach to transport planning so that at some stage an aggregated overview of trends in total transport mass movements are taken into account in the policy process. Since most policy innovations implicitly assume interaction between the various transport modes and transport carriers, it is important that inter-modal and cross-carrier comparative analysis becomes a familiar part of transport planning. This in turn will only be effectively achieved when there is recognition that transport policy must begin to address the notion of transport end-use matching.

Leach et al (1979) used the notions of end-use matching, inter-fuel substitution and best practice technological efficiency to guide their influential low energy scenario analysis. Although subsequently criticised, their study marked an important turning point in the evolution of the analysis of energy futures. An analogous study in the transport sector may also prove fruitful. The search for a low transport strategy for the UK could involve an extension of the policy measures discussed in chapter 6 in relation to the construction of the sustainable mobility scenario perhaps so that it would consider ways of achieving a *minimum* gross transport intensity. The sustainable mobility scenario targets a reduction in gross transport intensity down to a residual value of 0.8 btkme per pound GDP through analogy with the long term decline in energy intensity. A low transport scenario analysis would seek to establish the limits to which this could be minimised through the application of best practice transport efficiency programmes, initiatives and technologies. Ultimately, such a study could act as a benchmark against which the evolution of transport intensity could be compared.

8.1.4 Insights for the Development of Transport Efficiency Programmes.

A variety of problems analogous to those that preceded the rapid development of energy efficiency (including: environmental pollution; congestion; and social/welfare issues) have been replicated in the transport sector. The whole focus of energy conservation (formerly) then efficiency (latterly) schemes was about saving energy and saving money - a two pronged approach. In contrast to energy, however, a larger proportion of transport is visibly consumed. The remaining invisible transport is the transport element of the products and services which we consume and demand.

Whereas domestic energy use is not perceived to be associated with environmental degradation, its transport counterpart, personal travel, is very much associated with environmental damage. Lorries etc. are perceived by car users to be disproportionately more congesting than they really are (Goodwin et al, 1991) - perhaps because of their unfriendliness and size.

With the 1990s has come a renewed vigour to tackle the environmental and economic impacts of transport, giving transport policy analysis a wider perspective upon which to plan for the future. A way has to be found of balancing the many objectives served by a transport system with its unintended side-effects and their consequences. Experiences in energy policy indicate that there are no easy solutions to the problems of decoupling economic and transport growth either by exhortation and encouragement, fiscal measures, or legislative actions. Nearly two decades since the first energy efficiency policies were established, there is still much scope for them to be improved (Chesshire, 1992). The transport scenario analysis in chapter 6 indicates that long-term transport efficiency will require a range of policies and programmes if the first tentative steps on the road to sustainable mobility are to be achieved.

Since all non-metabolic transport uses significant amounts of fossil and other fuels, any changes in transport will have an effect on the demand for energy. In turn, this means there are implications for carbon-dioxide emissions, and emissions of other pollutants. Many of the policies for promoting transport efficiency emerge as similar to those which were discussed, and in some cases implemented, in the wake of the 1973 energy crisis, but this time they are emerging from concerns over carbon dioxide emissions, and the need to reduce congestion. A transport efficiency program would therefore serve multiple objectives and would have implications for other policy areas. Further research on the coordination of these related policy problems is needed, particularly to eliminate the likely duplication of research efforts, and potential objective conflicts. This has recently been called for in the energy sector; Fells and Lucas (1992) point out the need to integrate energy with other 'sectoral' policies such as macro-economic, fiscal, industrial, transport and environment, and the need to recognise that energy policy is often driven by non-energy related factors.

In addition, the analogy suggests that further work to collate evidence of any potential barriers to improved transport efficiency should be undertaken. When such work focuses on the behavioural aspects of transport usage, research in the energy sector (Schipper and Lee, 1992; Erickson, 1987) suggests that a cross-border comparison of attitudes towards transport use would provide valuable insights for the design of successful transport-efficiency policies, particularly those relying heavily on exhortation (Schnieder and Ingram, 1988).

The experience of energy efficiency policy has many implications for the development of transport efficiency policy and the speed at which the path to sustainable mobility is taken. An essential part of energy efficiency policy involved ensuring that people understood that efficiency could bring financial savings. Efficiency is an emotive word and can be used in very different contexts; for example, parcel delivery advertisements boast of being 'fast and efficient'- but they do not say from whose perspective. It is tempting to jump to the conclusion that somehow walking and cycling are the optimal form of transport, and therefore as transport modes are the logical outcome of any transport efficiency policy. They certainly are energy efficient, non polluting, healthy and serene ways of getting about, but they are not efficient in terms of time (particularly over long distances), safety, personal security, weather resistance, and for anything other than nominal freight movements.

The role of time in any transport efficiency policy must be considered. Time is included in 'generalised' costs of travel (e.g. Newbery, 1990), and as such will partly determine the distances and frequencies of trips. It may be that where transport efficiency policies are successful in reducing the length and frequency of certain trips and movements, the time saved may be used by individuals in some other way such as increased leisure trips (there is already some evidence of this, see Kitamura et al; 1991; Nye et al., 1976). This in turn will stifle the effectiveness of such policies in reducing gross transport intensity. There is also some precedence for this type of process occurring where part of the savings from domestic energy efficiency is taken as increased comfort (see DoE, 1991:118) therefore reducing energy savings.

Table 8.1 summarises the possibilities for further research in the areas described in section 8.1

Table 8.1: Possibilities for further research related to the energy-transport case study.

Chapter 5

- extend gross mass movement intensities back in history (c.f. Humphrey and Stanislaw (1979);
- reduce the uncertainties in the parameters in tables 5.2 and 5.3 even further;
- study methods for transforming the monitoring and reporting procedures for statistical information within the transport sector;
- addition of annual vehicle kilometres (including any empty running) across carriers to DTp's annual digest;
- disagregation of transport intensity by sub-passenger (e.g. NTS framework in table 3.1) and sub-freight sectors (e.g. NST/R framework in table 3.3);
- more work on relationships between gross mass movement and existing energy, environment and congestion indicators.
- extend the mass movement and intensity measures to other European countries, and then initiate follow up comparative research (c.f. Morovic et at., 1989; Mclachlan and Itani, 1991).
- research into transport theory of value (c.f. Herendeen and Tanka, 1976)

Chapter 6

- develop and refine other possible scenarios, using Jones et al.'s (1990) interfacing technique;
- explore scenarios with exponential rates of transition to target balance tables;
- extend scenario analysis to European levels of aggregation;
- study in detail the interaction between the NRTF and forecasts of traffic by other modes;
- publish transport balance tables in the DTp's annual digest;
- calculate the transport demands associated with different patterns of industrial development. Identify rogue industrial sectors. Investigate a feasible residual level of gross mass movement per capita or per pound GDP;
- investigate the impacts of the proposed increase in maximum permitted gross HGV mass to 44 tonnes on the gross mass movement measure;
- investigate relative eases of changes in carrier occupancies, modal splits, unladen carrier masses and passenger and freight elasticities.

