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A FRAMEWORK FOR ASSESSING STUDIES OF THE IMPACT OF TRANSPORT INFRASTRUCTURE PROJECTS ON ECONOMIC ACTIVITY

Report to The Standing Advisory Committee on Trunk Road Assessment

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A Framework for Assessing Studies of the Impact of Transport Infrastructure Projects on Economic Activity

National Economic Research Associates

Report to The Standing Advisory Committee on Trunk Road Assessment

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CHAPTER 1

Introduction

This report was commissioned by the Standing Advisory Committee on Trunk Road Assessment (SACTRA) as part of its current investigation into the relationship between transport infrastructure investment and economic activity.

The Department of the Environment, Transport and the Regions has asked SACTRA to examine:

- the relationship between improvements in transport provision and economic growth;
- the effectiveness of conventional appraisal methods in measuring the economic growth effects of improvements in transport provision;
- the appraisal of the economic growth effects of measures to reduce transport intensity.

As part of this examination, SACTRA is reviewing the existing evidence on the relationship between transport infrastructure investment and economic activity. The present Report is intended to provide a framework for SACTRA's assessment of the value of this evidence. The framework developed in the Report takes account of the fact that the Committee's particular interest is in the assumptions made about the links between transport and economic growth, and the extent to which those studies which focus on output: (1) make explicit the economic effects which are implicitly measured in conventional cost-benefit analysis; and, (2) present reliable estimates of the economic growth effects of schemes.

The rest of the Report is structured as follows.

Chapter 2 discusses the main types of approach that have been adopted in previous studies of the relationship between transport infrastructure investment and economic growth.

On the basis of an understanding of these different approaches, Chapter 3, the heart of the Report, develops a flow chart approach within which individual studies can be:

- *described*, so as to see how they fit into the overall framework of issues that are of relevance in understanding the relationship between transport infrastructure investment and economic activity; and
- *evaluated* against criteria that are relevant to assessing the quality of the evidence that they claim to provide.

Chapter 3 can be read on its own as a free-standing and relatively non-technical guide to the issues that are relevant to understanding the nature and quality of the evidence that individual studies provide.

To illustrate the use of the framework developed in the flow chart, Chapter 4 considers three of the approaches that have been used to study the relationship between infrastructure investment and economic activity.

Finally, Chapter 5 provides some brief conclusions.

CHAPTER 2

The relationship between transport infrastructure investment and economic activity: a review of the main alternative approaches

2.1. Introduction

Transport investments reduce transport costs.[1] Transport costs can be reduced in a number of ways. These are:

- reductions in the costs of transporting commodities, ie reductions in freight transport costs;
- reductions in the cost of business travel;
- reductions in the cost of travel to leisure and tourism destinations;
- reductions in the costs of commuting, which can lead to a widening of labour market catchment areas;
- reductions in the cost of other leisure trips made by road.

The reduction in transport costs is the usual starting point for any analysis of the impact of transport infrastructure investments. The immediate benefit of the investment is the fall in unit cost for each type of traffic, multiplied by the volume of that traffic. This represents the cost saving for existing traffic. Ultimately, output in the economy grows, and so GDP rises. The relationship between the immediate benefits to traffic, and the resulting final change in GDP has been of interest since Tinbergen's pioneering paper in 1957 (Tinbergen, 1957).

It is important to distinguish between theoretical models of this relationship, and empirical evidence. The ultimate test should be empirical evidence, but empirical evidence is extremely difficult to obtain and to interpret because of the difficulty of determining cause-and-effect when income and employment are determined by so many other factors.

1 Reductions in average transport costs in a spatial setting can be measured by some form of access cost, or accessibility measure (see Dodgson, 1974, Linneker and Spence, 1992a,b, and Spence and Linneker, 1994.)

Consequently, a plausible theoretical relationship is often required to back-up the empirical results. A theoretical model which does not have empirical backing will be of interest, but lacks the ultimate test of empirical validation.

What we seek to do in the present section of this Report is to categorise different approaches that have been used in previous studies. This will enable us to assess the relevance and plausibility of the different types of studies which are to be evaluated within the common framework to be developed in the next section of our Report.

Figures 1a and 1b provide a framework to show some of the links between these approaches. Figure 1a shows the relationship between unit transport costs and freight traffic, while Figure 1b shows the relationship between freight traffic levels, other inputs, and final output. Freight transport is treated as one of the essential inputs in the production process, and is assumed to be substitutable with other inputs such as manufacturing labour and manufacturing capital. Consequently the curves in Figure 1b, known as "isoquants", show combinations of freight transport and other inputs which yield constant levels of final output.[2] Thus output Q_1 can be produced using L_1 units of "labour", and T_1 units of freight transport, or using L_2 units of "labour", and T_2 units of freight transport. Profit maximising firms will minimise the cost of producing any given output level, so if relative input prices are given by the slope of the flatter of the "isocost" curves in Figure 1b, output Q_1 will be produced at minimum cost by using T_1, units of freight transport and L_1 units of the other inputs.

As we shall see, some of the approaches to transport infrastructure appraisal take explicit account of their impacts on final output and employment, and some do not. We consider alternative approaches in order of increasing complexity.

2.2. Cost savings to existing traffic flows

This simple approach involves the measurement of the cost savings to those transport flows that would have been carried in the absence of the investment. This is essentially the approach that is used in COBA. In Figure 1a unit transport costs fall from c_1 to c_2 , traffic remains at T_1 , the cost savings (or "user benefits") are measured by area c_2c_1ab, and output and employment in Figure 1b do not change.

2.3. Partial equilibrium (PE) approach with fixed commodity output

In this case output of the transported goods is held constant at Q_1 in Figure 1b, but firms substitute transport for other inputs. Freight traffic increases to T_2, and user benefits increase to area c_2c_1ad. There would be a reduction in employment of other inputs, but no change in total output. The nature of the relationship between benefits to existing and generated traffic in this case was investigated in my 1984 PTRC paper (Dodgson, 1984).

[2] For convenience (and to avoid having to draw a three-dimensional diagram to represent labour and non-transport capital separately) all other inputs are labelled as "labour".

2.4. Partial equilibrium (PE) approach with variable commodity output

In this case the reduction in unit costs permits an increase in output to occur, from Q_1 to Q_2 . Employment of other inputs changes, and might increase or decrease. As Figure 1b is drawn, they increase. If the supply of other inputs were fixed, then output could only rise to a level less than Q_2 , whereas if other inputs were not fixed in total supply output could rise above Q_2 . User benefits rise to area c_2c_1ae if output rises to Q_2 . The "conventional wisdom" is that these benefits (along with traffic user benefits to passenger vehicles, and allowance for changes in accident and environmental effects) measure benefits to society from the scheme as long as the economy is competitive (Dodgson, 1973; Jara-Diaz, 1986). This is because the demand for freight transport is a "derived demand", and in a competitive economy this reflects the valuation which consumers place on the transported commodities.

2.5. General equilibrium approach

The problem with the above methods is that they are partial. If transport costs change, then there will be changes in relative product prices because of differing transport cost intensities of different products.[3] This in turn will lead to changes in the relative demands for different products, and then to changes in the incomes of the factors used to produce the different products, and so on, until a new (general) equilibrium is reached. The practical approach to modelling in this case is to use a computable general equilibrium (CGE) model of the economy. These models use the building blocks of micro-economics – utility functions, which in turn determine demand functions, and production/cost functions – together with computational algorithms to determine equilibria. A transport investment then lowers transport costs, and the model computes the new equilibrium where everything in the economy (output levels, input levels, incomes etc) is determined. These models are quite stylised, and will be based on fairly simple utility and production functions, which in turn might partly pre-determine the results, but they have been used in analysing the relationship between transport and other variables, and the difference between final benefits and freight transport benefits when markets are not perfectly competitive. They can also take account of increasing returns in production. Both Hussain (1996) and Venables and Gasiorek (1997) are good examples of the application of this approach to the issue of the impact of transport infrastructure investments. The models are, however, highly technical, and it can be difficult for non-specialists to understand their basic structure, and even for technical economists to get a feel for how far particular conclusions are dependent on specific assumptions made in the construction of particular variants of the models.

[3] Diamond and Spence (1989) provide relatively recent evidence for the UK economy on the proportion which transport costs represent of total costs in different industries.

2.6. The macro-economic modelling approach

"Macro" models are a variant of standard macro-economic models which contain a series of inter-linked equations for predicting the main economic variables, including employment and output. They may have a regional disaggregation. Transport can be treated as a separate input, and reductions in transport cost can feed through the system (for example, in the same way that a reduction in labour costs might do) to predict the impact on output, employment and other variables. An important issue is whether the resulting changes in employment and income represent overall growth or inter-regional redistribution.

