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FOREWORD

The mission of the OECD Programme of Research on Road Transport and Intermodal Linkages (RTR) is to promote economic development in its Member countries by enhancing transport safety, efficiency and sustainability through a co-operative research programme on road and intermodal transport. To achieve this objective, the Programme recommends options for the development and implementation of effective transport policies for Members, and encourages outreach activities for non-member countries. All 30 Member countries participate in the Programme.

The 1998-2000 Programme of Work included a Working Group on "Effects of Transport Infrastructure Investment on Regional Development". The Working Group was chaired by Mr. Michael Walsh (United Kingdom) and the following countries participated in the study: Belgium, Canada, France Greece, Italy, Japan, the Netherlands, Norway, Poland, Sweden and the United Kingdom.

The Working Group investigated current evaluation studies of major transport infrastructure projects in OECD Member countries with an aim to identify impacts of transport infrastructure investment on regional development and to improve current appraisal methodologies.

ABSTRACT
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Faced with increased constraints in financing transport infrastructure, Governments need evaluation methods for project appraisals which enable their resources to be allocated in the most efficient way, *i.e.* with maximum net return to society as a whole.

The application of cost benefit analysis (CBA) in OECD Member countries for this purpose has tended to concentrate on the direct user benefits of transport. However, it has been suggested that transport infrastructure investment has wider impacts on regional development, which range beyond direct user benefits, and these should also be taken into account in order to ensure efficient allocation of resources.

The report summarises comprehensive study on current evaluation studies in OECD Member countries with an aim to find empirical evidence on wider impacts of transport infrastructure investment on regional development and to develop guidance for governments and transport administrations on how to identify such impacts and include them in appraisal methodologies.

Field classification	Economic and administration; environment; highway and transport planning; traffic and transport planning; vehicle operating costs.
Field codes	10; 15; 21; 72; 96.
Keywords	Accessibility; cost benefit analysis; decision process; demand (econ); economic efficiency; economics of transport ; evaluation (assessment); financing; impact study (environment); OECD; operating costs; regional planning; social cost; transport; vehicle.

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EXECUTIVE SUMMARY

Background and objectives

The belief that transport infrastructure projects have significant impacts on the development of regional economies has often been used to justify allocating resources to transport infrastructure investment. However, the clear meaning of these impacts or how they could be evaluated has yet to be established.

The general approach used by decision makers in the evaluation of transport investment is cost-benefit analysis (CBA). Traditional CBA, although varying in form from one country to another, is limited in its application since it concentrates on the direct user benefits of transport. Evaluation of projects using traditional CBA does not satisfactorily justify the socio-economic interest of the public or private sectors because it does not take adequate account of the likely regional impacts arising from the investment.

Faced with the increasing constraints of financing transport infrastructure, many countries are keen to allocate their resources in a way that maximises their net return to society. To facilitate such allocation, all of the wide-ranging impacts of investment in transport infrastructure should be fully understood.

It is extremely difficult to measure the exact relationship between transport infrastructure investment and regional development. Although some theoretical analyses indicate the presence of significant impacts, these studies need to be complemented by empirical evidence from existing *ex-post* evaluation studies.

The OECD Road Transport and Intermodal Linkages Research Programme established a Working Group to undertake a comprehensive study on how transport infrastructure investment affects regional development and how such impacts could be handled in project appraisals. The aim is to develop guidance for governments and transport administrations on how to identify such impacts and include them in appraisal methodologies in order to improve the efficiency of investment in transport infrastructure.

Approach

The main tasks undertaken by the Working Group were:

- To conduct a literature review of existing *ex-ante* and *ex-post* evaluation studies and methods in Member countries in order to assess the capacity of current methods to identify the effects of transport infrastructure investment on regional development.

- To undertake research to: *i)* identify and characterise the links that exist between transport infrastructure investment and regional development; and *ii)* evaluate the impact of transport infrastructure on regional development in a wider sense, looking at issues such as accessibility, employment, improved efficiency and social cohesion.

- Based on the results of these studies, to develop an evaluation framework, which includes these wider impacts, for analysing existing *ex-post* evaluations undertaken in Member countries.

- To analyse existing *ex-post* evaluation studies based on the evaluation framework to identify empirical evidence pointing to the existence and significance of the wider impacts that could justify their inclusion in the evaluation of transport infrastructure investment proposals.

- To develop guidance for policy makers, providers and managers of transport infrastructure on how to identify the wider effects of transport infrastructure on regional development and how to assess the relevant impacts in the evaluation of infrastructure projects.

The evaluation framework

The direct effect of transport infrastructure investment is to improve travel conditions for its users. Users' behaviour will thus change, with wider impacts on the network. There could be further impacts, including accessibility, level and location of employment and increased efficiency, that will contribute to the regeneration of a region. The externalities generated by the investment in transport infrastructure also need to be recognised.

These wider impacts (which are not taken into account in traditional CBA) can be assessed in two ways: *i)* extending the scope of traditional CBA by incorporating impacts which go beyond the direct user benefits; and *ii)* presenting the direct user benefits of traditional CBA and the wider impacts as complementary analyses, thereby providing a wider appraisal framework. The Working Group has taken the latter, "complementary", approach". In this approach, it is important to note that transport infrastructure investment can contribute both to overall growth and to redistribution of benefits. It is necessary to distinguish between the two in order to avoid double-counting.

Direct user benefits

The main direct user benefits identified in traditional CBA are travel time, vehicle operating costs and safety. Travel time savings are usually regarded as the largest economic benefits of transport infrastructure investment, although the extent and value of the benefits are open to debate.

In defining the transport infrastructure projects to be assessed, the long life span of the projects gives rise to the question of the appropriate timeframe over which to estimate benefits and costs. When timeframes are fixed, the issues that need to be addressed include risk assessment, discount rate and identification/estimation of benefits and costs. Setting payback periods (the number of years before the project breaks even) is another possible way to conduct project appraisal. The various combinations and weights of risks are often tested by applying sensitivity analysis.

Wider effects on the transport network

The improvement of travel conditions resulting from transport infrastructure investment may have wider impacts on the network by inducing and affecting demand on a cross-modal basis as well as improving reliability and quality of transport service.

Socio-economic spillovers

Accessibility

In many cases, the objective of transport infrastructure investment is to improve the accessibility of a given region by reducing travel time or increasing the potential to travel. Accessibility can be measured as the quantity of economic or social activities that can be reached using the transport system. Improvement in accessibility will increase the market size for manufacturing, tourism and/or labour, leading to increased competition and/or centralisation. On the other hand, the impact for the region concerned could be both positive and negative, depending on its initial level of competitiveness.

Employment

Regional employment is often an important government objective. The impacts of construction, operation and maintenance of transport infrastructure on employment include both created and relocated jobs. The impacts of construction could be assessed by methods which allow the direct, indirect and induced employment impacts of transport infrastructure projects to be assessed. Direct and indirect employment linked to the operation and maintenance of transport infrastructure are largely related to the level of traffic, which can also be assessed.

Efficiency

For industry in a given region, time and cost savings as well as gains in accessibility and reliability, arising from the transport infrastructure would allow productivity gains to be achieved by improving their production and distribution. Wider access to the market will create both new business opportunities and increased competition, leading to further increases in profitability. The market will be redistributed to the advantage of those companies which are able to adapt to the new market. The same process could occur for the labour market. Thus, transport infrastructure project could be said to have an impact on private capital and labour productivity, and hence on overall economic growth.

Social inclusion

Where regions suffer from economic or social problems, transport infrastructure projects could either result in further exclusion of such communities or could contribute to addressing the problem of social exclusion by improving accessibility and mobility. In both cases, these effects need to be understood and assessed in the evaluation of the project.

Environment

In planning transport infrastructure investment, external effects on the environment need to be included in the appraisal. Thus, various environmental impacts are commonly assessed, both in strategic and project planning. These impacts include air and water quality, noise, severance and regional impacts and use of natural resources.

Case studies

An evaluation framework was used to analyse existing *ex-post* evaluation studies in order to find evidence for the inclusion of wider impacts in the evaluation of transport infrastructure proposals. The Working Group found that very few completed *ex-post* evaluation studies had analysed the broader impacts arising from investment in transport infrastructure.

The difficulty in comparing the *ex-post* studies found by the Working Group is that the "observation areas" for analysing the regional impact differ significantly from one study to another. Hence, if *ex-post* studies are to be undertaken, a clear definition of the regional area under consideration for assessing the development impacts must be determined at the outset.

There is a lack of systemic vision of the different transport infrastructure impacts on regional development. In general, the *ex-post* studies focused on one mode and avoided issues relevant to the intermodal or multimodal dimensions of transport projects. Furthermore, clear project objectives were not systematically stated.

Those variables which were common to most case studies included travel time, vehicle operating costs, accessibility and safety. Employment and business impacts (*i.e.* created or destroyed) were also included. Moreover, other variables that were often stated as important to policy objectives, but not always taken into account, included: environment impact variables, relationship to other developments, social cohesion, quality and level of service, reliability and regional redistribution.

Conclusions

The basic conclusion reached by the Working Group is that there is a lack of information derived from *ex-post* studies which could provide a firm, quantitative basis for claims about the impact of infrastructure investment on regional economies and regeneration. Thus, ability of the Working Group to provide guidance on improving project appraisal methodology is limited.

That being said, the Working Group identified a number of lessons which are relevant to any appraisal. It pinpointed areas where progress is being made in assessing wider economic benefits. This relates in particular to the assessment of local employment impacts and to the contributions which transport can make to improving economic efficiency. There is a need for further research to obtain firm indications of the way in which such positive impacts can be ensured and to indicate the potential level of such impacts. The Working Group recognised the risks implicit in what the Standing Advisory Committee on Trunk Road Assessment (SACTRA) has termed the "two-way road", *i.e.* that improved infrastructure can not only attract development into an area, it can also draw it out.

The Working Group stressed that employment impacts and contributions to improved accessibility and social inclusion are unlikely to be created by transport investment alone. There is a need for a whole range of initiatives, covering training, housing, social services, etc., in order to ensure that spending on regeneration will have the desired effect.

The Working Group pointed to the necessity of setting clear objectives for infrastructure projects concerning regional development; these should include the context and specific strategic needs of the regions. A description of the relationships of these objectives to policies in other sectors and their relevance to other tiers of government should be included, in order to allow decision makers to co-ordinate their policies and infrastructure plans. The impacts of the project should always, in both their *ex-ante* and *ex-post* evaluations, be evaluated against these broader objectives.

Finally, it is recommended that a major research effort should be initiated with a view to improving our understanding of the issues raised in this report. A number of ongoing “before and after studies” (*e.g.* the JLE Impact Study in London) are a useful step in this direction. There is also a commitment from the UK Government, in response to the SACTRA Report on “Transport and the Economy”, to introduce an Economic Impact Report as a fundamental part of its appraisal methods.

Chapter I

INTRODUCTION

Objectives

The analysis of the *Impacts of Transport Infrastructure Investment on Regional Development* was set up as part of the Programme of Research on Road Transport and Intermodal Linkages. The primary objective of the research was to obtain a better understanding of the impact of transport development and infrastructure investment on regional economies. Improved understanding would prove to be very useful in the design of transport projects and in developing the theory and practice of transport project appraisal. It is common, when justifying transport infrastructure projects, to claim that they will have a significant effect on "economic development", either at a national or regional level. However, there is no firm understanding of what this statement actually means, nor how its significance should be incorporated into project appraisal. Various countries have addressed this issue in different ways. However, it requires a thorough understanding of how transport infrastructure investment contributes to the level and structure of economic activity and output. It also calls for an analysis of how such impacts should be handled in project evaluations in the context of the appraisal methodologies in current use.

The Working Group's key objective was to improve the efficiency of allocating funds for transport infrastructure. Its second objective was to develop guidance for governments and practitioners on how the effects of transport infrastructure on economic development can be identified and how related benefits might be included in appraisal methodologies.

Structure and scope of the report

The analysis focused entirely on what could be learned from successful *ex-post* monitoring, or "evaluation" studies of major transport infrastructure projects. While the Working Group examined existing *ex-ante* appraisal frameworks, including an assessment of wider economic benefits, its main goal was to assess what evidence exists for the inclusion of a broad set of variables in the evaluation of infrastructure investment proposals.

Chapter II provides a discussion of the policy setting within which the issues explored in the research are relevant. This is combined with an explanation of the evaluation framework developed for the analysis. In Chapter III, there is a discussion of the Group's suggested format for a project description suitable for future assessment, which could be useful to both policy makers and analysts. This is followed in Chapter IV by a discussion of the case studies analysed throughout the study and the lessons they may provide for the specification and carrying out of *ex-post* studies, as well as suggestions for further research. Summaries of these case studies are provided. Annex 2 provides an overview of work on land-use and transport interactions in dealing with the impact of infrastructure on regional development.

Defining regional development

There is no universal understanding of the appropriate definition of "region" on which the Group could base its analysis. As a result, it examined the issue under a number of headings.

Definition of a region

In the impact assessments towards which this analysis is directed, it is possible (at least in principle) to examine impacts of transport investment at different levels of spatial detail. The aim of this analysis is to provide guidance and a common classification of "region" that will be at a recognisable and operational level of analysis for policy makers.

As a first approach, the Group explored how the issue of defining a region has been treated in the literature. An early definition introduces the concept that a region can be given its coherence either by being homogeneous in some way or heterogeneous through intra-regional trade. "The term 'region' is generally used to describe a group of geographically contiguous areas which have certain common or complementary characteristics *or* which are tied by extensive inter-area activity or flows" (Perloff *et al.*, 1960).

Richardson (1969) identifies three types of regions:

- Uniform or homogeneous regions.
- Nodal regions.
- Programming or planning regions.

The first type defends "…the idea that separate spatial units can be linked together on the grounds that they exhibit certain uniform characteristics. Such characteristics might include similar production structures, homogeneous patterns of consumption and like occupational distributions of the labour force; they might reflect geographical factors such as the ubiquity of a dominant natural resource, or a similar topography or climate; or again, they might include non-economic variables such as uniform social attitudes, a 'regional' identity or a similar socio-political outlook. A major problem in attempting to delimit homogeneous regions is that some areas will in some respects seem to be similar to one region but in other respects will show features suggesting a closer link with a neighbouring region. Boundaries are, therefore, likely to be blurred and arbitrary".

The second type of "region" defined by Richardson states that "nodal, or polarised, regions emphasise the interdependence of different components within the region rather than inter-regional relationships between homogeneous regions. Since the functional links between spatial units are limited by space, nodal regions usually take explicit account of the distance factor as revealed, for example, in gravity potential models". He emphasises that "...the nodal region focuses attention on the controlling centre of the region rather than on drawing the boundaries".

The third type, referred to as a programming or planning region, "…is defined in terms of the coherence and unity of economic decision making" and reflects established political or administrative boundaries.

Perloff *et al.* note how a customised region could be assembled from smaller area units for which data are available:

> "In economic analysis the investigator's choice of component areas (the "building blocks") depends both upon the extent to which such areas can be combined in terms of specified physical, socio-economic, or other criteria and on the form in which statistical data are available or can be made available for the purpose involved. This latter element imposes some serious constraints on choice."

Within their "other criteria" classification, the following could be included:

- Social equality, including regional distribution of transport service availability and accessibility.
- Population density.
- Environmental criteria.

The Group's main focus, however, is on the need for a definition of region that allows the contribution of transport infrastructure to, and its impact on, the economy and society, to be assessed. With this in mind, the Group agreed that, first and foremost, any regions identified should be *policy relevant* – *i.e.* if particular spatial areas or industry sectors are of policy interest, ideally the boundaries of a region would be drawn around the area of interest. Then the impacts of a transport policy or project on this particular region can be analysed in relation to the wider range of policy objectives for that area.

For example, under European Union regional policy, areas of "industrial decline" are those where:

1. The unemployment rate in the three years prior to 1988 exceeded the EC mean.
2. In some year(s) since 1975 the proportion of industrial employment exceeded the EC mean.
3. There had been an observable fall in industrial employment in the region compared to the year(s) selected for (2).

In an older, but still pertinent, account of European regional policy, Diamond (1974**)** lists the following as possible goals of regional policy:

- To reduce unemployment in areas where it is persistently high.
- To reduce the pressure of population in already congested areas.
- To increase the average rate of utilisation of national resources.
- To reduce interregional differences in the pressure of demand in order to relieve inflationary pressures.
- To preserve and strengthen regional cultures and regional identities.
- To achieve a better balance between the population and the environment.

In order to develop a useful definition of "regions" in the context of analysing transport, it is crucial to identify the policy goals to which transport infrastructure investment is meant to contribute, so that an appropriate type of region with appropriate indicators can be developed. For example, some policy goals specifically for transport infrastructure investment may be:

- To improve the global competitiveness of regions, for example by improving the provision and/or quality of urban transport systems (for travel-to-work purposes), enabling the available pools of skilled labour to expand.

- To stimulate international trade by improving strategic links in the freight transport networks, including ports and cargo-handling airports as well as road and rail infrastructure.

- Social objectives, *i.e.* to redistribute economic activity between spatial areas, countries or sectors, in order to reduce income disparities and promote social cohesion.

Each of these definitions, and others not listed, may suggest a different type of definition of a region. For example, one definition might suggest a nodal region or a national or planning region perspective, while another definition might suggest a series of homogeneous regions based on policy relevant variables such as income per capita.

At the policy level, actions and initiatives are usually taken for a mixture of social, economic and political motives. Further, there is a wide range of possible areas for which such objectives are relevant. These depend both on the nature of the item of infrastructure being assessed and on the context into which it is being placed. Thus the Group arrived at the conclusion that no one definition is feasible and that in order to ensure the maximum benefit from its analysis and recommendations, it should consider the whole range of possible areas, provided they represented an appropriate policy context. In some situations, these will be areas contained entirely within one country, in others they will coincide with national territories while in others they will transcend national boundaries.

Concept of "peripheral"

The Group felt it necessary to address the significance of the term "peripheral" in the analysis since European regional policy has traditionally placed great emphasis on the problems of 'peripheral' regions. This has been driven by the perception that many of the poorer areas in the international community were at the geographical periphery. The proponents of this policy argued that integration of such regions into the European economy would improve living standards and further reinforce growth in "core" regions. However, more recently, the Commission's view has shifted, and the core/periphery split, defined in this way, is now regarded as an oversimplification:

> "Dramatic contrasts such as those between the centre and the outlying regions are being overtaken by a more complex pattern of territorial organisation. […] This diversification of disparities is generating a patchwork in which privileged areas border directly onto depressed areas." (Millan, 1993)

"Peripheral" is a term conventionally used for one particular combination of economic/social problems. The Group did not base its analysis on this particular definition, but rather on the contribution transport infrastructure can make to any area where there is a perceived need for economic development in order to bring it closer to the median level of well-being.

Chapter II

POLICY SETTING AND EVALUATION FRAMEWORK

Introduction

The focus of this chapter is on the policy setting and evaluation framework of this analysis. The section which follows addresses the contribution of transport to policy objectives, while the third section describes the context of the current analysis. In general, the approach used to determine whether or not a project contributes to policy objectives is cost-benefit analysis (CBA). However, traditional CBA has certain limitations. Critics believe that it does not capture the broader economic benefits of transport because it concentrates solely on the user benefits of transport.

The intention of this report is to assess this debate and, where it is judged appropriate to do so, to examine issues that go beyond traditional CBA and take these broader economic effects into account. There are, in principle, two ways to proceed. One is to extend the scope of traditional CBA by taking into account the consequences of imperfect competition. The other method is to present the user benefits of traditional CBA and the wider economic impacts as complementary analysis.

Which method should be used is a matter of ongoing debate. In the evaluation framework for the analysis described in the fourth section of this chapter, user benefits and wider economic impacts were brought together through the concept of externality, with the different effects being presented as complementary analysis to traditional CBA.

It should be kept in mind that the main questions dealt with in this project are:

- In theory, what are the (wider) effects that may be expected from infrastructure investments on regional development (Chapter II)?

- How can these (wider) effects be identified, qualified and, if possible, monetised in practice (Chapter III)?

- What are the lessons that can be learnt from evaluation studies (*ex post*) (Chapter IV)? What are the “best practices” that stand out?

Policy setting

All countries face the basic economic problem of allocating scarce resources among competing uses in a way that maximises the net benefits to society. In general, market forces can be relied upon to ensure an efficient and productive rate of capital formation in the private sector. In the public sector, however, market forces are weak and investment objectives are often multifaceted. This is especially true for transportation infrastructure investments. It often follows that transportation decision makers require additional information about the effects of investments and policies on the environment, business, productivity, economic growth, income distribution and other public concerns in order to ensure that investments yield benefits to the community that exceed the cost of achieving them.

A growing awareness of the wide-ranging social and economic impacts of transportation infrastructure has led decision makers to ask how desirable transport investments and policies can best be identified. This report is directed towards meeting the needs of public administrations and transportation professionals concerned in particular with the relationship between transport infrastructure investment and general economic performance and with the identification and measurement of socio-economic impacts in specific geographic areas.

Transportation projects can contribute to different goals of government. A set of economic objectives relates to the overall volume of economic activity. Transport infrastructure investment can contribute to growth by expanding the stock of capital available for use in producing goods and services. With more capital and more efficient production, both real income levels and standard of living can be expected to rise. There is an abundance of literature on the productivity of infrastructure investment. The general conclusion reached is that public capital has an impact on private capital, on labour productivity and hence on economic growth, but the magnitude and significance of these effects are not clear. The key issue in any analysis of these complex interrelationships is the understanding of this relationship and the direction of causality (the extent to which high investments are the cause or the result of economic growth is not always clear).

The relationship between transport investment and economic growth becomes much more complicated when a broader view of economic development is taken, linked to the concept of sustainable growth. This takes into account the effects on the environment, society and the economy – both local and national. In this report, this broader view has been adopted. This reflects, in a way, the changes in transport infrastructure investment policy in Europe, for example, as summarised by Banister and Berechman (2000, p. 19). The policy focus has shifted from priority to rural areas (investment in road and rail extensions to existing motorways in the "peripheral" countries in 1950-70), to economic integration and social cohesion objectives, the Trans-European road network and the high-speed-rail network.

A second type of economic objective concerns the distribution of transportation-generated economic benefits and changes in the incidence of these benefits across locations. There have also been strong (both urban and regional) distributional arguments for investment in transport infrastructure. The regional development policies in the European Union, where powerful and substantial investment has been transferred from rich countries to areas where this investment is needed, are a good example of this. The argument used by the EU is that regional development policy strengthens integration and cohesion in the EU as a whole, while at the same time reducing the disadvantages of poorly connected countries.

There remain, however, many unresolved questions. It is unclear whether such a policy provides greater benefits to the poorer regions and whether it will lead to overall economic development in the longer term. Little empirical evidence is available on whether infrastructure investment at the regional level actually strengthens the recipient, since it extends market area and permits migration of labour to the centre where opportunities are perceived to be greater. It is difficult to determine whether the local economy in that region benefits over the longer term (Banister and Berechman, 2000, p. 5).

At present, it is impossible to determine unequivocally whether expansion of the transport infrastructure will encourage economic development in underdeveloped regions. An obvious reason is that development has many dimensions and can, for example, be expressed in economic, social or environmental indicators that should be weighted against each other. Another reason is that the distribution of the benefits of investments in regions is unclear, and that what is beneficial for one region may be detrimental for another.

Clearly, it is extremely difficult to detect the exact relationship between investment in infrastructure and regional economic development. One method allowing this issue to be dealt with, at least in theory, is the development of a spatial general equilibrium model (Venables *et al.*). However, in practice it proves more difficult, since, as noted in Chapter I, one important weakness of this approach lies in empirical data constraints.

Theoretical studies on the relationship between infrastructure investment and regional economic development must be complemented with more detailed studies at the project level and material gained from *ex-post* evaluation studies. For this reason, the Group decided to focus its attention on attempting to obtain such evidence.

Context: cost-benefit analysis

CBA is the main instrument used by decision makers in the appraisal of transport investment projects. This analytical framework aims to estimate the costs and benefits of a given project in money terms and ascertain that limited resources are being allocated efficiently with the aim of maximising the welfare of society as a whole. This form of project appraisal method varies somewhat from one country to another; there is no universal agreement on the extent to which costs and benefits should be disaggregated, which impacts should be included in the analysis and how they should be monetarily quantified.

The use of standard CBA as an important decision-making instrument has given rise to concerns. The main reservations include the fact that CBA:

- Understates the economic development benefits of certain investments [*e.g.* the industrial reorganisation benefits which arise from modern logistics practices (Mohring and Williamson, 1969)].
- Favours some groups of users to the detriment of others (bias resulting from CBA's reliance. on willingness-to-pay as a measure of opportunity costs).
- Fails to incorporate all of the external effects of projects (*e.g.* environmental impacts, social effects and wider economic effects).
- Fails to deal with distributional effects (*e.g.* impacts on deprived areas).

In the standard cost-benefit approach, only the user benefits are taken into account. Such an approach ignores spillover benefits (and costs) for non-users as well as many of the broader aspects of business productivity benefits such as the value of the network connection, intermodal linkages, logistic scale opportunities and business scale economics (Weisbrod, 1997). The major argument is that only direct travel cost savings, namely travel times and operation costs, should be regarded as benefits of transportation projects. The inclusion of other effects (such as growth effects) leads to double-counting, since these effects are in essence the manifestation of capitalised travel costs savings. Under certain conditions, the wider economic impacts should be taken into account. As has been pointed out (Sactra, 1999), these special conditions imply the premise of perfect competition, in which case the change in consumer surplus (measured by the willingness to pay for travel improvements and the willingness to accept them in case of negative environmental effects, for example) is presumed to represent the entire project benefits.

In reality, however, it is possible to claim that infrastructure investment is associated with scale effects and externalities that produce more than just travel costs savings. Moreover, in market economies there can be wider economic effects associated with transport cost reductions such that the benefits or costs may fall within or beyond a region.

There are two responses to the recognised weaknesses of CBA. The first is to expand the impacts, both positive and negative, which can be given monetary values and incorporated into the CBA methodology. A number of countries are currently developing, and in some cases implementing, values for environmental externalities in their CBA systems.

The second approach, which in most cases is complementary to the first, is to incorporate the CBA analysis and results into a wider appraisal framework. In this wider framework, those impacts which cannot, either in principle or in current practice, be attributed monetary values are identified, described and, where feasible, measured. This latter approach is the approach used for this report, in which a structure for such a framework is presented and discussed. The main focus of the report is on the issue of finding *ex-post* evidence of the identified impacts, which can be used to populate such a framework.

The main concern with the traditional application of CBA analysis to transport infrastructure projects is that, unless due recognition is given to the generation of broader benefits arising from such investment activity, an inefficient outcome may result. That is, there may be the potential for wider socio-economic benefits to accrue to society from alternative infrastructure investments which otherwise could be "lost" through the application of an "inadequate" decision-making framework. These benefits may include employment generation; more efficient enabling networks for industry development, improved accessibility for regional communities, greater reliability of the transport system, and enhanced environmental outcomes. Of course, there may be other more dispersed benefits. However, unless an attempt is made to encapsulate these benefits in the framework for *ex-ante* analysis of investment proposals, inferior outcomes may result from an inefficient allocation of investment funds.

Evaluation framework

This section addresses the following question: What effects are to be expected, in theory, from transport investments and how do they work through the system? This is used as the basis for an evaluation framework.

The expected direct effect is to improve travel conditions, which in turn may alter individuals' behaviour in terms of mode choice, route choice, time of travel choice and destination choice. The aggregate results of these improved travel conditions at the individual level are manifest on the network in traffic volumes and patterns in travel times and costs by facility type and in the relative accessibility of locations. They also impact on the mobility, reliability and quality of transport services.

On a wider level, the altered choices of individual and business decisions have impacts on the environment. Other potential impacts affect the level and location of employment, industrial location and performance, social structures and relations and land-use patterns.

The evaluation framework developed for the analysis of case studies to determine which effects can be qualified or quantified is presented in Table II.1.

Table II.1. **Evaluation framework**

Traditional CBA	**Complementary analysis**
User benefits (see Chapter III)	Transport network effects (see Chapter III)
- Travel time	- Induced travel
- Vehicle operating costs	- Modal shift
- Safety	- Reliability
	- Quality of transport service
	Socio-economic spillovers (see Chapter III)
	- Accessibility
	- Employment
	- Efficiency and output
	- Social inclusion
	- Land use effect
	Environment (see Chapter III)

User benefits include travel time, vehicle operating costs and safety. There is consensus among economists that direct travel time benefits are the most important gains of transport. Chapter III concentrates on different methods to evaluate these impacts and on the wider effects to the transport network. It also looks at methods (based on US practice) to determine the quality of transport service. These gains could lead to an overall change in accessibility and ease of access between spatial opportunities. These can be measured by using a gravity model as part of the discussion on socio-economic spillovers. Chapter III also discusses effects on employment, which are often important aims of specific transport projects. The issue here is whether transportation improvements lead to improvements in labour force participation in the area under consideration, although displacement effects may also be relevant.

An important aspect of the impact of infrastructure is the contribution it makes to improving economic efficiency and the level of output in the area relevant to the appraisal and in the economy more widely.

Chapter III also looks at the environmental impact of transport activities and as such reflects the concern of sustainable development. It concentrates on issues of air pollution, noise and qualitative issues such as lack of aesthetic qualities.

In many areas, there is growing interest in the distributional impact of infrastructure investment. This goes under a range of various titles in different countries (*e.g.* environmental justice in the United States; social inclusion in the United Kingdom), but what they have in common is an interest in reflecting in appraisals the extent to which spending on transport affects different income, social or racial groups differentially and how it helps to allow disadvantaged groups to fully partake in society. These issues are discussed in Chapter III.

One spillover effect which has received a great deal of attention and analysis over the years is the impact of transport on the structure of land use and its development. A report was commissioned by the United Kingdom on the specific question of the land-use impacts of transport infrastructure (see Annex 2).

Also in Chapter III, these effects are related to general topics concerning project implementation, such as the funding and financing of transport projects and the evaluation of political support for the project. In general, the issue of policy making is of crucial importance for the potential impact of transport infrastructure investments on local economic development, including such elements as the organisational structure and range of responsibility of decision making, the nature of the legal system, the level(s) of government at which the decisions are made and implemented, and the involvement of political agents. Policy making, which affects both economic conditions and investment types, plays an important role in determining the possibilities of economic development (Banister and Berechman, 2000, Chapter 12).

Decision and policy making

In order for evaluation practices to be used effectively, attention should be paid to the way they are embedded into institutional frameworks. This report does not explore the institutional mechanism underlying different decision-making processes on transport investments at length since institutional frameworks differ widely from one OECD country to the next.

There are four different levels of decision making that may need to be taken into consideration for the purpose of analysis: *i)* the international or supranational level; *ii)* the national level; *iii)* the regional level; and *iv)* the local or municipal level. The authority which has the responsibility to decide on infrastructure investments should reflect the principle of subordinate government. For example, local/municipal level objectives and those of the state concerning infrastructure investment projects must reflect or complement each other in order to be effective. In practice, however, there is often a lack of co-ordination across different levels of political decision making.

Relevance to national and regional policy objectives

The purpose of this research is to provide insight on the potential effects of transport investment and their relevance on the basis of *ex-post* evaluation studies in several OECD countries.

In an international context, it is important for countries to compete for high levels of accessibility and a high-quality network. These qualities may be connected to the extension of the physical infrastructure or to improvements in the knowledge base of the economy. In modern economies, these latter improvements are becoming increasingly important and should be reflected in transport policies by intelligent use of managerial, information and control systems, increased flexibility and by the knowledge of private parties in the market.

At a regional level, the issues of accessibility and (high-) quality of the network are also significant. Key questions include whether these effects will lead to a redistribution of benefits or whether they promote overall efficiency gains.

At a local level, decision making leads to the re-use of space and change in the environment. It is important to consider the general concern of local authorities about a particular project. In general, only the question of whether a project conforms to the general strategy set out in the development plan is considered by the local authorities. Not taking local considerations into account, however, could increase the project costs and lower the benefits. National and regional policy objectives of sustainable growth and regional development were the primary issues for the national and regional authorities, although this in no way denies the relevance of these issues to local policy objectives.

Chapter III

FORMAT FOR PROJECT DESCRIPTION

Defining the project

Transportation projects can take many forms. Engineering descriptions provide useful information for transportation analysts and are the basis for traditional CBA. Investment proposals usually specify the transportation mode(s) directly affected by the improvement. Project location descriptions are frequently given and can provide insights into the geographic incidence of costs and benefits. In the case of highway improvements, the road system classification (administrative and functional definitions can apply) under which a project occurs can be indicative of design criteria, purpose of the facility, and construction standards. Generally, a variety of physical descriptions, such as number of lanes, length of improvement, type of materials used, and expected volume of traffic are available, together with administrative and financial information including cost estimates and sources of funding.