Chapter 7

- investigate some of the institutional implications of a transport efficiency agency in terms of possible problem, actor and policy space interactions;
- establish the credentials of transport efficiency in terms of cost savings;
- develop and refine techniques of transport end-use matching. Look at equivalent of energy cascades (see Patterson, 1983);
- undertake equivalent of the DoE's (1991) 'Attitudes to energy conservation in the home' study for passengers (NTS travel groups) and for freight (industrial sectors);
- evaluate the success of information based incentive programmes in the two sectors;
- undertake study of transport efficiency and human activity similar to those by Schipper and Meyers (1992) and Bridger Robinson (1991).

Transport efficiency will have to meet transport end-uses by a similar matching process to that which occurred in energy end-use matching. End-use matching in transport will initially involve taking into account all the benefits derived from travel coupled with significant actions to influence modal shares which is not as much about price, but about changing behaviour; for most people, cycling and walking are without doubt cheaper than car travel and perhaps bus and train travel too - yet they haven't switched.

Extreme calls for fewer overall passenger and tonne kilometres, fewer trips, less speed, and less time spent travelling, are not recommended by the analogue with the energy efficiency experience; it was never suggested that useful energy consumption be reduced without first improving efficiency elsewhere in the flow of energy from source to user, whilst there have never been calls to, for instance, reduce industrial process working temperatures, but rather to try and match them to the optimum fuel. The demand for transport is as heterogeneous as the landscape which moulds it and will not react obediently to naive and extreme calls for doing without. But as energy efficiency policies have shown, there is a role for the sensible and considered coordination of several policy measures over a sufficient period to help reduce the economy's dependence on gross mass movements, provided these are introduced in a considered way; in the energy sector for instance, although it would have been more efficient to switch from coal to oil, this would have conflicted with other objectives such as dependency on imported energy supplies, and was never suggested.

Other fruitful research may focus on some of the failures in energy policy (such as the lack of uptake of renewable energy resources) investigating their implications through the analogy with transport. Or the basis of the transfer of ideas could be reversed altogether, by looking at the implication of successes in transport (such as uptake of car ownership and use) for the development of energy strategies.

8.2 Insights from the Theory.

8.2.1 Methodological Insights.

The notion of cross-sector policy research is a generalisation stemming from one study. To deserve recognition as a new methodology, it ought to have meaning in the study of policy between other sectors. It was for this reason, that at the same time as the specific comparative themes were being developed, attention was also given to the development of a suitable theory of cross-sector policy research. The theories that were eventually collated in chapter 2, come from a diverse collection of backgrounds and sources. But whereas the literature review has shown that the sector view of policy arises as a side issue in other contexts, this study has attempted to grapple with it 'head on'.

The study has revealed that the notion of policy is difficult to define (being partly cognitive in its nature), and that the theory of comparative research within established social sciences (such as politics or sociology) is still contentious. The second aim of the thesis was to use the case of the energy-transport study to synthesise a theory of cross-sector research, capable of realising cross-fertilisations between other policy sectors. The method pursued in the development of this dissertation was a combination of simultaneous theoretical research and more practical, specific research on the energy-transport analogy. Work on the energy-transport analogy, and the pursuit of suitable comparative themes did not explicitly proceed via analysis at the levels identified in table 2.1. The case study has produced some valuable insights, and aided the development of theory, but the theory still needs subsequent development and application if the second aim of the thesis is to be achieved at some stage.

In particular, the theory lacks sufficient development in three specific areas:

1. the stage at which the two potentially fruitful sectors for comparison are recognised. At least one of them will be familiar (the base sector), most probably because it will be part of some existing problem situation and whilst comparisons between any two areas may prove useful to some extent, some combinations of sectors may be more suitable than others. Research is therefore needed to find ways in which fruitful comparisons can be accessed;
2. the subsequent structured comparative analysis of two sectors; and
3. the eventual identification of suitable comparative themes between them.

Rather than conceive of a methodology beforehand and then evaluate it by choosing two sectors such as energy and transport, the methodology grew simultaneously as the parallels between the two sectors were explored in an unstructured way. Cross-sector research involves the use of analogy and similarity and as such is a 'thinking methodology' with a tangible potential to improve processes by which problem situations are acted upon. Once the connection between the two areas had been made, the analogy took on a life of its own and provided a way of thinking which eventually took no effort once it had been 'stepped into'. Indeed I found that it sometimes took effort to suppress the cross-sector analysis and 'switch it off'.

8.2.2 Parallels With Other Social Science Research Methods.

The idea of an unfamiliar way of thinking readily becoming part of an established method of analysis is characteristic of at least one other existing social science methodology. Soft Systems Methodology (SSM), is an existing research methodology which has been used in a wide variety of 'problem situations' to stimulate 'action to improve the problem situation' (Checkland and Scholes, 1990). Two important features have emerged from its use, and are relevant to the development of cross-sector policy research as policy analysis discussed elsewhere. In his observations of the development of SSM, Peter Checkland has pointed out the evolution of two distinct forms of SSM. Originally, SSM was used as a formal stage-by stage research methodology (this is referred to as a 'mode 1' use), and secondly it became used as a less formal, less structured thinking process (referred to in this sense as a 'mode 2' type use). The main distinction between mode 1 and mode 2 relevant here, is that mode 1 orientates itself towards the act of improvement of a problem situation, focusing on *outcomes*, whilst mode 2 orientates itself towards improving the *process* of purposeful improvement of problem situations (see Checkland and Scholes, 1990:283). SSM used in its mode 2 capacity is not suitable to be analysed by rigorous reduction, as it is partly a subjective and unconscious process. In these respects, it provides a good description of cross-sector policy research as it was developed in the energy-transport case study.

Whereas SSM evolved from an emphasis on outcomes towards emphasis on the process of learning, cross-sector policy research, if anything, needs to develop in the other direction, i.e. towards a more formal understanding of how comparisons of different sectors can improve outcomes. The main reason for this lies in the execution of the energy-transport case study. To recapitulate, it was the existence of similarities between energy and transport which led to the subsequent research into further similarities and the search for the appropriate theories of sector-based policy analysis. There was no formal way of analysing the similarities between the two sectors, other than something that could be described as 'continuous organic development' (as de Bono (1970) notes, good analogies often take on a life of their own). As the analysis of similarities and differences between the sectors proceeded, the way in which they were perceived became dynamic; what were initially perceived as deep similarities, gradually became more surface like. The cognitive processes governing these phenomena may be similar to those in the relationship between SSM modes 1 and 2.

Furthermore, the process through which suitable comparative themes are highlighted and selected is not clear. This is not surprising, since the equivalent sociological and anthropological selection of analogues is not developed either, even though much comparative research in these fields has been undertaken (Kohn, 1987; Parkin, 1987; Holy, 1987). In some senses, it is quite natural that the cross-sector method should develop bottom-up from problem-oriented specific case work. In an example of the cross-fertilisation of ideas between other fields, Wilson (1969) suggests that Geographers should look at Physics to *learn* (rather than be *taught* by physicists). The underlying principle of the energy-transport research was that data, ideas and arguments are taken from energy and *applied* to transport. Just as Wilson advocates that geographers should learn, if cross-sector policy research were used to help transport policy analysts learn from energy, then further fruitful insights may occur. Hence further research could be undertaken to develop a framework within which policy stake-holders could engage themselves in cross-sector comparisons with different policy sectors. This might, for instance, take the form of an interactive computer based decision analysis model or discussion forum as developed for the resolution of opposing viewpoints in energy policy by Jones et al (1990). The outcome of such research would likely be an augmentation of the theory set out in this dissertation from insights based on experiential styles of learning (see Scott, 1990).

