Lake, M. and **Ferreira, L**. (2002*). Towards A Methodology To Evaluate Public Transport Projects.* Physical Infrastructure Centre Research Report 02-03, School of Civil Engineering, Queensland University of Technology, Brisbane.

Towards A Methodology To Evaluate Public Transport Projects

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SUMMARY

The document is intended to form the basis for the development of the **Public Transport Evaluation (PTE) Framework,** which is be used in practice by planning agencies and transport operators in Queensland**.** The main underlying **aim** is to be able to answer the question:

What does the community get for each $ spent on Public Transport (PT) projects?

The full community benefits of PT investment and recurring operating fare box subsidies are often difficult to identify and quantify, either in monetary or other units. This is mainly due to the nature of the externalities involved (eg. reduced road space requirements; reduced road based congestion, environmental impacts and energy consumption; increased access for non-car owning households; etc.). Such quantification is necessary for strategy/project evaluation and to justify investments in PT initiatives to the community at large.

Currently, the levels of consistency and uniformity in the procedures for the evaluation of road projects are not matched in the evaluation of PT projects ands strategies. The lack of a structured evaluation methodology is, in part, due to the level of complexity of impacts and affected groups. Compared to public transport, road projects tend to have fewer impacts and affect fewer groups. The complex nature of potential impacts is directly related to the range (eg. economic, financial, environmental, social; direct/indirect) and affected groups (users, non-users, as well as government and private operators).

The main **benefits of a common evaluation framework** include:

- Potential to improve the quality of investment and policy decisions;
- Ability to compare projects across transport portfolio on a consistent basis;
- Help the ‘value for money’ arguments for PT projects;
- Identify affected groups and impacts;
- Identify trade-offs between gainers and losers; and
- Help design specific evaluation studies to assess the degree to which claimed benefits have been/are being achieved.

The framework proposed here is intended as a user-friendly spreadsheet based tool which can be used to assess individual projects or strategies within a comprehensive and consistent basis, using Queensland related evaluation parameter values where appropriate. Currently, an EXCEL based prototype for the framework has been built. The following main components make up the framework:

- **Project/Strategy definition** – the user specifies the project or strategy using a suggestion typology;

- **Identification of impacts** – the system suggests impact types likely to apply based on project definition and the user finalises impact list;

- **Before & After input data (or conditions ‘with’ and ‘without’ project)–** this relates to road and PT link data on volumes, patronage, speeds and other data

needed for impact assessment. The affected road and PT links or segments are identified separately to allow a reasonable level of disaggregation of impacts. At this stage, the user has the option of using estimates given default values and relationships (eg; speed/flow curves to obtain estimates of delay impact on road traffic) or input his/her own estimates independently arrived at;

- **Impact quantification –** for each impact type, the user can opt to make use of default parameters applicable in Queensland , to quantify impacts; and

- **Summary outputs** are shown by main impact type to enable sensitivity analysis results to be easily compared.

Two methods are primarily used for in road and public transport project evaluation, namely: cost benefit analysis and multi-criteria analysis. For some impacts, such as equity, environmental effects and regional development, there is no consensus on their incorporation or quantification in money terms. Other issues that require careful consideration in an evaluation methodology include:

- The measure used to reflect public transport ridership. This can have a major influence on the results, since a number of the impacts are estimated on the forecast ridership estimates;
- The life of the project. Some benefits are long term and hard to quantify with certainty, resulting in the evaluation being less robust as the life of the project is extended;
- The implementation risk factors. Some measures, such as the likelihood of successful implementation or difficulty of construction, should be considered;
- The definition of the base case and the geographic scope of the evaluation; and
- The evaluation method used should not focus on a final Net Present Value (NPV) or single 'best' solution. This approach may exclude: non-quantifiable benefits; uncertainty in the cost and benefit estimates; and alternative weighting of the project objectives.

Thus, an evaluation methodology needs to cater for sensitivity analysis, including the impact of changes in the weighting factors for each objective.

TABLE OF CONTENTS

PART I: THE PROPOSED EVALUATION TOOL

1 INTRODUCTION 5
- 1.1 Background 5
- 1.2 The Evaluation of PT Operating Subsidies 7
- 1.3 Structure of this Report 8

2 THE PTE FRAMEWORK 9
- 2.1 Objectives 9
- 2.2 Proposed Practical Framework 9
- 2.3 Defining Projects and Strategies 10
- 2.4 Types of Impacts 11

PART II: LITERATURE REVIEW

3 EVALUATION METHODOLOGIES 13
- 3.1 General 13
- 3.2 International Comparison of Evaluation Methodologies 17
- 3.3 Quantifying Impacts 21
- 3.4 Valuing Externalities 25

4 CONCLUSIONS 28

5 REFERENCES 29

PART I: THE PROPOSED EVALUATION TOOL

1 INTRODUCTION

1.1 Background

Public transport share of the total person travel market has continued its decline as private vehicle use increases in Australian urban areas. This downward trend in the use of public transport is aligned with the reduction in the proportion of all work trips to the CBD major urban areas, with the following the key influences on change in urban passenger transport (Hensher, 1998):

- The changing composition of the labour force and work schedules;
- The suburbanisation of work opportunities and the accompanying loss of high-density corridors;
- The changing incidence of the population in each life cycle stage;
- The commitment or lack thereof from government to pricing/regulatory reforms;

In Australia, the average growth rate per annum in patronage is 1.5% for bus and 0.8% for rail, in comparison to 4.3% for passenger cars (Hensher et al., 1997).