Unlike in CGE models, where standard benefit measures can be evaluated using the usual expenditure-function-based measures like compensating variation and equivalent variation, the link between predicted changes in variables such as output and conventional benefit measures is not explicit in these models. Examples of such models are the CBER model (CBER, 1994), and Patrick Minford's regional development of his Liverpool macro model (Minford, et al, 1991, 1994). One problem which these models have in common with CGE models is that they can appear to be something of a "black box" to outsiders. Their specific predictions about relationships between transport cost changes and resulting output and employment changes may also be difficult to test empirically, though they may form an important link between micro-based approaches and the empirical investigations of the relationship between infrastructure investment and growth which are discussed next.

2.7. Empirical approaches

By empirical approaches, we mean approaches which seek to determine an empirical link between transport investment and economic growth measures. These approaches might, or might not, contain a theoretical justification. The relevance of the theoretical justification varies. If we discovered that there was always a clear link between investment in roads, and subsequent growth in economic activity, but we had absolutely no idea why this occurred, we might not actually worry about understanding why the link existed. Where the link was less clear-cut (and the present SACTRA study is necessary because such a link has proved extremely difficult to identify in practice), then we might feel happier about any evidence that emerged if we had a theoretical explanation for it.

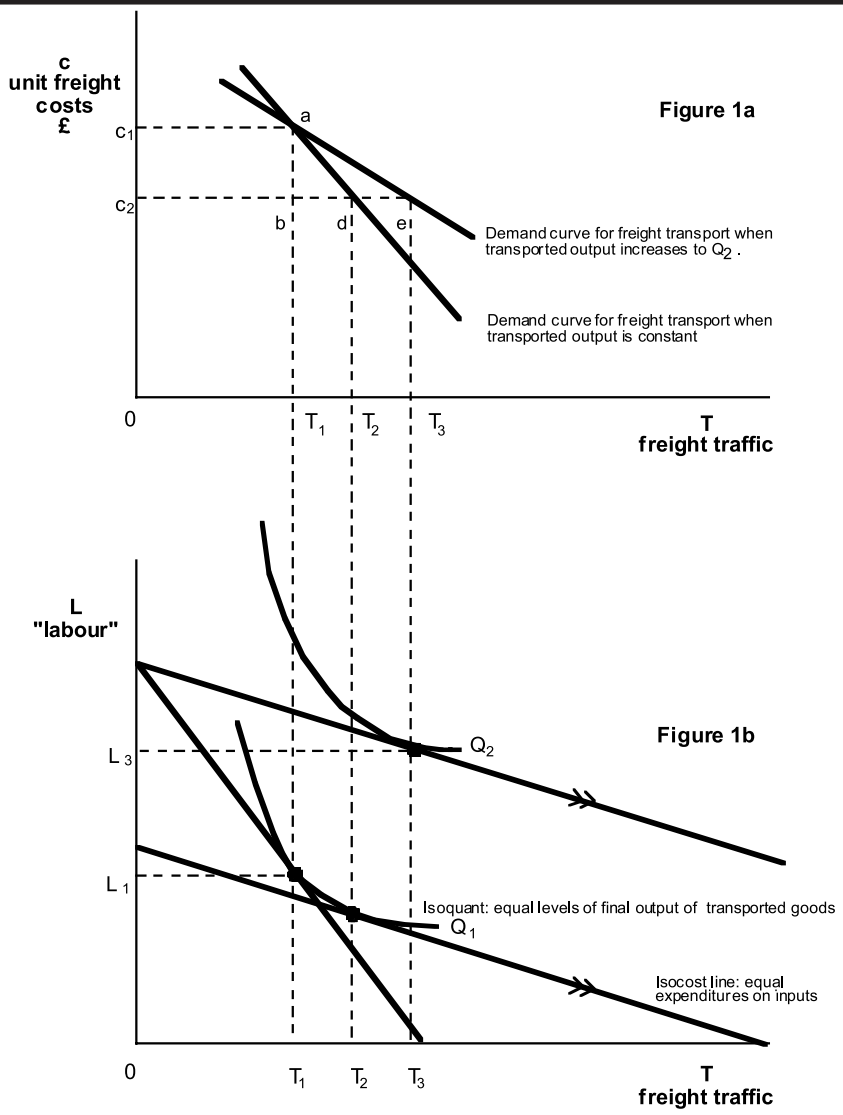
2.7.1. EMPLOYMENT GROWTH MODELS

There are a number of types of empirical study. Both my own work (Dodgson, 1974) and that of Ron Botham (Botham, 1980) tried to identify an empirical link between reductions in transport costs (as measured by accessibility, or related access cost, measures) and employment growth in different parts of the UK. Both studies had some theoretical justification for there being a link, but did not attach monetary evaluations to the employment changes that were measured. A more recent study along these lines is that by Bruinsma *et al* (1995), which tried to determine a statistical link between a major highway investment in the Netherlands and employment growth rates in different regions. Other evaluations in the UK have linked specific transport investment proposals with anticipated employment growth using a variety of methods, including surveys of firms in the affected areas.

2.7.2. MACRO-ECONOMETRIC STUDIES

A further empirical approach which has generated a considerable, and often sceptical, literature in recent years is the so-called macro-econometric approach. In this approach a statistical relationship is sought between infrastructure investment, and economic activity in the form of output, using time-series, and/or cross-section data. The starting point for this literature was Aschauer's 1989 *Journal of Monetary Economics* paper (Aschauer, 1989), and the most recent may be Morrison and Schwartz' December 1996 *American Economic Review* contribution (Morrison and Schwartz, 1996).[4] Gramlich (1984) provides a fairly critical survey in his *Journal of Economic Literature paper*.[5]

Figure 1: **Impacts of transport investments on freight traffic, final outputs and employment: partial equilibrium approach**



[4] Morrison and Schwartz use a dual, cost function, approach rather than the more usual production function approach. In their approach public infrastructure investment is seen as having the potential to reduce the variable cost function for manufacturing industry. Although there is the expected negative correlation between infrastructure investment and variable costs (ie greater infrastructure is associated with lower manufacturing costs) the study still appears to suffer from the commonly-identified problems with macro-econometric studies, that they do not adequately address issues of causality, and of the time stream of cost-reduction benefits of infrastructure investments.

[5] The Australian Bureau of Transport and Communications Economics has also investigated this issue in the last few years (BTCE, 1996).

CHAPTER 3

A framework for evaluating studies of the links between transport infrastructure investment and final economic benefits

3.1. Introduction

This Section of the Report provides an approach within which the quality and relevance of different attempts to estimate the overall impact and benefits of transport infrastructure projects can be evaluated.

This approach is demonstrated by a flow chart framework. The basic framework is shown in Chart 1a (page 17). Charts 1b, 1c and 1d present modifications of this framework to allow for changes in transport infrastructure which:

- impact on the leisure and tourism industries (Chart 1b);
- affect the size of labour markets (Chart 1c);
- lead to reductions in transport infrastructure rather than to enhancements (Chart 1d).

We consider the basic framework by working through Chart 1a. In part the flow chart is concerned with a *description* of what a particular study does, and in part with an *evaluation* of the quality of what is done. The main evaluation components are shaded.

3.2. Transport infrastructure definitions, and direct project benefits

We start with the nature of the change in transport infrastructure. While it is most logical to think of a specific infrastructure project as being the object of interest, studies which have tried to determine a link between transport infrastructure investment and economic activity have been based on a number of approaches. The main such, as shown along the top of Chart 1a, are:

- a specific and clearly-defined (though not necessarily fully designed and costed) project, such as a particular road, or a particular railway line;

- a broad type of project, such as extra spending on roads, or on roads in a particular region of the country;

- a general increase in infrastructure expenditure. This is the approach adopted by macro-econometric studies, which generally link total levels of infrastructure spending in a country or a region with levels of economic activity in that country or region. Many of these studies do not distinguish between transport infrastructure expenditure and other types of infrastructure spending;

- a general reduction in transport costs in a region. This might be measured simply as a percentage reduction in freight transport costs seen as one of the inputs in the production process (CGE models, such as those of Hussain, and Venables and Gasiorek) or as a reduction in some measure of access costs, a concept closely related to that of economic potential.

This last measure of infrastructure investment provides a direct measure of transport cost improvements. The other three measures may also involve an estimate of the reductions in transport costs. For reasonably-clearly specified projects, there will usually be an estimate of the reduction in unit freight transport costs and other transport costs along each link of the network calculated for the normal transport evaluation procedures, such as COBA, where benefits are evaluated primarily in terms of user cost savings. In the simplest form of this evaluation, the impact of the project on overall traffic volumes is not modelled (though traffic flows are likely to be re-distributed across the network). In more complex evaluations, the impact of the project on traffic generation, and even second-round impacts on traffic congestion, will be forecast. In either event a traffic benefit measure will be evaluated, so that there will be a "direct" benefit measure.

These traffic benefits can usually be disagreggated by link, though it is less likely that they be disagreggated by the region of the beneficiaries unless a matrix-based evaluation is used.[6] Where the evaluation method cannot identify the location of beneficiaries this can also create problems where some of the benefits accrue to foreign nationals when the objective function is simply to maximise the welfare of UK nationals.