8.2.3 Insights For Policy Science.

In terms of Wiess's framework (see section 2.1), cross-sector policy research as a methodology is essentially an idea which uses data to develop arguments. Wiess suggests that research as ideas is more likely to be influential: (a) when existing policy is in disarray - under conditions of failure and crisis, even crusty old die-hards will look for a way out of the situation; (b) when uncertainty is high - when nobody knows what to do or what will work, ideas are in demand; and (c) in decentralised policy arenas, where many separate bodies decide - in arenas like criminal justice or education, where authority for decisions is dispersed, a relatively simple idea can travel further and faster than detailed data. The transport sector in the 1990s can be appropriately described by all three of the above characteristics, demonstrating its suitability for comparison with the energy sector, as it was in the 1970s.

Wiess's three types of policy research products appear to resemble elements of each of Majone's three policy worlds (table 2.1). Even without an adequate theory, the notion that data, ideas and arguments are the constituent basis of any substantial policy research study means that any comparable analysis of policy studies from different sectors may encounter some of the more detailed issues in Majone's policy worlds without actively and explicitly seeking them.

If policy itself is partly determined by policy research, then it may be possible to add three further categories to Hogwood and Gunn's ten definitions of policy. These would correspond to Wiess's three types of research products. In terms of the notion of the rational policy process, cross-sector policy research from one perspective may seem more rational in that, it helps generate suggestions for alternative courses of action. However, since it does not already occur naturally or spontaneously, it may perhaps be seen as injecting some degree of extra-rationality into the policy process.

As a policy study, the cross-sector research methodology, is not characterised by any of Hogwood and Gunn's eight existing policy science categories. The cross-sector method could be described as a 'generative' or supplementary policy study as it is not at present directly part of the ways in which policies are conceived, processed and implemented.

The case study indicates that the identification of suitable cross-sector analyses will require additional characteristics to those already put forward by Majone (section 2.2). In particular, some way of comparing the 'objective' differences between policy areas needs to be addressed. Further work needs to be done on the relationship between previous attempts to construct policy typologies (see Steinberger, 1980) and the objective nature of the policy areas themselves. Work in the field of management studies is already dealing with some similar issues in relationship to firms competing within partly objectively defined sectors (e.g. Child and Smith, 1987) and typologies of industrial characteristics are being increasingly used (see Porter, 1990; Wilks and Wright, 1988b).

A rationale for the continued development of cross-sector policy research can be taken from analogous attempts in the systems movement to construct a general systems theory (GST) with the aims of:

> 1. investigating the isomorphy of concepts laws, and models in various fields, and to help in useful transfers from on field to another;
> 2. encouraging the development of adequate theoretical models in areas which lack them;
> 3. eliminating the duplication of theoretical efforts in different fields;
> 4. promoting the unity of science through improving the communication between specialists (Checkland 1981:93).

In terms of the framework developed in table 2.2, the barriers to more spontaneous cross-sector comparisons are mainly constructed by the deep entrenchment of policies in the problem space. Policy issue knowledge is so clearly demarcated that it prevents connections being made between policy areas at the actor and policy space levels. The idea of policy sectors themselves grows out of notions that the issues which they contain are all in some sense distinctly different. Cross-sector research partly challenges these conventional schemes, by placing emphasis on the problems rather than benefits of dividing policies into distinct compartments. Schneider and Ingram note that there are, however, many benefits to the active pursuit of cross-sector comparisons:

> 'Systematically comparing policy ideas not only expands the experiences of policy makers vicariously, but also opens up the design process to participation by general policy analysts without specific previous expertise in the policy area. This is especially important in emerging policy areas and areas undergoing redefinition' (Schneider and Ingram, 1988:78).

8.2.4 Insight into the role of Government.

Prince (1983) notes that Government reforms in the late 1960s and 1970s were partly constructed on the belief that policy units (distinct organisations to undertake policy planning and research functions across various areas) would secure greater overall efficiency. Setting up specific organisations to perform policy planning and research functions was justified on the grounds that the fragmentation of scarce and expensive research resources in various policy fields was wasteful. Such fragmentation of research was thought to lead to the diffusion and potential duplication of effort, inconsistencies in work, and missed opportunities to apply new concepts in various policy fields. In 1970, Edward Heath established the Central Policy Review Staff (CPRS) which was aimed at eliminating the problems that were created by the structural division of Government between ministries whose joint cooperation had become the exception rather than the rule; the departmentalisation of information had obscured a more panoramic view of government policies (Booth, 1988:192). Prince notes that

> 'Moreover, operational departments often face similar kinds of data and technique problems, and methods developed in one are often applicable in another. The specialisation of research and planning was often linked with administrative efficiency and effectiveness. Specialisation would permit greater skill and expertise to be developed within policy units in the performance of their functions.' (Prince, 1983:28)

The CPRS partly addressed these problems by creating umbrella groups of unified fields of policy. Apart from the political basis upon which such innovative organisational changes occur, insights from cross-sector policy research could have major implications for the way issues are dealt with by Government.

Table 8.2 summarises possibilities for further research of the issues dealt with in section 8.2.

Table 8.2: Further research related to the theory of cross-sector policy research.

Chapter 2

- extend and calibrate Majone's generic policy space structural characteristics (look for similar actor and problem space characteristics);
- look for evidence of Majone's and related theories (table 2.1) in various policy sectors;
- assess a range of policy studies to evaluate the framework in figure 2.3;
- link the policy categories in figure 2.3 to Kohn's ideas of object/context/unit/trans-types of analyses (figure 2.4);
- identify the generic characteristics of Geertz's (1983) experience near and experience far concepts within the context of policy research.

Chapter 3

- investigate role of technology in both sectors (i.e. extend context and some unit analysis).
- review the future of British Rail in terms of the experience with British Coal;
- review treatment of uncertainty in the forecasting procedures of energy and transport sectors.

Chapter 4

- investigate the structural analogy between energy and transport (figure 4.1) in more depth;
- investigate the role of the environment in promoting policy convergence between the two sectors;
- hold interactive policy workshops to gather evidence on the analogy at work;
- undertake a thermodynamic interpretation of transport end-use matching.

Ultimately, the subsequent development of cross-sector research depends, like any other innovation in the world of academic policy analysis, on its ability to help satisfy the four intentions of the generic policy researcher (Wiess, 1991): to be a reputable and respected social scientist; to make a difference; to advance the cause of analytically based decision making; and to advocate a political position. As an idea, it has managed to sustain itself thus far.

9. Appendices.

Appendix 9.1: Sources of Other Carrier Assumptions.

9.1.1: Freight Train.