Public transport projects are mainly aimed at improving environmental quality; increasing accessibility for all; and improving economic efficiency. The specific objectives related to each goal are given in Table 1.

Table 1: Public Transport Goals and Objectives

Ultimate goals	Specific objectives
Environmental and urban amenity	• Increase air quality and reduce emissions • Reduce traffic noise and impact • Improve safety and reduce accidents, injuries and deaths. • Reduce transport energy consumption and CO_2 emissions • Improve visual, aesthetic and other aspects of urban amenity
Accessibility	• Improve accessibility to work and other activities • (car and non-car trips)
Economic efficiency	• Reduce costs for urban freight and commercial traffic, including cost of congestion and reduce cost to health • Reduce travel times and costs for all trips

- Reduce capital and other subsidies for providing transport expect where these form part of a wider pricing policy
- Increase opportunities for economic interaction

Source: Browne, 1995

The use of subsidies to public transport is some time justified on the basis of the above, as well as:

- *Reducing the rate of urban sprawl;*
- *Providing a 'second best' option to road pricing;*
- *Public transport as an option value*: Public transport is valued on the basis of potential utilisation, rather than on the basis of actual use. When the existence of a possibility in the future, or an option, gives rise to a higher level of expected utilisation that without it, the option is said to have a value, whether or not the option is exercised or not. The existence of an option value may explain the willingness to pay, through public funds, for public transport services that are little used (Roson, 2000);
- *Transport as a social need:* Economic polices are often designed to sustain the standard of living of the poorest groups in the population, in addition to avoiding excessive income disparities. It could be argued that transport itself should be included on the list of social needs, which could be achieved by means of relatively cheap public transport (Roson, 2000); and
- *Regeneration of local economies.*

Arguments against public transport subsidisation include:

- *Lack of convenience, comfort and speed:* Urban travellers want convenience, comfort and speed, for which a car best fits these requirements (Semmens, 2000).
- *Inferior good*: Public transport is an inferior good by economists' definitions, as quantity consumed drops as income rises (Semmens, 2000).
- *Unwillingness of users to pay full cost*: The only measure of need we have is people's willingness to pay for something. The unwillingness of transit providers to ask consumers to pay the full cost of the service is proof that the service is not perceived to be worth what it costs to provide (Semmens, 2000).
- *Lack of environmental effects*: Often dual mode trips (eg. car and rail) and low public transport occupancy levels will nullify the relative emission benefits between public transport and personal car usage (McRobert, 1997). The improvement made in air quality over the last two decades in the US is due to the improvements made in cars, with public transport ranking near the bottom in terms of cost-effectiveness in reducing air pollution (Miller, 1997).
- *Induced traffic:* the capacity released on the road network is taken up by the suppressed demand. There is only a marginal effect on relieving road traffic congestion and the main impact is the redistribution of public transport patronage between modes (Younes, 1995).
- *Unattractive levels of service:* No public transport system within affordable political budgets is ever likely to provide the level of service of sufficient appeal

to attract large numbers of car users to switch to public transport across the many travel markets (Hensher, 1998).

Accepting that public transport is being implemented, the most benefit for the community is required for the subsidisation levels that are received. Funding available for public transport will always be limited and it is therefore incumbent on policymakers to invest these limited funds in ways that produce the greatest value for the taxpayer's dollars. To enable the most appropriate public transport service and operational policies to be adopted, a methodology is required to compare the public transport options and permit a method of assessing the best option.

1.2 The Evaluation of PT Operating Subsidies

Strategies to increase or maintain the role of PT include restrictions and pricing of car trips, as well as incentives to the use of PT. The provision of subsidies to PT operators to cover revenue shortfalls in the provision of services, can be seen as part of the range of PT policies available. In that context, subsidies can, in theory, be evaluated in the same way as other projects or strategies which have the potential to enhance PT. That is, the benefits are potentially available in the form of reduced car tips; local jobs; increased spending on consumption locally and other impacts as detailed elsewhere. In practice, this type of evaluation is difficult to undertake due to data availability constraints.

In addition, subsidies have the potential to bring operating efficiency gains and hence reduced PT unit operating costs. The relationship between operating subsidies and PT performance, including operating efficiency, has been studied by several authors, Taylor (1994 and 1996); Fielding (1992); Hartman et al. (1994) and Cerevo (1990). Taylor (1996) points to evidence from 16 States in the U.S. to suggest that there are very little linkages between subsidies and operator performance due to conflicting equity based objectives. The latter are mainly geared to provide geographical equitable distribution of funds, as well as equity amongst operators and the general taxpaying community.

If it can be demonstrated that the benefits of subsidies will include efficiency gains for operators and level of service gains for users, it is possible to estimate the impacts in terms of user costs and modal shifts. The comparison which needs to be made is between the current service levels and those which would prevail without the subsidy. The base-case here is the ‘without subsidy’ situation and the subsidy benefits represent the difference between the base-case and the current services.