Even where transport cost savings are measured, most usually in terms of savings in vehicle operating costs and driver time cost, there may still be doubts as to whether all the distribution cost savings to industry have been included, such as savings in the levels of inventory needed to be held, and any other benefits in terms of improved reliability of delivery.

[6] Matrix-based evaluation is the norm for the appraisal of projects for the Scottish Office, using the TREVAL program.

3.3. Indirect impacts of transport projects

3.3.1. IDENTIFYING LINKS BETWEEN TRANSPORT INVESTMENT AND ECONOMIC ACTIVITY

We next consider the section of the flow chart which shows links between transport infrastructure investment and economic activity. As Chart 1a illustrates, there may be a link between infrastructure investments and economic activity via reductions in freight transport and business travel costs, or there may be a direct link between the investment and the change in economic activity. There are three main measures of economic activity which are considered in studies of the impact of transport infrastructure improvements. Transport infrastructure changes will impact on all three measures in practice, but individual studies often concentrate on just one of the links. The three measures considered are:

- measures of income;
- measures of employment;
- measures of economic surplus based on consumer surplus and firms' profits. The former need to be estimated from estimates of changes in final goods prices, and of pre- and post-investment levels of final goods outputs.

It is only if there is such a link, of one or the other type, that we can say that a study represents a study of the impact of transport investment on economic activity rather than simply a conventional transport evaluation study.

3.3.2. EVALUATING EVIDENCE ON THE LINKS

We next need to evaluate the evidence on the link. This is shown in the first of the four evaluation boxes in the chart. We need to consider the following questions about the link:

- Is the link *transparent*, in that it is clear how the link has been derived? Transparency may be a matter of theoretical transparency, in that there is a theoretical explanation of the link in terms of a formal or informal model which is clearly specified (this does not preclude a verbal explanation, rather than an explicit mathematical model). Alternatively it may be empirical, in the sense that the link is seen purely in terms of an association between infrastructure investment and levels of economic activity and/or consumer prices.
- Is the link *theoretically plausible*? If there is a theoretical explanation, it needs to be a "good" theoretical explanation, by which I mean a logically-consistent one. However, a theoretical explanation is not necessary if there is a clear empirical link between infrastructure investment and levels of economic activity – though (see below) causality will still be an important issue.
- Is the link *empirically verifiable*? This means it must be possible to test the hypothesis of a link between infrastructure investment and economic activity against real-world data.

- Is the link *empirically verified*? This is the "proof of the pudding". One form would be the case where models were first developed to link levels of economic activity with transport infrastructure investment. The models would secondly be used to predict the impact of specific infrastructure investments on economic activity. Third, after the investments had been made, the levels of economic activity would be monitored to see whether the predictions had proved to be correct. Given that economic activity is affected by so many factors, the problem of constructing the counter-factual outcome in the absence of the investment means that this approach would be extremely difficult to apply in practice. However, empirical verification can take other forms. One is to estimate a model using standard measures of statistical significance, and judge the model against these measures. Another related approach, common in macro-economic forecasting exercises, is to estimate the model over part of the data sample, and then use the model to generate forecasts over the rest of the data sample.

A final, and important, issue in the evaluation of links between transport infrastructure investments and economic activity is that of *causality*. This has proved to be a particular problem in the macro-econometric studies of such links. There may well be a strong association between infrastructure investment and economic activity, but this does not necessarily imply that it is the investment which determines the activity.

3.3.3. BENEFIT MEASURES ASSOCIATED WITH CHANGES IN ECONOMIC ACTIVITY

Whether one is satisfied in the evaluation stage of the links between investment and economic activity or not, the next issue is that of whether there is a benefit measure associated with the change in economic activity. The benefit measure will depend on the type of economic activity being considered.

- Where the study is considering the impact of transport infrastructure investment on income, the normal benefit is the change in total income. This was the approach adopted by Tinbergen.[7]

- Where the study is considering the impact of transport infrastructure investment on employment levels, then some "shadow wage" needs to be applied to the employment changes.[8] One such "shadow wage" might be the actual wage, but this is likely to ignore the opportunity costs of employment. Where governments were concerned with regional distribution of employment growth they might wish to associate different weights against changes in employment in different regions. These weights might reflect differential unemployment rates in the different regions.

- Finally, where the study is concerned with economic surplus changes, the benefit measures will be measures of changes in consumer surplus and economic profits.

[7] As with consumer surplus measures, such as compensating variation (CV) and equivalent variation (EV) there is an index number problem in measuring the change in income, since either initial or final prices can be used, ie we can measure the change in income either as:

$$\Sigma P_{i1} Q_{i2} - \Sigma P_{i1} Q_{i1}$$

or

$$\Sigma P_{i2} Q_{i2} - \Sigma P_{i2} Q_{i1}$$

[8] The analysis of Figure 1 in section 2 of this Report indicates that it is possible that a reduction in transport costs could actually reduce manufacturing employment. This would be particularly relevant where transport cost reductions enabled firms to take advantage of economies of scale by concentrating production at fewer individual plants.

When benefit measures are also calculated from transport cost reductions, the two alternative benefit measures should be compared with each other to see if they are equal. If they are equal the conclusion is that conventional cost-benefit appraisal of projects, using traffic benefit measures, accurately measures the total benefits of projects. However, where the measures differ, then conventional appraisal will give misleading answers.

The type of study which most commonly compares benefits in this way is the CGE study, where multipliers are estimated between final benefits and conventional traffic benefits. Hussain measures the ratio of the equivalent variation benefits to consumers to the full traffic benefits (including benefits to generated traffic), which he calls TBN, the "true benefit multiplier", while Venables and Gasiorek consider the multiplier SW/CBA, where SW is the change in consumer plus producer surplus, and CBA is the traditional cost-benefit analysis benefit to freight traffic.

Of particular concern in the UK is the relevance of studies which derive estimates of employment changes which are anticipated to result from transport infrastructure investments. The first question to be asked is whether the forecasts of employment change are correct. The issues involved in evaluating this were discussed in section 3.3.2 above. The second question is that of how plausible changes in employment should be evaluated. There are a number of reasons why employment changes might be evaluated as an addition to traffic benefits. These are:

- The employment changes might act as a marker to indicate that total benefits of the project exceed measured traffic benefits. Although the CGE models' contribution is to show that total benefits could exceed traffic benefits, I am not aware of any consistent way in which the size of employment changes can be linked with the size of the "true benefit multipliers". This is clearly an important factor for further consideration.

- Society, or governments, might see increases in total employment as desirable. This would be the case if there were involuntary unemployment in the economy. Again this requires plausible evidence that a particular transport infrastructure project would increase total employment in the economy.

- Society and governments are concerned about the regional distribution of employment, and it is clear that transport investments will change this distribution, even though it might be difficult to predict in advance how they will do so. Once a plausible prediction has been made, it will be necessary to use weights to assess gains in employment in some areas (perhaps where unemployment is relatively high) against losses in others (perhaps where congestion and pressure on public resources are high).

3.4. Disaggregation by area or region

3.4.1. IDENTIFYING SPATIAL DISAGGREGATION

The final parts of the chart consider the issue of spatial disaggregation. Governments may be interested not just in the overall benefits of a transport benefit project, but also in its regional or local impact. We therefore need to ask whether impacts are disaggregated by area.

3.4.2. EVALUATING METHODS OF A REAL DISAGGREGATION

If there is a spatial disaggregation of impacts, then a second evaluation procedure is needed. This is shown in the second shaded box in Chart 1a.

This shows that we need to ask:

- Is the disaggregation *transparent*, in that it is clear how the disaggregation has been achieved? Transparency may be a matter of theoretical transparency, in that there is a theoretical explanation of the procedure in terms of a formal or informal model which is clearly specified[9] (again, this does not preclude a verbal explanation, rather than an explicit mathematical model), or it may be empirical, in the sense that the link is seen purely in terms of an association between infrastructure investment and local or regional levels of economic activity and/or consumer prices.

- Is the procedure *theoretically plausible*? Again a theoretical explanation of the methodology needs to be a logically-consistent one. However, a theoretical explanation is again not necessary if there is a clear empirical link between infrastructure investment and local or regional levels of economic activity.

- Is the disaggregation procedure *complete*, in that the impacts are not just assessed at one local level? For example, a road might increase employment in areas close to the road, but employment might fall in other areas. An appraisal which measured gains in the areas where employment rose, but ignored losses in areas where employment fell, would therefore be incomplete.

- Is the disaggregation procedure *empirically verifiable*? This means it must be possible to test the local/regional impacts of infrastructure investment against real-world data.

- Is the procedure *empirically verified*? One form would be where models were developed to link local or regional levels of economic activity with transport infrastructure investment. The models would then be used to predict the impact of specific infrastructure investments on economic activity, and after the investments had been made the local or regional levels of economic activity would be monitored to see whether the predictions had proved to be correct. Given that the spatial pattern of economic activity is affected by so many factors, the problem of constructing the counter-factual means that this approach would be extremely difficult to apply in practice. However, empirical verification can take other forms. One would be to estimate a spatial model using standard measures of statistical significance, and judge the model against these measures.