Aviation investments are typically classified as either airway or terminal improvements, and funding sources may differ depending on where the improvement takes place. Similar distinctions are made between portside and land-side projects in the case of waterborne transport. Highway pavement improvements are typically distinguished from bridge improvements, and road projects are frequently described in terms of the type of improvement undertaken. Technical definitions based on the kind of construction activity performed are widely used to classify road improvements into categories such as new construction, relocation, major widening, reconstruction (with and without added lanes), restoration, rehabilitation, resurfacing, traffic control, safety, or environmental. Individual projects may involve more than one type of improvement. For example, a major widening of an existing road may involve bridge reconstruction, environmental mitigation and safety improvements. This information may be helpful, since different components may be associated with different benefit categories. However, improvement type definitions may vary from country to country.

Project cost is another descriptor frequently provided to decision makers. The amount of spending necessary to bring an improvement on line allows projects to be classified in terms of their relative magnitude. Spending details may also provide information about the funding sources. However, terms like small, medium and large are contextually defined and can vary significantly from one country to another.

No comprehensive physical classification scheme for transport projects is proposed in this report due to a lack of uniformity in technical definitions of improvement type, road classification and relative size. Consequently, the study focuses on the purpose and objectives of transportation infrastructure investment rather than on its physical characteristics.

Project purpose and objectives

In developing the case for major transport infrastructure proposals, it is essential to clearly specify the goals they are designed to achieve. The answer to this question can be expressed at varying levels of generality or detail, from broad statements of vision, through strategic objectives, to more specific objectives and lists of problems to be overcome.

Stated objectives serve several functions. They help to identify the problems to be overcome, both now and in the future. They provide guidance on the types of solutions that might be appropriate and the locations where they are needed. Finally, they provide the basis for appraisal of alternative solutions and for monitoring progress in implementation. When the aim/objective of a proposal concerns regional development, special attention should be given to the decision makers' ability to provide real *ex-post* assessment of the extent to which the objectives have been achieved.

While most people associate the virtuous cycle of investment, production, income and further investment with the private sector, evidence shows that public capital can also play an important role in expanding an economy's efficiency and productive capacity. Thus, it is often noted that public capital may enhance the productivity of private capital. Clearly, the usefulness of privately owned and operated cars and trucks depends on a network of roads and bridges. The same is true for aircraft, which require airports, and for private ships and barges, which require ports and navigable waterways. Although responsibility for the provision of right-of-way and other facilities required by transport vehicles can vary across modes and from country to country, improvements in the quantity and quality of transportation infrastructure can reduce the amount or cost of private inputs needed for a given level of output. For example, better road designs, materials and highway maintenance can reduce the wear and tear on privately owned and operated vehicles, thus reducing total transportation cost. Costs of production, and especially business logistics cost, are affected positively by travel time savings, reductions in loss and damage, less packaging and dunnage requirements, and improved shipment time reliability.

Publicly provided transport infrastructure may have much the same effect on output and productivity as privately owned fixed plant and equipment. Recent studies show, for example, that rates of return on public highway investment in the United States are competitive with returns on private capital investments. In the final analysis, classification of productive assets as public or private capital may reflect institutional and political choices rather than economic distinctions. Whether or not a particular component of the transport system comes under public or private responsibility will depend on the customs and laws prevailing in a given location. However, in general, since the quantity of private capital greatly exceeds that of public capital in most free-market economies, it is common to view public investment as supporting private investment.

Two rationales supporting public infrastructure investment programmes are frequently cited. First, public transportation investments are needed to remedy the "public goods" market failure problem. That is, joint-use public goods such as transportation infrastructure would be under-supplied by the private market because there is no incentive for the private sector to provide the amount of capital required to maximise economic welfare. Examples of market failure also arise when there are significant externalities or spillover benefits and costs. Second, transport investments facilitate the achievement of various other social and economic goals. Examples of this include the need for transport investments that improve physical access to educational facilities, health care, emergency services and social amenities. Also, government transportation programmes can support income and employment objectives, provide opportunities for disadvantaged people, foster economic integration and advance political goals such as national cohesion.

As noted in Chapter II, project evaluation methods provide information to guide policy and investment decisions. Since different methodologies are available to measure different aspects of economic performance, it is important that the objectives of infrastructure investment be defined before the evaluation methodology is selected. Objectives should be stated precisely and should be realistic in terms of the capabilities of transport infrastructure investment. Vague, confusing or contradictory objectives can lead to evaluations that answer the wrong questions, yield inappropriate or inaccurate results and produce inefficient outcomes.

It would be presumptuous not to accept the pronouncements of politicians, transportation planners and the general public as appropriate statements of project purpose. However, case studies indicate that objectives can vary from very broad concepts like stimulating the economy, promoting regional development and enhancing political integration to more specific purposes such as reducing travel time, providing access, replacing a ferry, building a safer road, replacing exhausted infrastructure or repairing a structurally deficient bridge. Succinct project objectives require an understanding of the range of economic outcomes that transport infrastructure can serve, knowledge of the distinctions between different economic objectives, and a willingness on the part of decision makers to balance multiple objectives when setting minimum requirements for success.

Timeframe

By their nature, most infrastructure projects have a long expected physical life. It is often difficult to conceive how economic development, with or without a project, will proceed in the long term. That may explain why certain devices are sometimes used in appraisal calculations, such as repeating the benefits in the last year calculated in the analysis for the following decades. Another device is a fixed time horizon that is shorter than the expected life span of the project. This has, as far as infrastructure projects are concerned, a considerable disadvantage: the profitability can become sensitive to the time horizon. In particular, when the rate of increase in benefits has remained level with the discount rate for a long time, or even when it exceeds this level, as the impression is given that each infrastructure project can be made profitable by merely taking a sufficient number of years into consideration. The practical significance of the time horizon depends strongly on the discount rate in combination with the rate of growth in the benefits that a project generates.

The problem of a long life span is less significant if the project appraisal takes place according to payback periods. This measure is often used in respect to business investments. A payback period is the number of years before a project breaks even; when total (discounted or not) benefits (net of ongoing costs) equal capital costs. A payback period ignores all benefits and costs arising after the break-even date and is thus likely to distort project choice. It may be used as part of an assessment of optimistic bias where, for example, a long payback period may indicate that a project's viability is fragile. It can also serve as a supplementary criterion for prioritising projects. Shorter payback periods limit the degree of uncertainty and are a useful indication of the robustness of the profitability of the project if the return, for whatever reason, should fall short afterwards. For this reason, when choosing between two projects with equal benefits, the project with the shorter recovery period would be preferable.

Risk evaluation

Any course of action may have unforeseen consequences and the magnitude of risk can vary greatly across projects, programmes and policies. Good management entails a thorough appraisal of such risks and, in particular, requires taking a realistic approach to the likelihood of preferred outcomes relative to others. Risk identification, estimation and evaluation are the first steps in risk appraisal and management. The culmination of the process is the cost-effective reduction of the likely impact of risk by pilot projects, further research, flexible or standard designs, and the transfer of risks to where they can be managed most effectively.

This section discusses the approach to risk in appraisals. It does not explicitly address risks during implementation and operation as these depend upon project management and on forms of contract. Nor does it cover the issues of risk transfer, which are specific, and central, to the negotiation of contracts for privately financed projects.

There is no generally agreed definition of risk. In everyday language, a distinction is often drawn between risk, referring to the likelihood of something going wrong, and uncertainty, which means that the outcome of a course of action is indeterminate or subject to doubt. A more formal distinction is that "risk" is measurable and pertains to situations with known probabilities, while "uncertainty" is vague and refers to circumstances with unknown probabilities. In practice, the distinction is rarely clear-cut. Probability may be assigned to a particular event, but it is seldom known with absolute certainty. On the other hand, few events are so uncertain that no judgement can be made on the likelihood of their occurrence.

In more precise language, risk is characterised by the probability of an event occurring and the resulting impact if it were to occur. The impact of a risk is its consequences or effects. Risk exposure is the extent to which a project is vulnerable to a given risk. It is the product of probability and impact, or the 'expected value' of the impact.

In addition, allowance must be made for the risk that predicted outcomes do not fully allow for the likelihood of things going wrong.

The likelihood of this bias should be judged against the outcomes of previous projects with similar features. Assurances, however sincere, that past problems, or similar problems, will not occur in future should be examined on their merits. Where there is no similar previous experience, the component aspects of the project, both costs and benefits, should be examined separately to remove any overall optimism. Experience suggests that on balance, outcomes are likely to be much worse than an original estimate rather than much better. Risk analysis should aim to eliminate optimistic bias.

"Variability" (or "variance") is the term used to describe a spread of possible outcomes around an expected outcome. Ranges are much wider for some projects, such as those employing new technologies, and variability is therefore much more likely. Variability can sometimes pose difficulties for budget management, or for particular individuals affected by the project. Defining "attitudes to risk" can illuminate the circumstance in which variability should be taken into account in appraisal and how it should be dealt with.

Risk neutrality is the willingness to accept a "fair gamble" based on accurate information. This is an uncertain prospect with a zero expected value, where the chances of loss multiplied by the impact of loss are exactly offset by the product of the chances of gain and the impact of the associated benefits. A decision maker who is risk-neutral will only take into account the expected values of outcomes, not their variability.

This is the position that is normally taken when considering the desirability of projects, programmes or policies from the taxpayer's viewpoint. By and large, government is sufficiently capable of pooling the financial risks from its projects and policies and hence the impact of a given proposal generally has a negligible net effect on variability. It is also argued that the impact of variability is spread very widely, for example by small adjustments in public taxation or borrowing, so has very little impact on any given person.

Risk aversion is an attitude that leads a decision maker to decline some gambles that have positive expected values and to pay for certainty by, for example, buying insurance. A decision maker who is risk-averse cares about the dispersion or variability of outcomes as well as the expected values. From society's point of view, it may be appropriate to be averse to risk in situations where the possible negative outcomes could bear heavily on particular individuals. Thus, variability may have a significant cost such that individuals would accept a significantly lower expected benefit in exchange for a guaranteed or a much more certain outcome or, conversely, would require a higher expected benefit to compensate for a less certain outcome. This should be taken into account in appraisal.

It may also be appropriate in some circumstances to consider the managerial costs of variability. A project with a wide spread of possible outcomes and associated cash flows may be more difficult to manage and plan, especially when the project represents a large proportion of a fixed budget. As any such extra managerial costs would not normally be included in the project costs, they might justify requiring a higher expected net present value (NPV) than would be acceptable if the costs were more certain.

If variability is to be taken into account in appraisals, then it raises the issue of how it might be priced. The price or cost of risk is the maximum price that a decision maker is willing to pay for the greater utility of a certain, rather than an uncertain, prospect of a given value.

Efficient option choice, or *risk management,* will normally entail reducing the chances of the downside risk, thus raising the expected value of the outcome. It may also reduce the size of the more adverse payoffs, again raising the expected value of the project while lowering the variance. Risk neutrality will be sufficient to select the appropriate course of action. Only where option choice or management reduces the chances of the downside risk but increases the adverse payoff might some form of risk aversion be warranted.

Where a project or programme would rule out important, later investment opportunities or use of the resources that might subsequently be preferred, account should be taken of this "irreversibility" Examples of irreversibility are destruction of natural environments or historic buildings.

Irreversibility is often associated with facilities on which people place "option values" (the value of knowing a facility is available to enjoy if they wish to do so). Another link is with "existence values" (the value of knowing that something continues to exist, even if the valuer does not expect to make any practical use of it). Such values, while sometimes very important, are not easy to quantify. Advice on the appraisal and evaluation of irreversibility should generally be sought from economists.

Identifying and estimating risk

The extent of risk and uncertainty confronting project options can be identified, clarified and, in many cases, quantified and valued, using a risk matrix. This is a listing of the various risks and uncertainties to which particular project options are exposed, together with an assessment of the likelihood of their occurrence, and the impact on the outcome of the project. This is sometimes combined with a risk register, which identifies who will bear the risk.

A well-known and widely practised method of dealing with risk and uncertainty is the application of sensitivity analysis. This is the calculation of how changes in particular assumptions would affect

NPVs, total costs or other project outcomes. Its application requires judgement about the weight to give to alternative assumptions. For a thorough assessment, the effect of various combinations of risk and uncertainty on project outcomes should be tested for robustness using sensitivity analysis.

The application of sensitivity analysis is especially important when:

- There is uncertainty in the estimates of costs or benefits. This applies to any project entailing significant new technology, for construction costs of all large projects and to forecasts of market demand.

- There are options in which the uncertainties present a potential budgeting problem for management. This applies to any project that is large relative to the total budget, or to projects subject to large uncertainties.

The alternative outcomes should be chosen to focus especially on those uncertainties which are most important, and on where uncertainties are much greater in one direction than another. All significant risks must be considered and account should be taken of any significant relationships between factors. The advice of experts such as surveyors, engineers or industrial experts should be sought where appropriate.

For some projects, the probabilities of different outcomes can be estimated objectively by statistical techniques. However, for transport infrastructure projects, probabilities cannot always be calculated in this way because the necessary data either do not exist or are not available. On the other hand, some past data are almost always available to allow at least a broadly informed judgement to help apply and interpret sensitivity analysis (for example, past records on cost and time overruns, and records on the accuracy of forecasts of demand). Commercial insurance premiums can sometimes be a helpful guide to probabilities. In the absence of objective measures of risk, employing subjective probabilities informed by information and experience is better than ignoring some important risks altogether.

It can be useful to group together variables in the sensitivity analysis by setting up “pessimistic” and “optimistic” variants. This allows a broad assessment of the likelihood of these outcomes by those responsible for deciding whether or not a project should proceed.

Sometimes a single factor is crucial to the decision as to whether or not a project or option is worth undertaking. In such cases, a useful form of sensitivity analysis is to calculate the amount by which the value of this factor would have to fall (if it is a benefit) or rise (if it is a cost) in order to make it not worth undertaking the option. This value is called a switching value or switching point. Once the switching point has been established, it may then be relatively easy to assess the likelihood of the outcome being worse than this.

Monte Carlo analysis is a widely used, sophisticated form of sensitivity analysis. It allows for an assessment of the consequences of simultaneous uncertainty about key inputs, taking into account correlation between these inputs. It involves replacing single entries with probability distributions of possible values for key inputs. Typically, the choice of probabilistic inputs will be based on prior sensitivity testing. The calculation is then randomly repeated a large number of times to combine different input values selected from the specified probability distributions. The results consist of a set of probability distributions showing how changes to key inputs affect key outputs. A number of software packages provide relatively simple ways of employing this theoretically complex technique.

Major projects may justify the use of fully structured scenarios. "Scenario planning" looks at the consequences of various possible "states of the world". A scenario is not a forecast, but rather an internally consistent description of a possible future economic and political environment. Scenarios are often useful for planning an investment programme and may also be justified for exceptionally large and complicated projects.

Scenarios should be chosen to draw attention to the major technical, economic and political uncertainties upon which the success of the project depends. Generally, the best approach is to set up two, possibly three, scenarios. If three scenarios are chosen, they should differ along different dimensions so that no single scenario is seen as central or the most likely. The expected NPV can be calculated for each scenario. It may also be helpful to undertake some sensitivity analysis within a scenario.

Scenario planning is sometimes associated with the decision criteria of maximin-returns (the option which offers the least bad or "worst possible" outcome) or, more often, minimax-regret (the option which offers the least potential cause for regret). These criteria can be useful for presentation purposes, but give no more than a partial picture of how the options compare. There is no escape from having to judge, at least implicitly, the likelihood of each scenario.

Projects involving sequential decisions can usefully be analysed with "decision trees"; graphical representations of the set of possible strategies. Different strategies result in different NPVs depending on the different events (or states of the world). An extension of the technique can be employed when the probability of any particular risk is assigned.

Occasionally, the payback period may be employed as a supplement, although not as an alternative, to other techniques for appraising risk.

Reducing the cost of risk

Flexible designs may reduce the cost of risk. Where future demand and relative prices are uncertain, it may be beneficial to choose a flexible design adaptable to future changes, rather than a design suited to one particular outcome. For example, different types of fuel can be used in a dual-fired boiler, depending on future relative prices of alternative fuels. Preparatory earthworks and suitable bridge designs can reduce the cost of future road widening, should it be justified later by a growth in traffic. Dividing a project into stages, with successive review points at which the project could be stopped or changed, can also increase flexibility.

Building in flexibility will almost always entail some cost. The cost-effectiveness of a flexible design should be appraised by estimating the likelihood of different outcomes, the costs of adapting to change during the project lifetime and the penalties of "being wrong" if future demand or relative prices differ from expectations.

Risks to one party in a transaction can be reduced by transferring them, at a cost, to another party, either by the terms of contract between suppliers and customers, or by insurance. The government often maintains the ultimate responsibility for the provision of a service – or the consequences of the non-delivery of a service – even when a private business is contracted to supply. Transferring a financial risk does not always transfer other aspects of that risk.

Governments, in general, tend to be self-insurers. This is mainly because governments can spread risk widely and do not need to insure simply to protect corporate financial viability. On the other hand, the principles of insurance, the identification of specific risks and pricing coverage according to past incidences of loss, can be an effective form of risk management in some circumstances. It can lead to more careful examination of risks, both by the buyer and the seller of insurance, and the adoption of additional measures to reduce exposure.

The costs of budgeting for uncertainties may sometimes be reduced, without an unacceptable loss of control, by increasing flexibility between years and/or budgets. Any benefits this might bring in terms of greater certainty must be set against any adverse effects on incentives.

Discount rate

Transportation investments generate benefits and incur costs over time. From today's vantage point, future benefits and costs are worth less than the same amount received or expended in the current period. Future benefits are less valuable because they are not immediately available for consumption or reinvestment. Future costs are less burdensome because they could be funded with fewer amounts today, if those amounts were set aside (*i.e.* invested) and allowed to grow at some compound interest rate.

The difference between the value of a benefit (cost) received (expended) today *vs.* tomorrow is not due to inflation. Rather, it is due to the opportunities that are forgone by undertaking the investment. Discounting allows all costs and benefits, whenever they may occur, to be considered in terms of current forgone opportunities.

The discounting technique is the only available methodology to facilitate comparisons among projects whose benefits and costs accrue at different rates over time. Making benefit and cost streams of projects comparable requires converting estimates of future impacts into equivalent current values. Although society is willing to forgo current consumption to reap future gains, discount rates that are too low will encourage over investment and vice-versa.

In many countries, the ministry/department of finance determines the discount rate for public infrastructure projects. This report takes such rates as given and does not explore the way in which such rates have been determined in individual countries. While, in principle, they reflect estimates of social time preference and/or estimates of the social opportunity cost of capital employed, there are variations in the precise methodology and parameters employed.

Alternatively, the Internal Rate of Return (IRR) approach may be applied to estimate the expected rate of return from the project. This is calculated by dividing the discounted sum of benefits by the discounted sum of costs. This may then be compared with the discount rate used by the government, or with the rate of return from competing investments, known as the "hurdle rate of return".

Traditional cost-benefit analysis

As was pointed out in Chapter II, direct user benefits (measured by consumer surplus of direct facility users) are the only benefits taken into account in traditional CBA, which operates under the assumptions pertaining to the general condition of perfect competition. In practice, three main types of such benefits are recognised as arising from an infrastructure project: travel time savings, vehicle operating costs reductions and safety improvements.

Travel time

There is a consensus among analysts that travel time savings are the largest economic benefits arising from transport infrastructure projects. However, there is still debate over the determination of the extent of these savings. The value of time savings is likely to vary considerably with the specification of the model adopted for its estimation and also according to the trip or user characteristics (passengers as well as freight carriers). Numerous studies have been pursued on the valuation of time savings, given that the magnitude of these transportation efficiency benefits is likely to significantly affect the acceptability of infrastructure investment projects. While there is great diversity in the research results, they are consistent enough that road authorities have sufficient confidence in them to have selected values and used them routinely in evaluation (unlike the environmental benefits).

The principle underlying the assessment of benefits associated with travel time is that transport system users' economic decisions regarding the location of their homes, businesses, mode choice or route followed to get to a specific destination and behaviour in traffic, reflect their valuation of travel time. In other words, users' willingness to pay in order to save time or the amount they would accept in compensation for losing time could be inferred from their behaviour.

Time savings are benefits resulting from an improvement in the efficiency of the transport system (shortened routes, increased traffic fluidity, better access to connection services, etc.). For freight carriers, time savings will take the form of money savings given that reductions in travel time reduce hourly costs of transport services (*e.g.* drivers' wages, insurance, etc.) for shippers. For consignees, travel time savings may be converted into reduced inventory costs. Some analysts argue that the common practice in CBA of valuing commercial vehicle time savings on the basis on drivers' wage produces estimates for value of travel time that are too low, thus capturing only part of the true potential cost savings of freight carriers. The concern is that costs of capital equipment, benefits from accrued reliability and reduced delivery time of shipments are not explicitly accounted for. The suggested alternative approach is to conduct, as for passengers, behavioural experiments in order to determine shippers' willingness to pay to avoid delays and get a better sense of the true value they place on time. For passenger transportation, travel time savings normally bring no direct monetary reward.

Time savings are valued on the basis on what time would be worth in the best alternative use (opportunity cost). The value of time savings occurring during work-related trips is generally assumed to be equal to the employee's average hourly wage (including overheads); that is, the cost of time to the employer. It is implicitly assumed that no productive work is performed en route and therefore that time spent travelling generates no benefits for the employer. Valuing working-time savings by average wages is not an approach unanimously supported by analysts. Some argue that these time savings are not all convertible to productive work, therefore concluding that the value placed on business time savings should be reduced to some percentage of the wage rate.

Private travel time savings are usually estimated to be less highly valued than work-related time savings. The valuation of non-business time savings has been carried out mainly on the basis of behavioural experiments: revealed preferences – observation of individuals' behaviour in different trading situations such as choice of travel mode or route, or stated preferences – responses to hypothetical choices among travel alternatives gathered through surveys, travel demand studies, etc., or estimation of discrete mode choice models. The resulting values are uncertain and are often expressed in relation to the average wage. An average value for all non-business travellers (approximately 50% of the prevailing individual wage rate) is commonly used in project appraisals, although it is acknowledged that values of travel time are likely to vary substantially according to the mode used and travellers' income level. The nature of the relationship between income and the value of travel has not been clearly identified, although many studies have found that time savings increase less than proportionately with income. Separate estimates by traveller classes – children, pensioners, working-age adults, etc. – are sometimes used when traffic conditions in the region affected by a project are suspected to be significantly different from the average figure. Further, in some project appraisals, a decomposition of time savings is made to distinguish waiting and walking time from the in-vehicle component of travel time since their values have been found to be between two and four times as high as the corresponding value of in-vehicle time.

When it comes to the valuation of small time savings and to whether or not they should be included in the calculation of the overall benefits of a project, there is no internationally accepted convention. However, the constant unit cost approach is currently prevalent. There is a certain amount of uncertainty in the measurement and evaluation of small time savings.

Vehicle operating costs

The measurement of vehicle operating costs savings requires identification of the incremental costs of vehicles; that is, the elements of costs that vary with their use. Vehicle ownership and operating costs can be divided into fixed and variable components. The fixed costs are those incurred regardless of vehicle use such as the capital cost of acquiring the vehicle, the depreciation (loss in value as the vehicle ages), licence fees, etc. The variable costs normally include fuel, lubricating oil, parts, repair and maintenance costs. In the appraisal of projects that are spread over longer periods of time, a portion of the capital costs might be attributed to use; that is, the loss in value of the vehicle resulting from an increment use.

Safety

Whatever the extent of the benefits associated with safety in the assessment of a transport project, safety remains a key factor delimiting the social acceptability of the project. Many infrastructure projects bring reductions in risks of crashes and casualties, which should be captured as benefits by the CBA preceding any decision. Safety savings can be defined as the monetary value of the benefits to society as a whole from the avoidance of or the reduction in the number and the severity of crashes. The measurement of these savings necessitates an analysis of the risks of transportation accidents associated with a project to determine the probability and the consequences of these events. Estimating safety benefits implies placing a monetary value on the reduction in expected or potential losses resulting from accidents whatever their nature. Therefore, in order to produce appropriate values for safety, the relevant losses need to be properly identified.

The consequences of accidents are normally classified in three categories: fatalities, injuries and damage to property. For some components of accident costs, such as damage to the vehicles or cargo, emergency and medical services, or lost earnings, an economic value can be inferred from the existing market price of these goods and services. Material damage, for instance, can be valued on the basis of the replacement or repair costs, or according to the insurance coverage premium. However, when it comes to setting an economic value on reductions in intangible dimensions, such as grief and suffering, personal injuries, quality of life and human life itself, for which there are no market values, substantial difficulties can arise. In the absence of a market, the value associated with intangible benefits remains an uncertain and subjective issue, and consequently one exposed to criticism. Accurately reflecting the potential social impacts of a project on safety constitutes a sizeable challenge.

In the past, two methods were commonly recognised in the literature for valuing the benefits of avoidance of death: the *gross output* approach and the *willingness-to-pay* approach.

Gross output (or human capital)

The gross output method involves calculating the discounted present value of the potential losses in future earnings or of consumption resulting from the death of an individual. The expected contribution of a victim to the national output is calculated according to a predefined average active life expectancy, discount rate and average income, under the assumption that over the defined period the individual would have been fully employed. Special imputations are carried out for individuals whose services do not have a market value, such as housewives/husbands, unemployed people, children, etc. Some countries also make an allowance for subjective (or emotional) losses such as grief and suffering (of the dependants, relatives and friends) and other losses such as unpaid community services.

Some of the shortcomings of this method are that the estimates are extremely sensitive to the discount rate chosen and dependent of the assumptions made by the analysts regarding the income progression of individuals over their lifetime. It is also argued that the "gross output" method produces values of avoiding a fatal crash that are far too small and that this method is not a good representation of the way people intrinsically value avoidance of death.

Willingness to pay

The second method used to estimate the cost of accidents, which is now used almost "exclusively", is referred to as the willingness-to-pay approach. This method assigns a value to safety improvements according to an estimate of the amount people would be willing to pay in order to reduce risk or to avoid a casualty accident, or the compensation they would accept for an increase in risk. It relies upon the assumption that people are the best judges of their own welfare and that their behaviour is a good indicator of the value they place on transport safety. Two different methods are employed to obtain empirical estimates of the amount people would willingly pay to avoid an accident resulting in personal injuries or death, and to infer the level of their risk aversion: revealed preferences and stated preferences.

There is some debate about the willingness-to-pay method. Some argue that it could be misleading to assume that people always act in their own self-interest, as they could be ignorant or have a poor perception of the precise risks they run in certain situations. The principle according to which the appropriate values for safety are those the population at risk would pay to reduce risks or accept in compensation for increases in them, is somehow challenged by the quasi-omnipresence of safety standards and regulations restricting individuals' behaviour on the network. This would reinforce the idea that in some circumstances, the intervention of government could be justified to enhance safety and assure the welfare of society.

Wider effects on the transport network

While it is true that conventional CBA recognises and measures these three main types of benefits, other benefits are sometimes included. Among these are the net benefits of induced traffic, the impacts on other modes, journey reliability, and aspects of journey quality such as improvements in comfort and convenience. These apply both for public transport and for road infrastructure.

Induced travel

The traditional method of carrying out highway appraisals on an assumption of fixed trip matrices has now been replaced by one which takes into account the impact of infrastructure in inducing new trips or causing changes to trip ends or trip times, particularly over a longer time scale. It has to be recognised that such changes can provide benefits for those trips affected but that there may also be significant losses of benefit to other users as a result. There is a need for detailed modelling in order to assess the net impact and to be able to reflect this in appraisal. These issues were explored in detail in the UK Standing Advisory Committee on Trunk Road Assessment (SACTRA) Report on "Trunk Roads and the Generation of Traffic", and a great deal of progress has been made in developing techniques which allow for satisfactory analysis of induced travel.

Modal shift

Switches between travel modes are often an important aspect of an infrastructure investment. Further, in many cases and particularly for public transport investment, modal shift is an important objective of government transport policy. There is a need to explicitly model these cross modal impacts. Guidance on modelling and appraisal of modal shifts has been produced in the United Kingdom and published as "Guidance on Methodology for Multimodal Studies".

Reliability

There are two aspects to the issue of reliability. First, a transport link may be systematically unreliable when travel times vary or are unpredictable relative to travel times for other parts of the network of equivalent standard. Second, a link may be unreliable when external events (such as flooding and its impact on low-level bridges or roads) cause closure or major disruption to the network.

Quality of transport service

There is a range of elements which have in various contexts been included in cost-benefit appraisals and which come under the headings of comfort and convenience. In public transport, such elements as ride quality, crowding and quality of information, cleanliness and ambience have been incorporated, using stated preference techniques to generate measures of willingness to pay. In addition, many studies have included the so-called "Mohring effect", which arises when increases in patronage lead to higher service frequency thus providing benefits to all existing users. For road travel, such factors, although less commonly incorporated, are not unknown. Thus, for example, in the United States there is a "ride comfort index" which reflects the smoothness of the highway surface.

Socio-economic spillovers

As well as the wider impact on the transport network, the impacts of major infrastructure permeate the economy and the society more widely. These impacts are central to the concerns of this report, with its focus on the impact which such spending can have on regions. As listed in Chapter II, a range of impacts which are of significance in this context have been identified. These are discussed in this section. However, there is a need to pay careful attention in appraisal to the risk of "double counting" benefits under different headings. Also, it is very important to be clear on the focus of attention of an appraisal. Thus, for example, there may be significant differences between the assessment of a project from a national as against a regional perspective.

Accessibility

When the aim is to measure the regional impacts of infrastructure investments, accessibility is a key concept. It highlights the specific characteristics of the result of investments, for the users of the infrastructure. Thus there is a direct link between the concept of accessibility and the purpose of investment, which is very often to reduce travel time or increase the potential to travel. The notion of accessibility enables us to examine how regional impacts arise: what types of improvements in travel opportunities, for what type of users, to what type of area.

However, accessibility is difficult to define. There are many aspects of accessibility that might be emphasised differently depending on the situation. Thus it is useless to search for a standard definition which can be used in all settings. A more fruitful approach, in this general context, is to discuss the different aspects of accessibility and their relationship to regional development.

One common aspect, however, must be recognised. The concept has to do with increasing the *possibility* to travel by reducing travel time and/or cost of travel or other barriers to travel/transport. Further, there must be some external positive effects of reducing travel barriers and thus increasing the potential to travel. An implication is that there must be someone able to exploit the increased transport potential. Therefore, a *functional* definition of accessibility – one linking it to activities that are dependent on transport, and thus focusing on types of transport and travel purposes – seems to be reasonable.

On the other hand, economic activities might change in the long run, posing new accessibility requirements. For instance, the Norwegian metal processing industry is located along the fjords, where easy sea import of bauxite and sea export of half-fabricated material and cheap electricity were important considerations. Today, however, that industry is experiencing new transport requirements with the output of manufactured parts for the European car industry being transported by truck to the European continent almost on a scheduled basis. Accessibility policies should therefore also take into account the need for changes in industrial structures over time.

Accessibility and nature of transport

For *freight transport*, access to markets is essential. For short- or medium-distance distribution transport, the range of daily service or of overnight distribution is an important consideration. Range could be measured both in physical distance and in market size that could be reached within a given time limit. For long-distance transport, often of export goods, cost or reliability might be more significant aspects. High-value goods or perishable products (*e.g.* vegetables or fish) might pose strong accessibility requirements, where both travel time and reliability is important. Time and cost savings may have different effects on firms:

- For industry and commerce in a region, time and cost savings result in an improved competitive position through lower costs and improved market access.

- A more indirect effect is achieved if accessibility is so favourable that it provides a basis for a new and more efficient method of production. The shift to just-in-time production involving frequent, but reliable, small deliveries can be cited as an example.

- This may in turn lead to the formation of networks where specialisation advantages are achieved, *e.g.* through an increase in firm-to-firm market transactions (emergence of sub-suppliers). In this system, the road is used as an extended warehouse by the firms.

For *passenger transport,* three types of travel are noted in an economic context: business travel, travel to and from work, and tourism travel. The importance of business travel is increasing. First, freight transport has become economical, reliable and fast. Second, product cycles change increasingly rapidly, and international competition is becoming increasingly fierce. Personal contacts and good access to market and innovative centres are crucial in order to remain competitive. Management resources are becoming scarcer, and managers' ability to communicate with business partners is essential, thus emphasising the importance of available time to physical and mental communication.