One series of publications in particular gives a comprehensive breakdown of all rolling stock currently used (Marsden, 1984). A typical wagon is the HAA, HBA class for bulk transportation. The tare (unladen mass) of the wagon is given as 14.5 tonnes, and its maximum carrying capacity is 32.5 tonnes. This ratio between unladen mass and carrying capacity is essentially the same when the unit of analysis becomes the train as opposed to wagon, apart from the necessary inclusion of a tractor unit to pull the wagons (typical mass of 60 tonnes). Assuming a train to have 20 wagons this gives the train a total unladen mass of 350 tonnes and a maximum carrying capacity of 650 tonnes.

9.1.2: Passenger Train.

Marsden (1987) gives a comprehensive breakdown of all passenger rolling stock. The 'Tourist Second Open (TSO) class is typical of the carriges used by British Rail. It has an unladen mass of 33 tonnes and carries 54 passengers (second class) when full. Assuming a passenger train tractor weighs 50 tonnes, a train with six TSO carriages would have a total unladen mass of 250 tonnes and a maximum occupancy of 324 passengers.

9.1.3 Ships.

Martin and Shock (1989) give details of the average size of ships used for domestic purposes. The average size for all commodities and uses is approximately 2130 dead weight tonnes (DWT). The design of ships differs greatly depending on the purposes they perform. Car ferries, oil tankers and container ships all have very different designs and consequently will have very different ratios of unladen mass to maximum payload. In shipping terms the unladen mass is referred to as 'light displacement tonnage' (LDT) and the carrying capacity is usually described in terms of the ship's 'dead weight tonnage' (DWT). The combination of the LDT and the DWT is known as the loaded displacement. Table A1 below gives details of the relationship between LDT and DWT for typical classes of ships

Table A1: LDT and DWT: by type of ship.

'000 Tonnes

ship	general	cargo	container carrier	bulk tanker	tanker
LDT	5.5	6	18	30	7
DWT	12.5	17	54	190	27
LDT/DWT	.44	.35	.33	.15	.35

source: Alderton, 1984:16

From table A2, the average dead weight tonnage (M_{ship}) of ships used for UK domestic water transport is estimated to be 2130 tonnes. Table A2 also calculates the average energy consumption of such ships from data contained in Martin and Shock (1989); this figure of 0.3 MJ/dwt/km is used in section 5.9.

9.1.4 Bus and Coaches.

In 1991, over 70 per cent of all buses and coaches registered had at least 36 seats (DTp, 1992b; DTp, 1992e). Statistics which fully disagregate the number of buses and coaches by their seating capacity are not published by the DTp. The designs of buses have changed dramatically over the last five years (see for example Transport Engineer, 1991) towards lighter and smaller vehicles. Buses have a long service life however, and so the effects of the 1980 and 1985 bus deregulation acts for instance (implicitly encouraging smaller vehicles) have not all been observed yet. Even some of the older bus and coach stock are being modernised and re-used (Transport Engineer, 1991). A double decker bus has 97 seats and the average single coach will hold around 70 people. The smaller town buses can carry 30 passengers. The average bus is assumed to carry 60 passengers and have an unladen weight of 7 tonnes.

Table A2: Estimation of Average Payload of Ships Used for Domestic Water Transport.

Sector	Net Output	Average Ship size	Weighted[1] Average Ship size	Energy Use	Weighted[1] Average Energy Use
	tkm	dwt(M_{ship})	dwt	MJ/dwt/km	MJ/dwt/km
Internal	.04	400	0.3	.80	.00
Coastwise	.04	4000	3.0	.20	.00
Foreign	1	4000	96	.18	.00
One-port	.50	1800	17	.30	.00
From rigs	11	1800	368	.30	.06
To rigs	.40	1800	13	.30	.00
Dredged	.60	1000	11	.50	.01
Dumped	.20	1000	4	.50	.00
Oil	34	1800	1124	.30	.20
Coal	4.0	6000	398	.15	.00
Other	3.0	2000	96	.25	.01
Total	54.0		2130		.30

source: Martin and Shock, 1989: table 10.2; [1] weighted according to net output

9.1.5 Mass of 'average' passenger.

The definition of the average passenger is derived from the range of ages considered in the National Travel Surveys (DTp, 1988). It includes children, persons aged 16-59, and aged 60 and over. A value of 50 kg was assumed for the years 1952-1990.

9.1.6 Average distance walked per person per week.

The 1984/85 National Travel Survey was used to estimate this assumption (DTp, 1988). Although there have been other surveys of this kind dating back to 1965, data on the changes in distance walked per person per week is not readily available. The figure of 8.64 kilometres has therefore been assumed to be constant over the period.

Appendix 9.2: Motor Car Specifications and Sales Figures: 1952-1991.

Table A3: Cars of the British motor industry 1952 and 1963: unladen masses and engine sizes.

1952 Make	Model	(kg)[1]	(cc)[2]	1963 Make	Model	(kg)[1]	(cc)[2]
Austin	A.30	673	800	Austin	Mini	597	1316
	A.40	972	1200		Mini Countryman	635	1400
	A.40 sports	934	1200		Mini Cooper	597	1316
	A.70	1226	2199		A.40 Mark II	775	1708
	A.125 Shearline	1886	3995		Hirecar	1727	3808
	A.135 Princess	1969	3995		1100 2 door	813	1792
Ford	Anglia	742	933		A.60	1092	2408
	Prefect	820	1172		A.60 Countryman	1143	2520
	Consul	1026	1508	Austin	Sprite II	597	1316
	Zephyr Six	1110	2262	Healey	A.110	1524	3360
	Hillman minx	905	1265		3000 Sports Conv.	1067	2352
	Humber Hawk	1295	2267	Ford	Anglia Super	762	1680
	Super Snipe	1757	4138		Anglia	737	1624
	Pullman	2026	4086		Consul Cortina	787	1736
Jaguar	VII	1676	3442		Consul Corsair	902	1988
	XK120	1219	3442		Zephyr 4	1168	2576
Morris	Minor	775	918		Zephyr 6	1245	2744
	Minor(4)	775	918		Zodiac	1295	2856
	Oxford	1041	1476	Hillman	Imp	660	1456
	Traveller	1097	1476		Minx de Luxe	9901	218
	Six	1268	2215		Super Minx	1067	2352
Riley	1.51	1232	1496		Husky	940	2072
	2.51	1422	2443	Humber	Sceptre	1118	2464
Rover	75	1451	2103		Hawk	1473	3248
	Land Rover	1181	1997		Super Snipe	1486	3276
	SingerSM 1500	1158	1497	Jaguar	2.41	1422	3136
	SM Roadster	841	1497		3.41	1448	3192
	Standard Van.	1156	2088		3.81	1575	3472
	Sunbeam 90	1295	2267		Mark X	1778	3920
Triumph	Mayflower	956	1247		E type	1143	2520
	Renown	1295	2088	M.G.	M.G.B.	864	1798
	2 Seater	711	1991		Midget	660	1098
Vauxhall	Velox	1064	2262		1100 2 door	822	1098
	Wyver	1000	1507		Magnette Mk I	1143	1622
Wolseley	four/44	1168	1250	Morris	Mini Minor	610	1344
	Six/80	1220	2215		Mini Cooper	610	1344
					Minor 1000	749	1652
					1100 2 door	813	1792
					Oxford Series VI	1016	2240
					Oxford Series VI	1181	2604
				Riley	Elf	610	1344
					1.51	940	2072
					4/72	1168	2576
				Rover	95 Saloon	1461	3220
					110 Saloon	1486	3276
					2000 Saloon	1245	2744
					3.01	1524	3360
				Singer	Gazelle	1016	2240
					Vogue	1067	2352
				Sunbeam	Rapier	1029	2268
					Alpine	940	2072
				Triumph	Herald 1200	775	1708
					Vitesse 6	876	1932
					2000 Saloon	1168	2576
					Spitfire	673	1484
					T.R.4	940	2072
				Vanden	3.01	1575	3472
				Plas	Princess 4.01	2121	4676
				Vauxhall	Viva	686	1512
					Victor Saloon	914	2016
					VX 4/90	978	2156
					Velox/Cresta	1168	2576
				Wolseley	Hornet Saloon	610	1344
					1500 Saloon	940	2072
					16/60 Saloon	1118	2464
					6/110 Saloon	1435	3164