3.4.3. DISAGGREGATED BENEFIT MEASURES

In principle one could disaggregate the benefits of changes in local or regional activity, and compare them with disaggregated traffic benefit measures. One difficulty in making such a comparison is that it would likely be difficult to disaggregate traffic benefits by region. In addition, the ultimate beneficiaries of the project would be different from the immediate beneficiaries. I am not aware of studies which have attempted to do this.

[9] Where the details of a model's structure and equations are not published, they should at least be "open to inspection" by qualified observers in order to be credible.

3.5. Impacts on leisure and tourism industries

The evaluation of appraisals which consider the impacts of transport infrastructure projects on leisure and tourism industries are shown in Chart 1b. The factors considered in this chart should be treated as additions to those shown in Chart 1a, rather than as alternatives.

As in Chart 1a, the first stage is the identification of the nature of the changes in transport infrastructure being considered. These are most likely to be projects in areas where the tourism industry is of particular importance to the local economy.

Traffic benefit measures may, or may not, specifically distinguish benefits to tourist travel, and there may, or may not, be links from the travel cost reductions to changes in employment and income in the tourism and leisure industries. Again, the crucial issues in evaluating the legitimacy of links between investment and the economy are those of transparency, theoretical plausibility, empirical verifiability and verification, and the identification of causality.

3.6. Impacts on labour markets

Chart 1c shows the modification of the basic framework to consider impacts on labour markets. Here the issue is to assess the links between reductions in commuting costs and resulting impacts on labour market areas and the productivity of the labour market. Improved labour utilisation and flexibility might contribute to economic growth, though it might be noted that increases in average length of car commuting journeys might conflict with SACTRA's recommendations on methods to reduce transport intensity.

3.7. Policies which reduce transport infrastructure

The final modification of the basic flow chart is shown in Chart 1d. This reverses the basic procedures to consider the effect of reductions in transport infrastructure. A major previous reduction in infrastructure facilities in Britain came with the withdrawal of rail passenger services, particularly in the Beeching era of the 1960s. Present day policy may be more concerned with pedestrianisation and closure of roads in urban areas for environmental reasons.

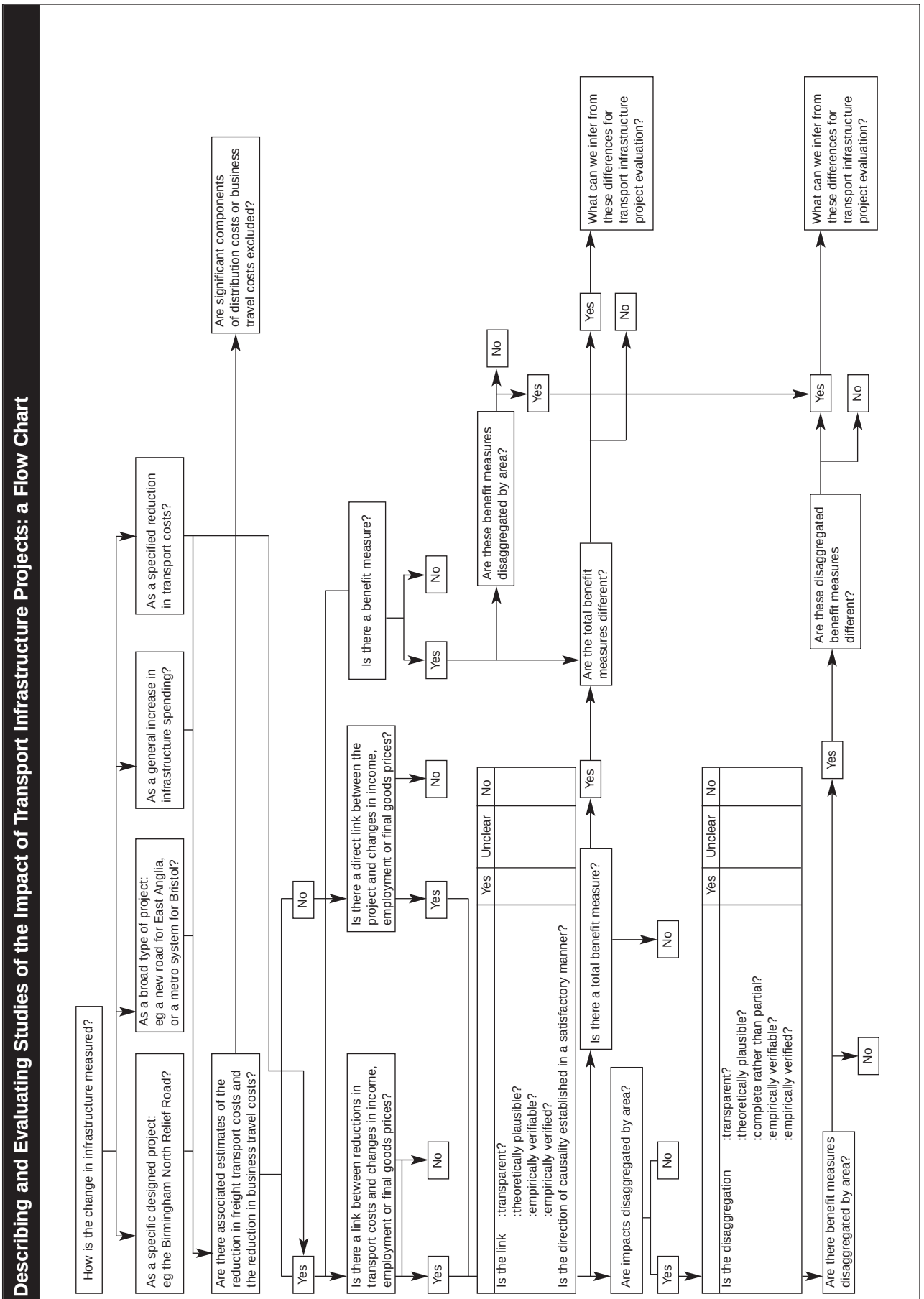


Chart 1a: Describing and Evaluating Studies of the Impact of Transport Infrastructure Projects: a Flow Chart
How is the change in infrastructure measured?
As a specific designed project: eg the Birmingham North Relief Road?
As a broad type of project: eg a new road for East Anglia, or a metro system for Bristol?
As a general increase in infrastructure spending?
As a specified reduction in transport costs?
Are there associated estimates of the reduction in freight transport costs and the reduction in business travel costs?
Are significant components of distribution costs or business travel costs excluded?
Yes
No
Is there a link between reductions in transport costs and changes in income, employment or final goods prices?
Is there a direct link between the project and changes in income, employment or final goods prices?
Is there a benefit measure?
Yes
No
Yes
No
Yes
No
Is the link :transparent? :theoretically plausible? :empirically verifiable? :empirically verified?
Yes
Unclear
No
Is the direction of causality established in a satisfactory manner?
Are these benefit measures disaggregated by area?
Yes
No
Is there a total benefit measure?
Yes
No
Are the total benefit measures different?
Yes
No
What can we infer from these differences for transport infrastructure project evaluation?
Are impacts disaggregated by area?
Yes
No
Is the disaggregation :transparent? :theoretically plausible? :complete rather than partial? :empirically verifiable? :empirically verified?
Yes
Unclear
No
Are these disaggregated benefit measures different?
Yes
No
What can we infer from these differences for transport infrastructure project evaluation?
Are there benefit measures disaggregated by area?
Yes
No

Chart 1b: **Describing and Evaluating Studies of the Impact of Transport Infrastructure Projects on the Leisure and Tourism Industries: a Flow Chart**