Karlaftis et al. (1997) found that there was an inverse relationship between PT performance and operating subsidies for a data set of 11 fixed route system in the U.S. They used factor analysis methods to arrive at a set of performance indicators grouped under 3 main headings, namely: overall performance, effectiveness and efficiency. The strong inverse correlation between all 3 categories of measures and level of subsidy found in that study, follows similar conclusions found in earlier work Cervero (1986); Karlaftis and McCarthy (1998); Bly and Oldfield (1986); Pickrell (1985) and Pucker (1985 and 1995). Most of the past evidence suggests that subsidies, whilst improving the effectiveness of PT, do not have a positive impact on efficiency levels.

1.3 Structure of this Report

Part I puts forward a proposed **evaluation framework** which could be used in practice by planning agencies and transport operators in Queensland. The document is intended to form the basis for the development of the **Public Transport Evaluation and Assessment (PTEA) Framework.** The latter is intended as a user-friendly spreadsheet based tool which can be used to assess individual projects or strategies within a comprehensive and consistent framework, using Queensland related evaluation parameter values where appropriate. The underlying theoretical underpinnings of well established techniques, such as comprehensive social cost-benefit analysis, are not presented here.

The main underlying **aim** is to be able to answer the question:

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- Identify trade-offs between gainers and losers; and
- Help design specific evaluation studies to assess the degree to which claimed benefits have been/are being achieved.

The next section outlines the framework objectives and provides an overview of its proposed main components. Section 2 also discusses the issues of project/strategy definition and the way in which impacts are categorised in the framework. Part II summarises the results of a literature review undertaken as part of the framework development task. This review is organised into the main headings of general evaluation and assessment methodologies; the main issues related with impact quantification.

2 THE PTE FRAMEWORK

2.1 Objectives

There are numerous evaluation guidelines for capital projects issued by State Treasury Departments, as well as those issued by the relevant transport Departments in Australia. The proposed PTE Framework is not designed to duplicate such guidelines but to help the evaluation task by:

- Showing the evaluation framework required to capture the main impacts of specific types of PT projects and strategies;
- Identify the impacts and affected groups;
- Assign monetary values to impacts wherever appropriate;
- Quantify and/or qualify non-monetary impacts;
- Provide worked examples for some of the more important project types.

2.2 Proposed Practical Framework

The use of 'typical' or 'average' values for each project type, together with the set of conditions for which those values apply, will be a useful output of this process. A set of linked worksheets are proposed to help with the process of impact identification and quantification. This approach enables sensitivity analysis to be undertaken, with respect to changes in the main input assumptions. Given the level of uncertainty attached to some of the impacts, as well as the debate about quantification in dollar terms in some cases, it is more appropriate to develop a tool that can provide a range of types of outputs rather than a single approach. The user will need to make choices at every stage of the process regarding the assumptions to be used, as well as the methodology to be adopted. The framework will provide suggested methods rather than prescribing a single methodology to be followed in all cases.

Default values for impact quantification will be given, together with the associated distribution functions. Each quantifiable impact needs to have attached to it the probability that it will actually eventuate; and the distribution function for the unit value assumed in the estimation. For example, in the case of a project which will bring a shift from car to PT for some trips, we need to know what is the probability of that happening and the likely distribution of the $/veh-km value used to calculate the air pollution impacts of such a project.

In this way, it will be possible to test the effect of changes in the levels and occurrence probabilities of input assumptions on the overall result. It will also be possible to estimate the effect of using different methodologies (eg. CBA versus multi-criteria analysis and monetary quantification versus alternative approaches for specific impacts).

How does it work?

The framework is spreadsheet based and menu-driven. The user is guided through a sequential series of menus that follow a hierarchy approach. The choices made at each level will help define the exact nature of the project or strategy and lead to a suggested set of impacts that can be overridden. Default values for input assumption and associated distributions will be available at this stage and so will a set of methodologies.

Currently, we have built an EXCEL based prototype for the framework which will be used to obtain feed-back from key players. The following main components make up the model:

- **Project/Strategy definition** – the user specifies the project or strategy using a suggestion typology;

- **Identification of impacts** – the system suggests impact types likely to apply based on project definition and the user finalises impact list;

- **Before & After input data –** this relates to road and PT link data on volumes, patronage, speeds and other data needed for impact assessment. The affected road and PT links or segments are identified separately to allow a reasonable level of disaggregation of impacts. At this stage, the user has the option of using estimates given default values and relationships (eg; speed/flow curves to obtain estimates of delay impact on road traffic) or inputing his/her own estimates independently arrived at. It is necessary to identify cause and effect by separating historical trends from project impacts;

- **Impact quantification –** for each impact type, the user can opt to make use of default parameters applicable in Queensland , to quantify impacts;

- **Summary outputs** are shown by main impact type to enable sensitivity analysis results to be easily compared.

The user needs to use the results using whatever methodology is more appropriate for the task at hand. . For example, a **cost-benefit analysis** (economic efficiency criteria) may be undertaken in conjunction with a **financial analysis** (affordability and impact on cash-flows) and an assessment of environmental and safety criteria. Some of these analyses may to some extent double-count impacts and hence they are not additive. However, they may be required to satisfy a range of criteria which cannot all be measured in monetary terms. Evaluations methodologies are further discussed in Section 3.