Concerning travel to and from work, at least two aspects are linked to accessibility:

- *Increased labour force productivity.* Improved accessibility might reduce travel time, which could then be used in productive activities.

- *Increased geographical size of the labour market region.* If improved accessibility leads to an increase in travel distances for the same travel time, then the range of choice for individuals (and firms) has increased. This allows for increasing specialisation in regional labour markets through a better match of skills supplied and demanded in these markets.

For many regions, especially remote ones, tourism plays a key role in promoting growth in the service economy. Accessibility – often long-distance accessibility – is therefore relevant. For tourists, fast access to and from sites is of growing importance. The trend towards dividing annual vacation time into several short holidays reinforces the need for good access. Travel in itself might be of value in some segment or for some tourist products, but the overall trend is towards a reduction in travel time and cost.

Accessibility and distance segmentation

In addition to the functional aspects of accessibility, sheer *distance segmentation* might offer useful insights with regard to accessibility in the context of regional development. For many analytical purposes, segmentation into three types of accessibility (local, regional and inter-regional) has been used. This distinction is related to spatial competition and the discussion of the absolute and relative aspects of the concept of accessibility. By segmenting into local, regional and inter-regional accessibility, effects can more easily be evaluated as "real" or only redistributional in terms of the way they affect the different types of accessibility. This provides the basis for a discussion on the limits of the geographical system within which effects are to be evaluated. Further, it has bearing on how the effects of a given investment would be evaluated at a global, national, regional or local scale, which might be useful depending on the decision-making context.

At the *local level*, the issue is often the functionality of the local traffic system, in particular congestion issues. Since there would normally be some correlation between travel time by car and by public transport, the two modes should be analysed simultaneously. Average travel time or speed, travel time between zones, during and outside of peak hours, and by different modes of transport might then be measures of accessibility.

Within a city, accessibility not only involves the quality of the transport system, but also the land-use pattern. Locational policies for housing and activities might contribute to increased accessibility by reducing distances between activities. Further, associated individuals might improve their own accessibility by adjustments within a given transport system and land-use pattern. The degree of such adjustment might be seen as an indicator of the quality of the transport system. Individual travel patterns all over the city, from one city limit to the other, would not be possible if the transport system is inadequate. Findings showing that the time for personal travel has been fairly constant at just above one hour a day in many countries, indicate that individual actions/adjustments tend to smooth out initial differences in accessibility due to quality differences in the transport system.

At the *regional level*, the focus might depend on the type of region considered. In a nodal region with a large, dominant city, key issues would typically be access to the hinterland, the purpose of such access being the provision of services and goods to the hinterland and access to labour. An important aspect of accessibility would then be travel time to a central point in the region.

If the region consists of a network of cities, none being dominant, developing an infrastructure network that gives all cities, or parts of the region, good access to all others might be relevant. Good internal infrastructure systems might be regarded as a prerequisite to developing industrial clusters in the Porter sense. High internal accessibility creates meeting places for developers of technology and products, users and market knowledge. Through the need for a specific accessibility policy, endogenous development theory may put public authorities back into an active role where infrastructure plays a part. However, an industrial environment and culture, in a broad sense, is by far the most important element.

The effects of improved regional accessibility can manifest themselves in several ways. An area may become increasingly attractive; this can deter out-migration and is often selective. People are given improved access to services and thus feel more a part of a large community. In some cases, there may be increased in-migration, including firms which, following investment, no longer consider a previously peripheral location to be a drawback. A more "modern" business structure may thus be an effect.

Increased regional accessibility may have unintentional consequences at the local level. For example, services in more remote areas of a region that were previously sheltered by distance may be exposed to competition with larger and more efficient entities that are centrally located. The result is a centralisation at the local/regional level. The role of infrastructure development is thus to accelerate a necessary process of modernisation.

Inter-regional accessibility is focused on competition between the regions in Europe. The attractiveness and growth potential of cities in the single European market depend on good communication. One reason for this is that increasing international competition entails a greater need for personal contacts in product development and marketing activity. Thus, transportation should not be an obstacle to contacts between major cities or regions. Good air communication is important for remote cities in Europe, while high-speed trains may play a more significant role in central areas.

One should, however, be aware of the relative aspect of accessibility. The effects of improved accessibility very often result from a relative improvement in the spatial competition on behalf of other regions (although sometimes both parties gain from this). Further, peripheral areas will always remain peripheral, even if investment makes access to central areas easier.

Inter-regional accessibility may also be regarded as accessibility within a *network*, for instance a network of cities that interact. Such nodal networks are most often hierarchic. A typical example of such a network in action is the spread of innovation, which very often follows a combination of hierarchic and surface spread patterns, thus reflecting both physical and mental accessibility structures.

The accessibility of a given city within such a network might be measured in terms of total travel time or cost to reach the other cities in the network. In a hierarchic network, accessibility potential might be weighted according to the rank of the cities or their mass (population, GDP, etc.) or both.

For networks, the issue of network spillover effects is often raised. The argument is that when the attractiveness of a network, for instance the high-speed rail network in Europe, reaches a certain level, spillover effects occur. Such effects would normally lead to increased traffic, and would by definition be included in the CBA. Spillover effects beyond this, affecting the function of the whole cluster of cities included in the network, might also occur. They might occur because new possibilities are discovered among the system of cities, thus improving their common position in the global competition against other networks or global regions.

The measure of accessibility

Accessibility can also be defined as the ease with which an economic or social activity can be reached using the transport system.

This approach involves an assessment, on the one hand, of the relationship between the transport system and the movements of individuals or firms and, on the other hand, of the spatial distribution of activities. The advantage of this approach is that it takes into account both the value users ascribe to different destinations and their travel behaviour.

Therefore, accessibility can be defined in terms of a quantity of goods, services and jobs or, alternatively, the size of the population that an individual can reach from a given point, taking into account the level of road supply, the opportunities provided by the national or regional territory, the individual's travel behaviour and the attractiveness of the possible destinations. The opportunities provided by the national or regional territory only take on meaning through transport conditions that provide access to them and, conversely, the transport conditions provided by the network are only of value in relation to the destinations served. Ultimately, the indicator of accessibility must express this dual concept with its formalisation being the result of the interpretation of observed travel behaviours.

Accessibility and travel

People are willing to use roads for a given type of trip (tourism, professional, personal). Surveys have demonstrated that, for a given destination, the volume of journeys decreases as the cost of transport or the journey time increases. This behaviour is due to the fact that the utility of trips decreases as the cost of transport increases.

However, individuals also travel because their needs (consumption, study, work, entertainment, etc.) cannot be met at their origin but can be satisfied at their destination. An individual's satisfaction will be higher if more goods or services are available, as the probability of finding the desired product or service will be higher. However, any increase in the transport cost or time to reach this destination will reduce its attractiveness and therefore the utility of the trip. Remoteness therefore affects the level of utility. Each destination is ascribed a coefficient of remoteness (a factor that attenuates the utility of the trip) which is derived from the transport demand function.

Accessibility is therefore related to the travel behaviour of the individual or firm and the spatial distribution of activities and services. There are several types of accessibility, for example the accessibility of its workforce basin to a firm, the accessibility of the market to a firm that sells its products elsewhere than at the place of production, or the accessibility of a tourist site from a zone of potential customer location.

The following is an example of the application of such an approach as applied in France.

For each of type of activity, it is necessary to know the travel demand functions of individuals for home-to-work, business and tourism purposes. These functions can be constructed from survey data, and fitting functions of the following type is straightforward:

$$y = a\,e^{-\alpha t}$$

where:

y is the trip frequency;

t is the journey time;

a and α are calibration coefficients.

In addition, accessibility also depends on the spatial distribution of activities with reference to transport cost, which is measured in an approximate manner by the transport time. However, the spatial distribution of activities is not uniform. Towns and cities are not equidistant from each other and do not all provide the same level of goods and services.

The distribution of activities around a reference point is an increasing function of transport time. Furthermore, the number of jobs is a useful indicator of the supply of goods and services at a given location. It is relatively easy to obtain an approximate estimation of the true form of the spatial distribution of activities from a digitised road network for which hypotheses have been made about the journey times between the different urban centres and activity nodes and the number of jobs they provide.

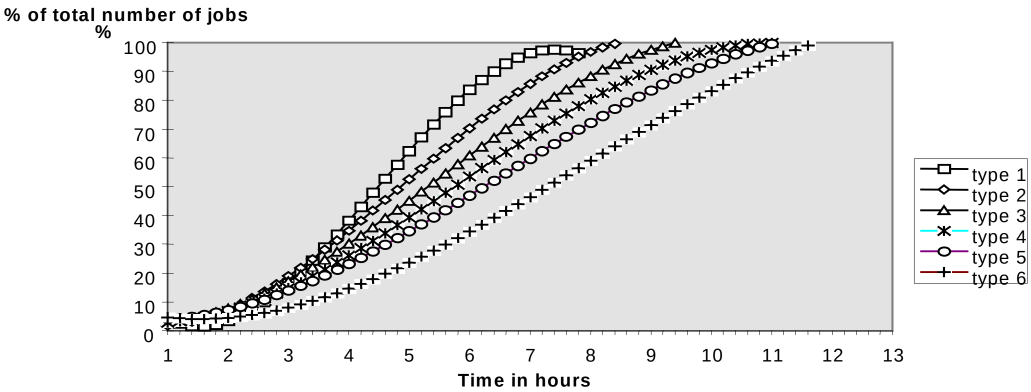
From a given pole, the spatial distribution of jobs can be expressed on the basis of the journey time between it and all other points relevant to the given location. In order to reveal this distribution more clearly, some French towns and cities have been classified according to the time taken to reach all of the workplaces. The results are provided in Table III.1.

Table III.1. **Distribution of cities according to the time taken to reach workplaces**

Number of cities	1	17	19	31	16	4	1
Maximum time taken to reach 100% of jobs (hours)	8	9	10	11	12	13	> 13

Each distribution corresponds to a certain level of job supply according to journey time. There are therefore six types of distribution of the spatial supply of jobs. For each town or city, the time taken to reach all the others can be estimated in order to determine the additional percentage of the total number of jobs added by each town or city. Thus, for a reference town or city we have n – 1 points. When all the points for a class are plotted, a scatter diagram is obtained on which a function can be fitted by means of regression analysis. Figure III.1 provides a graphical representation of the time taken to capture additional jobs in other towns.

Figure III.1. **Distribution of jobs according to journey time from a reference town or city**



These curves show the unevenness of the spatial distribution of activities. Thus, for a type 1 curve, 50% of the activities are located within a travel radius of slightly more than 4 hours 30 minutes, while for the type 6 curve, the equivalent time is 7 hours 20 minutes.

It is interesting to consider the case of a type 6 job distribution. A five-hour travel radius provides access to 22% of jobs. If transport conditions are improved, the same time will provide access to a greater potential number of jobs than previously, and will have moved to a point on curve 5. In this case, an individual would be able to reach a number of additional jobs, and would therefore benefit from improved accessibility.

From a reference point i, accessibility to a destination j can be estimated by:

$$Qj \times e^{-\alpha tij}$$

where:

Qj is the amount of goods, services or jobs located at destination j;

$e^{-\alpha tij}$ is the coefficient of remoteness and α is the calibration coefficient;

^{tij} is the journey time between i and j.

Next, the accessibility of all possible destination zones from a zone i is determined using the following formula:

$$Ai = \sum_{j} Qj . e^{-\alpha tij}$$

Improvements to the road network will change tij. Therefore, all other things equal, one can deduce that Ai will also change.

In order to implement this method, the first requirement is the possession of a digitised road network, broken down into arcs for which information is available concerning engineering features (length, transverse and longitudinal profiles) and the type of road [motorway, 2 x 2 lane or 2 x 3 lane road, other major road, principal county road, cross-town link, specific tolled structure (bridge, tunnel)]. A journey time is allocated to each arc.

The second stage is to break down the territory in question into zones. For example, in France, there is a useful zoning system for this type of study based on the 341 employment zones that completely cover Metropolitan France. The total number of jobs in each zone is allocated to it and each employment zone centroid (*i.e.* its centre of gravity) is connected to the nearest node on the modelled network.

Lastly, off-the-shelf traffic modelling software can be used to compute the journey time between the reference zone and each employment zone.

Effects of highway construction, maintenance and operations on employment

Traditional CBA methodologies treat income and employment due to expenditures on highway construction, maintenance and facility operation as a cost, not a benefit. Payments to labour in the construction industry and other sectors of the economy are included in the capital costs and operating expenses of the project being evaluated. This is as it should be since the main purpose of project evaluation is to identify opportunities that generate benefits large enough to warrant diverting labour and other scarce resources away from alternative uses. As a general rule, including income and employment resulting from project expenditures as a benefit would nullify the purpose of the analysis.

Income and employment due to project spending are not part of the benefit-cost calculation in any of the cases surveyed. However, several of the studies reported construction-related employment impacts for information purposes. No doubt this is in response to considerable interest in the effects of infrastructure spending on labour markets. Transportation policy makers and elected officials have an intuitive appreciation for the labour-intensive nature of road construction and maintenance, and share a common concern for the generation of employment opportunities at the national, regional and local level.

Both the United States and France have developed different but similar methodologies for evaluating highway construction-related employment impacts. Input-output analysis is used in the United States, while an “effects method” is used in France. In general, the US methodology is structured to provide national level (macroeconomic) evaluations of the federally funded highway capital improvement programme. The French method is focused more on project-specific evaluations and includes employment effects linked to routine maintenance and operations activities. Further information about both methods and sample results will be presented below. However, before proceeding with this discussion, two issues concerning interpretation of employment estimates require further comment.

Are project-related jobs a benefit?

There is considerable interest in assessing the full range of economic impacts associated with major expenditures of public monies on highway infrastructure. Clearly, transportation projects confer specific economic benefits in the short term due to the purchase of goods and services – especially labour services – which are required during the construction phase. However, the magnitude and spatial incidence of these benefits may vary with the type of improvement undertaken, the location of the improvement and the kinds of construction materials required. Estimates of project-generated income and employment are important for a full understanding of the socio-economic effects of infrastructure investment.

As was noted above, project-related income and employment are not generally considered in traditional CBA studies. However, under certain conditions it may be appropriate to include employment effects as a benefit. Conceptually, this could occur when there are considerable macroeconomic imbalances in a region, resulting in persistent unemployment. To justify including employment benefits in a traditional project evaluation framework, it would have to be shown that project spending affects long-term, structurally unemployed workers and that the employment benefits included are net benefits; that is, only income and employment impacts over and above those which could be obtained by using the funds in another way or by returning revenues used to finance the highway improvement to their original source. Net benefits are likely to be small during periods of high industrial capacity utilisation and concern over inflationary pressures, but could be large during prolonged periods of recession or economic downturn. These are stringent conditions and, given the current state of the art in analysing employment effects of construction, maintenance and operations expenditures in general, it is not surprising that such benefits are not normally included in formal CBA treatments.

Are jobs created?

It is often difficult to determine whether highway construction and maintenance jobs should be considered newly created jobs, relocated jobs, long-term jobs or short-term jobs.

First, it should be noted that the number and type of available workers in the building and civil engineering sector is roughly proportional to the total population of the region in question (metropolitan area, county, region or country). When an "exceptional event" such as a major motorway construction or repair project occurs in a region, local resources available in that region can become "saturated". This can occur very quickly if the region is sparsely populated or lacks specific types of human resources. When the number and size of local companies are not sufficient to meet the requirements of the contracting authority, resources from outside the local region are required. In this situation, contracting companies manage their employment policy according to two basic parameters:

- Their human resource management culture (*e.g.* maximise local recruitment, relocate workers from other areas, minimise management of staff turnover).

- Characteristics of the available labour pool (human resources available in the sector, skills and capabilities of local companies).

From a national perspective, relocated workers may not represent created jobs unless they are unemployed in their original location and unemployable in any other location. However, from the local perspective even a relocated worker represents an additional job throughout the construction period. While hiring a local unemployed worker constitutes a job created for the duration of the work, the period of employment might be relatively short. Furthermore, using employees from local companies does not constitute job creation on the local scale unless it avoids redundancy. Finally, completion of the work invariably leads to the departure of relocated workers, termination of contracts for workers hired for the duration of the project, reduction in the number of temporary workers, and termination of subcontracts with local contractors.

Considering the different meanings, the notion of employment cannot be used with the same acceptance as in the usual framework. For this reason, rather than focusing on created jobs, French research considered the content of employment (maintained and created jobs) during the construction period. The indicator used to measure the content of jobs is the number of jobs (x) years (number of full-time jobs throughout the total construction period). The US treatment avoids using such terms as “new jobs” or “created jobs”, and refers to job estimates as the number of person-years of employment supported by highway capital expenditures.

It should be made very clear that the employment impacts considered here are not related to employment opportunities resulting from industrial restructuring or other types of economic spillover benefits due to highway investment. The income and employment effects considered here result from construction expenditures working their way through the economy, much as in the case of other types of exogenous spending. In fact, because the employment estimates considered here are based on fixed relationships describing the use of human resources, the possible productivity benefits of transportation improvements on the construction industry, materials supplying industries, or other sectors of the economy are not considered.

Employment impacts related to construction of infrastructure

Two different approaches

- The input-output method

The ongoing US study on “Evaluating Federal-aid Highway Construction Program Employment Impacts and Productivity Gains” seeks to make accurate estimates of the number of direct, indirect and induced jobs generated by federally funded highway projects. A working model became available in March 2001 and is currently undergoing testing. Income, employment and spending estimates reported later in this section should therefore be considered preliminary. New US research which is underway will address the separate, but related, issue of changes in productive efficiency in the highway construction industry.

Methods and data needs for employment modelling

In the United States, income and employment impacts of Federal-aid Highway Programme spending are estimated using input-output analysis techniques. Employment income, person-years of full-time employment, and gross expenditures for goods and services are estimated at three points in the economic process. The first point occurs when capital expenditures on highway projects generate a first round of “direct” employment impacts in the highway construction industry and in other sectors of the economy that supply construction materials and equipment. Since materials supplying industries require inputs from other production sectors of the economy, a second round of “indirect” income and employment benefits will occur when these sectors expand output and employment to meet the new demand. Finally, when construction and other production sector employees spend their incomes, a third round of induced employment is generated. Induced employment is the result of income expenditures that are directly traceable to project spending for construction services and materials. This methodology ties material and labour intensities for specific types of highway construction and capital maintenance activities to producing industries and thus refines the gross indirect and induced employment estimates obtained from general equilibrium models that were previously used to generate employment estimates.

The main contribution of the current study to employment modelling lies in greater detail to the available input-output (I/O) accounts that is made possible by expanding the number of industry groups that provide road and highway construction services. The “six-digit” version of the Commerce Department’s 1992 Benchmark I/O Accounts[1] defines two industries that reflect the input-output structure of road construction activities: 11.0400: New Construction of Highways and Streets and 12.0214: Maintenance and Repair of Highways and Streets (these will be indicated hereafter by the subscripts n and r respectively). Using project-level data, these industry groupings were expanded to 14 construction industry groups, each of which corresponds to one of the improvement types defined by the US Department of Transportation, as listed in Table III.2.

Table III.2. **Construction improvement type codes**

Code	Improvement type
01	New route (new construction)
02	Relocation
04	Major widening
05	Minor widening
06	Restoration/Rehabilitation
07	Resurfacing
08	New bridge
09	Bridge replacement
10	Bridge rehabilitation
11	Minor bridge rehabilitation, bridge deck overlay
12	Safety/Traffic/TSM
13	Environment related
14	Bridge programme special action (inventory/inspection/classification)
15	Reconstruction with added capacity (adding lanes especially for HOV lanes)
16	Reconstruction with no added capacity

Source: OECD.

This expansion involves replacing two columns in the I/O accounts (n and r) with 14 new columns. Two approaches were used to do this. The first – the “direct sample approach” – assumed that all projects within an industry have the same input-output structure. Thus, the new I/O technical coefficients are calculated directly from data on a sample of projects in each improvement type. In the second approach – the “regression approach”, it was recognised that the input-output structure of projects may vary within an industry due to differences in scale, location or year of construction. Under this method, statistical analysis was conducted on the sample data in order to estimate parameters that could represent these effects before calculating new input-output coefficients.

In the direct sample approach, the creation of the expanded matrix of technical coefficients was based on observed information on individual projects. Each project type c = 1,2,…14 corresponds to a new input-output industry group. For each project type there are several individual actual projects o = 1,2… O_c .

Define:

1. For a description of these accounts, see Lawson (1997a, 1997b).

y_{oc} : the dollar value of type c project o.

s_{koc} : the physical quantity of input k used by type c project o.

p_{koc} : the unit price of input k used in type c project o.

Define a technical coefficient – representing the dollar value input k per dollar of expenditure on type c projects – as a weighted average across observed type c projects o:

$$a_{kc} = \frac{\sum_{o=1}^{O_c} s_{koc} p_{koc}}{\sum_{o=1}^{O_c} y_{oc}} \quad (1)$$

Each input class k is associated with only one input-output industry i. Technical coefficients that can be used directly in the input-output accounts are calculated:

$$\mathrm{a}_{\mathrm{ic}} = \sum_{k \in K_i} a_{kc} \quad (2)$$

where K_i is the set of all inputs k produced by industry i.

This method can be used to provide input coefficients a_{ic} for each of the newly defined industries, but reveals nothing about the role of these sectors as providers of outputs to other industries (*i.e.* the a_{ci}). Fortunately, this is not problematic since in general it is not expected that these industries provide inputs to other industries; that is, one can assume that $\mathrm{a}_{\mathrm{ci}} = 0$ for all c and i. This means that with very few exceptions, values of a_{in} and a_{ir} are zero in the existing input-output accounts.[2] Furthermore, assuming that all $\mathrm{a}_{\mathrm{ci}} = 0$ is consistent with assuming that $\mathrm{x}_{\mathrm{c}} = \mathrm{y}_{\mathrm{c}}$ since it implies that industry c has no intermediate output.

A coefficient e_{c} representing the value of labour input per dollar of output for project type c can be calculated in an analogous fashion:

$$\mathrm{e}_{\mathrm{c}} = \frac{\sum_{o=1}^{O_c} l_{oc} w_{oc}}{\sum_{o=1}^{O_c} y_{oc}} \quad (3)$$

where l_{oc} is the labour input in person hours of type c project o, and w_{oc} is the average hourly wage paid on that project. A vector of employment coefficients for all other industries can be calculated by

2. All these values are zero for new construction; for repair and maintenance, a non-zero value exists for only two industries: 71.0201 real estate agents, managers, operators and lessors; and 79.0300 other state and local government enterprises. In both cases, the values are low: .00815 and .00458, respectively.

dividing payments to labour in the value-added section of the input-output accounts by total output for each industry:

$$\mathbf{e} = \begin{bmatrix} e_1 \\ \vdots \\ e_c \\ \vdots \\ e_N \end{bmatrix} \quad (4)$$

In order to estimate direct and indirect employment income generated by a proposed project of type j of value y_{*c}, a final demand vector is defined:

$$\tilde{\mathbf{y}} = \begin{bmatrix} 0 \\ \vdots \\ y_{*c} \\ \vdots \\ 0 \end{bmatrix} \quad (5)$$

The incremental direct and indirect output generated by the project is:

$$\tilde{\mathbf{x}} = (\mathbf{I} - \mathbf{A})^{-1}\tilde{\mathbf{y}} \quad (6)$$

and the incremental employment income is $\mathbf{e}'\tilde{\mathbf{x}}$. To obtain the incremental employment in terms of labour hours, the following vector is defined:

$$\mathbf{l} = \begin{bmatrix} e_1 / w_1 \\ \vdots \\ e_c / w_c \\ \vdots \\ e_N / w_N \end{bmatrix} \quad (7)$$

where the *w*'s are hourly wages. The incremental number of employment hours is now $\mathbf{l}'\tilde{\mathbf{x}}$, which can be further transformed to the incremental number of jobs.

In the direct sample approach, it is necessary to assume that a single set of technical coefficients applies to all projects within each of the 14 types. It is possible, however, that significant variation in input structure may exist even within these improvement types. In order to take account of this possibility, a regression-based approach was also tested. By this approach, a custom set of technical coefficients is generated for each project on the basis of its type and a number of other characteristics that affect its input structure.

To test for systematic impacts of these characteristics, a series of regression analyses were undertaken. For example, define l_{oc} and w_{oc} as above, s_{oc} as some measure of scale, t_{oc} as the year in which construction is completed and $\mathbf{d_{oc}}$ as a vector of regional dummy variables such that the value corresponding to the location of project o is set to 1 and all others are set to zero. The labour input ratio for project o of type c is estimated with the following regression equation:

$$\frac{l_{oc}}{y_{oc}} = \alpha_c + \beta_{1c} s_{oc} + \beta_{2c} w_{oc} + \beta_{3c} t_{oc} + \mathbf{b_c d_{oc}} + \varepsilon_{oc} \quad (8)$$

where α and β are unknown coefficients, $\mathbf{b_{oc}}$ is a vector of unknown coefficients and ε_{oc} is an error term. Note that the regression coefficients are specific to project type c.

If the estimated values of the unknown coefficients in Equation 8 are all equal to zero, then the direct sample approach may be adopted. If the regression equations indicate significant systematic variation within a project type, then it is more accurate to generate fitted values based on scale, date, labour cost and location for each project using the regression results.

Implementation of the analyses described above requires a set of project level data records that provide estimates of the quantities used of as many construction inputs (including labour) as possible. To calculate I/O coefficients, a measure of the "output" (cost) of each project is also needed. It is critical that each of these data records be assigned to a specific improvement type. Also, since I/O coefficients are expressed in dollar terms, input price data are needed to transform physical quantities into dollars. For the purpose of the regression analysis, some measures of project scale and the wage are needed and each record should indicate the location and date of the project.

Example of estimated employment impacts of construction spending

The income and employment estimates that follow are based on the following assumptions. Federal-aid construction expenditures are USD 1 billion. With state and local matching funds set at 20%, combined programme expenditures total USD 1.25 billion. Programme composition by improvement type as a percentage of total cost is:

- New route construction: 9.34%
- Relocation: 2.03%
- Major widening: 6.05%
- Minor widening: 2.20%
- Restoration and rehabilitation: 11.44%
- Resurfacing: 12.51%
- New bridge construction: 7.34%
- Bridge replacement: 9.80%
- Bridge rehabilitation: 3.36%
- Minor bridge rehabilitation: 2.00%
- Safety/Traffic/TSM: 9.57%

- Environment related: 4.32%
- Reconstruction (with added capacity): 13.04%
- Reconstruction (with no added capacity): 7.00%

Given these assumptions about the level and composition of programme spending, first-round direct employment income is estimated at USD 572.7 million. First-round direct employment in construction and materials supplying industries is 19 672.8 person-years. Of this total, 12 453.5 person-years occur in the construction sector and 7 219.3 person-years occur in materials supplying industries. In addition to substantial numbers of jobs in the construction sector, first-round employment effects are particularly large in Transportation and warehousing, Business and professional services, Stone and clay products, Petroleum refining, Wholesale trade, Fabricated structural metal products, and Non-metallic minerals mining.

A second round of employment and income effects occurs in the production sector in response to the demand for additional inputs required by construction materials supplying industries. An additional 6 851.2 person-years of indirect employment benefits in the production sector are generated, yielding employment incomes totalling USD 212.9 million. These indirect employment effects are distributed across a much wider array of industry sectors than the direct effects. In addition to employment gains in Business services, Transportation and warehousing, and Wholesale trade, relatively large numbers of jobs are also observed in Restaurants and amusements, Primary iron and steel manufacturing, Finance, insurance and real estate, Automotive repair services, Machinery and equipment, Crude petroleum and natural Gas, Chemicals, and Rubber products. Overall, the dollar value of first- and second-round goods and services produced due to highway construction expenditures is USD 2.93 billion. This implies a direct and indirect spending multiplier of 2.34.

When direct and indirect employment incomes are spent, a third round of employment and income benefits occurs. This is termed "induced" employment and reflects producers' response to an increase in the demand for all goods and services. The total number of person-years of employment generated by this additional spending is 21 052.38. Third-round employment income generated is estimated at USD 527.5 million. The largest employment gains occur in the service sector, including Wholesale and retail trade, Business services, Health services, Restaurants and amusements, Educational and social services, Finance, insurance and real estate, and Communications. However, large induced employment effects are also observed in Textiles and apparel, Construction, Agriculture, forestry and fisheries, Food and kindred products, Printing and publishing, Electric equipment and electronic components, Motor vehicles and parts, Paper and allied products, and Rubber products.

Total employment income due to first-, second- and third-round (*a.k.a.* direct, indirect and induced) effects of highway construction spending is USD 1.313 billion. The total number of person-years of employment supported by Federal-aid Highway programme expenditures of USD 1 billion and total highway project expenditures of USD 1.25 billion, is 47 576.4. The dollar value of goods and services generated across all sectors of the economy is USD 6.097 billion, implying a spending multiplier associated with highway capital investment of about 4.77.

Of course, the magnitude and incidence of income and employment estimates will vary with the level of programme spending, the amount of state and local matching funds, and programme composition, since different types of capital improvements have different labour and materials intensities. These estimates are provided to illustrate the order of magnitude of employment impacts due to highway capital improvement expenditures.

- The effect method

This method was developed in France (Cherval, 1987) and implemented in transport projects. The goal is to assess the impact of projects on the production chain of the economy in terms of additional domestic intermediary consumption and additional value added. This would allow the number of jobs concerned to be estimated.

Types of jobs

Construction projects give rise to direct and indirect effects concerning primary contractors and subcontractors both on- and off-site:

- *Direct jobs linked to the site and in head office.* Direct jobs comprise the following operations: design, land clearance, earthworks, drainage, engineering structures, pavement, safety equipment, buildings and plantations. The number of jobs is determined by analysing the breakdown of these operations over several sites and by site employment ratios according to the costs of the different components of these operations.

- *Indirect jobs linked to manufacturing of site supplies.* This method consists of dividing the cost of the project into domestic intermediary consumption, imported intermediary consumption and the value-added component of the supply sector (salaries and social charges, company profits, taxes).

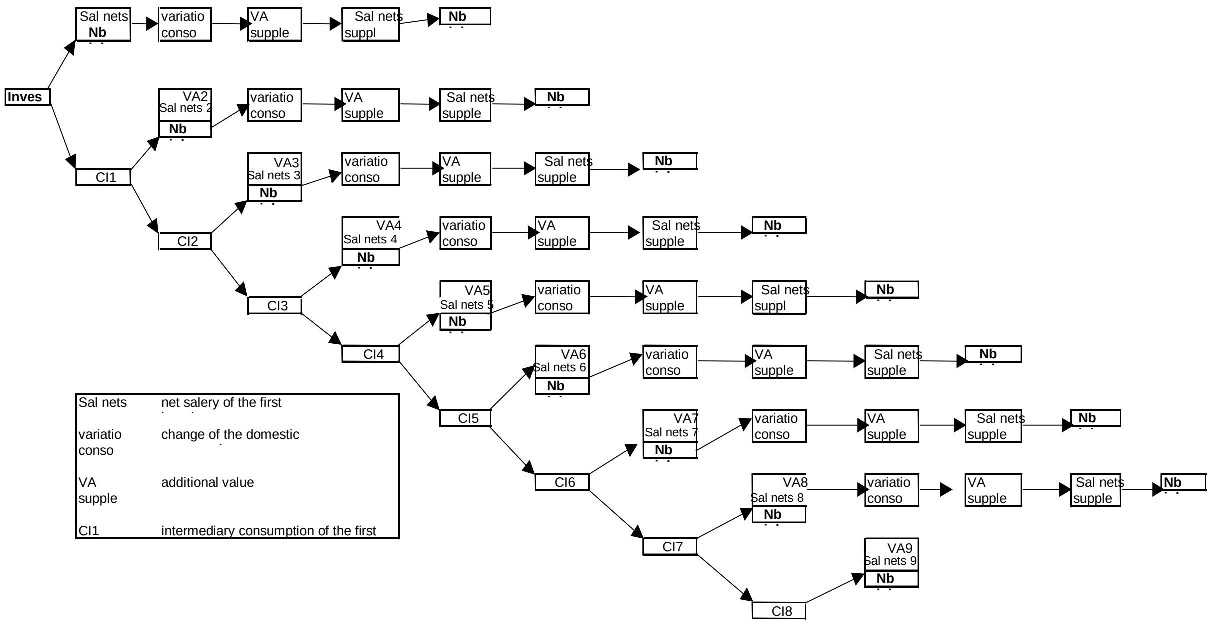
Site supplies mainly concern quarry materials, cement, power, transport, services, steel, wood, equipment and plantations. Some of these materials are imported, while the remainder are produced on national territory. The need for products for the construction site creates a demand for goods and services for the production of non-imported site supplies (*e.g.* lime for cement or steel for guard rails, diesel fuel for material transport vehicles, prefabricated concrete products). In turn, this additional production creates demand for additional goods required to make the products; this continues until the effect is exhausted. The additional production is estimated by simulating the impact on each sector of the economy. The modelling converges after eight iterations:

- *Jobs in the construction supply economy.* These jobs correspond to additional production of goods and services used.