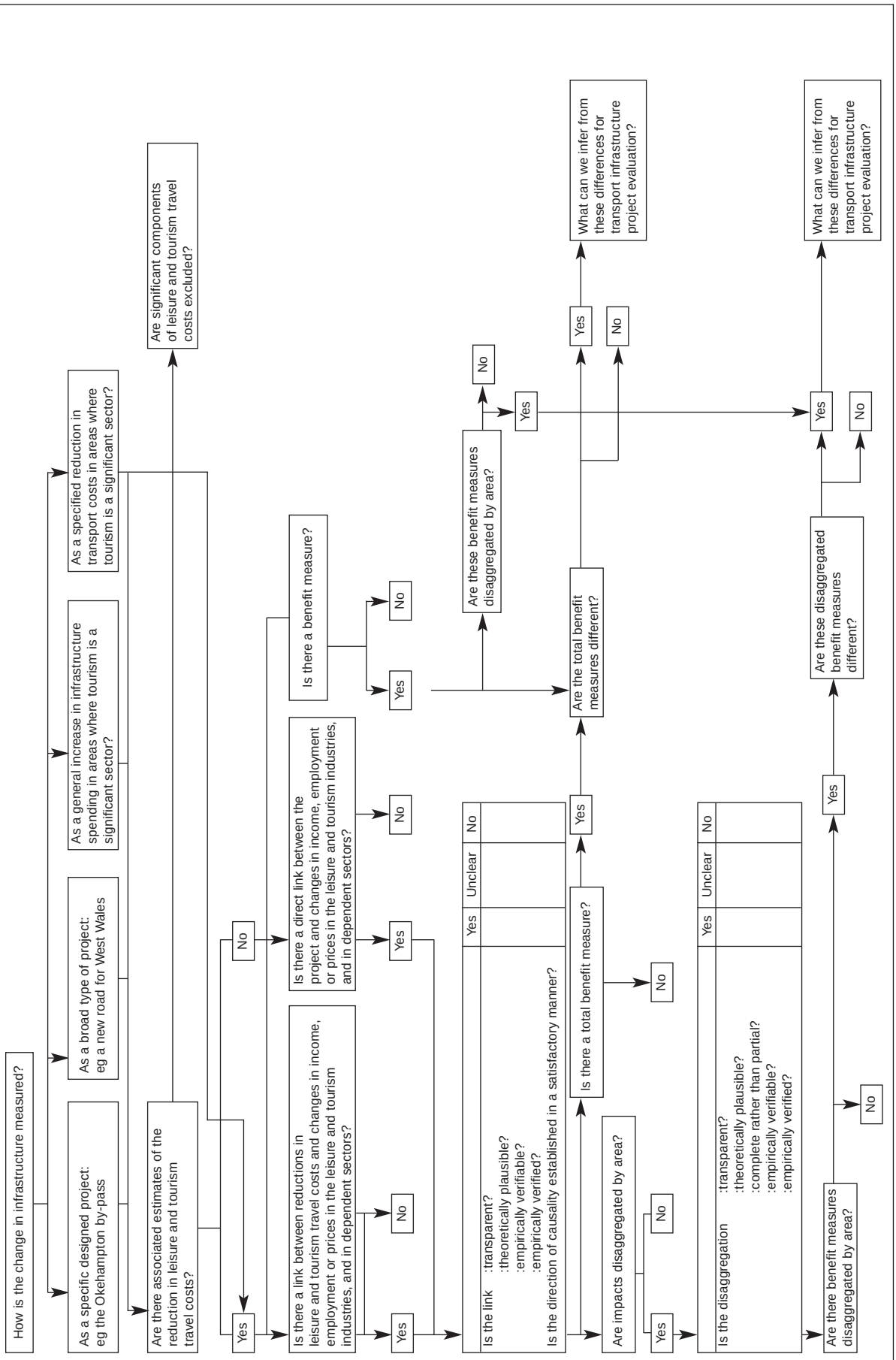
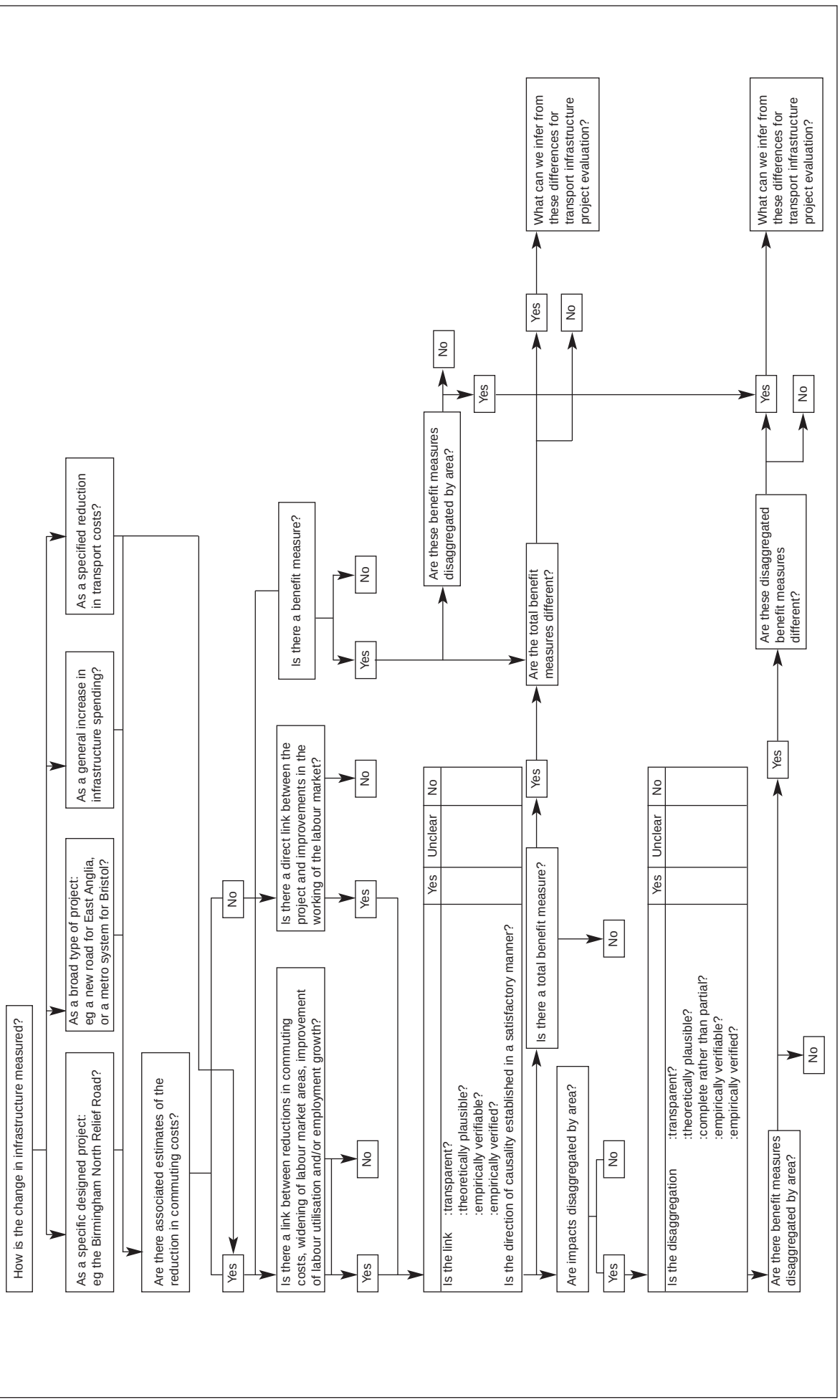


Chart 1c: Describing and Evaluating Studies of the Impact of Transport Infrastructure Projects on Labour Market Areas: a Flow Chart