2.3 Defining Projects and Strategies

The first step in the use of the proposed evaluation framework consists of identifying the exact nature of the project or strategy being considered. This will guide the user onto the types of impacts which are likely to be present and finally onto their quantification. It is possible to use the framework to evaluate **single projects** for a specific geographic area or a combination of area-wide measures, which will be referred to here as **strategies.**

Table 2 shows the proposed categories used to define projects and strategies. The main headings used are: main mode, nature of project, location type and target time period.

Table 2: PT Projects and Strategies: Main Categories

Main mode	Project/Strategy type	Target area	Target time period
• Bus - fixed route • Bus - on demand • Bus - feeder • Heavy rail • Light rail • People mover • Other	**PT Provision** • New services – fixed route • New services – on-demand • P-N-R • Interchanges • Terminals & Stations **PT Management Measures** • HOV lanes • Busways • Bus lanes • Bus priority measures • Service levels • Fleet management systems **PT Information** • Passenger Information systems • Operational information systems **Pricing** • Pricing measures • Fare changes • Ticketing systems • Subsidy levels	• Large urban radial • Large urban circular • Large urban CBD • Medium/small urban • Inter-urban corridor	• Peak • Off-peak • Week-ends • All day

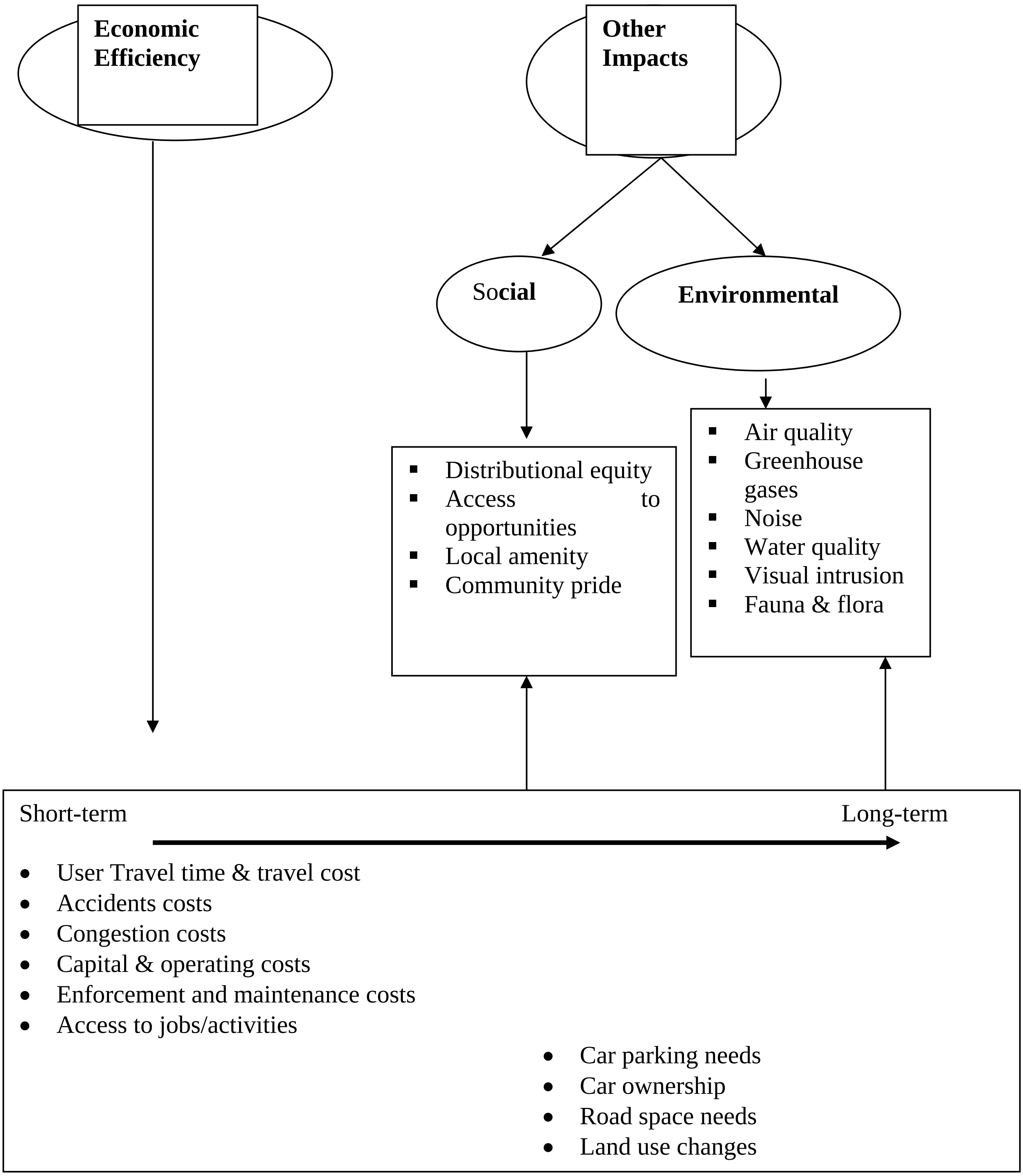
2.4 Types of Impacts

Impacts will generally fall under three main headings, namely: **economic efficiency; environment and social**. Figure 1 shows the main individual impact types under each of these main topic areas. It may be important in some cases to classify impacts according to a defined set of objectives or evaluation criteria. For example, in the UK, impacts are assessed on the basis of five objectives, namely: economy, environment, accessibility, safety and integration, DETR (2000).