[1] *unladen mass (kerb weight);* [2] *engine size. source: Times Survey of British Motor Industry: 1952, 1963*

Table A4: Top 20 best selling cars 1981 and 1991: unladen masses and sales figures.

Great Britain

1981 model	(kg)[1]	('000)[2]	%[3]	1991 model	(kg)[1]	('000)[2]	%[3]
Ford Cortina	1067	160	.16	Ford Fiesta	843	117	.11
Ford Escort	838	141	.15	Ford Escort	965	110	.11
Ford Fiesta	737	111	.11	Vauxhall Cavalier	1102	110	.11
Austin Metro	757	110	.11	Ford Sierra	1174	94	.09
Morris Ital	935	48	.05	Vauxhall Astra	1016	71	.07
Vauxhall Chevette	864	37	.04	Rover 200 Series	1067	68	.07
Vauxhall Cavalier	1006	34	.03	Rover Metro	853	60	.06
Datsun Cherry	793	33	.03	Peugot 205	859	47	.04
Vauxhall Astra	864	31	.03	Vauxhall Nova	787	45	.04
Austin Morris Mini	625	29	.03	Peugot 405	1077	41	.04
Volkswagen Golf	777	29	.03	Ford Orion	1011	40	.04
Datsun Sunny	838	26	.03	Volkswagen Golf	955	34	.03
Renault 5	787	25	.03	Nissan Micra	1092	33	.03
Ford Granada	1356	25	.03	BMW 3 Series	1270	26	.02
Volvo 300 Series	980	24	.02	Rover 400 Series	1077	25	.02
Ford Capri	1041	22	.02	Ford Granada	1331	25	.02
Rover	1422	22	.02	Volkswagen Polo	777	24	.02
Renault 18	965	21	.02	Volvo 400	1031	23	.02
Volvo 200 Series	1407	21	.02	Rover Montego	1092	23	.02
Austin Allegro	864	21	.02	Peugot 309	914	22	.02
weighted average	907			weighted average	1004		

[1] unladen mass; [2] number of cars sold; [3] % of total number of top 20 cars sold.

sources: SMMT, 1982, 1992; What Car, 1981, 1991.

Table A5: Car survivor rates, 1974 and 1991.

Year of Reg	89/90	87/88	85/86	83/84	81/82	79/80	77/78		pre '77
mean age in 1991	1	3	5	7	9	11	13		17
per cent of all cars registered	20	20	17	16	12	7	4		4

mean age of all cars in 1991 car park = 5.14 years

Year of Reg	73/74	71/72	69/70	67/68	65/66	63/64	61/62	58/60	pre'58
mean age in 1974	1	3	5	7	9	11	13	15	19
per cent of all cars registered	19	21	15	15	13	9	3	3	1

mean age of all cars in 1974 car park = 5.81 years

source: DTp, 1975, 1991

Appendix 9.3: Mass Movement Statistics.

Table A6: Net, Essential and Gross Mass Movements and Intensities: 1952-1991.