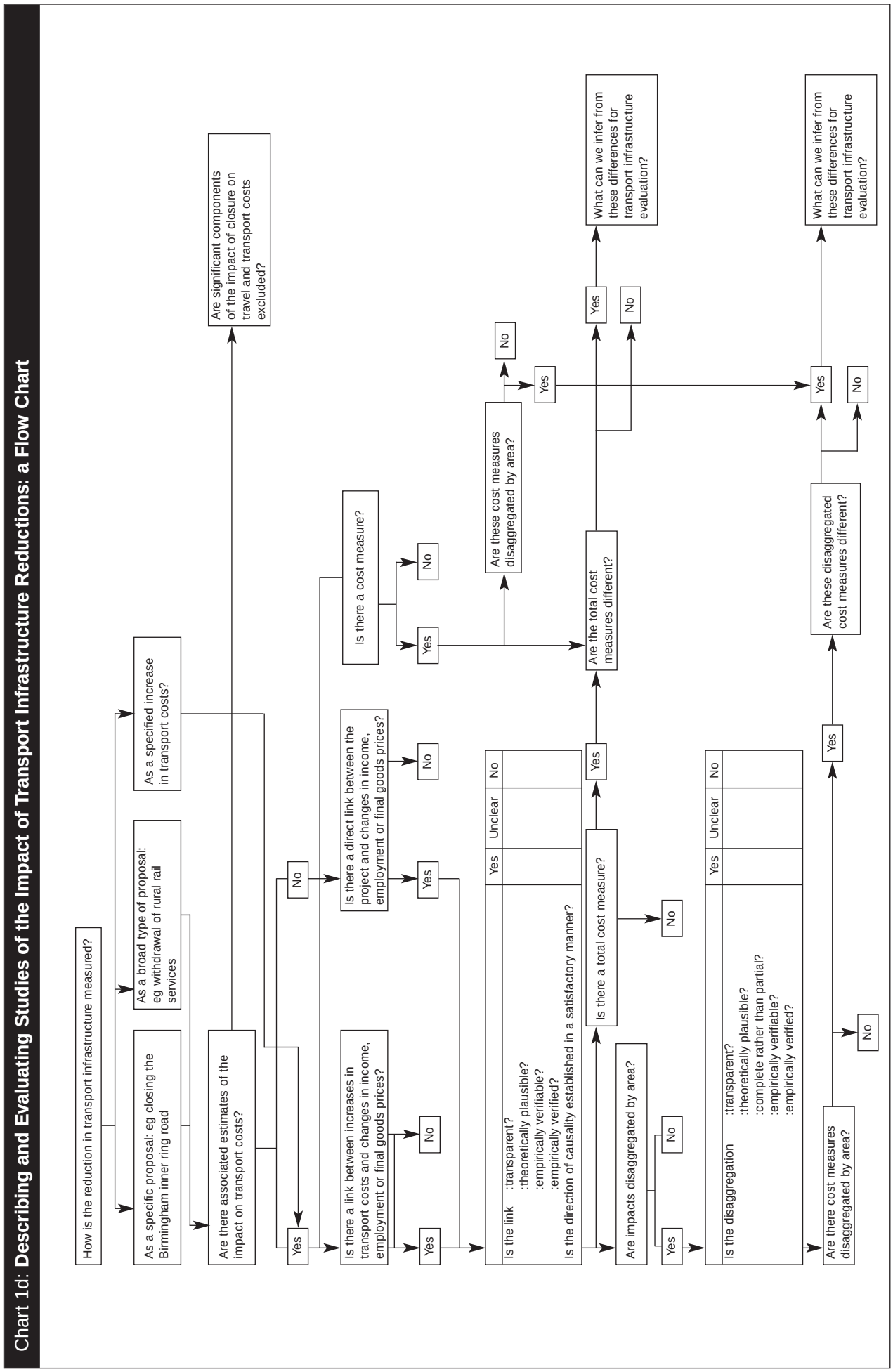


Chart 1d: Describing and Evaluating Studies of the Impact of Transport Infrastructure Reductions: a Flow Chart
How is the reduction in transport infrastructure measured?
As a specific proposal: eg closing the Birmingham inner ring road
As a broad type of proposal: eg withdrawal of rural rail services
As a specified increase in transport costs?
Are there associated estimates of the impact on transport costs?
Are significant components of the impact of closure on travel and transport costs excluded?
Yes
No
Is there a link between increases in transport costs and changes in income, employment or final goods prices?
Yes
No
Is there a direct link between the project and changes in income, employment or final goods prices?
Yes
No
Is there a cost measure?
Yes
No
Is the link :transparent?
:theoretically plausible?
:empirically verifiable?
:empirically verified?
Is the direction of causality established in a satisfactory manner?
Yes
Unclear
No
Are these cost measures disaggregated by area?
Yes
No
Are the total cost measures different?
Yes
No
What can we infer from these differences for transport infrastructure evaluation?
Are impacts disaggregated by area?
Yes
No
Is there a total cost measure?
Yes
No
Is the disaggregation :transparent?
:theoretically plausible?
:complete rather than partial?
:empirically verifiable?
:empirically verified?
Yes
Unclear
No
Are these disaggregated cost measures different?
Yes
No
What can we infer from these differences for transport infrastructure evaluation?
Are there cost measures disaggregated by area?
Yes
No

CHAPTER 4

The use of the framework: some examples

4.1. Introduction

In this section of the Report we illustrate the use of the framework developed in the previous section by applying it to a number of previous studies or approaches. The studies are:

- My own study of the employment impact of the M62 motorway (Dodgson, 1974);
- Hussain's CGE study (Hussain, 1996). This was chosen because the CGE approach seems to be particularly a useful approach to understand all the complex inter-relationships which exist in disentangling the relationship between transport infrastructure and economic activity, and in ensuring that the analysis is complete rather than partial.
- The macro-econometric approach to model the relationship between infrastructure investment and productive performance at the (US) state level.

4.2. Employment effects of motorway construction

My own early study considered the anticipated impact of construction of the M62 motorway on manufacturing employment at a sub-regional level across the North of England. The way in which this study relates to the general version of the flow chart is shown in Chart 2. As Chart 2 shows, there was a clearly-defined specific project (whose construction was well under way when the study was being conducted).

My study estimated the impact of the motorway on average industrial transport costs in each of thirty areas using the gravity-model-based concept of access costs. As noted previously, this concept is closely related to that of economic potential. It has been developed more recently in a series of papers by Linneker and Spence which have calculated the impact of different highway projects, such as the M25 motorway, on spatial cost patterns.

While my study considered the impact of the M62 motorway on industrial transport costs, it did not involve direct measures of freight (or other traffic) benefits. This would have been undertaken as part of the Government's road appraisal procedures using a pre-COBA form of cost-benefit analysis but, as far as I know, these results were never published.

The study sought to establish a link between changes in access cost using a model of employment growth based on the hypothesis that the relationship between demand and supply of labour depended on the industrial structure of the area, the location of the area, and a (crude) measure of congestion.

The model was statistically – significant, but only just, and the specific variable of access cost was just about statistically significant, but only if one took a fairly generous view of the concept. This equation was then used to predict the impact of the motorway on employment in the different areas by projecting the predicted changes in transport costs into the estimated equation. Impacts were therefore disaggregated by area, though there was no attempt to associate any benefit measure with them.[10]

4.2.1. HOW DOES THE MODEL STAND UP TO EVALUATION?

On transparency, I think it is clear how the study derives its results in obtaining predictions of employment change at a disaggregated sub-regional level. The study was published in an academic journal and the methods used set out in full.

The results were not empirically verified, in the sense that after the motorway had been built, no attempt was made to measure whether the changes in transport costs created by the motorway had led to the employment changes predicted by the model. In fact, this would have been almost impossible to do given that the predicted changes were small in relation to total employment in the areas, and that these employment levels would be affected by so many other factors.[11]

This does suggest an important test of the credibility of arguments linking transport infrastructure and economic activity is ex post measurement. This involves looking for studies that have claimed that particular projects will change levels of economic activity and then finding clear evidence that such projects have done so once they have been built.

4.3. A computational general equilibrium study

Imdad Hussain's study uses a CGE framework, primarily to investigate the relationship between user benefits and final benefits. The way in which this study relates to the general flow chart is shown in Chart 3.

4.3.1. A NOTE ON THE CGE APPROACH

A CGE model is a computable general equilibrium model of the whole economy. The two main building blocks of these models are:

- utility functions for individual consumers, or for groups of consumers;
- production functions for specific goods, or groups of goods.

[10] The general underlying presumption of this work was that total traffic benefits, if measured correctly, would equal total final benefits because the economy was reasonably competitive.

[11] There was some indirect verification of the prediction that the motorway would have only small changes on the spatial pattern of activity, since the M62 project team monitored before and after traffic patterns across the trans-Pennine screenlines and concluded that there was no evidence of significant generation of traffic.

In the simplest two-sector versions of the model there are two inputs (capital and labour) with two input owners (capitalists and workers) who produce two goods. Given preferences, the state of technological knowledge, and the initial endowment of resources the models determine equilibrium in which "everything else" is determined. "Everything else" is defined as:

- the split of capital between the two goods;
- the split of labour between the two goods;
- relative input prices for capital and labour;
- total incomes of capital and labour;
- demand functions for the two groups for each of the two goods;
- the quantities of the two goods produced;
- prices of the two goods;
- "national income" defined as $P_1 Q_1 + P_2 Q_2$.

Given the choice of particular functional forms for activity functions and production functions, these models are "calibrated" on the existing base-case values for the economy being modelled and on empirical values, for example of the elasticity of substitution from previous empirical studies. An algorithm is then used to solve the model for a new equilibrium which results from a change to the system, such as the introduction of a tax or a subsidy, a change in one of the parameter values, or a reduction in transport costs.

4.3.2. HUSSAIN'S MODEL

Hussain's version of the CGE model has two variants. In the first of these there are three regions, the two inputs of capital and labour are immobile, and freight transport is treated as an intermediate good. In the second version, labour is mobile and commutes, while capital is also mobile between regions. Both models are based on Stone-Geary utility functions, and CES production functions.

Hussain computes the benefits to existing freight traffic (B^E), to generated freight traffic (B^N), to total freight traffic ($B^T = B^E + B^N$), and final consumer benefits in terms of equivalent variation (EV). The total benefit multiplier, TBN, the ratio between EV and B^T is equal to unity under a wide range of assumptions, but the two measures are not equal under two main circumstances:

- where the equilibrium commodity prices do not reflect competitive market behaviour: this is modelled as a situation of increasing returns where a regulated natural monopolist sets a price equal to average cost;
- where non-neutral transfers take place in the economy.

Chart 3 maps out Hussain's contribution to the understanding of the relationship between transport infrastructure investment, freight transport benefits and the ultimate benefits of reductions in freight transport costs.

The study characterises infrastructure investments in terms of their impacts on freight transport costs. The CGE approach then provides estimates of benefits to existing traffic and, since the model predicts changes in outputs in different regions and changes in the derived demand for transport that results, it also calculates benefits to generated freight traffic.