The difficulty in the evaluation of PT projects and strategies, as well as travel demand management measures in general, has been well documented in the past, Brown and Evans (1991) and May (1991). The main issues relate to:

- the presence of often conflicting objectives (economic, environmental and social objectives); and
- the nature and type of impacts. The latter can have short (travel times) and long-term implications (land use impacts); their quantification can be fairly precise and in monetary terms (fuel costs); or in rather vague and uncertain qualitative terms (loss of local amenity).

Figure 1: Main Impact Categories



PART II - LITERATURE REVIEW

3 EVALUATION METHODOLOGIES

3.1 General

Public transport evaluation has been described as essentially conflict analysis characterised by technical, socioeconomic, environmental and political value judgements. Therefore, it is very difficult to arrive at straightforward and unambiguous solutions (Tsamboulas et al. 1999). The available methodologies can be classified into Cost Benefit Analysis (CBA), Multi-Criteria Analysis (MCA), Social-Based Analysis, Decision-Analysis, other specific type-application and Simulation/Mathematical Modelling (Tsamboulas and Mikroudis, 2000).

CBA allows comparison of projects across modes, as well as comparisons between capital projects and management strategies. The evaluation of PT projects presents CBA with several difficulties, including the nature of impacts (often difficult to quantify in money terms); and the nature of the objectives themselves (not necessarily always related to economic efficiency), Petersen (1995).

To address some of these concerns, DeCorda-Souza et al. (1997) have proposed a modified form of CBA referred to as total cost analysis (TCA), which is to be used mainly to compare alternatives across modes. All impacts related to user ‘benefits’, in terms of transport cost savings (eg: travel time, vehicle operating costs and accident costs), are summed for each alternative. The total value of costs is then traded-off against the non-monetary impacts attributed to each alternative. In TCA, alternatives are compared with each other without the presence of a common base-case. The drawback of this approach is the results do not produce a net present value which allows for the ranking of alternatives within the transport portfolio and across government portfolios.

The multi-criteria approach is well suited to PT evaluation with its multiple objectives which are often in conflict with each other, as well as having different relative weights in the overall decision-making process. There have been a number of ways proposed to deal with the problems of vagueness and ‘fuzziness’ attached to the definition of the evaluation criteria and the estimation of weights to be attached to them. The analytic hierarchy process has been proposed by Saaty (1980). This approach is a systematic way of representing the components of an alternative in a hierarchy. It consists of breaking a problem down into a number of sub-problems and prioritising each element of the sub-problems. Each level in this hierarchy is defined by a set of criteria and experts’ opinions are sought to arrive at a set of relative weights at each stage. An overall preferred solution is obtained based on the summed results for all hierarchy levels. This methodology has been applied in the selection of transportation alternatives by several authors, Vargas (1990) and Saaty (1995). Hsu (1999) has proposed the use of fuzzy set theory to evaluate the integration of a rapid transit system and bus network in Tawain, using the principles of analytic hierarchy process.

Cambridge Systematics (1998) has produced a practical manual on economic evaluations applied to public transport projects. This guide is specifically designed for U.S. projects and conditions with the methodology having an economic analysis background.

The U.S. Federal Highway Administration has developed a spreadsheet based model to evaluate transportation projects and policies across modes. Conventional road projects can be compared with PT strategies and demand management policies. The Surface Transportation Efficiency Analysis Model (STEAM) is based on cost-benefit analysis using monetary values for user benefits and leaving environmental and other impacts in non-monetary units, to be traded-off against the dollar based net benefits. The model accepts as inputs the outputs from the conventional four-step modelling process. Default analysis parameters are provided using national averages for seven modes (car, truck, carpool, local bus, express bus, light and heavy rail), DeCorda-Souza et al. (1998). Default values for input parameters should be used only when local values are not available.

Several Studies in the U.S. have described available methodologies to deal with PT evaluation at the local and/or regional levels. References dealing with general methodologies which can be used include Cambridge Systematics (1995a, 1998 and 1999); Litman (2000) and Beimborn et al. (1993).

When comparing alternatives with and without the PT project or service, Beimborn et al. (1993) define four main benefit categories which can be further sub-divided, namely:

1. The effect of PT trips being taken by other modes. This refers to changes in:
    - user costs;
    - facility needs; and
    - congestion, environmental and energy impacts.

2. PT as an option to be used in emergencies even though it is not used at present (existence value).
3. PT and land use. Impacts on land values; open space; interaction amongst people; efficiency of public services provision (secondary impact); and
4. PT can impact on the local economy through: jobs for PT employees; capital expenditures locally; and local demand for goods and services (secondary impacts).

A large number of economic impact studies quantify the impact of PT at the local level by comparing existing services with a base-case where all PT services are withdrawn. This may be a valid assumption at the local level where the impact of current subsidies is being studied for a given set of services in a well defined area. Alternative methodologies apply in large urban areas where PT projects are being evaluated against a background of continuing support for some form of PT.

Due to the reality of collecting and analysing data, including limited resources, time and expertise, the use of simplifying assumptions and default parameters for information that is unavailable is often required (Pansing et al, 1998). The response to the changing objectives of transport projects in recent times, for example, the includsion of noise reduction and air quality, has been to adapt the established cost-benefit procedures or use a form of multi-criteria analysis. According to Tsamboulas et al. (1999), it is almost impossible to arrive at totally reliable and fully accepted monetary values for impacts that are intangible, externalities or political priorities.