Year	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Net Mass Passenger (BTKME)																				
walk	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
pedalcycles	1.15	1.04	.91	.91	.81	.80	.71	.68	.60	.54	.47	.41	.40	.35	.31	.28	.25	.23	.22	.21
motorcycles	.35	.35	.40	.40	.40	.45	.45	.55	.55	.55	.50	.40	.40	.40	.35	.30	.25	.25	.20	.20
car/taxi	3.10	3.45	3.80	4.40	4.80	4.80	5.90	6.60	7.30	8.20	8.85	9.55	10.95	11.80	12.80	13.50	14.05	14.40	14.95	15.70
bus/coach	4.60	4.65	4.60	4.55	4.45	4.20	4.00	4.05	3.95	3.80	3.70	3.65	3.55	3.35	3.35	3.30	3.20	3.15	3	3
train	1.95	1.95	1.95	1.90	2.00	2.10	2.05	2.05	2.00	1.95	1.85	1.80	1.85	1.75	1.75	1.70	1.70	1.75	1.80	1.80
air	.01	.01	.02	.02	.03	.03	.03	.03	.04	.05	.06	.07	.08	.09	.09	.10	.10	.10	.10	.10
Total Mass	12.41	12.70	12.93	13.43	13.74	13.63	14.39	15.21	15.69	16.35	16.68	17.13	18.48	18.99	19.91	20.43	20.80	21.13	21.52	22.27
Net Mass Freight (BTKME)																				
LGV	1.00	1.07	1.15	1.22	1.30	1.37	1.44	1.52	1.59	1.67	1.74	1.81	1.89	1.96	2.04	2.11	2.19	2.26	2.33	2.41
HGV	30.00	31.00	34.00	37.00	37.00	36.00	40.00	45.00	48.00	51.00	53.00	55.00	64.00	67.00	71.00	73.00	76	80	82	83
train	37.00	37.00	36.00	35.00	35.00	34.00	30.00	29.00	30.00	29.00	26.00	25.00	26.00	25.00	24.00	21.00	23	23	25	22
water	20.00	20.00	20.00	20.00	22.00	21.00	21.00	21.00	20.00	22.00	24.00	25.00	25.00	25.00	26.00	25.00	25	24	23	22
pipeline	.20	.20	.20	.20	.20	.20	.20	.20	.30	.50	.70	.80	1.10	1.30	1.60	1.70	2.40	2.60	3	3.60
Total Mass	88.20	89.27	91.35	93.42	95.50	92.57	92.64	96.72	99.89	104.17	105.44	107.61	117.99	120.26	124.64	122.81	128.59	131.86	135.33	133.01
Essential Mass Passenger (BTKME)																				
walk	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
pedalcycles	1.61	1.45	1.28	1.28	1.14	1.12	.99	.95	.84	.76	.65	.58	.56	.49	.44	.39	.35	.32	.31	.30
motorcycles	.70	.70	.80	.80	.80	.90	.90	1.10	1.10	1.10	1.00	.80	.80	.80	.70	.60	.50	.50	.40	.40
car/taxi	19.78	21.75	23.66	27.06	29.15	28.79	34.93	38.57	42.10	46.66	49.68	52.88	59.79	63.52	67.93	70.60	72.40	74.26	77.15	81.07
bus/coach	15.33	15.50	15.33	15.17	14.83	14.00	13.33	13.50	13.17	12.67	12.33	12.17	11.83	11.17	11.17	11.00	10.67	10.50	10	10
train	32.04	32.04	32.04	31.22	32.86	34.51	33.69	33.69	32.86	32.04	30.40	29.58	30.40	28.76	28.76	27.93	27.93	28.76	29.58	29.58
air	.08	.08	.12	.12	.20	.20	.20	.25	.33	.41	.45	.53	.61	.70	.74	.78	.78	.78	.82	.82
Total Mass	70.80	72.78	74.49	76.90	80.24	80.77	85.30	89.30	91.65	94.89	95.77	97.78	105.25	106.69	110.98	112.56	113.88	116.36	119.50	123.42
Essential Mass Freight (BTKME)																				
LGVs	1.86	1.99	2.13	2.27	2.41	2.54	2.68	2.82	2.96	3.10	3.23	3.37	3.51	3.65	3.78	3.92	4.06	4.20	4.33	4.47
HGVs	50.23	52.10	57.34	62.61	62.81	61.30	68.31	77.06	82.42	87.80	91.47	93.81	108.10	112.26	118.14	120.76	125.08	131.08	133.83	134.99
train	56.92	56.92	55.38	53.85	53.85	52.31	46.15	44.62	46.15	44.62	40.00	38.46	40.00	38.46	36.92	32.31	35.38	35.38	38.46	33.85
water	26.45	26.45	26.45	26.45	29.10	27.77	27.77	27.77	26.45	29.10	31.74	33.06	33.06	33.06	34.39	33.06	33.06	31.74	30.42	29.10
pipeline	.20	.20	.20	.20	.20	.20	.20	.20	.30	.50	.70	.80	1.10	1.30	1.60	1.70	2.40	2.60	3	3.60
Total Mass	135.66	137.67	141.51	145.37	148.36	144.12	145.12	152.47	158.29	165.11	167.15	169.50	185.77	188.72	194.84	191.75	199.99	205	210.04	206
Gross Mass Passenger (BTKME)																				
walk	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
pedalcycles	1.61	1.45	1.28	1.28	1.14	1.12	.99	.95	.84	.76	.65	.58	.56	.49	.44	.39	.35	.32	.31	.30
motorcycles	.95	1.02	1.09	1.15	1.14	1.28	1.29	1.53	1.55	1.52	1.37	1.16	1.15	1.07	.95	.82	.72	.67	.60	.59
car/taxi	38.51	41.49	45.55	51.24	55.24	53.40	64.48	71.36	77.03	85.75	91.91	98.74	112.29	120.94	129.94	136.38	141.44	146.55	153.60	163.50
bus/coach	34.21	34.19	33.86	33.88	33.85	32.34	31.51	31.77	31.53	31.73	31.56	31.30	31.20	30.72	30.58	29.83	29.94	29.82	27.99	27.85
train	74.75	78.94	79.10	76.39	80.03	81.99	83.20	82.92	83.73	88.35	85.68	99.30	111.45	105.07	102.41	100.00	97.96	96.98	97.36	98.19
air	.82	.82	.91	1.02	1.22	1.35	1.31	1.33	1.54	1.73	1.71	1.81	2.12	2.20	2.48	2.61	2.51	2.44	2.50	2.55
Gross Mass	152.10	159.16	163.03	166.22	173.87	172.74	184.03	191.12	197.48	211.11	214.13	234.14	260.02	261.74	268.05	271.29	274.17	278.04	283.61	294.24
Gross Mass Freight (BTKME)																				
LGVs	14.05	14.65	15.05	15.89	16.30	16.63	18.93	21.72	23.58	25.55	25.76	27.22	27.34	29.10	29.08	28.60	28.80	29.30	30.65	31.94
HGVs	56.17	58.69	64.21	70.52	71.14	69.99	77.87	87.05	93.57	98.52	101.80	109.40	129.10	137.00	146.82	152.76	163.07	171.82	180.20	189.85
train	99.72	100.20	98.69	94.62	95.23	94.44	86.28	83.21	84.64	91.51	84.42	83.24	89.14	80.89	73.04	64.99	66.44	67.16	70.22	63.14
water	32.67	32.67	32.67	32.67	35.93	34.30	34.30	34.30	32.67	35.93	39.20	40.83	40.83	40.83	42.46	40.83	40.83	39.20	37.56	35.93
pipeline	.20	.20	.20	.20	.20	.20	.20	.20	.30	.50	.70	.80	1.10	1.30	1.60	1.70	2.40	2.60	3	3.60
Gross Mass	202.81	206.40	210.83	213.90	218.80	215.55	217.59	226.48	234.76	252.01	251.88	261.50	287.51	289.12	293.01	288.88	301.53	310.09	321.64	324.46
GDP	136.90	142.30	148.30	153.70	155.80	158.40	158.10	164.50	173.70	178.40	180.90	188.10	198.50	204.40	208.30	212.90	222.20	227.70	232.30	236.20
Intensity (tkme/pound GDP)																				
net	.73	.72	.70	.70	.70	.67	.68	.68	.67	.68	.68	.66	.69	.68	.69	.67	.67	.67	.68	.66
(passenger)	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.10	.10	.09	.09	.09	.09
(freight)	.64	.63	.62	.61	.61	.58	.59	.59	.58	.58	.58	.57	.59	.59	.60	.58	.58	.58	.58	.56
essential	1.51	1.48	1.46	1.45	1.47	1.42	1.46	1.47	1.44	1.46	1.45	1.42	1.47	1.45	1.47	1.43	1.41	1.41	1.42	1.39
(passenger)	.52	.51	.50	.50	.52	.51	.54	.54	.53	.53	.53	.52	.53	.52	.53	.53	.51	.51	.51	.52
(freight)	.99	.97	.95	.95	.95	.91	.92	.93	.91	.93	.92	.90	.94	.92	.94	.90	.90	.90	.90	.87
gross	2.59	2.57	2.52	2.47	2.52	2.45	2.54	2.54	2.49	2.60	2.58	2.63	2.76	2.69	2.69	2.63	2.59	2.58	2.61	2.62
(passenger)	1.11	1.12	1.10	1.08	1.12	1.09	1.16	1.16	1.14	1.18	1.18	1.24	1.31	1.28	1.29	1.27	1.23	1.22	1.22	1.25
(freight)	1.48	1.45	1.42	1.39	1.40	1.36	1.38	1.38	1.35	1.41	1.39	1.39	1.45	1.41	1.41	1.36	1.36	1.36	1.38	1.37