The model links changes in transport costs to changes in outputs and prices, so that it is possible to estimate resulting changes in final goods prices and demands. The utility-maximising consumer behaviour implied by these models leads to estimates of equivalent variation, which is a measure based on the cost (or expenditure) minimising behaviour which is the dual of utility maximisation. There are therefore final benefit measures to be compared with freight transport benefit measures. As indicated, the study is able to identify certain circumstances in which final benefits will differ from freight transport benefits, even where the latter take correct account of benefits to generated freight transport.

Although Hussain's model is a regional one, his study does not discuss the regional disaggregation of effects explicitly, though it would be possible to do so.

We turn now to evaluation. The model is transparent, in that it is set out in full. Moreover, the approach is one that is now widely-used, and generally accepted. Nevertheless, CGE models are complex, so that this reduces transparency to some extent in so far as the reader may have problems in feeling comfortable that they understand the complex interactions that these models entail. The model is also theoretically plausible, in that it is based on standard neo-classical analysis.

Empirical verifiability creates greater problems. These models are not estimated in the normal way, but are "calibrated" on the basis of parameters from previous studies. Thus the CES (constant elasticity of substitution) production function is based on estimates of the elasticity of substitution from previous studies (though sensitivity of the results are tested using a range of different values of the elasticity of substitution). The functional forms of utility and production function are also assumed rather than estimated.

Although the model yields predictions, it would be difficult to test them in practice given the way in which the model represents such a stylised (few region and few sector) model of the economy. It might be said that these models can give valuable insights into how an economy might behave, especially in situations of non-perfect competition, but it is difficult for them to be used to provide *verifiable* predictions.

4.4. Macro-econometric studies

Chart 4 shows a stylised version of the macro-econometric approach, rather than any specific study. Infrastructure investment is measured as a general increase in infrastructure spending. There are no estimates of the impacts of the infrastructure spending on freight (or other) transport costs, but there is an attempt to discover a direct link between changes in infrastructure spending and changes in the level of economic activity.

In terms of evaluation it is fairly transparent what is being done, since these studies generally do not have a very complex underlying theoretical model. Theoretical plausibility is couched in terms of infrastructure reducing costs and this reduction in costs being a factor encouraging growth. The studies, by their empirical nature, are empirically verifiable. Empirical verification is partly a matter of statistical significance (and results differ between the studies), and partly a matter of determining causality, which is where the approach is particularly weak.

The models do not provide explicit benefit measures, except in terms of changes in income, although some attempt to compare the changes in income with the levels of infrastructure investment.[12] Since they do not include measure of transport costs reductions, they would be unable to answer the question of whether conventional traffic cost-benefit measures correctly reflected true benefits even if they did derive a convincing causal statistical relationship between transport infrastructure investment and levels of economic activity.

[12] Morrison and Schwartz compare the costs (ie the levels) of infrastructure spending, deflated by the opportunity costs of public funds raised through taxation, with the associated reductions in manufacturing costs.

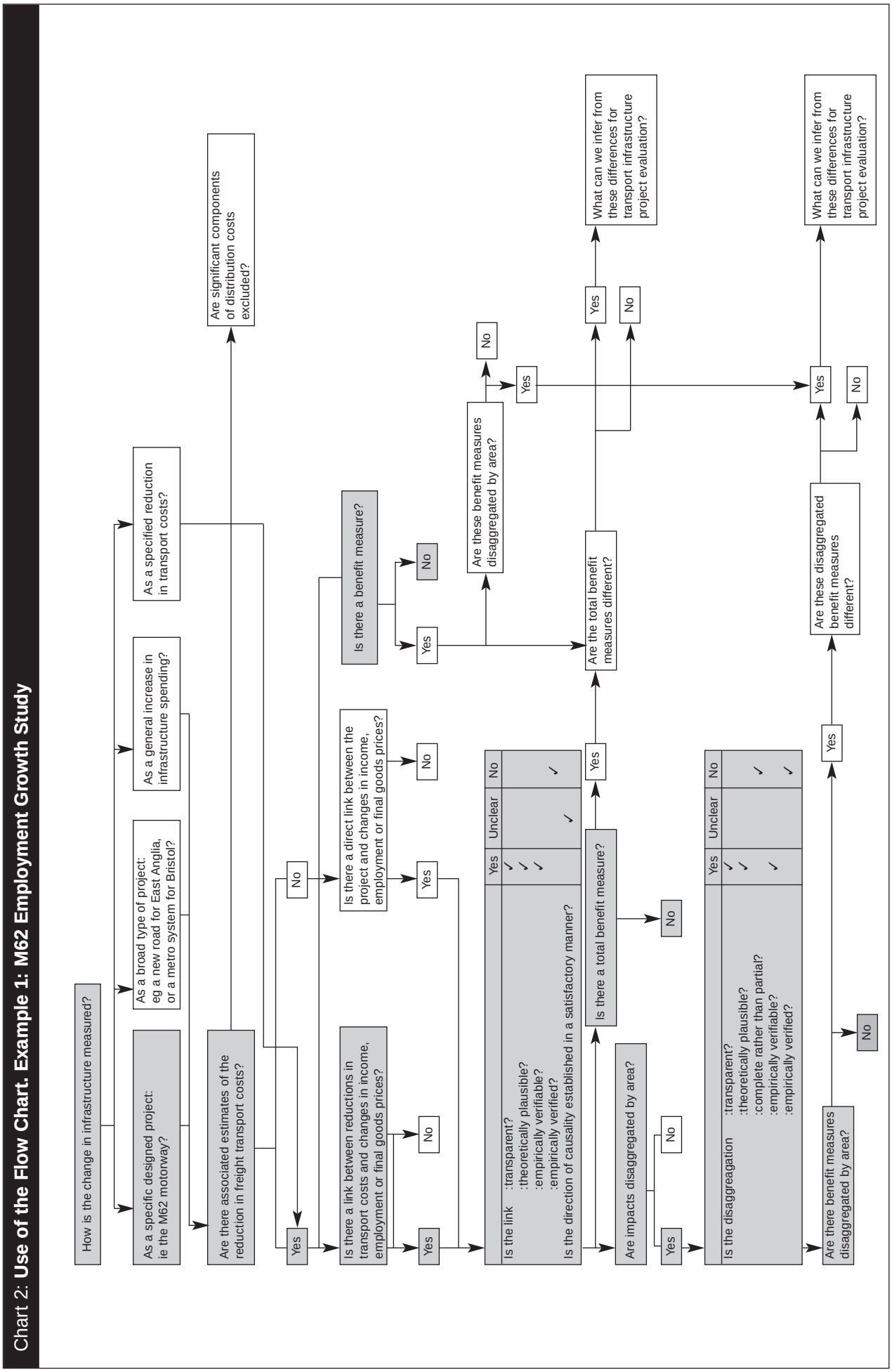
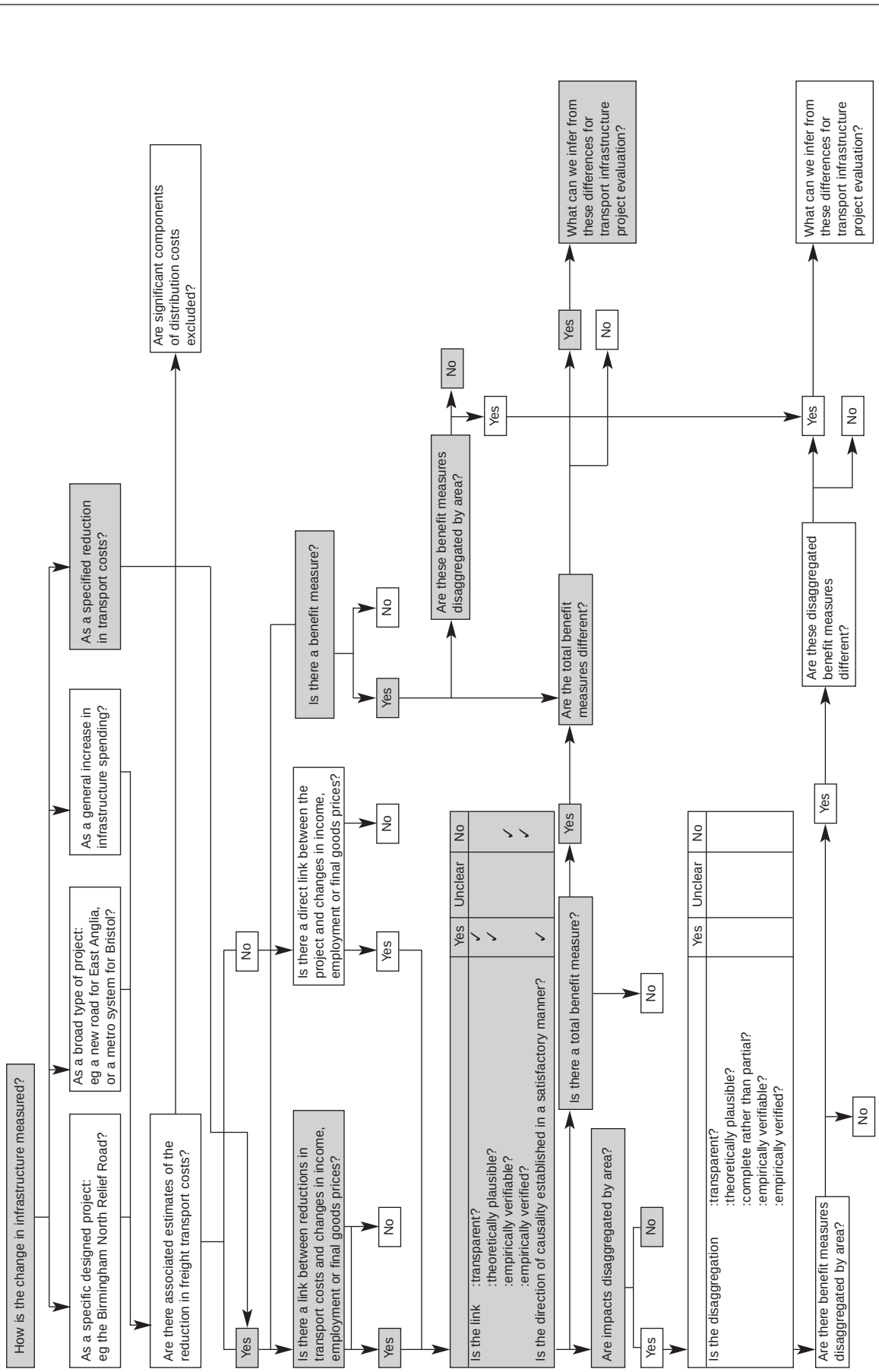