'Multi-criteria decision making accounts for the fact that almost no-real world decision can be made based on only one criterion. It acknowledges that generally several, often competing, criteria (objectives) have to be considered in the decision-making process. In the case of competing objectives, an improvement with respect to one objective has to be paid for with decreased performance with respect to the other objective – there is no objectively "best" solution.', Frohwein et al. (1999). Therefore, the evaluation method used should not focus on a final Net Present Value (NPV) or best solution and exclude the non-quantifiable benefits, uncertainty in the cost and benefit estimates and alternative weightings of the competing objectives in the final recommendation.

The US Federal Transit Administration (FTA) relies on a combination of a variety of factors to determine project merit which, in addition to the readiness of the project to proceed, include (Federal Transit Administration, 1994):

- *Cost effectiveness:* The cost per new transit trip;
- *Mobility improvement*: The projected total number of hours of travel time saved per day compared to the baseline alternative;
- *Environmental Benefits*: The US Environmental Protection Agency classification of the city for ozone as an indication of the severity of the region's air quality; and
- *Operating Efficiencies*: The estimated system-wide operating cost per passenger.

Younger (1994) compared the evaluation methods of two metropolitan planning organisations in the US for project selection for road and public transport projects. Both evaluation methods have a minimum requirements screening as a first step to ensure the project is consistent with the long range transportation and land use plans, has reasonable cost estimates and a funding plan and is justified on the basis of need. One planning agency creates a benefit cost ratio with a form for the quantitative and qualitative benefits. The other transport authority ranked projects out of 100 total points, with:

- 30 points: maintain/sustain the transport system;
- 30 points: improve the efficiency and effectiveness of the system;
- 15 points: system expansion;
- 25 points: external impacts.

It was concluded that screening projects for their minimum requirements, evaluating their merits and establishes an equitable program based on predetermined principles does work, however, the merit based project selection process is highly data dependant and that data is not always readily available (Younger, 1994).

Schwartz et al. (1998) uses a method which multiplied the score for each option by the likelihood of successful implementation, so that little value is gained from pursuing alternatives that have little realistic chance of being implemented. As part of a CBA, in addition to the financial analysis, user benefits, regional impact and qualitative factors, D'Oro (1988) included the risk factors associated with each project. For example, requiring relocations, other agency involvement, the time to complete and construction complexity. In selecting the most appropriate project, the risk factors in of implementing each project is very important, therefore some measures, for example, the likelihood of successful implementation or the uncertainty or difficulty of construction should be considered in the evaluation. D'Oro (1988) also considered the adherence of public transport projects to the transportation polices for the region.

Tsamboulas et al. (1999) compares the most commonly applied multi-criteria methods for assessing transport projects using the criteria of transparency, simplicity, robustness and accountability, including several variants of MCA. These methods were all found to: have a theoretical background philosophy consistent with the transport decision making framework; be relativity easy to use and have the potential to be a decision support tool for transport project selection; and be capable of receiving inputs concerning preferences and generate outputs permitting the evaluation of direct and indirect effects. It was concluded that there does not exist a globally optimum method for transport assessment, with the performance of each method dependant on the characteristics of the decision situation.

According to Frohwein et al. (1999), the previous research into applying multi-criteria decision making to roadway improvement project selection generally aim to rank alternatives using weights, multi-attribute utility functions or an analytic hierarchy process. Frohwein et al. (1999) develop a framework which does not make a decision or obtain the 'best' option, instead graphically illustrating the trade-offs between three competing objectives: crash risk reduction; performance improvement; and project cost. The identification of the preferred project(s), incorporating additional, perhaps intangible, factors, is then the task of the planner/decision-maker, aided by the developed framework. This type of graphical analysis will only work, however, for up to 3 objectives, which would usually make it unsuitable for public transport evaluation.

Anagnostopolous et al. (2001) evaluated transport infrastructure works in Greece based on a CBA for which the multi-criteria method Analytic Hierarchy Process (AHP) was used. The AHP involved ranking the alternative projects using several quantitative and/or qualitative criteria, depending on how they contributed in achieving an overall goal. For every project two hierarchies were formed, one for costs and one for benefits, with a resulting priority for each. A benefit-cost ratio is then calculated to rank the projects.

There are a number of major issues to be dealt with in the selection of the most appropriate methodology and its implementation in practice, namely:

The Study Area Boundary
This needs to be well defined in advance. Benefits which apply at the local level (eg: increases in expenditures), may become economic transfers at the regional or national level.

Economic Transfers
Some benefits are merely transfer payments between groups or areas, without a net increase in benefit to the community at large. For example, local increases in consumption spending as a result of PT may be offset by decreases elsewhere.

Double Counting of Benefits

Benefits which tend to be double counted include those which use travel costs as the basis for measurement. Reductions in travel costs, including congestion costs, are counted as user related benefits. There may a tendency to include the benefits to local industry and commerce in the form of lower freight costs and higher productivity and competitiveness. Such benefits are valid as secondary or indirect impacts (economic multiplier effects), as long as travel cost reductions are not counted twice.