Year	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Net Mass Passenger (BTKME)																				
walk	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
pedalcycles	.20	.19	.19	.22	.25	.30	.26	.23	.25	.27	.32	.32	.32	.30	.27	.29	.26	.26	.26	.26
motorcycles	.20	.20	.25	.30	.35	.35	.35	.35	.45	.50	.50	.45	.45	.40	.40	.35	.35	.30	.30	.30
car/taxi	16.45	17.30	16.75	16.65	17.45	17.80	18.50	18.35	19.45	19.80	20.40	20.65	21.70	22.15	23.35	25.05	26.80	29.05	29.55	29.50
bus/coach	3	3.05	3.05	3	2.90	2.90	2.80	2.80	2.60	2.45	2.40	2.40	2.40	2.45	2.35	2.35	2.30	2.35	2.30	2.25
train	1.75	1.75	1.80	1.75	1.65	1.70	1.75	1.75	1.75	1.70	1.55	1.70	1.75	1.80	1.85	1.95	2.05	2	2.05	1.90
air	.11	.12	.11	.11	.12	.11	.14	.15	.15	.15	.15	.15	.15	.20	.20	.20	.25	.25	.26	.24
Total Mass	22.96	23.86	23.40	23.28	23.97	24.42	25.04	24.88	25.91	26.13	26.57	26.92	28.02	28.56	29.68	31.44	33.27	35.46	35.97	35.70
Net Mass Freight (BTKME)																				
LGV	2.48	2.56	2.63	2.70	2.78	2.85	2.93	3	2.70	2.70	2.70	2.80	3.30	3.80	4.30	4.70	5.40	5.70	5.60	5.40
HGV	85	87	87	89	93	95	96	99.30	89.70	90.20	91.10	92.30	96.60	99.10	101.10	108.60	124.80	132.10	130.60	124.60
train	21	23	22	21	21	20	20	19.90	17.60	17.50	15.90	17.10	12.70	15.40	16.50	17.30	18	17.30	15.80	15.30
water	23	25	25	21	26	41	48	55.50	54.10	52.70	58.70	60.20	59.70	57.60	54.80	54.10	59.30	57.70	52.50	55.90
pipeline	3.50	4.80	5.30	5.90	5.70	8.80	9.80	10.30	10.10	9.30	9.30	9.90	10.40	11.20	10.40	10.50	10.80	9.40	11	11.10
Total Mass	134.98	142.36	141.93	139.60	148.48	167.65	176.73	188	174.20	172.40	177.70	182.30	182.70	187.10	187.10	195.20	218.30	222.20	215.50	212.30
Essential Mass Passenger (BTKME)																				
walk	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
pedalcycles	.28	.26	.27	.31	.35	.43	.36	.32	.36	.38	.45	.45	.45	.42	.38	.40	.37	.36	.37	.36
motorcycles	.40	.40	.50	.60	.70	.70	.70	.70	.90	1	1	.90	.90	.80	.80	.70	.70	.60	.60	.60
car/taxi	85	89.46	86.67	86.21	90.42	92.29	95.99	95.27	101.05	102.94	106.13	107.51	113.05	115.47	121.81	131.81	142.23	155.48	159.49	160.55
bus/coach	10	10.17	10.17	10	9.67	9.67	9.33	9.33	8.67	8.17	8	8	8	8.17	7.83	7.83	7.67	7.83	7.67	7.50
train	28.76	28.76	29.58	28.76	27.11	27.93	28.76	28.76	28.76	27.93	25.47	27.93	28.76	29.58	30.40	32.04	33.69	32.86	33.69	31.22
air	.90	.98	.86	.86	.98	.90	1.11	1.23	1.23	1.23	1.23	1.23	1.23	1.64	1.64	1.64	2.05	2.05	2.09	1.96
Total Mass	126.59	131.28	129.30	127.99	130.48	133.17	137.49	136.87	142.21	142.91	143.53	147.27	153.63	157.33	164.12	175.68	187.95	200.44	205.15	203.45
Essential Mass Freight (BTKME)																				
LGVs	4.61	4.75	4.88	5.02	5.16	5.30	5.43	5.57	5.01	5.01	5.01	5.20	6.13	7.06	7.99	8.73	10.03	10.59	10.40	10.03
HGVs	137.81	140.66	140.30	143.19	149.31	152.22	153.55	158.57	143.02	143.93	145.47	147.49	154.47	158.58	161.89	174.02	200.11	211.95	209.68	200.17
train	32.31	35.38	33.85	32.31	32.31	30.77	30.77	30.62	27.08	26.92	24.46	26.31	19.54	23.69	25.38	26.62	27.69	26.62	24.31	23.54
water	30.42	33.06	33.06	27.77	34.39	54.22	63.48	73.40	71.55	69.70	77.63	79.62	78.95	76.18	72.47	71.55	78.42	76.31	69.43	73.93
pipeline	3.50	4.80	5.30	5.90	5.70	8.80	9.80	10.30	10.10	9.30	9.30	9.90	10.40	11.20	10.40	10.50	10.80	9.40	11	11.10
Total Mass	208.64	218.65	217.39	214.19	226.86	251.31	263.04	278.45	256.76	254.86	261.88	268.52	269.50	276.71	278.14	291.41	327.06	334.86	324.82	318.76
Gross Mass Passenger (BTKME)																				
walk	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
pedalcycles	.28	.26	.27	.31	.35	.43	.36	.32	.36	.38	.45	.45	.45	.42	.38	.40	.37	.36	.37	.36
motorcycles	.57	.59	.67	.81	.98	.97	.97	.99	1.22	1.39	1.42	1.28	1.26	1.14	1.11	1.02	.95	.89	.86	.84
car/taxi	172.97	182.33	178.29	179.79	188.63	192.46	200.76	199.51	213.39	218.42	225.51	229.55	242.54	248.61	262.69	286.19	309.60	339.02	347.08	349.65
bus/coach	27.85	27.27	26.01	25.61	26.14	25.44	25.90	26.11	27.24	26.95	27.04	28.30	29.42	28.07	28.18	30.91	32.47	34.06	34.36	35.71
train	97.15	96.81	98.83	102	100.76	102.69	104.34	104.21	107.96	106.51	94.66	102.74	102.21	103.04	103.15	107.61	112.36	113.64	116.94	116.85
air	2.78	3.06	2.91	2.69	2.92	2.72	3.13	3.48	3.63	3.75	3.81	4.05	4.41	4.58	4.70	4.88	5.23	5.65	5.84	5.76
Gross Mass	302.85	311.57	308.24	312.46	321.04	325.97	336.71	335.87	355.05	358.65	354.14	367.62	381.54	387.11	401.47	432.27	462.23	494.88	506.69	510.43
Gross Mass Freight (BTKME)																				
LGVs	33.08	34.55	35.03	34.71	35.48	36.02	36.83	36.57	37.41	37.80	37.49	37.54	40.04	41.56	44.04	48.17	53.48	58.79	59.12	61.22
HGVs	199.71	213.68	215.50	221.71	238.72	243.82	256.31	267.45	265.83	261.32	260.63	267.83	281.66	289.57	298.72	329.32	363.87	389.79	385.81	381.28
train	59.18	61.86	58.88	55.07	52.24	49.16	47.07	45.88	41.03	39.45	35.34	37.44	30.04	31.89	29.38	30.25	31.34	30.04	28.12	26.51
water	37.56	40.83	40.83	34.30	42.46	66.96	78.40	90.65	88.36	86.07	95.87	98.32	97.51	94.08	89.50	88.36	96.85	94.24	85.75	91.30
pipeline	3.50	4.80	5.30	5.90	5.70	8.80	9.80	10.30	10.10	9.30	9.30	9.90	10.40	11.20	10.40	10.50	10.80	9.40	11	11.10
Gross Mass	333.04	355.72	355.54	351.69	374.61	404.76	428.40	450.84	442.73	433.95	438.63	451.03	459.64	468.28	472.03	506.60	556.34	582.26	569.80	571.41
GDP	242.80	260.90	257	255	261.70	268.40	276.30	284	278.20	275	279.70	290.10	295.40	306.70	317.70	332.20	345.90	353.40	356.90	348.30
Intensity (tkme/pound GDP)																				
net	.65	.64	.64	.64	.66	.72	.73	.75	.72	.72	.73	.72	.71	.70	.68	.68	.73	.73	.70	.71
(passenger)	.09	.09	.09	.09	.09	.09	.09	.09	.09	.10	.10	.09	.09	.09	.09	.09	.10	.10	.10	.10
(freight)	.56	.55	.55	.55	.57	.62	.64	.66	.63	.63	.64	.63	.62	.61	.59	.59	.63	.63	.60	.61
essential	1.38	1.34	1.35	1.34	1.37	1.43	1.45	1.46	1.43	1.45	1.45	1.43	1.43	1.42	1.39	1.41	1.49	1.51	1.48	1.50
(passenger)	.52	.50	.50	.50	.50	.50	.50	.48	.51	.52	.51	.51	.52	.51	.52	.53	.54	.57	.57	.58
(freight)	.86	.84	.85	.84	.87	.94	.95	.98	.92	.93	.94	.93	.91	.90	.88	.88	.95	.95	.91	.92
gross	2.62	2.56	2.58	2.60	2.66	2.72	2.77	2.77	2.87	2.88	2.83	2.82	2.85	2.79	2.75	2.83	2.94	3.05	3.02	3.11
(passenger)	1.25	1.19	1.20	1.23	1.23	1.21	1.22	1.18	1.28	1.30	1.27	1.27	1.29	1.26	1.26	1.30	1.34	1.40	1.42	1.47
(freight)	1.37	1.36	1.38	1.38	1.43	1.51	1.55	1.59	1.59	1.58	1.57	1.55	1.56	1.53	1.49	1.52	1.61	1.65	1.60	1.64