- *Jobs linked to distributed revenues during the construction period (excluding transfer income).* These jobs are linked to additional expenditure corresponding to salaries paid at the construction site and to salaries paid to employees of the construction supply economy. This refers to additional business in the areas of food, housing, leisure and transport. Marginal changes in revenue mechanically create new consumption according to the marginal propensity to consume and import, and thus any additional production that generates new income. The process is represented in Figure III.2.

- *Jobs linked to distributed revenue.* These jobs are estimated using the approach applied above.

Figure III.2. **Employment modelling with the effects method**



Note: For the first step, the structure of intermediary consumption is estimated by surveys carried out on the construction site, while the share of imported products is assessed using national accounts data. For the others steps, the breakdown between value added and intermediary consumption comes from the national accounts. For each step after the first one, it is possible to calculate the number of salaried jobs affected using the percentage of salaries in value added and the average salary in the economy.

Summary

Table III.3. summarises the direct and indirect employment effects created by spending of FRF 1 000 million excluding tax (at 1995 prices) on major infrastructural works (motorways).

Table III.3. **Direct and indirect employment effects over the whole duration of the works for expenditures of FRF 1 000 million excluding tax (at 1995 prices)**

	Jobs (x) years
Direct jobs	
Jobs on site and at head office	1 210
Indirect jobs	
Jobs linked to manufacture of supplies	660
Jobs upstream of the site	570
Revenue effect	800
Total number of jobs	**3 240**

Comparing the results of the two approaches

For EUR 1 billion (FRF 6.56 billion or USD 1.11 billion),[3] the number of jobs affected is shown in Table III.4.

Table III.4. **Direct and indirect employment effects for expenditures of EUR 1 billion**
In worker*years

	United States	France
Direct jobs	11 059	7 940
Indirect jobs	12 493	8 070
Induced jobs	18 694	5 250
Total	42 246	21 260

Employment impacts related to maintenance and operation of infrastructure

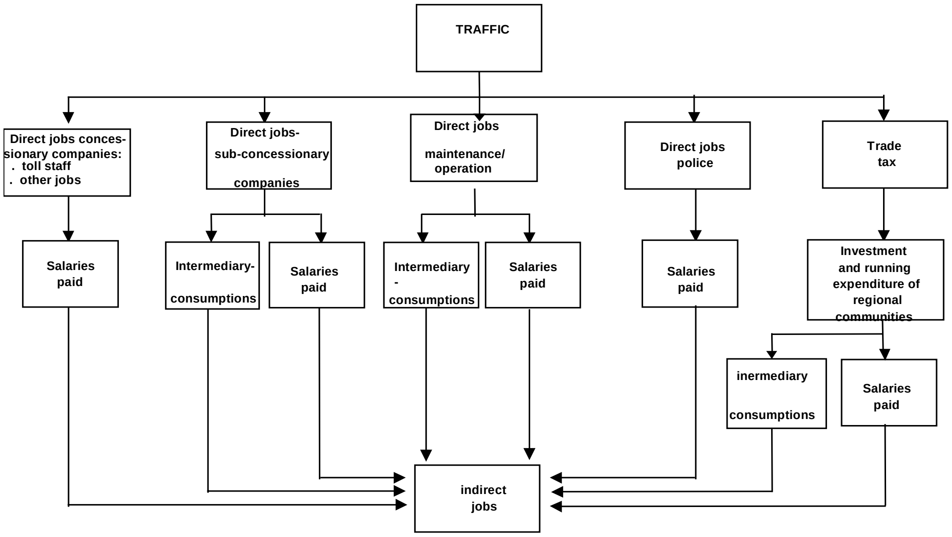
Methodological principles

The motorway, analysed as a "company", "sells a service" and thus brings in revenue, provides jobs, generates substantial intermediary consumption (which may benefit the region served). It also creates considerable fiscal resources for the communities it crosses, although this point will not be developed in this study. Logically, the general activity of the motorway is proportional to the traffic using it and its length.

It is possible to establish relationships between the level of jobs and traffic by determining the traffic flow, the number of jobs held in the concessionary companies, restaurants and fuel stations and their revenues.

General presentation

Figure III.3. **Evaluation of jobs linked to maintenance and operation of a road infrastructure**



3. USD 1 = EUR 0.90.

Approach used

- ***Jobs required to operate motorways (direct jobs).*** Jobs are expressed in annual equivalent. They take into account both permanent and temporary jobs:

  Toll jobs. The number of employees E_p per toll station depends on the output traffic T in veh/d: $E_p = a^* T + b$. This equation has given robust results for inter-city motorways operated in a closed toll system. It was based on current operating modes which make little use of electronic tolls.

  Other concessionary company jobs. This covers jobs in the regional operating divisions, districts and maintenance centres. These jobs are linked to the product of average traffic T in veh/d by the section length (in km).

  Jobs generated by sales of petrol and related products and jobs generated by catering (sub-concessionary company). The revenue from this business depends on traffic levels, thus making it easier to estimate the number of jobs in these areas.

  Jobs linked to motorway maintenance works. These jobs consist of work undertaken by companies independent of the infrastructure concessionary company. Expenditure concerns works on carriageways, fixed assets and maintenance of signing.

  Police jobs. The number of police officers varies according to section length and traffic.

- ***Indirect jobs.*** Indirect jobs associated with operating the motorway, jobs generated by intermediary consumption of sub-concessionary companies and jobs linked to salaries paid to employees are assessed using the same approach implemented to estimate the impact of road projects during construction.

Example

This method has been used in France to estimate the effects of operation of toll motorways on employment. For the section Poitiers-Bordeaux (this is an average example of 220 km and 20 000 vehicles/day), the estimated number of jobs is shown in Table III.5.

Table III.5. **Employment effects of the operation of toll motorways**

Direct jobs of the concessionary company	300
Direct jobs of sub-concessionary	290
Police jobs	100
Maintenance jobs	90
Sub-total direct jobs	***780***
Indirect jobs of sub-concessionary	320
Indirect jobs due to maintenance	60
Indirect jobs linked to salaries	130
Sub-total indirect jobs	***510***
Total	**1 290**

Most of these jobs are new jobs corresponding to a new service. However, most jobs listed under the direct sub-concessionary jobs were moved to this category from jobs on the road(s) which existed prior to the building of the motorway. However, considering the new traffic generated by the motorway (about 30%), 25% of jobs in the activity of catering and gasoline sales are job creations, the rest being job transfers.

Efficiency and output

Efficiency, output, and economic integration

There is significant potential for improved economic efficiency from the integration of different regional economies. As pointed out by SACTRA, there are similarities between this contribution and the gains forecast from reductions in trade tariffs and barriers, for example in the European Union Single Market. The impact of reduced costs on opportunities for both imports into and exports from a region will increase competition, thus helping to generate efficiency in industrial organisation and in production. More directly, the reduced cost of transport can lead to flow-on improvements in efficiency through an ability to reap economies of scale. The elements of such market efficiencies arising from improved transport are discussed elsewhere in this report.

As well as the direct impacts of infrastructure projects in a given region, there can also be positive and negative impacts on other regions either within the same country or outside. These need to be recognised in assessments.

In this section, socio-economic spillovers are considered, including the relationship between efficiency benefits and redistribution. Improving accessibility creates new jobs in the region, although it is often unclear as to whether this can be considered an additional benefit of improvements to transport or whether it merely leads to the relocation of activities. Nonetheless, it can be legitimate to have re-distribution of benefits as a goal.

In Chapter II, it was pointed out that in traditional CBA, the user benefits reflect all the benefits of transport in the case of perfect competition. Under conditions of perfect competition, there is no additional value to be gained from the wider impacts to the economy resulting from transport improvements, beyond the value of benefits calculated in cost-benefit analysis. The same benefits are passed through the system, which then leads to redistribution.

However, as SACTRA and others have demonstrated, wider economic effects are to be expected in the case of market failure.

In practice, users of infrastructure pass on some benefits to others, for instance by paying more for an office location close to a high-speed railway link. The redistribution of benefits may have a wider economic impact which would only increase national welfare insofar as these benefits create greater efficiency or reduce monopoly power.

The SACTRA report offers the following example: "...consider an area, which is very poorly connected with the outside world, and therefore within its own local economy there is a degree of monopoly power of local producers and traders. The general price level will be higher than it needs to be; the local monopolies will be attracting a higher than normal rate of profit. Consumption and production will be depressed and so therefore will employment. Overall, there is a loss of potential welfare. If an improved transport link is now provided with neighbouring economies, reducing the cost of movement between them, these inefficiencies now come under pressure of competition. Prices will be driven down, production and employment will increase and therefore the economic welfare...”

In the case where some degree of inefficiency and, consequently, loss of potential economic welfare mark the economy, genuine additional impact that has not already been fully accounted for in the transport user benefits can be expected. However, if local economic conditions were not based on monopoly prices but on prices that were subsidised to lower than their social marginal costs, the transport improvement would then be less than that calculated in the conventional CBA.

Therefore, the (re)distribution of user benefits through the transport system is not necessarily neutral for national welfare for two reasons:

- Redistribution can cross economic-geographic borders. In the case of redistribution within a country, profit and loss items have no consequences for national welfare, while in the case of transborder redistribution, there are consequences relating to welfare.

- From a social point of view, redistribution can stimulate activities from which enough (or too much) are generated. Market failure is central to this argument.

In practice, it is difficult to determine the magnitude of these wider economic impacts, while at the same time avoiding the practice of double counting. However, this approach has been used in this report.

Social inclusion

Social exclusion is a shorthand label for an extremely complex problem: what can happen when individuals or areas suffer from a combination of linked problems such as unemployment, poor skills, low incomes, poor housing, poor access to education, high crime environments, bad health and family breakdown. There are two aspects of this social problem where transport could play a role. In the first instance, reform of transport modes may result in the closure of rail branch lines, curtailment of bus services or other facilities, thus leading to the “transport” exclusion of communities. In this case, the associated effects such as those listed above need to be understood when decisions regarding transport disinvestment are made.

In the second instance, the issue is whether re-investment in transport and other services can lead to the rejuvenation of local communities. However, it is most unlikely that transport programmes alone will be sufficient to provide the catalyst necessary to address the social problems arising from social exclusion. A recent report for the UK Government (DETR, July 2000) explored the concept of social exclusion and the role of transport. In a summary of the current state of knowledge, it reports:

> *From the existing evidence it is clear that travel poverty can be a significant problem for those already experiencing social exclusion, with a lack of real travel choice and therefore a lack of choice in activities and destinations. It is also, in some cases, one of the causes of social exclusion. Travel poverty is strongly associated with the inability to participate, since it can result in lack of access to both essential and ‘non-essential’ services and facilities; work, hospitals, shops, education are examples. Travel poverty is not confined to “excluded” areas; individuals within affluent areas…can also be travel poor.*
>
> *Those without cars usually need more time, greater effort, and pay a higher marginal cost to reach the same destinations as people with cars. These problems apply in urban, peri-urban and rural areas, but take rather different forms and demand different solutions. Such solutions, although*

currently often embryonic, are being actively investigated in an encouraging number of local authorities.

Households without a car, in a society in which household car ownership is the norm (peri-urban and rural areas), are "socially excluded" within our definition of the term, since they cannot fully participate i.e. behave as the vast majority of society behaves. Even non-possession of a driving licence can be a disadvantage in that, to take a specific example, it reduces job opportunities.

Distances travelled by those in households with cars are substantially greater than those travelled by members of carless households. Thus, although non-car owners and non-drivers were not excluded from normal local social activities by virtue of existing local norms, they were excluded from the wider "social game", which has different norms.

Transport does not often appear to be one of the primary preoccupations of the socially excluded in urban areas. Previous studies have shown that it is a significant preoccupation for some older people, people with disabilities, women at night, and younger people with no car. For other groups, work, housing, security, etc., are likely to loom larger.

But the fact that it is not a primary preoccupation for some groups does not necessarily mean that it is not part of the problem of their "exclusion".

On the other hand, in rural areas transport problems are a primary preoccupation for a much wider group of people because access to most facilities is almost impossible in some areas without a car.

Poor transport is neither a necessary nor a sufficient condition for an individual or neighbourhood to be "socially excluded". It is, however, one of a number of contributory factors and can be a very important one. Some areas of "social exclusion" such as peri-urban post-war estates and rural areas are profoundly affected by the inadequacy of transport. There is a great variation between individuals and areas.

The more mobility there is, the greater becomes the expectation of mobility. For example, now that buses can be boarded by some wheelchair users, the users of bigger wheelchairs (which cannot board them) start to complain. Similarly, once low-floor buses have appeared in a particular locality, there is an expectation that they should be provided on all routes. One operator commented that while he was pleased to be able to transport more people more easily, he wondered what the limit would be to what public transport was expected to do. The demand for transport is probably insatiable and the opening up of one possibility may lead to a new set of demands.

There is a conflict…between the improvement of transport and the improvement of a neighbourhood. If better transport facilitates easy movement out of the neighbourhood, to jobs, schools, shops, etc., that are perceived as "better", then it could hasten the further decline of the neighbourhood.

There is also a conflict with the Government's sustainability objectives. Reduction of the need to travel is a current Government strategy to achieve sustainability and is incorporated into policy documents from the White Paper downwards. Despite the desired consequences of this strategy being an increase in very localised activity (which happens to be characteristic of some disadvantaged urban areas), it would appear that many of the socially excluded need to travel more if they are to participate fully in society. That is, until planning and transport strategies have been implemented long enough to be fully effective. However the two objectives need not necessarily conflict; it is a question of balance.

Thus, there is evidence that transport provision has a significant role to play in contributing to addressing the problem of social exclusion, and the impact of infrastructure on this dimension should be included in investment appraisal.

The first and most basic requirement given the link between social exclusion and poverty is to include in all assessments an analysis of the differential impacts, both financial and non-financial, of projects on households of different income levels. There is a special need to disaggregate the wider economic impacts of a project in this way; the availability of increased employment opportunities is a major element of any advance in tackling social exclusion. This is not always easy, however, as the collection of the relevant income data can be difficult. A first, although inadequate, proxy can be car ownership. Levels of employment/unemployment can also act as a proxy.

There is also a need to ensure that any analysis of accessibility takes into account the differential impact on those recognised as suffering from exclusion. With this in mind, there are likely to be special benefits in improving inclusion through the provision of better public transport as well as better pedestrian and cycling facilities. In contrast, some infrastructures can act directly to "sever" communities from facilities or social contacts and indirectly to cause changes to land-use or service provisions that may be disadvantageous to vulnerable households and communities. These impacts should be fully reported and assessed in all appraisals.

Modelling land-use effects

There is extensive literature and modelling experience on the interaction between transport and land use. Clearly, the issue of location and the impact of transport on it is central to understanding the way in which transport can contribute to regional development. The United Kingdom Government commissioned a report from David Simmonds on this topic which concluded that a useful understanding of the potential economic and social responses to transport changes has been developed, although better in concept than in detail (Annex 2). The ability of land-use transport interaction models to operationalise this understanding is uneven but progress is being made, particularly when used in conjunction with research in economics and geography. However, there is a recognised need for improving our understanding and ability to represent business decisions, particularly with regard to freight and land-use transport interaction. As with much of the present report, there is a lack of available results which can inform generalisations beyond an ability to generate debate and discussion. Thus, on balance, the ability of such models to inform detailed and robust assessments of the impact of infrastructure on economic and social change, and related land-use changes, remains limited.

Environment

Environmental impact assessment is a standard part of planning procedures in OECD countries. This section provides a brief overview of the impacts and indicators that are commonly used or recommended for use. The OECD has undertaken a detailed analysis of environmental impacts on transport as part of its work on environmentally sustainable transport (OECD, 1996, 1998, 1999a, 1999b, 2000).

Policies for infrastructure investment to stimulate regional development concern both strategic planning and project planning for single projects. The case studies in this report illustrate this. The Appalachian Development Highways in the United States and the cases of Major Motorway Infrastructure in France are at a scale where strategic environmental assessment is recommended. The two other case studies, the Berrima and Mittagong bypass in Australia, and the fixed road connection to Kristiansund in Norway, are examples of single projects.

Table III.6 shows the impacts and main indicators used in different studies as presented in the ECMT (1998a) report on *Strategic Environmental Assessment in the Transport Sector*.

Table III.6. **Summary of key impacts and indicators for strategic environmental assessment**

Impacts	Indicators
Climate change	Emission of greenhouse gases
Acidification	Emission of $S0_2$, NO_X
Use of natural resources	Energy consumption, land take
Loss of biodiversity	Loss and damage of habitats and species
Air quality	Emissions or concentrations of pollution
Water quality	Number of water sources affected, concentration of pollutants
Visual impacts	Scale and key physical characteristics
Severance	Barriers, population size in affected areas
Noise	Noise levels, affected surface, population affected
Historical, archaeological, nature conservation	Recognised sites and areas of importance

Source: ECMT (1998a).

This list is relevant for both the strategic planning stage where a strategic environmental assessment (SEA) is recommended, and for the environmental impact assessment (EIA), recommended as part of the decision basis for single projects. The common EIA does not cover all of these impacts, but the methods are usually more detailed.

Climate change and acidification

These impacts are important parts of a SEA, but are not normally relevant at an EIA planning stage. The estimation of traffic volumes, modes and distances are linked with expected technological development for vehicle input to the measures. There is comprehensive international research on these issues, both on climate change and on the political instruments used to reduce the risk.

Use of natural resources

This has impacts for both SEA and EIA. The assessment of the impact in volumes is relatively simple if the resources are known and located. Monetising the future value may be far more difficult.

Loss of biodiversity

Reduction of biodiversity is caused by the infrastructure itself and by the traffic flow on it. The impact on biodiversity, however, is extremely complex. The threat against biodiversity from infrastructure construction is due to use of space. The use of space ranges from areas taken completely out of biological production to small changes in the ecosystem which cause established species to disappear or new species to occur. Roads and railroads divide landscape and fragment wildlife habitats. This distorts natural movements and may cause inbreeding, thereby threatening species in the longer term.

These issues are relevant both for the SEA and the EIA. Lack of knowledge on this topic makes it difficult to assess, especially at SEA level. For further information, the Group refers to the “Handbook of Incentive Measures for Biodiversity: Design and Implementation” (OECD, 1999) and to the handbook “Roads and Nature” published by the Norwegian Public Roads Administration (2000).

Air quality

Air quality is measured by the concentration of pollutants in the air. The magnitude of the problem depends on the levels of pollution, the time over critical levels and the number of people exposed to it. Air pollution from the transport sector comes from emissions of CO_2, NO_2, HC (VOC, PAH) and particles and dust (PM10) Climate conditions such as wind, rain and temperature, topography, settlement patterns, green spaces and the location of the main roads can affect the levels of air pollution.

The assessment of future air quality when new infrastructure is planned must be carried out at the local level. For SEA, rough assessments can be done using indicators such as changes in traffic and technology combined with some knowledge of the new infrastructure, *i.e.* the actual number of bypasses in a new road network. In some countries, air pollution has been assigned a monetary value for use in CBA.

Water quality

Water quality is measured by the concentration of pollutants in the water. Pollutants are caused by traffic, road surface, road metal and maintenance. Traffic causes emissions of NO_X, HC and heavy metals. The use of salt on roads and defrosting liquids on aeroplanes for winter maintenance is a source of water pollution. One indicator at a SEA level is the number of water resources that can be affected. When new infrastructure is planned, water pollution can be reduced and controlled by investments in cleaning parks and infiltration systems.

Noise

All transport modes cause noise. Actual indicators for the SEA and the EIA are noise levels, affected surface and the number of people affected. In several countries, noise nuisance has been monetised for cost-benefit analyses.

Severance and visual impacts

Transport infrastructure is often a visible problem. Railroads and motorways create barriers to local transport. In urban spaces, the problems of pollution, noise, barriers and lack of visual qualities often occur in the same places and reinforce each other. To illustrate this, it is useful to imagine the difference between living close to a major avenue and living beside a motorway viaduct.

The most important task is the shaping of the infrastructure in question; therefore assessing these impacts will be most effective when making guidelines for infrastructure shaping and in the EIA for each project.

Historical, archaeological and nature conservation

Cultural environments, historical monuments and sites and valuable nature are qualities that may be irretrievably lost. The transport sector is directly and indirectly responsible for a large number of the historic monuments and sites that are lost.

Valuable nature can be defined as uninterrupted areas, areas with high biodiversity, habitats for rare species, beautiful landscape, including that used for recreational activities. Wet areas and shore zones are often valuable for biodiversity. Open landscape, shore zones and green spaces in urban areas are valuable for recreational use.

It is difficult to assess, in a SEA, the extent to which valuable areas and sites are affected by infrastructure without knowing the precise location of the new infrastructure. For an EIA, however, the conflicts are easier to locate, although it is difficult to assess the importance and value.

Protection of environmental qualities to promote future development, including tourism as an industry

Throughout history, people have adapted to new economic situations. The environment, which might have had a low value in a given period, may be considered as being of great value in other periods, and vice-versa. Some examples are minerals, which require a certain level of technology before they become profitable, plants that become useful for medicine, certain species of fish, traditionally considered inedible, becoming a delicacy, old decayed sites or buildings becoming tourist attractions or extensive uninterrupted areas of open countryside becoming recreational areas for worldwide tourism.

Transport infrastructure encroaches heavily on landscape and may destroy or reduce the value of irreplaceable qualities. Investments aimed to develop a remote area may thereby become an obstacle for growth. The precautionary principle of “look before you leap” must be applied if environmental damage is to be avoided.

Project implementation

Relation to other projects

No project can be examined in isolation from other developments that can be expected to occur over its lifetime. These could include related transport proposals or initiatives in other fields. Therefore, in forecasting the impact of an infrastructure proposal, these other developments should be taken into account. In doing so, two different contexts can be considered. In the first case, there are factors that are committed or that can be firmly expected to proceed or occur. These must be included in the base case, with the single exception of the case where they are dependent on the project being appraised for their implementation. The second context is where the development in question is more speculative. In such a situation, the assessment should include a sensitivity assessment to examine the potential impact of the development in question on the case for the proposal.

In some cases, this will require the testing of a strategy of which a given project is a part, or even a range of possible variations of such a plan. This will include full implementation plans, as the timing and ordering of projects within a strategy can have significant implications for their economic value.

It is also interesting to see the contribution of infrastructure to development in the context of the full set of policies and other factors affecting the welfare and prosperity of a region. Where development is a key objective of a particular project, there is a strong likelihood that complementary policies will also be in place. It is important when appraising projects or evaluating their impact to ensure that other contributions to development are made.

Funding and rates of return

Governments are increasingly interested in the procurement of transport infrastructure through public/private partnerships or entirely through private financial agreements. This has been driven by perceived constraints on the availability of public funds in the short term and by a belief that there are benefits in the form of risk transfer or operating efficiencies from having such services provided by the private rather than the public sector. In assessing the case for this approach, governments need to examine the nature of such benefits and their robustness. This study does not examine these issues, on which there is a great deal of experience across many countries, and there is an increasing amount of literature aimed as providing guidance to governments that are contemplating proceeding in this manner.

Consultation

Full and effective public consultation and participation should be seen as an integral part of the development and assessment of infrastructure projects. As well as the basic democratic case for doing so, there are also more practical advantages to the project itself. Firstly, consultation will include those most likely to be affected by and benefit from the project. Thus, they are likely to have knowledge and insight which may not always be available to the project sponsors. They can be a source of innovative and appropriate solutions. In addition, by ensuring that their views and interests are recognised at an early stage, the likelihood of later objection and disruption can be reduced.

Consideration should be given to the best mechanism to be used in any given context in order to achieve the most effective participation. Techniques that can be used to ensure adequate levels of participation include:

- *Early involvement* – so that groups or individuals can influence developments.
- *Interaction* – to ensure a two-way dialogue.
- *Inclusiveness* – which involves all relevant interest groups.
- *Continuity* – to increase the sense of involvement.
- *Openness* – decisions should be transparent to ensure that people feel the consultation has been real and effective.
- *Effective feedback* – to assure people how their views have been taken into consideration.

An important aspect of the consultation process is to ensure the support of the relevant local governments in the region that may be affected by the proposed infrastructure project. Their involvement in selection of the "best" route in the case of a town by-pass, for example, may be critical to retaining local community support where land resumption is a contentious issue.

It is important to make clear, at the outset of consultation, the aims and limits of public involvement in order to ensure the appropriate techniques are employed and to avoid confusion or disillusionment later on. A number of manuals or guidance notes exist on the best methods for public involvement and an appropriate guide should be consulted.

Project decision making: limitations and trade-offs

All decisions are a matter of judgement, and the role of appraisal is to ensure that a decision is made in the best possible possession of all relevant information. The actual choice process is only the final part of a longer procedure which covers the identification of objectives, options and criteria to be used for the assessment and analysis of options.

In reality, most transport project decisions are made on the basis of some form of explicit or implicit use of multi-criteria analysis, with some element of CBA. In practice, it will be necessary to trade off a number of factors, some of which will be quantitative, others qualitative. In carrying out the appraisal, it is important to ensure that there is a full audit trail for all of the information and analysis used in its derivation.

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Chapter IV

CASE STUDIES

Need for *ex-post* studies

The major "result" of the research is the observation that there are very few completed *ex-post* studies of transport infrastructure projects.

The common *ex-ante* appraisals of projects were almost never compared with *ex-post* analyses in order to observe and interpret any changes to a region that they have been affected by the infrastructure in question. It is very important that studies be carried out *ex post*, and over a long period of time, after a major transport infrastructure is built, if we are to obtain confidence in our *ex-ante* forecasts and appraisals and in the effectiveness of projects and policies in meeting their objectives.

Lessons from the *ex-post* studies

Framework

An attempt was made to analyse the case studies using a common framework. For each *ex-post* report, the framework identified: *i)* the purpose, context, timeframe and funding (financial size); *ii)* a list of impact variables such as travel time and vehicle operating cost, safety, induced travel, reliability, accessibility, employment, land use, environment, safety and efficiency; *iii)* related issues such as the relationship to other developments and regional redistribution.

Table IV.1. ***Ex-post* case studies**

Country	*Ex-post* study	Title of the studies	Type of infrastructure projects
Australia	After 5 years	Berrima and Mittagong Bypass case studies	Highway system
France	Between 3 and 5 years after.	Studies identified by the number of the motorway and the main town at each end.	Motorway projects
Norway	After 3 years	Kristiansund Project	Road tunnels and bridges system project
United Kingdom	After 5, 10 or 20 years,	Severn Bridge, opened in 1966 Humber Bridge, opened in 1981 M62, opened in 1966 and 1976 M40 Motorway, A55 North Wales Expressway	Road crossing bridges Road projects: motorway
United States	Study (completed in 1998) on corridors built between 1965 and 1995	"Appalachian Development Highways Economic Impact Study"	Highway system made of different highway corridors from Mississippi to New York

Source: IM2 Group case studies

Table IV.1 identifies the ex-post studies examined. The following section looks at the lessons learned, both with regard to the impacts of interest and with regard to the coverage and coherence of the studies themselves.

Definition and size of the regional impact area

The difficulty in comparing the *ex-post studies* is that the "observation areas" for analysing the regional impact of a project differ significantly from one study to another. For example, the "Appalachian Development Highways Economic Impact Study" provides an *ex-post* evaluation of 12 corridors, or 165 counties, in the Appalachian region of the United States. The *ex-post* studies made in France or in the United Kingdom consider a short corridor that covers more or less the road, bridge or rail link construction area. In order to undertake this, a clear definition of the regional area observed for assessing the development impacts must be determined (Nellthorp and Mackie, 1999).

There is often a lack of systemic vision of the different transport infrastructure impacts on regional development. *Ex-post* studies are often based on one transport mode (road or rail), avoiding the more complex questions of multimodality or intermodality of transport projects. This also relates to the definition and size of the impact area considered.

Project objectives

Further, clear project objectives are not stated systematically, thus introducing new difficulties in the *ex-post* assessment exercise: How is it possible to calculate or determine whether objectives are achieved if they are not defined at the outset of the project?

Methods for analysing the regional development impact of the project

Another problem highlighted by the study of the *ex-post* cases is that there is a lack of a clear explanation of the methods used (when they are indicated at all) for assessing the impacts on regional development. It is difficult to determine whether the same model or method is being used for *ex-post* case studies and for *ex-ante* studies.

Data availability

There is often a lack of consistent and reliable data, making quantitative evaluations difficult. If objectives for the infrastructure projects were made clear at the outset and variables for assessing whether the objectives had been achieved were specified in the *ex-ante* studies, the necessary data could have been collected. However, this was not the case in the studies examined by the Group.

Variables common to almost all of the* ex-post *studies

Some variables were common to most case studies. These included travel time, vehicle operating costs and accessibility. These were considered and compared before and after, in order to identify the impacts attributable to the construction of the transport projects.

The amount of jobs effectively created by the construction of the project was also seen in the *ex-post* studies.

Ex-post studies also analysed the impact on businesses created or closed in the particular area.

Variables not always taken into account

Variables that could analyse back-up measures taken by the state, the regional councils, the departments or local districts in order to reinforce the beneficial effects of new road infrastructure and tackle their negative impacts. Special aids to deal with increased competition could balance the project impacts on regional development:

- Environmental impact variables.
- The relationship to other developments (improvements in one transport mode can have some impact on other modes).
- Social inclusion.
- Quality and level of service (comfort, usefulness, frequencies for rail projects, etc.).
- Reliability.
- Regional redistribution.

Case studies

The variables surveyed in the *ex-post* case studies are summarised in Table IV.2.

Table IV.2. **Variables surveyed in *ex-post* studies**

	Travel time and VOC	Safety	Induced travel	Modal shift	Reliability	Quality	Accessibility	Employment	Efficiency	Social inclusion	Land use	Environment
Berrima and Mittagong		☐						☐				☐
French motorway	☐		☐				☐	☐				
Kristiansund	☐		☐		☐	☐	☐	☐		☐		☐
Severn Bridge	☐		☐	☐	☐		☐	☐				
Humber Bridge	☐						☐	☐				
M62	☐		☐				☐	☐			☐	
M40							☐				☐	
A55	☐		☐				☐	☐				
Appalachian	☐	☐	☐				☐	☐	☐	☐		

Source: IM2 Working Group.

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AUSTRALIA

BERRIMA AND MITTAGONG BYPASS CASE STUDIES

(Reviewer's note: The study identifies local economic benefits associated with environmental and parking impacts that were not considered in the original Road and Traffic Authority (RTA) project analysis. Although the study speculates that regional development benefits may have been captured indirectly in road-user cost savings, it can offer no empirical evidence supporting this conclusion because regional development benefits are beyond its scope of analysis. An admonition against double counting if road-user cost savings is combined with regional development benefits is based on theory and the adequacy of generated traffic estimates. It then notes that many Australian studies (including Berrima and Mittagong) do not estimate generated traffic directly, but rely on projections of historical traffic volume. It should have avoided the issue altogether because it must acknowledge that "The BTCE obtained insufficient information for assessing traffic projections in the original bypass analysis….").

Purpose and context

The purpose of the study is to examine regional development effects of infrastructure investment and assess whether significant economic growth benefits are omitted or not adequately captured by conventional CBA.

The study also compares local commercial benefits to total estimated road user benefits. US studies of bypasses indicate that retail and service sales impacts are far smaller than total road-user benefits. The BTCE study estimates that the value of retail sales and tourism benefits in the Mittagong-Berrima area are about 7% of the total road-user benefits computed in the original RTA study. This is roughly the same order of magnitude as that identified in US studies.

Berrima and Mittagong are towns affected by newly constructed bypasses along the Hume Highway in New South Wales, Australia. The Hume Highway runs between Sidney and Melbourne. Both towns are located in the Southern Highlands, an area with a high quality of life and experiencing large population growth rates in recent years. In 1986, the population of Berrima was 655 and that of Mittagong was 4 240.

The main industries in both towns before construction of the bypass were tourism and retailing. Manufacturing activity in the area was limited. Berrima has more well-preserved colonial buildings with tourist appeal, but both towns offer access to the scenic and recreational attractions of the Southern Highlands.

Method and timeframe

Berrima and Mittagong are the main focus of analysis, but to investigate wider economic effects on the region, the study also looks at the towns of Bowral and Moss Vale which are situated to the south of Mittagong.