3.2 International Comparison of Evaluation Methodologies

An issue of Transport Policy (Volume 7, Number 1, 2000) was dedicated to the international comparison of evaluation methodologies used for transport infrastructure projects, including public transport and roads. Papers relating to the methods used in many developed nations, for example USA, Japan, France, UK and Germany, are included, in addition to developing countries. It was found that there is no universal method that is collectively agreed upon for the evaluation of transport projects, with variations between countries including the scope and method of evaluation in addition to the impacts of evaluation on actual decision making (Nakamura, 2000).

The conventional CBA procedure used in road project evaluation is biased towards major time savings and reductions in accidents and does not include any environmental costs or impact on surrounding areas directly included, Vickerman (2000). Therefore, the New Approach to Appraisal (NATA) incorporates the conventional CBA, based on a net present value calculation, with a number of previously excluded elements. There are five main criteria: environmental (noise, local air quality, landscape, biodiversity, heritage and water); safety; economy (journey times and vehicle operating costs, journey time reliability, scheme costs and regeneration); assessibility (access to public transport, community severance and pedestrians and others); and integration. Each criterion has, where possible, quantitative and qualitative elements, which are evaluated on a seven point scale from large negative to large positive. There is no weighting is implied between the criteria and the demand forecasts include a variable trip matrix to permit induced trips. The only environmental impacts quantified are carbon emissions, local air quality and noise, with the rest expressed in a usually 5 point scale.

Rothengatter (2000) describes the CBA used for infrastructure projects for Germany, with criteria expressed as monetary values, market prices or shadow prices measured through change of costs for the objectives. The seven objectives are: the reduction of transport costs; changes of infrastructure management costs; benefits of improved traffic safety; benefits of improved assessibility; beneficial spatial effects; benefits from improving the environmental situation and beneficial non-transport related effects.

Quinet (2000) explains that in the evaluation methods utilised in France there is a strong preference for a unique criteria technique instead of a multi-criteria one due to past misuse. In addition, the importance of the definition of the base case is emphasised, as an irrelevant base case will produce comparatively high net benefits, and it is recommended to the complete a net present value calculation with indication of the effects of land use and distribution issues. There are two profitibilities calculated for projects: financial profitability, related to the effect of the project on the operating company, and collective surplus.

Bristow and Nellthorp (2000) review the transport appraisal methods in use throughout the European Union, finding that CBA is used in all but four countries with a formal evaluation method, with these four countries utilising a MCA that contains a CBA. It is concluded that there is a strong consensus on the treatment of a number of direct impacts, where monetary valuation and inclusion in CBA is typical, with less agreement on the treatment of environmental and social impacts. The inclusion of the different factors in the evaluation process for each country is shown in Table 3, from Bristow and Nellthorp (2000), originally sourced from the EUNET project. Direct impacts are usually incorporated will all countries including the monetary value of the construction costs, vehicle operating costs, time savings and safety. The environmental impacts incorporated in the evaluation vary substantially between the countries, even for impacts included in all the procedures, such as noise and local air pollution, the methods of inclusion differs, for example monetary values or descriptive measures. The socio-economic impacts have the highest variation in the aspects included, as these effects are indirect, difficult to predict or measure and in dispute as to whether they are genuinely additional to the direct project costs and benefits.

Hayashi and Morisugi (2000) provide a comparison of the transport project evaluation methodologies detailed in the papers for the UK, USA, France, Germany and Japan. All these countries basically utilise variations of cost benefit analysis (CBA), with time savings, accident reduction and environmental impacts included. The weightings for the different criteria differ between the countries, with the UK emphasising the importance of the time savings and accident reduction for example.

Table 4 gives a summary of the major aspects of the evaluation methodologies used in each of the countries. The value of time was based on the wage rate for all the countries, however, the actual value of time varied with different factors, for example type of car and trip purpose, as can be seen in Table 4.

Traffic safety is incorporated into the evaluation for each country by the reduction in total accident cost, defined as the summation of the product of the cost per accident and the traffic accident occurrence (the accident probability multiplied by traffic volume). The cost of accidents included physical damage, injuries and fatalities for all countries, while Japan and the UK also added the police and other costs of dealing with accidents. The estimation technique for cost of physical damage differed, with two common methods, willingness to pay and the gross production method. The value of life varied significantly between the countries from 0.27 to 2.6 million, as shown in Table 4.

The evaluation methods did not include regional economic impacts, with the exception of the UK, which gave a positive value to job creation, and Germany, which included effects on employment (construction and operation phases), development and international trade. The inclusion and quantification of environmental impacts, project life, discount rate and indices also differed considerably between the five countries, as demonstrated in Table 4.