Chart 2: Use of the Flow Chart. Example 1: M62 Employment Growth Study
How is the change in infrastructure measured?
As a specific designed project: ie the M62 motorway?
As a broad type of project: eg a new road for East Anglia, or a metro system for Bristol?
As a general increase in infrastructure spending?
As a specified reduction in transport costs?
Are there associated estimates of the reduction in freight transport costs?
Are significant components of distribution costs excluded?
Yes
No
Is there a link between reductions in transport costs and changes in income, employment or final goods prices?
Is there a direct link between the project and changes in income, employment or final goods prices?
Is there a benefit measure?
Yes
No
Is the link :transparent? :theoretically plausible? :empirically verifiable? :empirically verified? Is the direction of causality established in a satisfactory manner?
Yes
Unclear
No
Are these benefit measures disaggregated by area?
Are the total benefit measures different?
What can we infer from these differences for transport infrastructure project evaluation?
Are impacts disaggregated by area?
Is there a total benefit measure?
Is the disaggreagation :transparent? :theoretically plausible? :complete rather than partial? :empirically verifiable? :empirically verified?
Are these disaggregated benefit measures different?
Are there benefit measures disaggregated by area?

Chart 3: **Use of the Flow Chart. Example 2: Hussain's CGE Model**



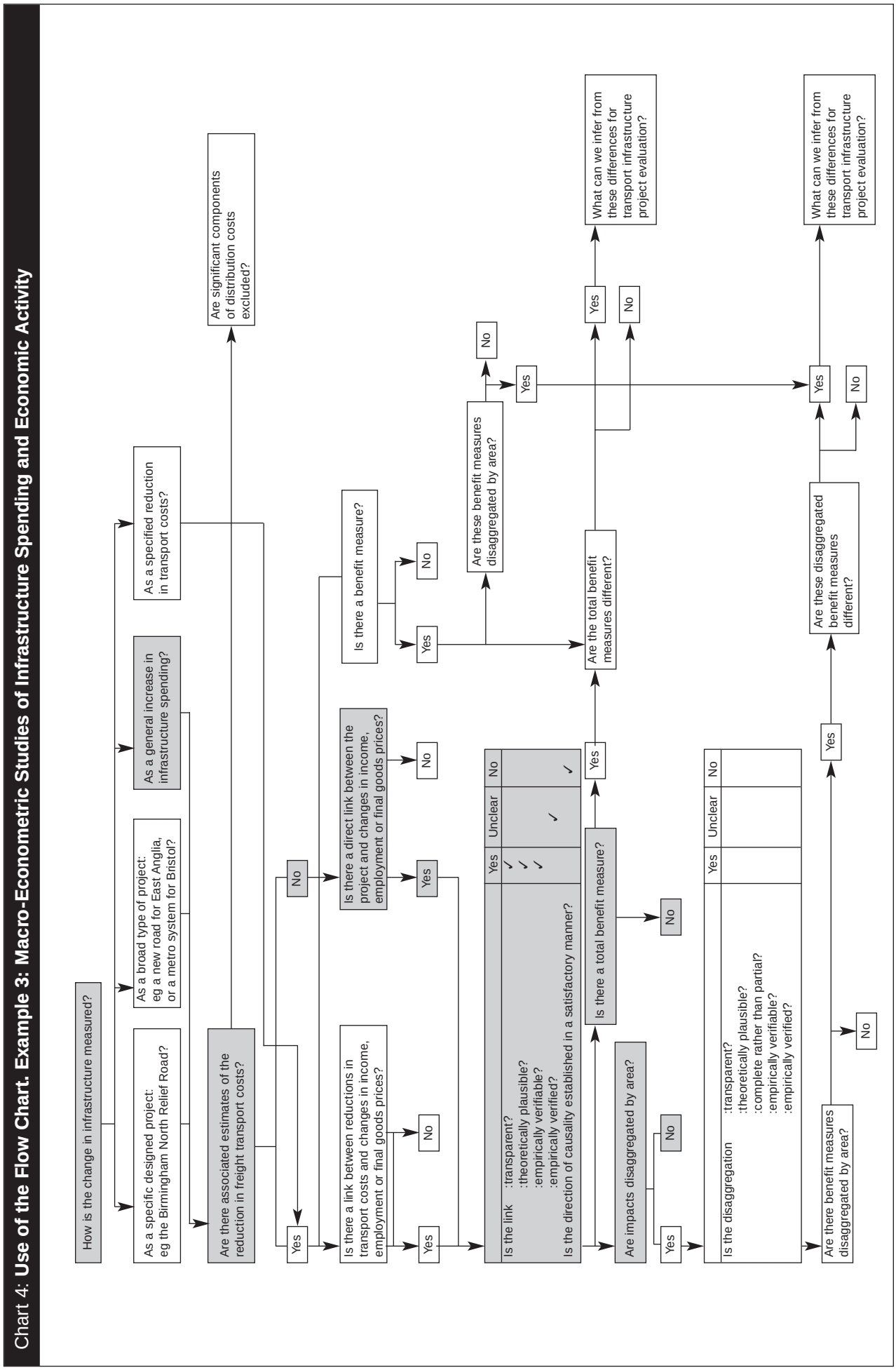


Chart 4: Use of the Flow Chart. Example 3: Macro-Econometric Studies of Infrastructure Spending and Economic Activity
How is the change in infrastructure measured?
As a specific designed project: eg the Birmingham North Relief Road?
As a broad type of project: eg a new road for East Anglia, or a metro system for Bristol?
As a general increase in infrastructure spending?
As a specified reduction in transport costs?
Are there associated estimates of the reduction in freight transport costs?
Are significant components of distribution costs excluded?
Yes
No
Is there a link between reductions in transport costs and changes in income, employment or final goods prices?
Yes
No
Is there a direct link between the project and changes in income, employment or final goods prices?
Yes
No
Is there a benefit measure?
Yes
No
Is the link :transparent? :theoretically plausible? :empirically verifiable? :empirically verified? Is the direction of causality established in a satisfactory manner?
Yes
Unclear
No
Are these benefit measures disaggregated by area?
Yes
No
Are the total benefit measures different?
Yes
No
What can we infer from these differences for transport infrastructure project evaluation?
Are impacts disaggregated by area?
Yes
No
Is there a total benefit measure?
Yes
No
Is the disaggregation :transparent? :theoretically plausible? :complete rather than partial? :empirically verifiable? :empirically verified?
Yes
Unclear
No
Are these disaggregated benefit measures different?
Yes
No
What can we infer from these differences for transport infrastructure project evaluation?
Are there benefit measures disaggregated by area?
Yes
No

CHAPTER 5

Conclusions

This Report has developed a framework within which SACTRA may be able to evaluate the varied forms of evidence they need to consider on the relationship between transport infrastructure investment and economic activity. As the demonstration of the use of the framework in Section 4 of the Report shows, professional judgement must be used in the evaluation of the quality of the more technical of the studies that will need to be considered. With regard to such studies, CGE models, with their ability to handle both imperfectly competitive markets, and the complex interactions which occur within any economic system, do provide an indication that final benefits may exceed freight traffic benefits, even where the latter are correctly measured. But clear ex post empirical evidence is also needed that transport investments do have significant impacts on economic activity at either national or local/regional level to back up these valuable, largely theoretical, insights. Conjecture or assertion are not enough.

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