Since the Berrima bypass was completed in March 1989, sufficient time (five years) had elapsed to observe medium-term economic impacts. On the other hand, the Mittagong bypass was completed in August 1992, so only quite short-term effects would be evident at the time of the survey.

The main research instrument was a qualitative survey, with respondents describing effects as small, medium or large. Respondents were also asked about their long-term expectations. The September 1993 survey consisted of face-to-face interviews of retail businesses in Mittagong and Berrima, a mail survey of retail business in Moss Vale and Bowral, and a mail survey of manufacturing business in all four towns. A follow-up telephone survey of a sub-sample of respondents was then done to better quantify effects on employment and gross sales. The mail survey of manufacturing companies asked about effects on production and freight costs. Estimates of changes in land values and tax revenues were also obtained using qualitative survey methods. *(It appears that little or no publicly available statistical data was gathered or used in the study).*

Survey of specific variables

Travel time and VOC

Not calculated in current study. The original project evaluation by the RTA determined that road-user travel time and operating cost savings comprised 90% of benefits.

Safety

Pedestrian safety in Berrima was improved by reducing traffic levels. Parking also improved. No statistical safety comparisons are provided. However, in the original project study by the RTA, safety combined with reduced maintenance costs on existing roads amounted to about 10% of total benefits.

Employment

Based on survey responses, the bypass at Berrima produced a medium-term increase in employment of about 2% and an increase in gross sales of about 7%. Long-term employment is expected to increase by an estimated 8%. Tourism and retail sales in Mittagong have declined by 6% and employment is down 3% in the short run. However, respondents in Mittagong expect increases of between 2% and 3% in gross sales and employment over the long term.

Efficiency and output

No measures calculated in current study. Original RTA benefit-cost ratios are not reported. In the RTA analysis, a benefit stream was calculated from 1986 to 2015. A 5% annual traffic growth rate was assumed. Discounting future benefits at 7%, the present value of road user benefits was estimated at AUD 277 million (in 1986 prices).

Environment

The bypass enhanced Berrima's appeal to tourists by reducing the level of automotive traffic in the town and virtually eliminating all heavy vehicle traffic. Noise declined substantially. In Mittagong, traffic has declined substantially but not by the amount expected in the RTA study due to an unexpectedly large volume of regional traffic. A study conclusion is that profiting from improved environment requires initiative and tolerance for risk, and calls for a constructive role by government. Moreover, even with optimal adjustments, bypasses may harm the economies of small towns which are highly dependent on traffic-serving business.

Other issues

Regional redistribution

Relationship to other developments: As a result of the bypass, land and property values in Berrima increased by 7.5% in the medium term. In the long term (*i.e.* after 1995), property values are expected to be almost 22% higher. Economic expansion in Berrima is evidenced by the increase in the number of businesses. About half the 45 businesses surveyed opened after the opening of the bypass and many are located on the bypass itself. However, the analysis does not deal rigorously with business openings and closings, and the survey instrument may even be biased by the omission of closed businesses. Social welfare objectives are not directly addressed but it is clear that the areas studied are not disadvantaged.

FRANCE

EX-POST STUDIES ON THE ECONOMIC IMPACTS OF MAJOR MOTORWAYS INFRASTRUCTURE AND THE NEW GUIDELINE TO ASSESS ROAD INVESTMENT PROJECTS

Purpose and context

In October 1998, the French Ministry of Transport published a new Guideline on assessing road investment projects in inter-city areas from an economic point of view. It contains an extensive list of evaluation variables and recommended values, and therefore is indicative of current empirical techniques and evaluation factors. It compares the proposed project to a reference case and proposes undertaking economic assessment both on effects in monetary terms and on effects that cannot be valued in monetary terms. The former is based on CBA but includes estimations on economic consequences on other modes of transport and the environment. The latter attempts to estimate the impact on employment, accessibility and changes in market size.

Studies on the economic impacts of major motorway infrastructure have also been conducted, summarising findings on how regions traversed by large roads are affected.

The studies were done with the aim to: *i)* better understand the evolution of regional economic development following highway investment; *ii)* gauge the degree of correlation between development and road investment; and *iii)* assist local public authorities in implementing measures to further develop positive effects or minimise negative impacts.

Method and timeframe

The results are based on seven project-specific studies. These projects are identified by their motorway number and the end points served (*e.g.* A10 Poitiers-Bordeaux) Evaluations involve both urban and rural areas. For example, one conclusion is that: “These studies show a faster development of activity around interchange points and especially in existing urban centres”. Another is that: “The only rural statistical areas experiencing favourable change are mostly situated within the urban peripheral or lie on the Atlantic coast.”

The seven project studies use a before-and-after methodology involving comparisons within and between study areas. In the latter case, areas along the road’s right of way are compared to areas initially presenting identical socio-economic characteristics but far enough away from the project to feel no direct effects of the investment. This methodology requires a system of statistical data collection over a sufficiently wide area and over a sufficiently long period of time.

Data gathering for the case studies concentrated on: *i)* creation and closure of commercial businesses; *ii)* changes in levels of employment; *iii)* tourist development; and *iv)* demographic changes. User surveys were used to gather information on mobility and generated traffic. Surveys of businesses and public authorities were used to analyse alterations in strategies and to assess the influence of the motorway improvements on company behaviour.

The analysis period (at least for employment and population impacts) appears to be 1975-90. The base period for job variations in urban statistical areas is 1975 to 1982, which is compared to the period 1982-90. Four of the project evaluation studies date from 1982 and three projects were added in 1985.

Survey of specific variables

Travel time and VOC

The paper reports "…one hour of time saved represents a saving of around FRF 170 for a transport company." It also notes that transport represents around 5% of product price.

The studies suggest that new infrastructures reduce transport cost by 15-20% on average, with as much as 40-50% of this being attributable to time saving.

Induced travel

Traffic increased due to time savings and improvements in service quality, including reliability, regularity and safety. Generated traffic estimates vary across projects. On one route, generated traffic was estimated at 20% just after opening and 40% after ten years of operation. On another route (the A51) 50% of the increase in mobility was attributed to commercial trips.

Accessibility

Accessibility gains for selected projects are reported in terms of tourist frequentation, intensification of competition, and industry reorganisation of transport and storage functions (*i.e.* logistics systems). Survey methods appear to have been used. This approach is substantially different from the suggested method for evaluating accessibility improvements set out in the Guideline.

Employment

Employment impacts "attributable to operation of the motorway" are reported. These are jobs created by concessionary companies (*e.g.* toll collectors, road maintenance personnel), local police forces, and sub-concessionary services (*e.g.* catering, fuel sales). The number of jobs is directly linked to the level of traffic, but employment gains are not proportional to traffic due to minimum workforce requirements for motorway operation. On average, motorway operations are estimated to generate between three and four jobs per kilometre. Although some of the jobs are transfers, having been initially located on competitive national roads, the net effect of motorway employment is positive. The employment estimates for motorway operation appear to follow the approach documented in the Guideline.

NORWAY

FIXED ROAD CONNECTION TO KRISTIANSUND

Purpose and context

This is a road project consisting of three strait crossings. One 5.1 km undersea tunnel, one 1.3 km suspension bridge and one 0.9 km floating bridge connected with a new 18 km ordinary road. This gave Kristiansund a fixed road connection to the mainland and replaced three ferry connections. The total cost for the project was NOK 1 billion (1992) or EUR 120 million.

Kristiansund, with 22 000 inhabitants living in the town centre and outskirts, is located in Nordmøre, 200 km south-west of Trondheim. The nearest town is Molde, which is 90 km away and approximately the same size as Kristiansund. Molde is an administrative centre for a larger region and has seen rapid growth. Oslo is situated at some 600 km.

Kristiansund is very close to the North Sea and was central for fisheries and sea transport. When land transport took over as the dominant transport mode at the national level, the site became peripheral. From the early 1960s onwards, the population of the area stagnated. Before the construction of the strait crossings, the main industries were maritime, among them a major shipbuilding firm. In the 1990s, the oil industry became important. Kristiansund was chosen as an oil-extraction base in Middle-Norway by national political resolution. This decision was related to the decision to build the strait crossings. The goal of both these decisions was to reverse a declining trend.

Method and timeframe

The road connection was opened in 1992. Two short-time effect studies were conducted. The first studied traffic before the project and one year after opening of the road connection. This study counted traffic and conducted interviews with road users. The second study was based on public statistics and *ex-post* interviews with local key informants and industry leaders 2-3 years after the opening. The main questions to the industry-leaders were how the project had affected their firms and how and to what degree the new connection had influenced their business strategies.

Survey of specific variables

Travel time and VOC

The largest contribution to reduced socio-economic costs was time savings. The weighted average time saved was 23 minutes.

Changes in VOC were not calculated. The substitution of ferries by fixed connections generated an increase in VOC due to the longer distance driven. There is also a toll on the new road. On the other hand, the ferry costs are no longer applicable. For road users, the total effect of these changes is an increase in travel cost.

For light vehicles, the value of time savings on average is larger than the increase in travel cost. For heavy vehicles, the result is not so clear-cut.

Induced travel

From 1990 to 1993, the traffic crossing the strait in the east-west direction increased by 22%. The general growth of traffic in the region during this period was low, and induced traffic caused by the project was estimated to be 20% in the first year. Traffic growth varies depending on type of vehicle, trip length and trip purpose, and is shown below:

	Traffic growth 1990-93
Light vehicle	24%
Heavy vehicle	4%
Short trips (<50 km)	25%
Middle trips (50-150 km)	31%
Long trips (>150 km)	-5%
Business personal travel	9%
Commuting	48%
Other purposes	19%

Reliability

The ability to predict how long the journey will take has improved. Before the project, the ferry-connections sometimes had capacity strains, *i.e.* on weekends.

Quality of transport service

Improvement

Continuous connection (including throughout the night), leading to less stress due to:

- Less hazardous driving to reach the ferry.
- Easier planning and time management when travelling.

Worsening

- Some people feel fear in long tunnels, particularly below sea level.

Accessibility

Accessibility has improved through reduced travelling time and due to the fact that the connection is now open at night. Accessibility is still limited by the toll.

Interregional accessibility

The main improvement in accessibility is reduced travel time between Kristiansund and Molde, with travel time between the two towns reduced from approximately 1 hour 35-45 minutes to 1 hour 15 minutes. This has led to an increase in commuting, with the number of commuters from Kristiansund to Molde rising from 110 in 1990 to 300 in 1995 and total commuting-trips crossing the straits in both directions rising from 300 in 1990 to 540 in 1995. This indicates that 70% of the total growth in commuting which took place after the project concerned inhabitants of Kristiansund working in Molde.

Local accessibility

Access for inhabitants of Kristiansund to winter-sport sites improved as did access to services for inhabitants on the mainland north-east of Kristiansund (some 3 600 people).

Employment

Construction period

No data available.

In operation

The new project had no significant impact on employment in the "base industries". In regional services, the project caused increased productivity followed by reduced employment as a short time effect. Employment in the most affected region was reduced by 1.7% in1990-95. There is no evidence to show how much of this decline was caused by the project.

Social inclusion

The project gave Kristiansund a 24-hour open connection, which was not possible before. It also gave Kristiansund a more up-to-date image. The perception of living in a declining area due to isolation caused by the dependence on ferries has been reduced. The advanced technology of both the project and the oil-extraction industry also contributed to a more modern image.

Environment

The project had small environmental impacts. The suspension bridge is a positive visual element in the landscape.

Other issues

Regional redistribution

The project contributed to considerable redistribution and centralisation of activity. From 1992 to 1995, several important distribution and regional service industries centralised their activities or reduced their staff by reorganising in a way that demanded more travelling over the straits.

The slaughterhouse, main fruit and vegetable wholesalers and grocery wholesalers closed their business in Kristiansund and moved their activity to the service centre of Molde and the bigger city of Trondheim. The same happened with mail sorting, telephone service, police office, and other small public services. Among the businesses which reorganised their activities were the hospitals of the region, energy supply and banking services.

The extent of this centralisation during this short period of time is related to the project. The interviews from the case study showed that the project was an important background for centralisation and reorganisation decisions. In addition, there is a general tendency against centralisation and reorganisation, therefore the project does not explain all of this.

Total employment in the region fell and workplaces were transferred from the north to the centre of the region. Kristiansund was the loser.

These were short-term impacts. The long-term impacts may be more positive for Kristiansund and the northern part of the region due to the lower costs for producer and consumer services and the enlarged labour market.

Funding

The funding was partly public and partly by road toll. The public part was slightly over 50%.

Stakeholders support

The project was pushed through by a local lobby. Local support was strong, and lobbying had been continuously organised since 1969.

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UNITED KINGDOM

THE SEVERN BRIDGE – LINKING ENGLAND TO SOUTH WALES

Purpose and context

The first proposals for a road crossing of the Severn Estuary were put forward by Thomas Telford in the 1820s, as part of a plan to improve communications between London and Ireland via the ferry port at Milford Haven in South-West Wales. These proposals were not pursued, although the ferry across the estuary (approximately at the location where the Severn Bridge was eventually built) was improved.

The first fixed link below Gloucester was provided by a single-line railway bridge at Sharpness, opened in 1879. This was clearly inadequate for the volume of trade between South Wales and Southern England, and construction of the Severn Tunnel began in the same year and was completed in 1886. The Severn Tunnel apparently provided a car-carrying shuttle train at one time.

The first suggestions for a road crossing were put forward before 1914, and were repeated mainly by local authorities throughout the inter-war period. These proposals were taken up again in 1945. A positive decision was finally taken in 1960, now considering the Bridge in the context of the initial 1 000 mile (1 600 km) motorway network of the United Kingdom.

An additional motorway bridge, known as the Second Severn Crossing, was opened in the mid-1990s. This crosses the estuary a few kilometres to the south of the 1966 bridge. Following the opening of the new bridge, some renumbering of the motorway system took place, so that the designated M4 London to South Wales Motorway uses the new bridge, with the older bridge now carrying the parallel M48.

Up to the changes associated with the Second Severn Crossing, the Severn Bridge was a key link in the M4 London to South Wales Motorway just west of its intersection with the M5 Birmingham to South-West England Motorway. However, it is important to note that the Severn Bridge and the few kilometres of motorway either side of it were opened before the rest of the M4 or the sections of the M5 immediately north and south.

Method and timeframe

A major impact study was commissioned by the Economic Planning Councils for the South West of England and for South Wales from the University of Bath, University College Swansea and the Newport and Monmouthshire College of Technology. This was published in 1973 (Cleary and Thomas, 1973), though most of the survey work was carried out in the period from 1967 to 1970 (including some limited fieldwork in the summer of 1966, just before the bridge opened). It is important to note that this study was carried out before the section of motorway over the bridge had been joined to the rest of the M4 or the M5. It was therefore never possible to examine the effect of the bridge as completing a missing link in the motorway network – the missing links at the time were the inland sections.

A second study was carried out by the Welsh Office circa 1980, by which time the M4 in Wales was complete westward to Cardiff and the English motorway connections to London (M4) and the Midlands (M5) had also been completed. The Welsh Office study was mainly concerned with the expected impact of extending the M4 from Cardiff to Swansea, but included a survey and analysis of the effects which had already been felt.

A third study was carried out by Cambridge Economic Consultants in 1987. This relied on the previous fieldwork and on other data sources, but carried out some additional analysis to produce more comprehensive estimates of the long-term employment effects of the Severn Bridge and the M4. For the most part, the bridge and the motorway were considered jointly rather than separately. This study was concerned almost exclusively with the employment impacts on Wales.

The Working Group also considered an MBA dissertation which considered the impact of the tolls charged for the use of the bridge (Miller, 1993). This makes reference to a number of reports prepared during the decision-making process which led to the building of the Second Severn Crossing; some of these may contain further analysis of the impact of the original bridge and associated motorway developments. We have not examined these.

Survey of specific variables

Travel time and VOC

Cleary and Thomas report (p. 84, para. 8.16) that the bridge reduced journeys between the two sides of the estuary by up to 50 miles (80 km) and by up to two hours travelling time (or possibly more, under congested conditions). These improvements would be experienced in full by anyone travelling from Bristol to Newport or Cardiff.

The time and distance savings represent a major improvement in accessibility between the two banks of the Severn, although this was significantly reduced by the imposition of tolls. Cleary and Thomas (para. 8.47) report that the initial toll was 2s 6d (GBP 0.125) per car.[4] This was in the range of 2s to 3s per hour (GBP 0.1/h to GBP 0.15/h) which they established as the value for non-working time (para. 8.49-50). Working time was valued as 8s 9d per hour for commercial (*i.e.* goods vehicle) drivers and at 13s per hour for other drivers (*e.g.* business travellers). Operating costs per mile are reported as being in the range 3d to 5d per mile for light vehicles and 16d per mile for heavy vehicles.

Other changes associated with the opening of the bridge included major reductions in the local railway services between North Bristol and South Wales (Cleary and Thomas, para. 9.15) and in the cross-Severn ferry services (Clearly and Thomas, para. 9.16). The fate of the Severn Tunnel car-carrying shuttle is not recorded, but it seems safe to assume that it closed as soon as the bridge opened, if not before.

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4. Although the Cleary and Thomas report was published in 1973, after the decimalisation of UK currency, it reports prices in the pre-1971 units of pounds (£), shillings (s) and pence (d). There were 20 shillings in the pound and 12 pence in one shilling. The pound was unaffected by decimalisation.

Induced traffic

During 1967, the first full calendar year of operation, the flow of vehicles over the bridge averaged about 16 000 per day (Cleary and Thomas, Appendix 2). By 1970 (the last year reported in the Cleary and Thomas survey), this had increased to 20 000 per day. By 1991, the flow had reached 51 149 vehicles per day, significantly in excess of the design capacity of 46 575 (Miller, 1993, p. 7).

The Cleary and Thomas study contains considerable detail from their traffic surveys. Of particular interest is Table IV.3 which shows their estimates of diverted and generated traffic in August 1967, approximately a year after the opening of the bridge. This information was obtained by asking drivers whether, had the bridge not existed, they would have made the same journey by a different mode or route (diverted). Drivers who answered "no" were assumed to be making "generated" journeys. Drivers in this category were asked whether they had chosen their destination or route specifically to see the bridge itself; those who answered "yes" were classified as "facility created".

Table IV.3. **Diverted, generated and facility created traffic by purpose, August 1967**

Purpose	Diverted	Generated	Facility created	Not known	Total
Firm's business	14 693	4 141		470	19 304
Collection and delivery	726	727	220	21	1 694
Service and maintenance					
Work	933	1 928		14	2 875
Shopping	655	1 941	133		2 729
Holidays	29 970	6 306	3 701	101	40 078
Visiting	14 090	7 650	1 253	40	23 033
Sightseeing	5 086	14 469	9 588	310	29 453
Paid entertainment	2 038	5 832	595		8 465
Other and multiple	1 882	1 124	125		3 131
Total	70 073	44 118	15 615	956	130 762

Source: Cleary and Thomas (1973).

The overall pattern was that:

- 54% of traffic was "diverted".
- 34% was "generated" but not "facility created".
- 12% was "facility created", *i.e.* had arranged the journey in order to see the bridge.

The combined proportion of "generated" and "facility created" was highest for sightseeing, where five-sixths of trips came into these categories. It was lowest – about one-quarter – for travel on firm's business and on holidays. None of the drivers travelling on their firm's business admitted arranging their journey specifically to see the bridge, but about one-eighth of the small number making collection, delivery or service trips did so.

Separate surveys of heavy vehicles (goods vehicles and a very small minority of buses) were carried out, including screenline surveys carried out by Gloucestershire County Council in August 1966 and August 1967. The location of the screenline does not seem to be stated in the Cleary and Thomas report, but the zones for which the information is given (Appendix 29 and Map B) are consistent with the obvious possibility, *i.e.* the Severn itself.[5] The figures show that total heavy traffic increased from 7 600 vehicles per August weekday in 1966 to 8 400 in 1967; of the latter, some 3 000 crossed by the bridge.

Reliability

In the years immediately after opening, the reliability of travel times via the bridge was a major attraction, compared with the risk of being held up by congestion in Gloucester. Cleary and Thomas (p. 87, para. 8.39) report that Gloucester was a serious bottleneck with marked seasonal variation, with journeys that took 15 minutes in winter sometimes taking over an hour in summer.

By the beginning of 1979, when the surveys for the Welsh Office study were carried out, the recurrent need for repairs to the bridge and the motorway network had become a significant problem. The surveys including an invitation to add other comments related to the impact of transport on the Welsh economy: 29% of respondents took that opportunity to express concern about the delays caused by repairs and maintenance work (Welsh Office, 1980, p. 27, para. 3.17). The problems continued throughout the 1980s, with occasional total closures causing chaos on the Gloucestershire road network (Miller, 1993, p. 7).

Reliability was also affected by the exclusion of high-sided goods vehicles during particularly windy weather.

Accessibility

The opening of the bridge, even with tolls, clearly represented a major improvement in accessibility to the other side of the Severn for both private car and commercial truck users. The reduction in local rail and ferry services may, however, have reduced accessibility for persons without access to a car, although to some extent this reduction would have been remedied by the development of extended or new local and long-distance bus and coach services (Cleary and Thomas, para. 4.74-80). Opportunities for leisure travel were significantly increased by the substantial development of coach excursions, consisting of trips and tours sold to public and of private hiring (*i.e.* coaches chartered for private group travel), predominantly from industrial areas of South Wales to shopping and tourist destinations in Southwest England (Cleary and Thomas, para. 4.81-90).

For freight, the surveys found a reduction in the use of rail, but this occurred as much in areas unaffected by the bridge as in those affected (Cleary and Thomas, para. 5.11). (It should be noted that the period of Cleary and Thomas' survey coincided with a period of rapid reduction in the railway network, with a 20% reduction in total route length between 1965 and 1970.)[6] They did, however, find that before the opening of the bridge, the use of railways for freight between South Wales and South West England had been higher than normal for the distances and goods involved, and that the bridge brought about a reduction in this use.

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5. In which case the results presumably exclude traffic on the M50, unless on-motorway interviews were possible at the time.

6. Transport Statistics Great Britain 1996, Table 9.8.

Employment and regional impacts

No data are available on employment impacts during construction.

Short-term impacts

For manufacturing industry, Cleary and Thomas examined:

- Organisational links.
- Changes in inputs (raw materials and components).
- Changes in service inputs.
- Changes in labour inputs.
- Changes in the sale of outputs.
- Other commercial benefits (*e.g.* vehicle utilisation).

For distributive activities, they examined the structure of the firms and their operations and the changes which followed the opening of the bridge. This included the experience of retailers with regard to the patterns of shoppers' travel. At the other end of the scale, the authors also considered the impact of the bridge on ports and docks in the region.

Cleary and Thomas provide a great deal of detailed information on changes in each of these topics, but in general they were unable, unwilling or perhaps not expected to reach any overall conclusions as the impact of the bridge on output or employment in the regional economies affected. They did however conclude for manufacturing (Cleary and Thomas, para. 9.20-29) that:

- There had been no significant relocation of factories.
- Both regions had become more attractive as locations for new manufacturing investment.
- There had been increases in purchasing of inputs and sales of outputs across the estuary.
- Associated with increases in business travel, change in distribution arrangements and increases.
- In choice for purchasers.
- Improved links between establishments within individual firms (notably between South Wales's factories and head offices in Southeast England).

Their overall finding was that the bridge had improved prospects for industry in South Wales without weakening those of industry in South-West England; that more rapid changes were observed in distribution, as would be (and was) expected; that there was a significant increase in the number of firms operating across the estuary, with greater advantages accruing to firms (or establishments) based in Bristol and adjoining areas of South Gloucestershire, who were closer to the economic centre of the

United Kingdom and, finally, that as with manufacturing, there were changes in the sources of supplies.

Cleary and Thomas estimated (para. 9.36) that changes in distribution produced some 40 redundancies on the English side of the bridge and 166 in South Wales (mainly in Cardiff). These redundancies were in surveyed firms wholly engaged in distribution; a similar change was estimated to have occurred in non-surveyed firms and firms primarily involved in manufacturing. About 430 new jobs were estimated to have been created on the English side and about 20 on the Welsh side, although some of the English jobs were relocations from Central Bristol to the fringes of the conurbation.

For retailing, anecdotal evidence suggested an increase in the number of people crossing the estuary to shop in the major centres of Bristol and Cardiff, but no net effect on sales figures was reported.

Apart from the figures on distribution employment quoted above, Cleary and Thomas made no quantified estimates of impacts on jobs or output.

Longer-term effects

The Welsh Office study likewise concentrated on quantifying reactions rather than assessing net change. Its survey of firms in Gwent found that 47% of large manufacturing establishments, 84% of small manufacturers and 85% of distributive firms considered that easier access to markets had "helped to increase business" (Welsh Office, 1980, p. 42, para. 8.7). Of manufacturing firms which had opened factories in Gwent since 1966 (*i.e.* since the opening of the bridge), 79% said that access to the (English) motorway network via the M4 and bridge had been a factor in their choice of location, and 51% said it had been a major factor – although it was thought unlikely that it had been a key factor in many cases. [The availability of labour and government financial assistance was the most frequently mentioned factor (8.10).]

One factor mentioned by local authorities in contributing to the Welsh Office study was that eastern Gwent was experiencing considerable demand for housing from people commuting either to Bristol (via the Bridge) or to Newport (via the M4).

It was left to the Cambridge Economic Consultants' (CEC) study to tackle the issue of estimating overall impacts, which they did with great enthusiasm. They first (CEC, 1987, pp. 204-207) estimated the employment created by the construction of the bridge and of the M4 in South Wales. This was done by taking the historical cost of the bridge (as quoted earlier) and estimated costs for the motorway, applying typical cost structures for civil engineering contractors to estimate the application of this expenditure, wage rates to convert this to employment, and assumptions as to proportions of inputs purchased locally.[7] On this basis they found that the bridge generated some 4 260 person-years of employment over a five-year period, and that the motorway west of the bridge generated some 10 300 person-years over 20 years. Some adjustment for displacement from other projects in the region was assumed (p. 207).

Employment in operation and maintenance was similarly calculated from estimates of the expenditure involved. For the M4 component, it was assumed that the high proportion of local traffic

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7. For the Bridge, it is not quite clear how the argument gets from the assumptions about the proportions of purchases in the South Wales/Bristol regions (p. 206) to the impact on the South Wales economy (p. 237); the figures seem to be the same.

using the motorway meant that expenditure and employment in maintaining the rest of the road network would be reduced.

CEC estimated the induced impacts of the bridge and motorway in several stages. For indigenous manufacturing (*i.e.* firms which were located in South Wales before the opening of the projects), they applied a simple elasticity to an assumed cost reduction. They argued that before the projects, South Wales was a high-transport-cost location; after the projects, it was an average-transport-cost location. From (unspecified) studies of the variation in freight transport costs between different locations, they argued that this difference would be equivalent to about 1% of gross output. An additional 0.5% saving in costs was attributed to time savings in business travel. This would allow South Wales to reduce prices by 1.5% without reducing profitability.

CEC suggested (p. 211) that the own price elasticity of output in a single region such as South Wales would be about 3, and that two-thirds of this would be achieved by increased productivity and one-third by increased employment.

Putting all these assumptions together indicated an increase of employment in pre-existing firms in South Wales of 1.53%, which on a base of 250 000 implied an increase of 3 825 jobs. This was the preferred central estimate; the effects of different assumptions were explicitly considered (Table 2, p. 212).

To identify the additional effect of changes in manufacturing location, CEC first considered the findings of the Welsh Office surveys (see above). They found that the reported influences on firms which had chosen to locate in South Wales were similar to those identified in equivalent studies of Scotland and Northern England, *except* for the Severn Bridge and the M4. On this basis, they examined the differential rates of new firm location and associated employment, and found that South Wales appeared to have attracted between 9 000 and 12 000 jobs in firms not previously located in the region. These are additional to the 3 825 jobs in indigenous firms, making a total of 12 800 to 15 800.

CEC also carried out an analysis of differential growth in total manufacturing employment in Wales, Scotland and Northern England. This gave a total positive impact of some 18 100 jobs by 1981. They argued that this was consistent with the 12 800 to 15 800 obtained from the other calculations, since it included additional jobs generated by linkage and multiplier effects. This impact, of +18 100 jobs, was taken as the overall impact of the Severn Bridge and M4 on manufacturing in South Wales.

CEC estimated impacts on employment in tourism from the changes in leisure travel patterns estimated in the Cleary and Thomas surveys, supported by more recent anecdotal evidence from tourist authorities. The overall effect was estimated as a net growth of 10% to 12% in tourist activity in Wales. The summary table (p. 239) shows this as a short-term impact (after 4 to 5 years) of 3 000-4 000 jobs and a maximum impact (15-20 years) of 6 000-7 000 jobs. It is not clear exactly how these absolute figures were obtained.

Again drawing on the Cleary and Thomas surveys, CEC estimated a short-term loss of 2 000-3 000 jobs in distribution, rising to 4 000-5 000 in the long term.

CEC's overall assessment, including additional effects tabulated but not discussed in their report, is shown in full as Table IV.4. They conclude (p. 239) that "this represents an increase in economic activity and employment in industrial South Wales of about 4%".

Table IV.4. **The impact of operation on the regional economy of South Wales**

	Number of jobs	
	Short-term impact (4-5 years)	Maximum impact (15-20 years)
Direct jobs in operation and maintenance of infrastructure	105	105
Jobs in local producers and suppliers	46	46
Displacement of other infrastructure projects and jobs	-50	-50
Net additional jobs in manufacturing industry (including linkages)	8 000 – 10 000	12 000 – 18 000
Net additional jobs in tourism	3 000 – 4 000	6 000 – 7 000
Changes in location of wholesale and retail distribution and other consumer services (net employment change)	-2 000 to -3 000	-4 000 to -5 000
Sub total (1+2+3+4+5+6)	9 100 to 11 100	18 300 to 26 100
Total after application of local income multiplier	11 800 to 14 400	18 300 to 26 100
Longer term impact on employment in house-building, public services and infrastructure and its local income multiplier effects		5 640 to 8 040
Total employment generated		23 940 to 34 140
Total additional houses built per annum (over 10 years)		6 128 to 8 739
Total additional population (all ages)		17 000 to 24 275
Total additional employment[1]		23 940 to 34 140

1. This represents an increase in economic activity and employment in industrial South Wales of about 4%.
Source: Cambridge Economic Consultants (1987).

Social inclusion

There was no *ex-post* analysis of social inclusion impacts reported, although the accessibility results above indicate that it is likely to have been positive.

Other issues

Funding

The original link (*i.e.* the Severn Bridge itself, the Wye Bridge and immediately adjoining motorways) cost GBP 16 568 000 at historical prices, which can be converted to GBP 20 900 000 at 1966 prices (Cleary and Thomas, para. 8.12). The project was funded by the UK Government, but under arrangements whereby tolls were charged to recover the investment.

High maintenance costs in the 1980s meant that the outstanding deficit on the bridge was increasing rather than being reduced (Miller, p. 11). The debt was effectively privatised by decisions taken under the Second Severn Crossing Act, which transferred the existing bridge, the deficit and the right to levy tolls to Severn Crossings PLC in return for the undertaking to build the Second Crossing. The subsequent increases in tolls have become a significant political issue, particularly in South Wales where some see the tolls as a tax on local economic activity.

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UNITED KINGDOM

THE HUMBER BRIDGE

Purpose and context

The Humber Bridge is a road bridge over the Humber Estuary on the east coast of Northern England. When it opened in June 1981, it was the world's longest single span suspension bridge.

Unlike the Severn Bridge, the road carried by the Humber Bridge is not a motorway and does not form part of a long-distance transport axis. The motorway network in the immediate vicinity follows the banks of the Humber, linked by a north-south route some 30 km inland.

The north and south bank of the Humber have traditionally been highly independent of each other. The north bank, dominated by the port and industrial city of Hull, was part of Yorkshire, while the south bank, with significant ports and related industries at Grimsby and Immingham and a major industrial centre (based on steel-making) at Scunthorpe, was part of Lincolnshire. On both banks, and indeed upon the water, the main lines of communication were east-west from the ports to the major industrial and service centres of West and South Yorkshire. The areas immediately to the north and south are predominantly agricultural, with some tourism on the coast.

A new administrative county, Humberside, covering both banks of the estuary, was created during the reorganisation of local government in 1974. (It is indicative of the traditional independence of the north and south that during the latest local government reorganisation, in 1996-97, Humberside was abolished, and the reformed authorities within its former area adopted names pointedly declaring their allegiance either to Yorkshire or to Lincolnshire.)

Proposals for a bridge across the Humber were first put forward in the middle of the 19th century, mainly by business interests in Hull wishing to expand into the agricultural markets of Lincolnshire and the port of Grimsby. South bank interests were generally less enthusiastic or positively hostile (Simon, 1984a, p. 26).