Appendix 9.4:
Gross Mass Movement, Energy Consumption, Emissions, and PCU Data.

Tables A7/8/9 tabulate data on gross mass movement, energy consumption, emissions and PCU data by carrier. There are two ways of considering the energy efficiency of transport. The first, and most often quoted, is to consider the energy consumption per passenger or tonne kilometre (4th column) and the second to consider the consumption per vehicle kilometre (5th column). In general, energy consumption per passenger or tonne kilometre for a particular carrier is dependent upon the occupancy of the carrier, as most of the energy is normally required to move the vehicle itself rather than its contents. The last column represents a third way of measuring energy consumption in MJ per tonne kilometre equivalent at full occupancy.

Table A7: Typical energy consumption of various carriers.

carrier	**Uc**	**Mc**	**Uc+Mc**	**MJ/pkm (MJ/tkm)**	**MJ/LVKM**	**MJ/TKME**
walk	.05	1	.05	.16 [1]	.16	3.11
bicycle	.02	1	.07	.06 [1]	.06	.89
m/c	.10	2	20	1.17 [1]	2.34	11.68
car	1	4	1.20	.79 [1,4]	3.16	2.63
bus	5.48 [4]	47	7.83	.27 [1,4]	12.55	1.60
train	306 [4]	397	326	.32 [1,4]	128	.39
air change	34	167	42	1.45 [1]	243	5.73
lgv	1.50	1.50	3	8.40 [3,4]	12.60	4.20
hgv	9.50	16	25.50	1.60 [2,4]	25.60	1.00
ftrain	350	650	1000	.80 [2,4]	520	.52
ship	745	2130	2875	.30 [3]	639	.22

[1] Potter and Hughes, 1990; [2] CEC, 1992; [3] Martin and Shock, 1989; [4] modified

Table A8: Typical emissions per loaded carrier kilometre.

carrier	**mass**	**CO**	**NOx**	**HC**	**SO2**	**CO2**
m/c[1]	.15	16	.10	14	n/a	163
car[1]	1.10	45	1.20	6.40	.07	315
bus[1]	8	18	15.50	12	1.70	1158
train[2]	250	21	256	10.1	220	30002
plane[3]	45	8	48.5	4.1	12.1	13009
LGV[1]	3.50	55	3	6	.18	498
HGV[1]	25.5	8	17.50	2.80	1.59	1158
ftrain[2]	1000	76	455	45	84.5	25675

sources: [1] CEC, 1992; [2] TEST, 1991; [3] Barret, 1991

Table A9: PCU equivalents and carrier masses.

carrier	**mass[1]**	**pcu**
pedal cycle	0.07	0.2
motor cycle	.15	0.4
car	1.1	1.0
bus/coach	7.4	2.0
lgv	1.6	1.0
hgv	13.6	2.3

[1] tonnes *source: Kimber et al., 1986*

Appendix 9.5: Design of Sustainable Mobility Scenario.

The design of the sustainable mobility scenario took into account the effects of changing the various parameters which have an effect on the value of gross mass intensity. Table A8 shows the influence of various changes in these parameters on gross mass intensity.

Table A10: Effects of changes in parameters on gross mass intensity relative to NRTF 2025.

code	Changes Relative to NRTF 2025	% reduction in gross transport intensity
a	10 % shift from cars to 3 % walk, 7 % cycle	3.08
b	10 % shift from cars to buses (O_{bus}=12, U_{bus}=5t)	2.24
c	10 % LGV to car	0.58
d	10 % shift from HGV to 1% pipe, 1% ship, 8% rail	2.11
e	10 % increase in O_{ptrain}, 11 % decrease in VKM	0.51
f	10 % increase in O_{cars}, 11 % decrease in VKM	3.14
g	10 % increase in O_{bus}, 11 % decrease in VKM	0.13
h	10 % increase in O_{lgv}, 11 % decrease in VKM	0.55
i	10 % increase in O_{hgv}, 11 % decrease in VKM	3.08
j	10 % increase in O_{ftrain}, 11 % decrease in VKM	0.02
k	10 % increase in O_{ship}, 11 % decrease in VKM	0
l	10 % shift from car, to m/c	2.76
m	10 % reduction in U_{car}	3.14
n	10 % reduction in U_{bus}	0.13
o	10 % reduction in U_{ptrain}	0.51
p	10 % reduction in U_{plane}	0.05
q	10 % reduction in U_{hgv}	3.08
r	10 % reduction in U_{lgv}	0.55
s	10 % reduction in U_{ftrain}	0.02
t	10 % reduction in U_{ship}	0.21
u	10 % reduction in elasticity of passenger movements wrt GDP	4.08
v	10 % reduction in elasticity of freight movements wrt GDP	5.92

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