Legislation establishing a Humber Bridge Board with powers to raise finance, to build the bridge and to charge tolls was passed in 1959. Nothing happened until 1969, when the then Ministry of Transport agreed to lend the Board 75% of the cost of construction, which began in 1972 and was completed, after substantial delays and cost overruns, in 1981.

The sequence of government decision making leading to the building of the bridge and of the motorways serving Humberside has been the subject of several other studies (referenced in Simon, 1987). In essence, the major regional transport planning decisions seem to have been to develop east-west motorways on both the north and the south banks of the Humber (the M62 and M180, respectively), connected by a north-south motorway (the M18) as well as by the A1 and M1 further inland. The Humber Bridge was seen not as part of this network but as enabling large-scale development on both sides of the Humber Estuary and fulfilling the resulting local transport requirements. In the event, very little such development has taken place.

Method and timeframe

The available studies of the bridge's impact are derived from a study of its effect on commercial (goods) vehicle operation and hence on industry. This was sponsored by the Economic and Social Research Council and carried out at the University of Leeds Institute for Transport Studies.

Survey of specific variables

Travel time and VOC

The Humber Bridge offers substantial savings in travel distance and time for movement between the opposite banks of the Humber Estuary, particularly between Hull and Grimsby or Immingham. From Hull to Immingham, the distance is 71.5 miles avoiding the bridge but only 25.8 miles using it.

Such significant savings are, however, only achieved for local journeys within Humberside or to the coastal areas immediately to the north and south, and these destinations are of limited importance. The major destinations in the region or beyond are generally further west, on or close to the A1 (the historic Great North Road). Moreover, the motorway network and the A1 generally offer higher speeds than the rural roads to the north and south of the Humber Bridge, and they are (to date) toll-free. The bridge is therefore an attractive route only for the relatively small amount of traffic between the two banks of the estuary or closely adjoining areas.

This is reflected in the low volume of traffic which uses the bridge. After an initial period in which many people crossed the bridge for its novelty value, daily traffic flows fell to about 4 000 vehicles per day, then rose gradually to 8 000-10 000 vehicles per day by 1984. This compares with forecasts of 24 000 vehicles per day when the bridge was being planned (which would still be barely enough to cover interest payments on the out-turn cost). The Working Group did not attempt to go back to the original analyses upon which that those forecasts were based, but it would appear from the summary (Simon, 1984a, p. 17) that the bridge was intended to be in place in advance of large-scale economic and demographic expansion of Humberside which was expected to take place after 1981, and to involve large-scale in-migration from other areas of the United Kingdom. This was not taking place at the time of Simon's 1984 study, and indeed it has not taken place since.

Accessibility

The time and distance savings quoted above imply that the bridge potentially offers very substantial time savings but only for local journeys across the estuary. There are therefore marked possible improvements in accessibility for residents and for activities operating on a local scale, but little gain for firms operating on a regional or larger basis. Moreover, the revenue-maximising basis of the tolls ensures that cost and time savings are, as far as possible, captured by the Bridge Board rather than remaining with the user. The accessibility benefits are therefore very modest.

Employment and regional impacts

The various papers by Simon provide a detailed picture of changes in commercial vehicle operation among firms which were regular users of the bridge in 1982 and 1983. As such, they cover similar issues to the work by Cleary and Thomas on the distribution industry impacts of the Severn Bridge.

The surveys confirmed that the catchment area of the Humber Bridge was limited, with firms from the north bank using it only to reach South Humberside, Lincolnshire and (in a few cases) East Anglia, and firms from the south bank using it only to reach North Humberside and the coast of Yorkshire as far north as Scarborough. This use was associated with:

- Increased market penetration, *i.e.* increased sales to the opposite bank.

- Changes to market areas, although in some cases these were constrained by institutional factors, such as fixed depot service areas which (up to 1984) had not been adjusted to the with-bridge situation.

- Internal rationalisation, *e.g.* closure of depots, or production being consolidated in one location in a way which would not previously have been possible.

The net impact on employment among commercial vehicle operators appeared modest. The firms considered in Simon's survey had reduced their fleets from 1 303 in 1981 to 1 275 in 1984. They had created 146 new jobs and lost 58, making a net gain of 88. Some of these changes were directly attributable to the bridge; some were attributed to reorganisation of other firms (*i.e.* the vehicle operators' customers) as a result of the bridge, others were attributed to other factors such as the decline of the fishing industry.

There are no quantified results available on the overall impact. The discussion of travel and accessibility suggests that the east-west motorway connections are likely to have been more beneficial to Humberside than the bridge. The bridge may have had some local effects (*i.e.* on the distribution of activity between the north and south banks) and may have contributed to some economies of scale in local activities. In this last case, the effect may have been to maintain output while allowing employment to be reduced.

Other issues

Funding

The bridge was originally projected to cost GBP 20 million. The out-turn price was GBP 97.2 million. The 75% contribution to finance made by the Ministry of Transport was to be paid back by the Humber Bridge Board over 60 years after a 13-year grace period, and the balance was financed through commercial loans.

Tolls were from the outset set at levels intended to maximise revenue. The resulting income has covered operating costs but has never been sufficient to cover interest charges, let alone to repay the capital borrowed.

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UNITED KINGDOM

THE M62 MOTORWAY – LIVERPOOL TO HULL

Purpose and context

The M62 Motorway extends 107 miles (approximately 175 km) across Northern England from Liverpool on the west coast nearly to Hull on the east coast. The first two-mile section opened in 1966, and the final section in 1976. The key section over the Pennines providing the first motorway-standard link between Lancashire and Yorkshire opened in 1971. The detailed chronology of the different sections is given in Judge (1983, Table 4.1).

The aims of the M62 were to provide an all-weather route across the Pennines linking the conurbations of West Yorkshire and Southeast Lancashire, and by extensions to the west coast at Liverpool and the east coast at Hull, to link all three conurbations and Humberside to each other and to major west and east coast ports (Dodgson, 1974, p. 75).

The M62 was planned as a key part of the UK inter-regional motorway network. However, it also serves as an urban motorway within the West Yorkshire conurbation and, to an even greater degree, within the Greater Manchester conurbation, where it forms the northern side of the soon-to-be-completed Manchester Motorway Box.

The eastern extremity of the M62 runs along the north bank of the Humber. The relationship (or lack of it) between this and the Humber Bridge is noted in the Case Study on the Humber Bridge.

Method and timeframe

Analyses of the impacts of the M62 have been carried out mainly by a number of academic researchers, all of them from institutions within the M62 corridor. The most widely referenced is that by Dodgson (1974). Although this is often quoted as an *ex-post* study, it was largely completed in 1972, before the motorway itself, and Dodgson's model-based analysis made no use of post-motorway survey data.

A true *ex-post* study, making use of before-and-after data (mainly on traffic flows) was carried out by Gwilliam and Judge (1978); our review is based mainly on the material published as Judge (1983). This makes reference to two detailed studies on firms in particular areas (Chymera, 1976; Thornton, 1978).

Finally, Cambridge Economic Consultants' (1987) review for the Department of Transport made use of these sources and made their own estimates of impacts, using broadly the same method as for the Severn Bridge/M4 but without carrying out a "full case study" (p. 273).

Survey of specific variables

Travel time and VOC

Judge's paper (p. 66) includes a table of journey time changes for selected zone pairs, obtained from an unspecified computer model. Not surprisingly, the greatest time savings are for Liverpool-Hull journeys, which benefit from the whole length of the motorway. The calculated time for this 129 mile trip fell from 233 minutes on the 1970 network to 189 minutes on the 1973 network (and presumably fell further when the remaining sections of the motorway were completed in the following years). However, similar absolute time savings are reported for a number of shorter journeys, and suggest that much of the time saving came from the higher motorway speeds in the urban areas, particularly around Manchester.

There is no particular information on cost effects, although it should be noted that savings would relate to the avoidance of slow and congested urban roads in the conurbations and of slow and hilly rural roads across the Pennines.

Induced traffic

Judge (pp. 69-72) includes results from screenline traffic counts on Trans-Pennine roads from 1970 to 1977. These are summarised in Table IV.5.

Table IV.5. **Trans-Pennine screen-line weekly flows, 1970-77**

	1970	1971	1972	1973	1974	1975	1976	1977
Northern routes	168.9	173.0	176.3	163.7	161.7	164.2	161.9	158.9
M62	0.0	43.1	174.0	179.4	195.6	285.8	286.2	286.7
Other central routes	205.7	172.6	112.8	100.8	121.3	102.9	102.9	106.2
Southern routes	69.6	70.0	55.1	50.3	49.5	42.3	48.6	44.6
Total, all routes	444.2	458.7	518.2	494.2	528.1	594.2	599.6	596.4
All routes excluding M62	444.2	415.6	344.2	314.8	332.5	308.4	312.9	309.7

Note: Northern routes are from West Yorkshire to Central Lancashire and points further north-west; central routes are from West Yorkshire to Greater Manchester; southern routes are from South Yorkshire to Greater Manchester.
Unit: Two-way automatic counts (axles/2).
Source: Adapted from Judge (1983), Table 4.3 (p. 71).

The total line shows that over the seven-year period, Trans-Pennine traffic grew by 28%. Judge quoted figures from the Department of Transport's Rural Roads Traffic Index, which showed a 25% growth over the same period. This suggests either that the M62 had a fairly small effect on traffic generation and distribution, or that the Index reflected substantial generation and redistribution (to longer journeys) as a result of motorway and other main road building throughout the country. Further analysis would be needed to establish which of these was the case. However, Judge quotes results from interview surveys on the screenline in 1970 and 1973 (p72) which showed that average journey time fell only marginally, from 86.9 minutes to 85.1 minutes, while average journey distance increased from 46.6 miles to 61.6 miles. These figures tend to suggest a very significant generation or redistribution effect.

Gwilliam and Judge (1978) estimated traffic models based on the partial matrices obtained from the Pennine screenline, and attempted to use these to disaggregate post-opening traffic changes into diverted and generated effects. Their intention was apparently to deduce land-use or economic impacts from the traffic generation effects. Not surprisingly, given that they had data only for the cross-screenline traffic, their analysis was inconclusive, although it tended to suggest that any development effects were small (see CEC, p. 287).

Accessibility

Dodgson calculated an indicator of the saving in the average cost of transporting a one-hundredweight (approximately 50 kg) consignment of a neutral commodity to the destinations likely to be served from each origin. The effect of the M62 (shown in Dodgson, 1974, Table 3, p. 87) was to reduce this indicator by a small percentage. The greatest reductions were around 3.5% for towns close to the Pennines and to the mid-point of the M62.

Employment and regional impacts

Direct effects

CEC (1987, pp. 275-276) estimated the direct employment generation effect from the construction of the motorway as 18 000 person years of employment over the ten-year period.

They also estimated that the annual maintenance of the M62 generated about 127 net additional jobs, after allowing for displacement of traffic and hence of maintenance from other local roads.

Short-term induced impacts

Dodgson used a model to estimate the "absolute maximum" impacts of the M62 over a five-year period, for each of some 30 areas.[8] The total effect is quoted (p. 88) as approximately +2 900 jobs per year over five years, or some 14 500 jobs in total. This would amount to an increase of 0.4% over the base total employment population of 3 400 000. The results contained in Dodgson (1974, Table 3 and Appendix 1) suggest that his local forecasts show largest absolute increases in the main urban centres – Liverpool, Manchester, Bradford and Leeds – but slightly large percentage increases in smaller towns even closer to the mid-point of the M62, such as Huddersfield.

Limited empirical evidence was obtained by Chymera (1976) and Thornton (1978). According to the summaries in Judge (pp. 67-68), Chymera studied the experience of the Euroway Industrial Estate in Bradford, adjoining the M606 which links Bradford to the M62 proper. This was intended to accommodate businesses employing some 2 500 people. By 1976, it had attracted some 20 firms but employed only about 300 people, mostly in retailing and warehousing. Thornton looked at new firms located in the Bradford area over the period 1973-77. Only five firms were identified, whose reasons for location were mainly to do with labour factors rather than with transport. Indigenous firms which had expanded were also surveyed and reported that transport was generally a minor factor in their decisions.

Longer-term effects

CEC considered longer-term induced effects in several categories.

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8. Somewhat curiously, Dodgson's zones extended as far north as Carlisle but not as far east as Hull.

For indigenous manufacturing industry, they applied the same cost-elasticity based approach as in South Wales, with different assumptions as to the scale of cost reduction, giving an estimate of 3 670 additional jobs due to cost savings and resulting increases on competitiveness.

For industrial relocation, they drew on survey results to estimate the significance of the motorway network as an influence on relocation, and applied this to known data on the number of firms moving into the regions in question. This gave a result of about 1 500 newly located manufacturing jobs attracted by the M62 over ten years (Table IV.6).

Table IV.6. **The impact of the M62 on access costs and employment growth**

Area	Access costs (in GBP)			Total 1961 employment (in thousands)	Possible employment increase due to the M62 (over a five-year period)	% change in employment
	Pre-M62	Post-M62	% change			
Leeds	0.98	95	-2.56	287	1 380	0.5
Bradford	0.98	94	-3.59	238	1 520	0.6
Wakefield	0.97	95	-2.07	63	250	0.4
Halifax	0.98	94	-2.59	86	480	0.6
Huddersfield	0.96	93	-3.65	101	650	0.6
Dewsbury	0.97	94	-3.09	87	560	0.6
Five Towns	0.99	97	-2.53	56	270	0.5
Barnsley	0.97	97	0	114	0	0
Sheffield	0.96	96	0	355	0	0
Doncaster	0.99	99	0	128	0	0
Stockport	0.94	93	-1.60	83	200	0.2
Ashton	0.94	92	-2.66	82	330	0.4
Oldham	0.94	0.92	-2.66	124	490	0.4
Rochdale	0.95	0.92	-3.16	64	360	0.6
Manchester	0.92	0.91	-1.63	680	2 180	0.3
Bury	0.95	0.93	-2.12	54	220	0.4
Bolton	0.95	0.94	-1.58	118	380	0.3
Leigh	0.96	0.94	-2.08	68	270	0.4
Wigan	0.97	0.94	-2.59	73	350	0.5
Warrington	0.96	0.93	-2.62	78	370	0.5
Blackburn	0.99	0.99	0	115	0	0
Burnley	0.99	0.99	0	118	0	0
Preston	1.00	0.99	-1.00	143	230	0.2
Blackpool	1.07	1.06	-0.47	93	150	0.2
Barrow	0.12	1.19	0	43	0	0
Lancaster	1.07	1.07	0	47	0	0
Liverpool	0.98	0.95	-2.56	671	3 220	0.5
Birkenhead	0.98	0.96	-2.04	116	460	0.4
Workington	1.22	1.22	0	62	0	0
Carlisle	1.17	1.17	0	63	0	0

Source: Dodgson (1974), Table 3 (p. 87) and Appendix I (pp. 90-91).

CEC found no evidence that the M62 had encouraged development in either the wholesale or retail distribution. They therefore arrived at a total of just over 5 000 jobs directly generated or induced, which was then almost doubled by application of multipliers and other long-term consequential effects (Table IV.7).

Table IV.7. **Summary of employment impact of M62 on the North West and Yorkshire and Humberside regions**

	Number of jobs
Employment generated by maintenance (gross)	190
Displacement from rest of road network	63
Net additional jobs	127
Impact on indigenous manufacturing firms	3 670
Impact on location of new manufacturing firms	1 500
Sub-total	5 297
Total after application of short-term regional income multiplier (1.35)	7 151
Longer-term impact on employment in house-building, public services and infrastructure	2 860
Grand total	10 011

Source: Cambridge Economic Consultants.

CEC's note included as an Appendix "a summary of previous work on the impact of the M62 motorway". This describes the Dodgson study as "relevant despite its concentration on a mainly theoretical evaluation", but does not comment on the comparison between the two sets of results. It seems only fair to add that parts of CEC's analysis are just as "theoretical" as Dodgson's, if not more so.

Other issues

Funding

The motorway was funded by central government as part of the national roads programme. Use of the motorway has always been free to users, although the possibility of charging tolls on this and other motorways has been discussed and studied in recent years.

CEC (1987) estimated that the capital cost of the motorway was "of the order of GBP 412 million at 1985 prices" (p. 275).

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UNITED KINGDOM

M40 MOTORWAY – LONDON TO BIRMINGHAM

Purpose and context

The M40 from London to Oxford was completed in 1973. Its continuation from Oxford to Birmingham opened in 1991, creating a second motorway route from London to the West Midlands (the first being the M1/M6, which opened in the 1960s).

In contrast with the other UK case studies, the area through which the southern M40 passes is highly prosperous. One of the key points developed by the studies discussed below is that although the M40 was not seen as an investment to promote development and economic growth, it has nevertheless had such effects.

Method and timeframe

This review is based on a report prepared by Headicar and Bixby (1992) for the Council for the Protection of Rural England – a charity and pressure group which lobbies for the care and improvement of the English countryside. The subtitle of the report, "Local Development Effect of Major Roads – M40 Case Study", is an accurate reflection of the report's content. It is not an impact study in general, but rather an analysis of the way in which the planning and building of major roads affects the local development process – which in turn has an important influence on local economic impacts.

Survey of specific variables

Travel time and VOC

The study is not concerned with measuring transport and accessibility effects in the conventional form. Rather, it emphasises two different local effects of motorway building (p. 55).

Employment and regional impacts

Firstly, the motorway alters the local topography, creating a major new division in previously open countryside and, in many cases, leaving a relatively narrow strip of countryside between the road and existing urban areas.

Secondly, the motorway changes the nature and pattern of accessibility within the motorway corridor such that:

- Certain types of development requiring large catchment areas (*e.g.* major shopping centres) become feasible.

- The focus of accessibility, in the minds of the car-owning population and of developers, shifts from the traditional town centres to the motorway intersections.

Detailed local case studies considered by Headicar and Bixby demonstrate that the combination of new physical divisions (the motorway itself), new patterns of accessibility and new pressures for development have brought about:

- Development on greenfield sites not identified for development before the motorway was built.

- Radical changes in the pattern of development.

- The generation of additional traffic on the motorway or at motorway intersections, undermining the original accessibility improvements and creating pressure for further investment in the highway network.

Headicar and Bixby found that national designations of areas for development restraint – in the M40 case, the [London] Metropolitan Green Belt and the Chilterns Area of Outstanding Natural Beauty – seemed to have been remarkably effective: "no significant development had taken place in contravention of [these] national policies to protect the areas of open land referred to". It is, however, well known that such policies, combined with improvements in accessibility brought about by (in this case) a motorway, can lead to considerable pressures on the housing market and the planning system in immediately adjoining areas – for example, long-distance commuters increasing the demand for housing in attractive villages and pricing out local residents.

Headicar and Bixby identified two additional factors, apart from the motorways' creation of new land divisions and new patterns of accessibility, which could explain why sites close to motorways[9] are particularly attractive to developers. The first is the value of a site which is visible to large numbers of passing motorists. Secondly, the noise and pollution generated by the motorway traffic may mean that adjoining areas become unattractive as sites for housing and suitable only for industrial or warehousing uses, for whom noise and pollution are relatively unimportant, or for large-scale commercial uses which can afford to "design out" the problems.

The specific developments studied by Headicar and Bixby shared a number of characteristics:

- Development took place on land which was unlikely to have been developed had the motorway not been built.

- Developments were more intensive than was initially anticipated.

- Development consists of uses with high car-parking and traffic-generation factors.

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9. More precisely, to motorway intersections – few if any developments in the United Kingdom have been allowed to create their own points of direct access from any motorway.

In each of the three major cases studied, the size and shape of the area developed appeared to be entirely a function of engineering considerations in the design of the motorway, not of planning considerations.

Both the economic and the planning context of the northern extension of the M40 were very different (pp. 61-62). In economic terms, being further from London, the pressure for development is less. The motorway was planned as a complete long-distance route, and the line was fixed some 15 years before construction took place, allowing the local planning process ample time to make plans which explicitly took account of the new road in identifying the amount, type and location of future development. The main limitation in this is that the time horizon of local planning – 10 to 15 years – is relatively short (shorter than the 20+ years which most analysts would agree to be the time needed for the impacts of the motorway to become fully apparent). There is also an element of risk that investor interest in motorway-related land with fewer protective designations, coupled with economic growth and increasing housing demand, may lead to development pressures on a much greater level than the planning system has foreseen.

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UNITED KINGDOM

A55 – NORTH WALES EXPRESSWAY

Purpose and context

The project in question has created a dual-carriageway east-west road close to the North Wales coast. Some of this has been achieved by a complete rebuilding of existing roads, but much of it is new. Some sections are literally “coast road”, running between cliffs and the sea; others are several kilometres inland.

Congestion at certain points on the North Wales roads led the Welsh Office to commission a study in 1966. The resulting report was published in 1968 and recommended the construction of an east-west dual-carriageway road by-passing the urban centres.

The proposals were developed further in 1969-71, and were the subject of a public inquiry in 1975-76. Objections made at the inquiry led the Welsh Office to agree to reduce the environmental impact of the road by building three tunnels that were not part of the previously proposed designs. The most expensive of these involved the building of a submerged tunnel under the Conwy Estuary which the road was originally proposed to cross on a viaduct and bridge which would have changed both the landscape and the background of Conwy Castle.

Method and timeframe

An impact study was carried out by the Welsh Economy Research Unit (WERU, 1996) of the Cardiff Business School for the British Road Federation. The A55 was also one of the subjects of the 1980 Welsh Office study (see Case Study on the Severn Bridge), but at the time the improvement of the road was far from complete and survey work was directed to respondents’ expectations of what would happen, not to their experience of what had already changed. (At the time it was envisaged that the comprehensive improvement of the route would be completed “by the late 1980s” – p. 1, para. 1.1.)

Survey of specific variables

Travel time and VOC

WERU (p. 1) reports that in 1969 the travel time between Chester and Bangor was between 2.5 and 5 hours; with the completion of the A55 improvements, this was reduced to a much more reliable 1.5 hours.

Induced traffic

The WERU report (pp. 17-19) gives average daily eastbound traffic flows for August of each year from 1987 to 1995 and February of each year from 1989 to 1995, at two points, Old Colwyn (Clwyd) and Penmaenbach (Gwynedd). In both cases, there is a continuing upward trend in both summer and winter, with more rapid growth at the Penmaenbach site. Given that the road improvements completed during the period covered by this data were completed in some ten stages, it is difficult to relate growth to the network changes or to other factors. There is, however, a clear jump in the August figure for Penmaenbach from 1991 to 1992, which WERU attribute to the opening of the Conwyn Tunnel. Curiously, there appears to be a distinct increase from 1991 to 1992 in February traffic at Old Colwyn but not in August traffic.

Accessibility

For most purposes, the main interest in accessibility is eastwards towards the markets and consumers of England. As a result, the gain in accessibility is greater towards the western end of the A55.

The improvement of the A55 from the Chester by-pass to Bangor has, however, concentrated attention on two as yet unimproved links:

- At Queensferry (where eastbound traffic can turn north towards Merseyside and the motorway network of Northwest England).

- The continuation of the A55 north-westwards across the island of Anglesey to the ferry port of Holyhead.

Employment and regional impacts

The WERU study considered economic and employment effects in two ways:

- Through the use of an input-output model.

- Through detailed interviews with a sample of business managers.

The modelling method used are the same cost-elasticity method used by CEC in their estimated for the Severn Bridge/M4 and the M62, but WERU then made explicit use of an input-output model (rather than assuming an overall multiplier effect) to calculate the effects which changes in one sector would have on other sectors.

The modelling is driven by an estimate that “the A55 improvements have reduced the road transport costs of North Wales firms and organisations by 10%; or, equivalently, that their road transport costs would be 10% higher in the absence of the A55 improvements” (p. 25). This is described as “an intentionally modest estimate, but one consistent with the typical experiences of firms consulted in North Wales”.

WERU assumed an elasticity of output to cost of 2, *i.e.* that a 1% increase in total costs would lead in one way or another to a 2% increase in sales and production. Unlike CEC, they explicitly include increases in output due to new firms locating in the area within this effect (p. 27).

The direct effect of this increase, less the decrease in output from the transport sector, is GBP 12.1 million (p. 28). The sectoral components of this were input to an input-output model for North Wales, which was estimated from a recently published input-output table for Wales as a whole (p. 21). The multiplier effects within this model produced an overall impact of the transport cost savings. This was an increase of GBP 20.1 million in output, associated with additional 354 full-time equivalent jobs. The full results are shown in Table IV.8.

Table IV.8. **Estimated impacts of A55 transport cost reductions**

	Output (GBP million)		Income (GBP million)	Jobs (FTEs)
	Initial	Final	Final	Final
Agriculture	0.3	0.8	0.2	21
Energy and water	0.8	1.5	0.2	7
Metals and minerals	5.5	6.1	1.0	43
Engineering	2.2	2.8	0.6	34
Other manufacturing	3.0	4.0	0.9	61
Construction	0.1	0.4	0.2	13
Retail and distribution	3.4	5.1	2.4	161
Transport and communications	-9.8	-9.4	-3.7	-164
Private services	3.1	4.6	1.4	77
Public services	3.4	4.3	2.2	100
Total	12.1	20.1	5.2	354

FTE = full-time equivalent.
Source: WERU (1996).

Questionnaire and interview findings

Manufacturing

Questionnaires were completed by 36 North Wales manufacturers; 16 of these were followed up by interviews. The general findings were that:

- Transport and communications had been markedly improved, especially for firms further west.
- The competitiveness of indigenous companies had improved through better access to both input sources and sales markets.
- However, local firms have been exposed to increased competition from outside; while this would be of long-term benefit to local firms and consumers, it involved a short-term cost.
- Little effect on investment had yet been felt.

The report includes summaries of three interviews – two with manufacturers of processed food, one with a manufacturer of automobile components.

The interviewees all mentioned the effect of the road improvements on both deliveries to customers and inputs from suppliers. Some of the changes in inputs were dramatic – for example, a shellfish processing firm previously dealing only with locally caught shellfish now obtained 50% of its input from other ports, including North Shields on the east coast some 450 km away.[10] What is not clear, in this case or the others, is whether these inputs from more distant sources are additional to or instead of more local inputs, or what effects these changes may have had on other firms. It was, however, noted that some local service suppliers had been forced to become more competitive as a result of the greater ease with which other suppliers could now reach local clients.

Road haulage and distribution

Effects on the road haulage sector were complex, with some local firms finding the road improvements a great advantage, some (operating on a European scale) finding them of little relevance, and others perceiving a threat that the elimination of problems would encourage national operators to move into the area rather than subcontracting work to local firms.

The A55 is critical as the dominant road link to Holyhead, which in turn is a major port for Irish imports/exports to the United Kingdom and the rest of the European Union. The extension of the A55 improvements across Anglesey to Holyhead was seen as important both by North Wales and by Irish distribution companies.

Tourism

The impact on tourism was seen as somewhat mixed. To some extent, the road has encouraged visitors to make day trips rather than staying overnight in the area, with a marked reduction in the amount they spend per person and in increase in traffic problems, particularly in the mountainous Snowdonia area. The resort town of Llandudno, in contrast, was seen as having gained from the combination of:

- Better access for tourists arriving from the east (more likely to bypass the other coastal resorts).
- Better access into Snowdonia (via the Conwy tunnel and the A55 to Bangor) makes Llandudno more attractive as a base for visiting the area.
- The town is several kilometres from the A55 itself and is therefore unaffected by traffic noise and pollution (unlike Colwyn Bay, where the A55 runs between the town and its beach).

Other issues

Funding

The WERU report gives the total estimated cost of the road as GBP 732 million. This appears to be the historic cost of some 25 different stages built over a 25-year period. As far as we aware, all of the cost was met by central government.

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10. Note that such inputs would be dependent not only on the A55 improvements but also the M62, the M6 and the A1.

Health effects

The development of the A55 has had a number of effects on the provision of health services for the population of North Wales. A number of hospital developments were planned in advance to take advantage of the road improvements. The greater ease of access between settlements along the North Wales coast made it much easier to refer patients for treatment in other towns' hospitals. It was also now possible for local patients to attend specialist clinics in Liverpool or Manchester without needing to spend a night away, and likewise visiting consultants were less likely to need to stay overnight. It was also argued that better access to the north-west conurbations made it easier to attract key personnel.

Crime impacts

A number of interview respondents apparently commented that the main negative impact of the A55 was the increase in attention from English criminals. WERU compared crime rates in North Wales with those for the United Kingdom and found that the increase in total recorded crime in North Wales over the period in question was no greater than that for the United Kingdom in general. No breakdown by type of crime is given. Discussions with North Wales Police confirmed that a high proportion of certain offences, *e.g.* burglary, were committed by persons from outside the immediate area, but it was not possible to say whether the A55 had led to any particular change in this proportion.

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UNITED STATES

APPALACHIAN DEVELOPMENT HIGHWAYS ECONOMIC IMPACT STUDY

Purpose and context

The US Congress established the Appalachian Regional Commission (ARC) in 1965 to promote economic and social development of the Appalachian Region located in the Eastern United States. The Region includes all of West Virginia and portions of 12 other states extending from Mississippi to New York.

Since 1965, funding in excess of USD 15 billion has helped provide highways, hospitals, land conservation programs, mine land restoration, flood control and water resource management, vocational education facilities and sewage treatment to the 21 million residents of the 399 counties in the Appalachian Region.

A key programme of the ARC is the Appalachian Development Highway System (ADHS). Federal funds are used to compliment state and local highway spending to improve access to areas with development potential. At the time the study was done, Congress had authorised 3 025 miles of ADHS network improvements. By 1998, about USD 4.6 billion had been spent on the ADHS and about 75% of the network mileage was either complete or under construction, mostly to four-lane standards. It is estimated that the cost of completing a fully built 3 440 mile ADHS will approach USD 8.5 billion.

The main objective of the study is to gauge, in retrospect, the extent to which completed portions of the ADHS have contributed to the economic well-being of Appalachia. The reasoning is that if completed corridors have succeeded in attaining economic development and social enhancement objectives then investment in the remaining ADHS corridors might be similarly successful.

Importantly, the US Interstate Highway System built in the 1950s and 1960s largely bypassed the Appalachian Region, going through and around the Region's rugged terrain as cost-effectively as possible. The ADHS network consists of 26 corridors, designed to: *i)* link key locations in the Region to Interstate highways and markets in other regions of the country; *ii)* provide efficient flows through the Region connecting markets on either side (east and west) of Appalachia; *iii)* facilitate commutation to jobs and public services within the Region; and *iv)* open up areas with potential for recreational development.

Method and timeframe

The study provides an *ex-post* evaluation of 12 of the 26 corridors comprising the ADHS. The 12 corridors were completely or principally built (*i.e.* 75% or more of the end-to-end corridor length completed) and open to traffic on 1 January 1995. These corridors occur in ten of the 13 states and have a combined length of 1 417.8 miles.

Since the corridors are already built and open to traffic, locations and alignments, construction costs, traffic volumes and other physical and performance characteristics are known. However, an *ex-ante* or historical base case for each corridor is needed to estimate the change in travel efficiency benefits. A "without ADHS" or base-case scenario for each corridor is defined by the existing regional highway system, excluding all ADHS improvements. Various sources were used to characterise the road system before the ADHS improvements were made; where detailed historical data are lacking, professional engineering judgements are used.

ARC's analysis covers the period 1965-2025. Life-cycle costs and benefits have been estimated. A minimum 30-year corridor life-cycle analysis was deemed necessary. However, because some corridor segments were authorised and built as early as 1965, some corridor segments can reflect as much as a 60-year life-cycle analysis period.

It is important to note that the study separately quantifies two kinds of "economic" effects. Corridor "travel efficiency benefits" and regional "economic development impacts". To avoid double counting, categories included in "efficiency benefits" and "development impacts" should not be added together. "Travel efficiency benefits" accrue to road users from travel time saving, reduced accident rates and lower vehicle operating costs. Travel efficiency improvements benefit both local traffic and through traffic. Travel efficiency benefits reported are for all road users combined, because they are net benefits to society as a whole and of interest to Congress and the ARC. However, only local resident (local traffic) benefits are used when travel efficiency benefits are used as inputs to the calculation of "development impacts".

"Economic development impacts", are calculated for the Appalachian Region. This part of the study relies heavily on the REMI economic model. REMI is a privately owned and developed inter-regional econometric model. It is a dynamic input-output model that allows interactions among industries and offers several advantages over static I/O models. For example, wage estimates are responsive to labour market conditions, population migration is a function of the expected income levels, and business shares of local and export markets are responsive to changes in regional profitability and export costs. In general, the REMI model accounts for the fact that the degree of economic development associated with highway investment varies depending on the stage of total socio-economic development in the primary impact region.

Primary impact areas are analysed using the REMI model. Primary impact locations are defined as those counties through which one of the 12 selected ARHS corridors passes, plus those counties that lie within a ten-mile buffer of the corridor. Accordingly, the analysis covers 165 of the 399 counties in the Appalachian Region. Primary impact areas are mostly rural but may contain small cities and towns. Major urban areas in the Region (*e.g.* Atlanta, Pittsburgh and Cincinnati) are classified as non-primary impact counties. Also, the study assumes economic development impacts are a transfer effect nationally, although this is not necessarily the case.

Although travel efficiency benefits and economic development impacts are estimated separately, this does not mean that efficiency benefits accruing to road users and economic development impacts (in terms of changes in employment, population, wages, and value added product) are not related. In particular, business travel efficiency benefits (after adjustment for in-area *vs.* through-area users) are distributed across industries as production cost savings. Once these values are placed into the REMI model, the model calculates the effect of these savings as a competitive advantage impact. That is, the amount of new business in the region attributable to the increased competitive position of industries within the region. Similarly, non-business vehicle operating cost savings result in an increase in disposable income, which is also evaluated in a general equilibrium framework.

Several other economic impacts related to travel efficiency benefits are identified and evaluated. For example, as traffic volumes increase so do the number of roadside service establishments and total expenditures on roadside services. Increases in roadside expenditures are entered into the REMI model which traces the economic repercussions of such expenditures. Another impact involves the influence of ADHS infrastructure on tourism. The economic impacts attributable to increases in tourist spending and the income effects of road construction and maintenance expenditures are similarly calculated using the REMI model.

Survey of specific variables

Travel time and VOC

There are three ways to reduce travel time: *i)* reduce trip distance; *ii)* increase travel speed with design standards; and *iii)* reduce congestion (or make it easier to pass slower vehicles) with additional facilities. The methodology used to calculate travel time saving recognises variations due to design, speed limits and level of congestion. Travel times on specific segments also vary with type of vehicle and grade. Monetary values used are: *i)* USD 16.50/hour auto (business use); *ii)* USD 7.64/hour auto (non-business use); *iii)* USD 21.48 to USD 28.95/hour truck depending on type. Travel time saving is the dominant type of efficiency benefit in the study.

Only use-related operating costs of motor vehicles are included in the analysis. Vehicle operating costs vary with length and number of corridor segments, speed on different segments, and type of vehicle. Extra costs arising from speed change cycles due to road geometry and type of vehicle are also calculated. Savings can be negative on some corridors if travel distances lengthen and/or operating speeds increase to less economical (higher fuel consumption) levels.

Safety

Accident costs savings estimates are based on national average injury rates by accident type and highway type. Monetary values used are; USD 2 854 000 per fatality, USD 654 000 per serious injury, USD 20 600 per other injury, and USD 1 800 in property damage (vehicle only). Estimates do not account for accident risk reduction due to improvements in roadway curvature and grades. Monetary costs savings can be negative on corridors where trip distance is lengthened, induced traffic occurs, and when change in functional classification due to the improvement is slight.

Induced travel

Realised travel is reported. Exhibits summarise minimum, maximum and average annual daily traffic (AADT) in each corridor. Annual hours of travel are given. Vehicle-miles of travel (VMT) for cars and trucks is by corridor and for different points in time. A traffic model was developed by the contractor to estimate traffic and travel data required to analyse future economic impacts of corridor improvements. Beginning year traffic volumes are based on historical traffic counts. Future estimates (30^{th} year) are based on historical growth trends, forecast population growth, and forecast changes in vehicle-miles of travel per person. Travel time and speed were also forecast, recognising that travel time varies according to level of congestion (*i.e.* induced speed change cycles) and by type of vehicle.

Reliability

Travel time variability is implicit in the analysis of efficiency benefits. However, the frequency and impact of recurring or non-recurring delay is not specifically noted.

Accessibility

Accessibility (potential travel) measures are reported as “corridor characteristics” in the study. Study corridor lengths with and without improvements are given. Improvements can increase trip length in some corridors and reduce trip length in others. Tables and exhibits in the study give minimum, maximum and average number of lanes in each corridor, roadway lane mileage, and climbing lane mileage. A summary of minimum, maximum and average speeds by corridor is given. Roadway type by functional classification is also provided along with roadway curvature and grades. Specific road segment and system capacity indicators are not given but congestion measures (*e.g.* volume/capacity ratios) are used in portions of the analysis and must be available. Connectivity indexes are not reported.

Employment

Reported employment impacts are net changes in number of full-time equivalent (FTE) jobs directly attributable to corridor use, including employment in sectors that indirectly support road users and employment changes in firms that expand or relocate in the region due to competitive advantage. Employment impacts from road construction and maintenance activities are calculated but these job and income benefits are treated differently than other developmental impacts when calculating NPV and rate of return on highway investments.

Efficiency and output

ADHS corridors were designed to access existing Interstate Highways running through the area that provide connectivity to national markets. However, effectiveness of ADHS improvements in meeting this criterion except in terms of road-user efficiency benefits do not appear to have been examined. Total costs, economic impacts and efficiency benefits for the period 1965-2025 (discounted at 7% per annum) are given. Sensitivity testing of 4% and 10% discount rates is also done. Benefit/cost ratios, internal rates of return and net present value estimates are given for road-user economic efficiency benefits and region economic development impacts, the latter with and without construction spending economic impacts added.

Social inclusion

Linkage to Interstate highways and major markets is an ADHS design criterion. Employment and personal income impacts are assessed but not income distribution changes. Cohesion measures are not specifically developed. Certain social benefits are not assessed; for example, the value of access to health care, education, cultural amenities and other social needs are not specifically considered because such consumer benefits are not easily measured in economic terms.

Other issues

Regional distribution

Population impacts attributable to the ADHS and associated with construction, tourism, roadside expenditures and competitive advantage for different points in time are reported. Real estate, land value changes, industry composition and industrial organisation changes (except for the effects of tourism) are not reported. Traffic diversion effects are embedded in efficiency benefits.

Funding

The ADHS is the product of a federal, state and local partnership. Funding to date and cost to complete the system is reported above.

Stakeholder support

Support by Congress, the Federal Highway Administration and the ARC itself is noted. No specific references are made to regional, state or local interest groups in the public or the private sector.

Annex 1

MEMBERS OF THE WORKING GROUP ON EFFECTS OF TRANSPORT INFRASTRUCTURE INVESTMENT ON REGIONAL INVESTMENT

Chairman: Mr. Michael Walsh (United Kingdom)

Mr. Laurent Donato	(Belgium)
Mr. Marc Lemlin	(Belgium)
Mr. Bart Soetemans	(Belgium)
Ms. Sylvie Mallet	(Canada)
Mr. Roger Roy	(Canada)
Ms. Odile Heddebaut	(France)
Mr. Jean Pierre Orus	(France)
Mr. Nicholas Christou	(Greece)
Mr. Francesco Gaeta	(Italy)
Mr. Katsuji Hashiba	(Japan)
Mr. Takuya Seo	(Japan)
Mr. Freddie Rosenberg	(Netherlands)
Mr. Jon Inge Lian	(Norway)
Mr. Toril Presttun	(Norway)
Mr. Ing. Andrzej Urbanik	(Poland)
Mr. Folke Snickars	(Sweden)
Mr. Michael Walsh	(United Kingdom)
Mr. Anthony Ockwell	(OECD Secretariat)

Annex 2

LAND-USE IMPACTS OF TRANSPORT INFRASTRUCTURE

Paper prepared for the Department of Environment, Transport and the Regions, United Kingdom

This Annex provides the results of a consultancy commissioned by the DETR to investigate the potential economic and social responses to transport change. The conclusion of Simmonds Consultants is that, although there is a good understanding of these relationships, it is generally better in concepts than in details. The ability of LUTI models to operationalise this understanding is uneven but is making progress, particularly where it is drawing on the results of other research in economics and geography rather than developing in isolation. There is a need for further work particularly in the representation of businesses and business decisions. This applies to freight transport in general as well as to land-use/transport interaction.

Consideration and generalisation of model results is limited by the shortage of published results, the difficulties of comparison and the general lack of detail in the available outputs. However, the material does suggest that available models, even in their simpler forms, can generate results which are complex enough to encourage discussion and debate. Many would argue that this, rather than the production of absolute forecast numbers, is the real and proper function of models, and on this basis the progress of LUTI models seems encouraging. The present debates about the influences of transport on regional development, and about how to forecast their impacts, should lead to further valuable developments.

This report has been prepared by David Simmonds Consultancy. The work reported herein was carried out under a contract with the Secretary of State for the Environment, Transport and the Regions. Any views expressed are not necessarily those of the Secretary of State for the Environment, Transport and the Regions.

Chapter 1

INTRODUCTION

1.1. Background and outline

This report has been prepared in response to a request from the UK Department of the Environment, Transport and the Regions (DETR), as part of a collaborative exercise co-ordinated by the Organisation for Economic Co-operation and Development (OECD). The collaborative exercise is concerned with the impact of transport change on the development of regions. The objective of the present report is to consider the relevance of what are traditionally called "land-use/transport interaction models" to the analysis and appraisal of such impacts.

This report as structured as follows. After this introduction, which deals with some questions of definition and scope, the overall approach is first to consider why transport matters to regional development and land use, and then to consider how land-use/transport interaction models deal with this linkage and what they can tell us about it.

The question of why transport matters is set out in Chapter 2. The discussion of land-use/transport interaction models is split into:

- A discussion of the key characteristics of land-use/transport interaction models available (Chapter 3).
- A summary of the main models, for which published results are available, attempting to consider their general findings about the regional impacts of major transport changes (Chapter 4).
- An outline of the strengths and weaknesses of these models (Chapter 5).
- And, finally, comments on the implications of LUTI modelling for the economic appraisal of transport schemes and other interventions (Chapter 6).

We conclude with some remarks about the usefulness and future development of land-use/transport modelling and its application.

1.2. What do we mean by "land use"?

We must make it clear at the outset that the term "land use" is used throughout this report to mean something much wider than simply considering what types of buildings and what categories of activities occupy each parcel of ground. "Land use" in this context refers to the whole range of human activity and of the built environment, and to some aspects of the natural environment, outside the transport system itself. We comment later on which aspects of "land use" are considered or omitted in current "land-use" models.

1.3. The scope of this report

This report is concerned mainly with impacts of major transport schemes at the "regional" level. This means that we are focusing on the impacts of changes in transport between regions and between major urban areas. This focus extends upwards to include changes in international transport, and downwards to include the impacts of transport on the total economic activity of cities. We exclude the impacts of transport on the distribution of economic activity within cities. Such urban impacts come about through different processes of change from those at the "regional" level. The differences between urban and regional level processes are discussed in Section 2.7.

Chapter 2

HOW DOES TRANSPORT AFFECT LAND USE AT THE REGIONAL SCALE?

2.1. Introduction

"Land use" as defined in Section 1.2 is of relevance to "transport" for at least three reasons:

- Land-using activities and the interactions between them generate the demands for transport.
- Those activities and interactions are to a greater or lesser extent influenced by the availability of transport.
- The linkages between transport and activities may be important to the appraisal of transport strategies – especially when trying to consider whether the transport system is providing the kinds of accessibility that activities (*i.e.* people and businesses) require, rather than simply providing mobility.

Figure 1 illustrates the role of transport in relation to the different groups of people and organisations which are influenced by transport. It identifies three main categories of actors:

- The population, as individuals and as households.
- Firms and other productive organisations.
- Government (as a consumer of goods and services, of labour and as an occupier of property; we exclude for the moment the role of government in controlling, taxing or initiating other activities).

In addition, we identify three particular categories of actors of special interest:

- Property developers.
- Transport infrastructure providers.
- Transport service providers (*e.g.* public transport operators), which may be special cases either of firms, or of government activity, or both.

The lines on the diagram show the major interactions between different categories of actors, classified so as to identify the main "markets" in factors, goods and services. The directions of the arrows on the diagram are such that:

- The arrowheads show the delivery of a factor, good or service.

- Payment for that factor, good or service goes in the opposite direction to the arrow.

Information also flows in both directions along each of the relationships indicated by arrows. This represents the often very partial information which people and firms obtain from their interactions with the market. Other information is obtained in other ways, which may themselves involve purchasing goods and services (newspapers with job and property advertisements, market research surveys, consultants' reports, etc.).

The five markets are, from top to bottom of the diagram:

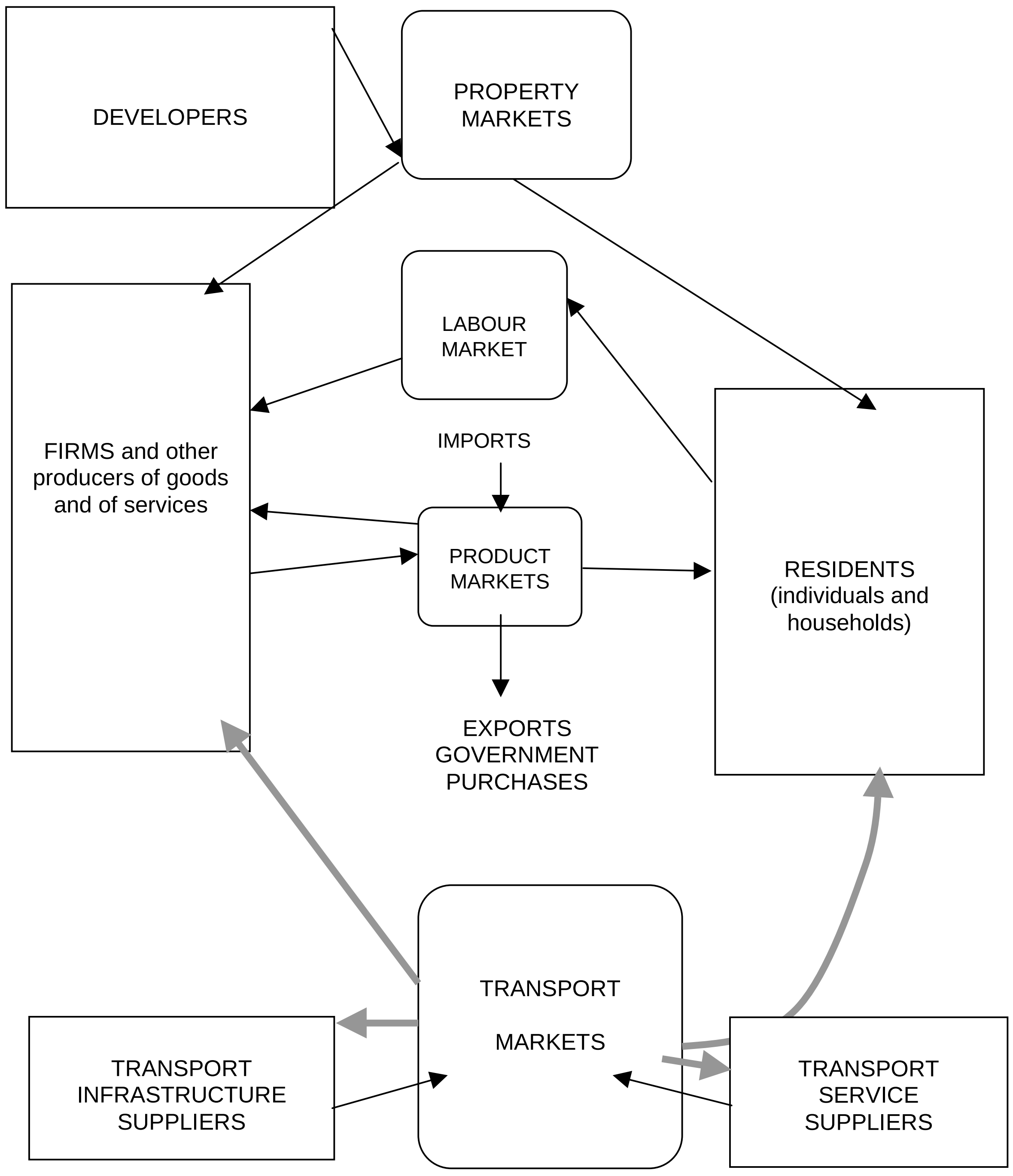
- The financial market(s).
- Property markets.
- Labour markets.
- Product markets (including both goods and services).
- Transport markets.

Note that the first three of these are markets in the conventional factors of production (capital, land and labour), and that the markets in transport are a special case of the markets in services. We have not attempted to separate categories of goods and services that are delivered via non-market mechanisms, such as public (state) education, and there are other whole sub-systems, such as taxation, welfare and benefits, which affect the behaviour of actors. The scope of the diagram as it stands is that which seems helpful to the discussion of "land-use/transport interaction models". For this discussion, we have however included the possibilities that products may be:

- Exported.
- Consumed by the government.
- Used in fixed capital formation (the arrow from product markets to the "invest" action of producers), and also that they may be supplied to the economy under consideration by imports as well as by local production.

"Land use", as understood here, includes all the elements and interactions in Figure 1 outside the area labelled "transport". It also includes environmental effects, which we have not attempted to include in the diagram.

Figure 1. **Actors and markets**



Transport influences the decisions of residents and firms in a number of ways, which we consider in more detail below (see Section 2.5). Residents and firms interact with each other through a number of markets, mainly:

- Property.
- Labour.
- Goods and services.

Through these interactions, changes in transport may have indirect impacts on people or businesses which have no direct interest in the transport change at all. We may therefore need to consider not only predicting the land-use consequences of transport change, but also the implications for prediction and appraisal of the ways in which the influence of transport is passed on through the interactions of different actors.

It is important to recognise that the "land-use" system is never static, and that "transport" is only one of the factors that influence how it changes. The treatment of all the other factors –demographics, the workings of the development process, etc. – are among the things which distinguish the different approaches to land-use modelling reviewed below.

The following points also need to be noted in order to clarify the scope of the following discussion:

- The land-use impacts of a transport change may extend far beyond the spatial scope of the transport proposal itself – they can extend at least as far as the area in which the transport change affects accessibility, and secondary effects may extend further.
- A great deal of locational change takes place through changing occupation of land and existing buildings, with changes in either the density or the nature of the occupation (for example, one type of business replacing another).
- The value of property is an important influence on its occupation; if improvements in transport influence household or business decisions so as to increase the demand for space in a particular location, the resulting increases in prices or rents may affect households or businesses who have no direct interest in the transport change itself (and possibly no knowledge of it).

It follows from the above points that in many cases changes in composition are likely to be more significant than changes in totals; for example, changes in provision for commuter travel may have a significant impact on where the working population and its dependants live, but a much smaller impact on the distribution of the total population (as households without workers move into the areas that the workers are leaving). It also follows that significant land-use effects may occur within the market for existing property, with no new development and no formal change of use, and therefore beyond the control of the planning system and the record of conventional land-use statistics.

It should also be noted that "regeneration", "socio-economic impacts", and so on, are all particular cases of what are here referred to as land-use effects.

2.2. Actors, decisions and markets

We expand Figure 1 into Figure 2 so as to identify the main types of decisions made by the different categories of "actors".

For clarity, we have not attempted to show within the diagram that many individuals are actors in more than one category; for example, self-employed persons are producers as well as residents, and many residents are also investors. Note also that one of the most important "actors", government of all levels, is omitted, except in its role as a consumer, even though its intervention through regulation, taxation and investment is an actual or potential influence on almost all the decisions considered. Much of the development of operational models has been led by the need to consider the impact of such interventions, given the behaviour of all the other actors involved.

2.3. Transport demand

The bold lines linking the transport market to the rest of the system emphasise that transport is generally a "derived demand", derived from interactions in some other aspect of the economy. In the diagram, the derivation of demands is split into five segments:

- Transport demands associated with product markets, that is, with the delivery of goods and services (through the movement of goods and persons, including consumers going to purchase goods or services) to intermediate or final consumers.

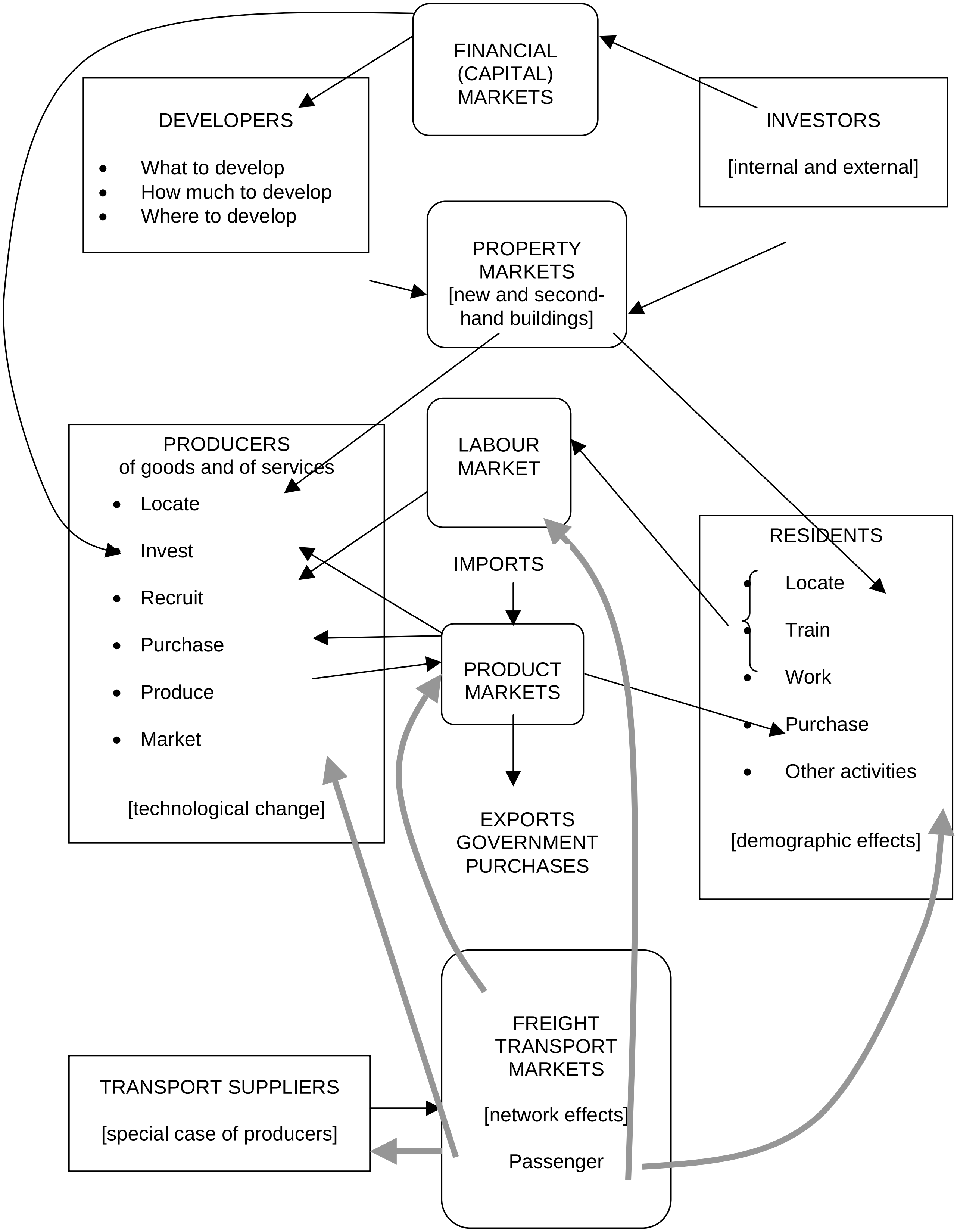
- Transport demands associated with labour markets (mainly the movement of persons travelling to work).

- Other travel demands associated with the activities of producers – these represent all business demands, mainly for passenger travel, not directly associated with trade in goods or services (travel to conferences, to internal company meetings, to meetings with regulatory bodies, etc.).

- Residents' travel demands other than travel to work or to obtain goods and services (*i.e.* all other personal travel).

- Transport demands associated with transport supply itself (*e.g.* the significant proportion of rail freight which is generated by maintenance and renewal of the railway itself).

Figure 2. **Actors and markets: the decision-making cycle**



Tourist travel can appear in various ways in this framework, either as a derived demand for a commercial service or as part of the "other" demand for personal travel. In some tourism, the journey itself is an integral part of the "good" consumed and is demanded in its own right rather than as a derived demand. While the segments of the travel market in which this is the dominant motivation are fairly distinct (cruises, rail tours over especially scenic routes or by historic trains, etc.), it should also be kept in mind that the experience of travel is part of the good consumed for a much larger part of the leisure market – and possibly for some of the business sector.

2.4. Business decisions

The bullet points listed under some of the "actor" headings are general descriptions of key types of decisions that have to be taken by these categories of actors. The conduct of business by producers is generalised into:

- Where to locate the business unit.
- Investment in the unit – how much to invest, in what equipment.
- Recruitment – what categories of staff to employ, how many, for what hours, at what wage rates, etc.
- Purchasing – what intermediate goods and services to purchase, from whom.
- Production – how much of what to make and when.
- Marketing – which markets to try to sell in, what to do to achieve this, etc.

Many decisions, particularly major ones, will of course deal simultaneously with most or all of these areas. The classification does, however, seem to be helpful in relating organisational response to different markets in goods, services and factors of production, and in relating model-building to other research conceived in terms of market behaviour and particular kinds of decision making.

2.5. Household and individual decisions

For residents, all human life is condensed into five headings:

- Where to locate (and hence what land and floors-pace to occupy).
- Training – what (if anything) to do to obtain/maintain employable skills.
- Work – whether or not to work, for whom, doing what, when, etc.
- Purchasing – how to spend (or save – note link to investors) income derived from work or other sources, including purchases of services as well as goods.
- Other activities – everything else that people do, including non-commercial leisure, non-vocational study, and so on.

Note that the first three items determine each person's involvement or otherwise in the labour market, and hence the sum of individual decisions about these determines the "labour supply". "Labour demand" is similarly determined by the aggregate location and recruitment decisions of producers.

2.6. Other effects

The diagram, and the discussion of it, could of course be elaborated endlessly, and we emphasise that it is a partial view of the world. As it is currently drawn, we refer to just a few other influences on activities and decisions, indicated in square brackets. These are:

- Technological progress as an "exogenous" influence on producers (including the sense that even if firms are technological leaders and innovators in their particular fields, investing to achieve original technological advances, they are strongly influenced by the development of technology in other aspects of the economy).

- Natural demographic processes (ageing) and social effects (marriage/cohabitation, separation) on residents and their grouping into households.

- Network effects (congestion) in the transport system (as distinct from the deliberate responses of transport operators and suppliers).

2.7. Urban and regional processes of change

Up to this point, we have said very little about the scale of the spatial choices under consideration (where to locate a firm or household, where to work, etc.). There is, however, considerable evidence that different influences come into play to determine different levels of spatial choice.

For households, this means that there is a distinction between "local" moves and what is normally thought of as "migration".

"Local moves", which most households make several times in their lives, are predominantly driven by the need and desire to obtain housing and immediate surroundings appropriate to the household's income and composition. Accessibility, especially to qualitatively distinct opportunities such as good schools, plays a part in influencing such moves, although for households with high levels of car-based mobility at low perceived cost this is a relatively weak influence. Such moves typically take place over distances which mean that the working member(s) of the household can continue in the same job(s), although they do not necessarily do so.

"Migration", in contrast, is less common, involves generally longer moves, and is much more likely to be linked with a change of job – although this may not be simultaneous with the move itself. UK research suggests that shorter distance migration is most strongly influenced by environmental factors (the desire to move to "a nicer area"), while longer distance migration is most strongly influenced by economic factors (the desire to obtain work or to increase income from work). The key influences might be significantly different in larger or smaller countries, or in areas of the world where there is less variation in environment between settlements in close proximity.

Similar contrasts can be observed in business decision making, where locational decisions (when they occur) are made on broader economic grounds at a higher spatial level (*e.g.* in which European country, and perhaps in which UK region, to invest) and on locally more sensitive criteria at the more local level. This explains the findings observed, for example, in one French study, where firms cited "motorway access" as the critical reason for investing in a particular area, yet chose to locate not near the motorway interchange but nearer to a town some kilometres away – the reason being that at the local level, easy access for the workforce was more important than the extra distance from the motorway.

Since the present report is concerned mainly with the "regional" level, as defined earlier, we are concerned mainly with modelling processes of decision at the higher spatial levels, and not primarily concerned with more local choices.

2.8. The influence of transport on non-transport decisions

We concentrate first on business decisions, which are more directly significant to the regional level of change.

We have classified the types of decisions above (Section 2.4). It is useful to think of each business as making each kind of decision more or less often, whilst also being affected directly or indirectly by the decisions of all the other kinds of actors identified. The relative frequency of different decisions will vary considerably between different kinds of businesses. We can consider some examples.

A manufacturing firm selling major equipment products to other businesses may need to make a constant stream of marketing decisions (to whom and how to try to sell the products, at what prices) which will be affected by the travel and transport implications of making contact with potential customers (in the customers' premises, or at trade exhibitions, etc.), of delivering the product, and probably of supporting the product with service and parts. The direct and indirect costs of transport will be reflected in the prices quoted to potential customers. The potential customers will consider (among many other factors) those prices, and other transport influences such as how the reliability of transport may affect the delivery of support services and parts, and the implications of any delay in delivery for their own production. The potential customers' decisions will determine the manufacturer's level of production, and the quantities of inputs which they need to purchase from others. If their range of products and level of production are fairly stable, they may have relatively long-term contracts for the supply of input materials; their choice of suppliers and of delivery arrangements (for example, levels of stock-holding) will also be influenced by cost and other aspects of transport.

A different manufacturing firm selling a changing mix of fashion-related goods to major retail chains may have longer-term relationships with a smaller number of customers, reflected in more stable arrangements for the delivery of its products, but more varied production and purchasing requirements to meet the fashions of the season (or the expected fashions of the next season). Again, decisions about contracts with customers and with suppliers will be influenced by transport through cost and other impacts.

A firm providing office-based services such as accountancy to a mixture of business and private clients will be influenced much more by passenger transport than by goods transport,[11] and may have

11. This is also true for some high-technology industries which produce very small quantities of high-value products, but have to undertake a lot of personal travel in order to do so.

much greater opportunities to substitute telecommunications for personal movement. Purchasing decisions will be relatively unimportant, since the major “input” is staff.

Manufacturing firms are likely to be relatively slow-changing in their location, because typically they have substantial investment in equipment, which is very expensive to move. They may only be likely to move if they need to re-equip – though in some sectors, notably electronics, the need to re-equip every few years for each new generation of product means that location decisions are becoming more frequent. Firms providing information-based business services such as accountancy may have very little investment which cannot easily be moved from one office to another, and are typically more mobile.

The general pattern that emerges is that:

- Each type of firm within each sector faces a range of decisions in which transport is, to a greater or lesser extent, an influence.

- The more frequent decisions are constrained by the less frequent ones – in day-to-day decisions about how to obtain or despatch goods, the location of the firm’s factory is fixed.

- The infrequent decisions are influenced by their expected effect on future frequent decisions – so decisions on the future location of the factory are influenced by expectations about whether it will be cheaper and easier to obtain and despatch goods.

This means that:

- Short-term frequent decisions, usually about some or all aspects of purchasing, marketing and production, are influenced by short-term expectations about transport, are specific to the arrangements with particular customers and suppliers and are highly constrained by existing arrangements.

- Less-frequent decisions, more often but not exclusively about location and investment, involve taking a longer-term view about future transport and its impact on the more frequent decisions. These may include views about the impact of transport on recruitment, even though the related travel decisions – how to get to work – are made by employees not employers.

2.9. The importance of transport in non-transport decisions

While the ways in which transport influences non-transport decisions are generally accepted, it is often argued that the costs of transport represent a very small part of the total costs of production in advanced economies, and that the influence of transport is therefore negligible. A number of points lead us to dispute this.

In the first instance, the average proportion of transport cost in total costs of production – generally found to be in the range of 2-4% – hides wide variations between different sectors. Figures for transport costs as percentage of gross output in Scotland, 1973, show percentages ranging from 0.8% to 11.4% in different parts of manufacturing; similar analysis for Northern Ireland, 1979, found values up to nearly 20% (all figures from PIEDA, 1984, Chapter 2).

These variations in turn conceal what are undoubtedly even wider variations between individual firms. Transport costs are therefore a very significant cost for some industries and some firms; the ways in which these respond to transport cost – for example, in pricing and location decisions – will affect other firms and other industries in ways that are not directly recorded as transport effects.

Secondly, transport costs as measured by national accounts and quoted in the previous paragraph significantly underestimate the total costs of transport. They typically include only the money cost of purchases by firms from other firms identified as being in the transport sector. This is likely to understate or omit:

- The costs of own-account transport (vehicles operated by firms to deliver their own goods).
- The costs of petrol and cars for employee travel.
- The value of the time spent travelling by staff.

Estimates of total money cost have been attempted (see, for example, Oelman, 1994). However the time spent travelling by staff may be the most important transport-related factor for knowledge-based industries and for any small firm with only one or a few managers.

Thirdly, transport costs are kept as low as they are by management effort; they are not necessarily naturally low. Research has shown that firms in peripheral areas, facing somewhat higher transport costs, devote more management effort to reviewing transport arrangements than those in central areas (PIEDA, 1984). They are also somewhat more likely to distribute their output through wholesalers rather than directly to their customers, which again tends to reduce the recorded level of expenditure on transport.

Finally, it is argued that transport costs may be more readily varied than some other costs and that therefore firms respond more to differences in transport cost in seeking to increase profits.

These points collectively suggest that transport is much more important to a wide range of business decisions than simple cost percentages in national accounts would suggest. The fact that many businesses and business organisations put substantial effort into lobbying for transport improvements is further evidence of this. Such efforts are of course quite rationally biased towards improvements, particularly in untolled roads, where firms do not have to pay the true costs of transport provision, but this does not detract from the overall conclusion that transport is, in one way or another, significant to most businesses and highly significant to many. This is further borne out by surveys of factors affecting business location, which typically give a high ranking to good access or other transport-related factors.

Chapter 3

LUTI MODELS AND THEIR RELEVANCE

3.1. Characteristics required for analysis

The "land-use" components of "land-use/transport models" cover varying proportions of "land-use" as defined in the previous section. In most cases their representation of the physical use of land is only a small part of the overall model. In some cases, the physical use of land is not considered at all. This characteristic stems from the focus with the "regional" level of choice identified at the end of the last chapter: in most circumstances, sites and premises are not a constraint at the regional level, and hence they do not feature in the models – unlike more local, "urban" models where they are important variables.

There are of course many models, which represent particular processes or effects (such as local demographic change) without relating it to transport. To be of interest in the present context, a model or modelling package must include:

- Some form of spatial representation of producers, residents, and transport supply (not necessarily traced back to transport suppliers).

- Sufficient detail of transport supply to allow changes in transport supply to be represented (distance alone is not sufficient).

- Links from the transport markets to the activities and markets which use transport, such that changes in transport have at least some impact on some decisions or responses of producers and residents.

Many models also include links from producers and residents, and/or from labour and product markets, to transport markets, as the main or only process by which transport demands are derived. However, for the purposes of considering the impact of transport change on regional development, this may not always be necessary.

The relevance of these models with these characteristics is that they allow systematic analysis and forecasting, with greater or lesser sophistication, of the impact of transport change on the variables we have labelled "land use". This allows:

- Systematic comparison of alternative changes to transport supply.

- Examination of the spatial incidence of the impacts modelled.

Both properties are in many cases valuable to the planning process. The rest of this report deals with:

- The kinds of models which may meet these criteria, explaining why our focus is on LUTI models.

- The main LUTI models of relevance.

- Some of the findings from use of such models.

- Their strengths and weaknesses.

- The relationship of such models to project appraisal, *i.e.* to placing values on the impacts forecast.

3.2. Modelling approaches of relevance

We reviewed the range of methods used to examine the regional impacts of transport schemes in a project for SACTRA in 1997 (David Simmonds Consultancy, 1999). The available formal methods include:

- LUTI models.

- Macroeconomic and similar models (at national or regional levels).

- Statistical models.

Macroeconomic and similar models are generally irrelevant to the present discussion in that they do not allow the user to distinguish between alternative transport projects; it is generally only possible to specify the (average) cost saving which results from the project. This severely limits the scope for comparing real transport schemes.

Statistical models (*e.g.* SETEC Economie, 1994) considered relate economic impact in a specific region to the level of user benefit which the transport scheme delivers (*e.g.* in terms of time saving to passengers). These require the use of a transport model in order to estimate those benefits, and therefore they do allow consideration of specific schemes – though only the magnitude of their impact on travellers will enter into the economic analysis. Their critical limitation is that:

a) They can only be calibrated on a region where an appropriate change in transport has taken place.

b) While it is evident that the calibrated parameters need to be adjusted in order to apply the model to another region (where a major transport change is proposed), there is no clear basis for making such adjustments.

Given the problems of these alternative approaches in relation to the requirements specified earlier, we do not consider these further, but concentrate on LUTI models. In the rest of this Chapter, we introduce the main classifications of LUTI models, and the main packages used to implement them.

3.3. LUTI models: static and dynamic

A first distinction in LUTI models is between static and dynamic models:

- *Static models* represent a single point in time with all the linkages (between transport and land-use, or between different aspects of land-use) being simultaneous.

- *Dynamic models* represent, at a minimum, a series of points in time with at least some linkages over time; in more complex forms, they represent processes of change over time.

It follows that a dynamic model[12] may be an essentially static model with just one time-lagged relationship, or something much more complex.

3.4. LUTI models: interaction and location

The discussion around Figures 1 and 2 has already mentioned that the subject of "land use" includes both:

- The location of activities (and various aspects of their behaviour in those locations).

- The economic interactions between activities in the various markets.

These economic interactions – such as the flow of labour from homes to workplaces, or of goods from producers to consumers – are not generally identical with transport demands, but are clearly related to them. There is equally clearly a close relationship or identity, in many cases, between the measures of economic interaction and certain measures of activity location: for example, the row or "home" totals a matrix of labour (measured in workers) flowing from homes to workplaces must equal the number of working residents living in each zone, whilst the column totals of that matrix must equal the number of filled jobs in each zone.

Models can be classified according to how they deal with the relationship between location and interaction.

One approach treats the interactions as the determinants of location, so that (for example) the number of workers living in a zone is found by summing the number of workers commuting from that zone of residence to all possible workplaces (including intra-zonal commuters). Likewise, the level of production or employment of an industry in a zone is found by summing (in appropriate units) the volume of that industry's output supplied from that zone to all consumers (again, including intra-zonal flows). Such models can represent long changes of relationships between different activities; to start these chains, some form of exogenous demand has to be defined, which may be either conventional "final demand", or some variant thereon, or a subset of activity defined as "basic". This approach may be called the "interaction-location" approach, since the central feature is to calculate interactions first and to calculate the location of activities by finding the totals of those interactions.

The alternative approach treats the location (and number) of activities as the main "driver" of change, and then models the interactions between those located activities. This can obviously be called

12. There is some debate between LUTI modellers and economists as to whether existing dynamic LUTI models should be regarded as "dynamic" or "quasi-dynamic". We follow the LUTI modellers' convention of describing any model in which there are explicit causal links over time as "dynamic".

the "location-interaction" approach. This allows the number and location of the activities to be determined by separate sub-models; these can consider any appropriate influences, but will typically include in the location choice some measures of zonal accessibility, which reflect the scope for interactions from each zone. Hence, for example, a sub-model for residential location within the "location-interaction" approach will include measures of accessibility to work, and possibly measures of accessibility for other interactions such as shopping, education and so on. These interactions are however only actually calculated later in the model process; this may produce some further changes in the "status" of activities, such as determining whether individuals are working or unemployed, but it does not directly modify their location or the fundamental number of activities.

Two kinds of tendencies follow from these alternative approaches.

Firstly, "interaction-location" models tend to be defined in terms of finding the equilibrium location and interaction of the different activities considered, given certain fixed variables such as the supply of land or floor space and the costs of transport. This is necessary because of the way in which the number and location of activities is built up from their interactions with other activities. For example, this approach generally requires that households are "generated" by the demand for their labour, and that demand depends in part on households' demands for services; this linkage has to be run to equilibrium, otherwise households and jobs will disappear from the system. In contrast, the "location-interaction" approach need not have any equilibrium between the location and number of different activities – it can for example readily predict an increasing supply of labour in an area of decreasing demand – but more consideration then has to be given, in the model design, to predicting the pattern of interaction that results (*e.g.* to predict increasing levels of unemployment in certain areas).

Secondly, "interaction-location" models by definition predict matrices of interactions which can be converted into matrices of the demand for transport. These matrices would in the ideal model generate all of the derived demands for transport, though in practice some demands are usually left as exogenous. "Location-interaction" models may or may not generate such matrices, or they may generate matrices for some purposes but not others. It follows that the transport model associated with an "interaction-location" model will not need to the generation and distribution of transport demands, because they have already been determined by conversion of the land-use interactions. The transport model associated with a "location-interaction" model may not need to consider generation and distribution, and in some cases these choice processes are left entirely to the transport model.

3.5. How transport effects are represented

A third major area of distinction is how transport affects land-use within these models. There are two main linkages defined by different variables directly affecting land-use activities:

- Through matrices of generalised transport costs.[13]

- Or through vectors of accessibility measures, often though not always based upon those matrices of generalised costs.

13. Generalised costs are money costs plus a money valuation of travel time and other aspects of the difficulty or inconvenience of travel, or travel time plus other money and other aspects converted into time units.

Generally, matrix measures are used as the transport – land-use link in interaction-location models, whilst accessibility vectors are used in location-interaction models. Again, generalised costs for freight movement are typically the accumulation of the various money costs (drivers' wages, fuel, tolls, etc.), while those for passenger movement include costs or fares and perceived values of time. In a few cases (*e.g.* Simmonds and Jenkinson, 1993), the time effects consider not only the journey itself but also the implications of time budgets, *e.g.* the inconvenience of not being able to make a round trip for a business meeting in one day.[14]

In addition, a minority of models include environmental impacts of transport as an influence on some aspects of land-use – mainly residents' choices. These effects are currently treated in fairly simple forms, using calculations of noise and pollution as variables affecting household decisions. There is scope for more sophisticated treatments which would also take into account:

- Non-transport sources of pollution.

- And, possibly, the diffusion of pollution impacts.

This would require the addition of a spatial environmental model into the overall system.

3.6. Models and packages

LUTI models of the kinds described above have been built in a number of regions over approximately the last 30 years. Many of these have been implemented using *ad hoc* software. However, a number of packages provided the software basis for a series of related models in different regions have been developed, and it seems appropriate to note the general characteristics of these. We consider them in chronological order of their original development.

TRANUS and MEPLAN are both descended from research carried out in the 1970s at the Centre for Land Use and Built Form Studies (now the Martin Centre for Urban and Architectural Studies) in the University of Cambridge. They are very similar to each other, and for present purposes can be treated as virtually identical (although they have some significant detail differences with affect their value in implementation). Their main characteristics are that:

- They are normally used in a dynamic structure, with transport output from one year influencing land-use at a later date; typically a five-year lag is adopted.

- The overall structure is primarily that of an interaction-location model (*i.e.* interactions are forecast and location of most activities is found by summing the interactions).

- The full set of interactions is estimated simultaneously in a spatial input-output model, so a high proportion of the land-use linkages in the model are simultaneous, the time lag in the *impact of transport being the main response over time.*

- Since the modelling of interactions is the basis of the land-use model, the linkage from transport to land-use is in terms of matrices of generalised costs.

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14. For a more recent study considering this, without undertaking land-use modelling, see Øresundsbro Konsortiet (2000).

DELTA has been developed more recently – from 1995 onwards. It is in itself purely a land-use model, and has to be combined with a transport model to create a land-use/transport interaction model. The full applications to date have linked DELTA to different implementations of the START multimodal transport model (see Roberts and Simmonds, 1997). The main characteristics are that:

- DELTA represents change in land-use over a relatively short period of time – one or two years – with a complex pattern of time lags in response to transport.
- The overall structure is that of a location-interaction model, with some interactions being modelled in DELTA and the transport model, others in the transport model only.
- There are relatively few simultaneous linkages, and many time-lagged responses between different parts of the land-use model itself.
- The influence of transport on land-use works mainly through accessibility measures and environmental impact measures, plus some use of generalised cost matrices.
- DELTA was preceded by the static package DSCMOD, which consisted of a location-only model driven by changes in accessibility measures.

All of the packages mentioned can be and are applied to either urban or regional levels. The characteristics mentioned above, and many of the details, are the same in either case; the differences are generally that:

- The transport model concentrates, sometimes exclusively, on passenger flows at the urban level but gives greater attention to goods at the regional level.
- At the urban level, the main activities are several different kinds of households and a small number of employment sectors (measured in employment; at the regional level, the main activities are a larger set of productive sectors (measured in production and value-added) and a simpler representation of population.
- The supply of land and/or floor space is a critical variable in *urban applications but is ignored in regional applications.*

TRANUS, MEPLAN and the much more limited DSCMOD are applied to urban and regional situations using the same software and very largely the same equations, but changing the content of the application in the above ways. DELTA, in contrast, has separate urban and regional processes, following the arguments outlined in Section 2.7 of the present document. The corresponding sub-models can be applied separately to create specifically urban or regional models, or combined to create an integrated urban/regional model. If separate urban and regional models are implemented in DELTA, they will tend to show the same distinctions as those listed above between urban and regional applications of TRANUS or MEPLAN. If an integrated urban-regional model is built, then it will tend to show combined characteristics, *e.g.* more equal treatment of passenger and freight movement.

The processes modelled at the regional level of DELTA are superficially similar to the structure of TRANUS/MEPLAN, in that a spatial input-output model is used to generate spatial-economic interactions; however, the location of production is heavily influenced by the location of capacity, which is determined previously by an investment location sub-model. The different processes are intended to represent the different kinds of decisions discussed in Sections 2.4 and 2.5, in so far as they affect regional-level characteristics.

So far as we know, these are the only model packages[15] with a regional modelling capability which meets the requirements set out above. There are various other packages with similar characteristics but which operate exclusively at the urban level. Details of these can be found in our work for SACTRA (David Simmonds Consultancy/ME&P, 1999).

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15. Note that:

- TRANUS is developed and marketed by Modelistica, Caracas, Venezuela.
- MEPLAN is developed and marketed by Marcial Echenique & Partners, Cambridge, England.
- DELTA is developed and marketed by David Simmonds Consultancy, Cambridge, England.

Chapter 4

SOME GENERAL FINDINGS FROM LUTI MODELS

4.1. Introduction

In this chapter, we try to develop some general observations from the range of available LUTI results at the regional scale. We discuss first the available material, then what we can note from it.

It should be kept in mind that this is based on what was available to the author at the time of writing, and not upon a full-scale literature search. More importantly, it must be recognised that generalising the findings from different models of different places is inherently difficult. The ISGLUTI study took about a decade to do this for the range of urban LUTI models available circa 1980; their comparisons required a substantial programme of work involving, in the first phase,[16] running the models to assess the impacts of a standardised set of tests, reported in a standardised format, and in the second phase[17] the implementation of multiple models for each city. The limitations on the present chapter, briefly considering readily accessible results of different tests from different models in different areas, should be clear.

4.2. Published model applications and results

We consider first the three packages mentioned in Section 3.6, and then the availability of results from other models known to us.

The TRANUS package and the underlying methods are described in de la Barra (1989). Several regional-level applications are mentioned, but with little detail of results. Recently, TRANUS has been used for the "First Generation" stage of the Oregon Transport-Land Use Model Improvement Programme (TLUMIP). Results from this application were presented to the Second Oregon Symposium on Integrating Land-Use and Transport Models in summer 2000, but have not yet been published in a form suitable for further examination.

Regional applications of the MEPLAN approach (or its predecessors) were developed in Argentina (Williams and Echenique, 1978), for São Paulo State (Brazil), and for the Basque Country in Spain. Regional applications of MEPLAN proper have been created for Sweden (Williams and Lindberg, 1989), for the European Community of 12 countries, circa 1991 (ACT *et al.*, 1996; Rohr and Williams, 1994) and recently for the Trans-Pennine region of Northern England (Jin and Williams, 2000). Fully published results appear to exist only for the European Community study in relation to the Channel Tunnel.

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16. Reported in Webster F.V., Bly P. H. and Paulley N.J., Urban land use and transport interaction: policy and models, Aldershot (1988).

17. Reported in a series of papers in *Transport Reviews*, see Paulley and Webster (1991).

The DSCMOD approach was applied to Western Europe initially at a 25-zone level (David Simmonds Consultancy, 1992), and subsequently at a 60-zone level. The latter was used for a series of analyses and underwent a number of refinements. Results were published in several papers by Simmonds and Jenkinson (1993, 1995, 1997). The use of the integrated urban/regional DELTA/START model to the Trans-Pennine Corridor Model (not to be confused with the MEPLAN Trans-Pennine model mentioned above) is described in Coombe *et al.* (2000).

Individual operational models known to us include:

- The IRPUD (University of Dortmund) Nordrhein-Westfalen model.
- The Italian National Transport Model [which takes the equilibrium aspects of LUTI modelling further towards Computable General Equilibrium (CGE) modelling].
- A multi-regional model of Japan (Okuda and Hayashi, 1999).
- A multi-area model of the central region of Japan (Miyagi, 1999).
- A model of the Oresund (Denmark-Sweden link).

We do not comment further on these, since either we have no results of strategy testing at all from these, or too few results to draw any conclusions.

4.3. Observations on these results

In general, the predicted effects of transport change are small, perhaps surprisingly and disappointingly so compared with the arguments for the importance of transport developed in Section 2.9. Regional impacts of fractions of one per cent are typical, for example, of the MEPLAN and DSCMOD models applied to the Channel Tunnel and connected infrastructure. At the regional scale, small percentages can of course be large absolute values (fractions of 1% can be tens of thousands of jobs) which poses a challenge for interpretation of the results – are these results significant or not?

Comparison of MEPLAN and DSCMOD results for the impact of the Channel Tunnel and associated links shows an interesting contrast. Firstly, DSCMOD generally produced slightly larger changes (as far as can be judged given differences in presentation and units). Secondly, MEPLAN predicted a corridor effect with, rather surprisingly, some of the highest growth in the South of France (in a zone immediately adjacent to some of greatest decline, in Spain). DSCMOD produced greatest mainland growth in a relative limited area around the tunnel terminal and relative high losses in South of France, similar to those in adjacent zones. Explanations may possibly lie in the MEPLAN network (which includes unspecified enhancements complementary to the Channel Tunnel) or in the greater detail of inter-industry linkages (Tunnel-related growth in exports from the South of France to Britain would have multiplier effects in MEPLAN which were excluded from DSCMOD).

Some of the DSCMOD results published as Simmonds and Jenkinson (1995), notably the road congestion scenario, show that one can get spatially rather complex results from a fairly simple model and a fairly simple transport supply change. The scenario in question involved reductions in road speeds representing worsening congestion throughout Europe. The impact can be generalised as showing activities moving in two directions:

- Towards a relatively small core area where travel/delivery distances are relatively short and the absolute effect of reduced speeds is less.

- Towards the peripheral regions of Europe, where higher proportions of movement are by air or sea, and where again the effect of lower road speeds is diminished.

This leaves an intermediate set of regions where longer road movements are more typical and more necessary, experiencing the negative impacts of the scenario.

Marked spatial patterns in results also followed from a simple scenario of transport change in some of the MVA/DSC Trans-Pennine work. Measures to restrain road traffic, especially private cars, were uniformly applied across the different urban areas affected. These included reductions in road capacity, particularly to create bus lanes. The effects differed markedly according to the prosperity (and associated traffic levels) of the different conurbations, and according to the levels and qualities of public transport available as alternatives to private car. One conurbation was particularly badly affected by the combination of high car demand and poor alternatives, and as a result suffered substantial very serious reductions in road speeds and substantial losses of employment.

Both these sets of results imply that it is important to fine-tune transport measures if unintended economic impacts are to be avoided.

A further observation can be made in respect of the contrast with urban analysis. Regional LUTI modelling generally has:

- Fewer constraints and negative feedback – in particular, it does not usually have land or floorspace limitation.

- More positive feedback, through the input-output relationships.

The result is that regional models typically show simpler response to transport change than urban models, where competition for a fixed or very slowly changing supply of buildings means that changes in the mixture of households or population in affected areas can be highly significant but changes in total numbers are often very small.

Detailed analysis of modelled results in this area could be valuable as an input both to transport and regional planning and to further model development. The difficulties of doing so should not however be underestimated. As noted earlier, the ISGLUTI study (Paulley and Webster, 1991) undertook such an exercise for urban LUTI models during the 1980s; it ultimately proved very valuable, but took about a decade and suffered from the inevitable drawback that the models considered had ceased to represent the state-of-the-art by the time the work was published.

Chapter 5

STRENGTHS AND WEAKNESSES OF THESE MODELS

5.1. Introduction

This chapter attempts to consider the strengths and weaknesses of LUTI models in general, without reference to any particular package or individual model application.

We address the issue of the strengths and weaknesses of LUTI models assuming that the main objective of analysis is to forecast the outcomes of transport planning measures through the kinds of decisions outlined in Chapter 2. A somewhat different assessment would probably emerge if one were to adopt an alternative perspective, such as the strengths and weaknesses of LUTI models in representing more abstract characteristics of the relevant market, or in terms of their ability to estimate particular kinds of benefits (of which more below).

The main observation to make is that the models are, at their best, relatively strong in representing the behaviour of households, and generally weaker in representing the behaviour of businesses. There are a number of contributory factors in this:

- The unit of analysis.
- The nature of the real decision-making units.
- The alternatives available to the decision makers.
- The state-of-the-art in freight modelling relative to that in passenger modelling.

The following sections consider these factors in turn.

5.2. Unit of analysis

Taking the unit of analysis first, decisions by residents are mostly made either by households or by persons within those households. Most, perhaps all LUTI models take households as the unit of analysis of location, car ownership and expenditure decisions, and persons as the unit of analysis for travel decisions. There are shortcomings in LUTI models in relation to the interactions between individuals' travel decisions, such as the question of who uses the car in a multi-adult, single-car family, but these are general to much transport modelling rather than specific to LUTI models. The level of detail in the treatment of households varies widely, from just a few types to about a hundred (based on full cross-classification of household composition, age of key household members, employment status and socio-economic group). The majority of models are aggregate and implicitly rely on representing the average household within each category, though others are disaggregate and operate by simulating an explicit set of individual households. In either case, the residential components of all the LUTI models known to us work in terms of a unit of analysis which appears to correspond to the real decision-making unit.

In contrast, the majority of LUTI models (and many other regional economic models with less explicit transport components) model businesses in terms of one or more of the following:

- Employment.
- Production.
- Value added.

by sector, not by firm. The few models which explicitly model firms as the unit of decision work only at the urban scale and only in terms of location decisions. There are therefore considerable problems in relating these models to research into business decision making.

5.3. The nature of the decision-making units

The above issue is closely related to the second one, the nature of firms compared with households and residents. It is not difficult to develop a classification of households, based on variables such as those mentioned just above, which appears to account for a high proportion of the variability in their location/housing, car-ownership and transport behaviour. In contrast, firms are much variable, ranging from a single person working part-time to enterprises with tens of thousands of employees in hundreds of locations. They may be profitable and well-managed, responding effectively to and indeed anticipating change (in transport and other influences), they may be insufficiently profitable to respond even though management knows what is appropriate, or they may be ineffectively managed, responding too little or too late to changes in circumstances. Representing firms remains a major challenge to modelling, and not doing so at all remains a source of weakness.

5.4. The definition of available choices

Both theory and common sense indicate that models can only predict outcomes correctly if the choices available to decision-makers are correctly identified in the model. Again, LUTI models are better specified for households and their members than for firms. The problem is that firms have more dimensions of choice than households do. A firm can decide (freely or under pressure of circumstances) to split it itself into several units, to reorganise itself, to make radical changes in what it produces and how it sells it, to make half its workers redundant or simply to close down. Households do not generally have analogous choices. Most of these possibilities are inadequately represented or ignored in existing LUTI models, partly because of the difficulty of considering them in sector-based rather than firm-based modelling.

5.5. Freight modelling

The reasons why transport affects non-transport decisions imply that freight transport will be more important for regional-level impacts – although, as we have emphasised, the balance of importance between freight transport and passenger transport will vary between sectors and between firms. Freight modelling is substantially less developed than passenger travel modelling. This seems to reflect the greater difficulty of freight analysis, and the lower priority attached to such analysis in much transport planning.

The factors contributing to the greater difficulty of freight model include the following on the demand side alone:

- Freight (other than livestock) is entirely passive, and the arrangements for loading and unloading are therefore critical; in many cases, these involve specialised infrastructure and/or equipment.

- Most freight requires packing, often in several stages (*e.g.* packets in boxes on pallets in a container); the type of packing used is related both to its handling during transport and to the requirements of the shipper and recipient, including their arrangements for storage.

- Many freight vehicles, especially railway wagons and bulk-carrying trucks or trailers, are specialised units for the carriage of a particular type of goods.

- The "unit of decision" (which for passenger travel is ultimately the person- or group-journey, though influenced by other decisions such as car ownership and season ticket purchase) for freight can vary from the despatch of a single parcel to a contract running for several years and involving hundreds of thousands of tonnes of goods.

- The characteristics of the journey itself are of very little importance to some consignments of freight (*e.g.* non-urgent shipments of bulk materials) but more critical than for passengers in other cases (*e.g.* the requirements of temperature-sensitive or very-high-value goods).

In addition, there are complications on the supply side:

- Prices are much less well known than in passenger transport – the majority of transactions (except for small volume users of public services such as post and parcel delivery) are commercially confidential.

- It can be difficult to define the supply of freight transport services without going into a lot of detail about the characteristics of available terminals, especially on the railway network – and these are not fixed, since the cost of changing the characteristics may be modest compared with the overall transport costs involved; supply characteristics such as frequency and capacity are undefined until a potential shipper makes an enquiry.

- Since the movement of freight itself is nearly always one-way, the economics of freight haulage are considerably complicated by the scope for back-hauling, *i.e.* the possibility that the truck or wagon can carry a revenue-earning load on the return journey rather than running empty.

Some of these factors have analogies in passenger transport which can be taken into account in some forms of passenger transport modelling – for example, group size (and the resulting sharing of car costs) can be taken into account more readily in disaggregate choice modelling than in aggregate approaches. Others have no equivalent at all.

The main implications of these factors are that:

- The classification of freight is highly complex, and many of the obvious classifications (*e.g.* bulk, containerised, other) are reflections of transport decisions rather than independent dimensions.

- The characteristics of the freight movement itself – the traditional focus of transport analysis – will in many cases be less important than the arrangements for packaging and handling, which are significantly more difficult to analyse.

The last point is of considerable significance in that, as noted in Section 3.5, LUTI models conventionally use the generalised costs of moving people or goods, or accessibility measures calculated from those costs, as the variables influencing land-use.

5.6. Conclusion

There is clearly a whole programme of work to be undertaken to enhance the inter-related business and freight aspects of LUTI modelling at the regional scale. It should however be recognised at the same time that LUTI modelling could in many cases provide more information about the impacts of alternative interventions in transport supply than any other available, practical technique. This is particularly true of the more complex models which can represent a considerable range of direct and indirect effects. The best approach to the prevailing limitations seems to be to ensure that formal modelling is supplemented by professional judgement with particular reference to the aspects omitted or under-represented.

Chapter 6

LAND-USE/TRANSPORT MODELS AND APPRAISAL

6.1. Appraisal in LUTI: the problem

Changing land-use complicates the assumptions on which conventional transport evaluation is based. It is not generally sufficient to apply a conventional transport benefit evaluation approach to the differences between the do-nothing situation and the changed situation including land-use effects.

The conventional economic view of the land-use impacts of transport change has been that such impacts change the distribution of costs and benefits – for example, transport benefits initially enjoyed by travellers may be captured by real estate owners through increasing rents – but that they do not modify the total net value resulting. This view would imply that it is not necessary for appraisal to forecast the land-use impacts at all, because they are simply transfers and transformations of the benefits, which can be estimated on the basis of a transport-only analysis.

The prevalence of this view has tended to hold back the development of LUTI models on the grounds that the forecasts they produce are irrelevant to appraisal. There are however at least three grounds for rejecting this view.

The first is that the distribution of benefits is often of concern, both spatially and socially. Most governments have policies which are intended (for example) to redistribute jobs to high unemployment areas, and transport investments which support such policies should be regarded as more beneficial than those which work against them.

The second is that the view that land-use impacts transform and redistribute transport benefits has been shown to be valid only under conditions of perfect competition (Jara-Díaz, 1986). More recent work (Martínez and Araya, 1998) has shown how highly unrealistic these conditions are, and has started to show how much the measures of benefit are modified by land-use effects.

The third, which is perhaps a less formal view of the second, is that if the costs and benefits of a transport change as one expands the scope of the transport analysis, it is implausible that the costs and benefits should not differ further if the analysis is extended into "land-use" effects. For example, the appraisal of a major motorway project will produce one result if it is based upon a fixed matrix of person-trips by road, but a different result it modal choice is taken into account and public transport operator response to changing demand is taken into account (*e.g.* if transfer from rail to road will lead to a decline in rail services). It is hard to see why further extension to include location and development effects would not lead to further modifications of benefit. This is especially true where land-uses may be influenced by environmental externalities as well as by measures reflecting the supply of transport.

6.2. Possible solutions to the problem

At present, there appear to be two approaches to appraisal in land-use/transport modelling practice.

One effectively ignores the issues identified above so far as quantification is concerned. It carries out a relatively conventional transport-only calculation of benefits (based primarily on time and money savings) by testing the alternative transport strategies with land-use held constant (see, for example, Coombe *et al.*, 2000). This could be extended by carrying out the test under both the Reference Case land-use pattern and the modified land-use pattern resulting from the land-use impacts of the strategy being tested; this would show whether benefits increased or decreased as land-use responded. Neither of these sets of calculations would actually show whether the calculated benefits were actually increased or decreased by the land-use response, or how the land-use effects would redistribute benefits.

However, it is possible to examine the predicted land-use effects and to include separately in the appraisal any impacts, which are identified as being particularly desirable or undesirable. Desirable impacts would include regeneration (however defined, *e.g.* new development, new jobs, or reduced unemployment) in areas where that is a policy objective. Undesirable impacts could include very much the same effects in areas where they are considered undesirable (*e.g.* increased demand for housing and associated pressure for development in National Parks or other designated areas).

At the other extreme, at least one modelling package attempts to carry out a comprehensive evaluation of benefits in the land-use system. This does respect the requirement to take land-use effects into account, as outlined above, though we are not in a position to comment on the exact method used. This of course produces measures of benefit different from those in transport-only analysis; it should include the benefit (or disbenefit) that households or firms obtain from paying different levels of rent, from living at lower or higher densities, from being in different (*e.g.* more or less attractive) locations, and so on. This clearly goes well beyond a conventional transport cost-benefit analysis, however desirable such an extended analysis is, it may come up against the institutional or administrative problems because it is unfamiliar and difficult to relate to the analyses from more conventional models. It is also perhaps more difficult to relate such analyses to policy considerations: for example, increased property values would (at least by default) represent benefits to property-owners, whether the property was in an area intended for urban regeneration or for conservation as open countryside.

There may be intermediate possibilities between the above extremes, which would allow conventional methods of appraisal to be used with appropriate corrections to take account of the land-use effects. We have recently carried out some work to design an appraisal system along these lines, on behalf of the Government Office for the Northwest (of England). We have concluded that it is possible and merits further work, but it has not yet been implemented and it is therefore too early to comment on its results.

There is also an issue of the assessment of environmental effects. In some land-use models, residents (and potentially firms) are influenced in their location decisions by the environmental impacts of transport. Negative transport impacts (*e.g.* increases in noise and in local air pollution) would decrease the willingness to pay to live in the locations affected, and would generate disbenefits (*e.g.* to the owners of property in those locations). This might start to duplicate environmental impacts, which have been conventionally considered in non-monetary terms as separate parts of the overall appraisal process.

6.3. Appraisal of land-use or combined land-use/transport strategies

A major attraction of the comprehensive evaluation of benefits (including the benefits derived from transport) in a land-use model is that such an approach should in principle be able to carry out a consistent appraisal of any combination of land-use and transport elements. This needs to be considered not only as an extension of transport strategy appraisal, but also in terms of its possible role in the land-use planning process.

The idea of a consistent, combined appraisal of land-use and transport choices has a theoretical appeal, and should help to ensure that the wider objectives of land-use planning are not made subordinate to the narrower objectives of transport planning. However, it is beyond the scope of the present study to investigate the complexities of assessing costs and benefits in this area. It is however appropriate to note that existing land-use models can provide a wide range of indicators (not just transport indicators) about the impact of alternative land-use strategies, alone or in combination with transport strategies. These indicators are the kind of information expected by current approaches to assessment in both fields of planning, under headings of “regeneration” or “socio-economic impacts” as well as “land-use” itself. There remain questions of whether such effects would necessarily be regarded as benefits in a stricter cost-benefit analysis based on an extension of traditional public project assessment.

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