Table 3: The Inclusion of Impacts for European Union Countries

		AUS	BEL Road	DEN Road	FIN	FRA	GER	GRE Road	IRL	ITA	NRL	POR	SPA	SWE Road	UK Road
DIRECT IMPACTS															
Capital	Construction Costs	CBA MCA	CBA MCA	CBA	CBA	CBA	CBA	CBA MCA	CBA	CBA	CBA MCA	CBA	CBA	CBA	CBA
	Disruption Costs		CBA MCA					CBA MCA					CBA		CBA
	Land and Property Costs		CBA MCA	CBA	CBA		CBA	CBA MCA	CBA	CBA		CBA	CBA	CBA	CBA
Recurring	Maintenance Costs	CBA MCA	CBA MCA	CBA	CBA		CBA	CBA MCA	CBA	CBA	CBA MCA	CBA	CBA	CBA	CBA
	Operating Costs				CBA		CBA	CBA MCA	CBA	CBA	CBA MCA	CBA			
	Vehicle Operating Costs	CBA MCA	CBA MCA	CBA	CBA	CBA	CBA	CBA MCA	CBA	CBA	CBA MCA	CBA	CBA	CBA	CBA
	Revenues	CBA MCA			CBA			CBA MCA	CBA	CBA		CBA	CBA		
	Passenger Cost Savings							CBA MCA	Measured						
	Time Savings	CBA MCA	CBA MCA	CBA	CBA	CBA	CBA	CBA MCA	CBA	CBA	CBA MCA	CBA	CBA	CBA	CBA
	Safety	CBA MCA	CBA MCA	CBA	CBA	CBA	CBA	CBA MCA	CBA	CBA	CBA MCA	CBA	CBA	CBA	CBA
	Service Level	Measured MCA						Measured MCA	Measured	CBA			CBA	CBA	
	Information							CBA MCA		CBA					
	Enforcement							Qualitative							
	Financing / Taxation							CBA MCA							
ENVIRONMENTAL IMPACTS															
	Noise	Measured MCA	CBA MCA	CBA	CBA	CBA	CBA	Measured MCA	Qualitative	CBA	Measured MCA	Measured	CBA	Measured	Measured
	Vibration		Measured MCA		Qualitative										Measured
	Air Pollution - Local	Measured MCA	CBA MCA	CBA	CBA	CBA	CBA	Measured MCA	Qualitative	CBA	Measured MCA	CBA	Qualitative	CBA	Measured
	Air Pollution - Global	Measured MCA	CBA MCA	CBA	CBA	CBA		Measured MCA	Qualitative			CBA		CBA	Measured
	Severance	Measured MCA		CBA	Qualitative		CBA				Qualitative	Measured	Qualitative	Measured	Measured
	Visual Intrusion				Qualitative			Measured MCA		Qualitative					Measured
	Loss of Important Sites		Measured MCA		Qualitative	Qualitative		Qualitative	Qualitative		Qualitative	Qualitative			Measured
	Resource Consumption				Measured			Measured MCA			Qualitative				
	Landscape	Measured MCA			Qualitative		Qualitative	Qualitative	Qualitative	Measured	Qualitative			Qualitative	Measured
	Ground / Water Pollution	Measured MCA			Measured			Measured MCA			Qualitative				Measured
SOCIO-ECONOMIC IMPACTS															
	Land Use	Qualitative MCA			Measured			Measured MCA		Qualitative	Qualitative MCA				Qualitative
	Economic Development	Qualitative MCA	Measured MCA		Measured	Qualitative	CBA	CBA MCA	Measured	Qualitative	Qualitative MCA	Measured			
	Employment		Measured MCA		Measured	Qualitative	CBA	Measured MCA	Measured	Measured		Qualitative	CBA		
	Economic & Social Cohesion							Measured MCA				Qualitative	CBA		
	International Traffic					Qualitative	CBA	Measured MCA		Measured					
	Interoperability							Measured MCA							
	Regional Policy		Measured MCA				CBA	Measured MCA			Qualitative MCA				Qualitative
	Conformity to Sector Plans		Measured MCA					Qualitative	Qualitative				Qualitative		
	Peripherality/Distribution					Qualitative		Measured MCA							

Key: CBA (Monetised Impacts) — Measured Impacts — Qualitative Assessment — **MCA** - included in Multi-Criteria Analysis

Note: it is understood that Luxembourg has no tradition of formal project appraisal in either the CBA or MCA paradigm.
Source: EUNET project (Nellthorp et al, 1998)

Table 4: A Comparison of the Evaluation Methodologies Used

	UK	France	Japan	USA	Germany
Value of Time	Based on working/ non working, driver/ passenger and type of vehicle	Values for working and non working the same	Based on type of vehicle, and weekday/ holiday, includes transfer time and congestion factors for rail	Depends on working (wage rate) or non working (fraction of wage rate)	Categories of trip purpose and mode type (bus, car, rail, truck)
Approximate Value of Time ($/hr) working time, car travel	18	21	20	8 – 40	20
Value of Human Life ($m)	1.0	0.56	0.27	2.6	0.79
Environmental Impacts	Not evaluated in monetary terms, included qualitatively and quantitatively	Evaluated carbon emission, local air pollution and noise in monetary terms	Evaluated global warming, air pollution (NO_x and CO_2) and noise in monetary terms	Not evaluated in monetary terms	Evaluated air pollution (CO) and noise in monetary terms with additional risk factor
Project Life (years)	30	20	40	20 (road)	40 (average)
Discount Rate (%)	6 (minimum)	8	4	7	3
Evaluation Method Indices	NPV and Cost-benefit ratio	Modified NPV	Cost-benefit ratio (predominantly)	NPV	Cost-benefit ratio
Use of Indices	Cost-benefit ratio to rank projects, but not decision criterion	Cost-benefit index used for efficiency, with other factors (eg equity) taken into account informally	Cost-benefit index used for efficiency, with other factors (eg equity) taken into account informally	Cost-benefit index used for efficiency, with other factors (eg equity) taken into account informally	Cost-benefit ratio used to priortise projects

3.3 Quantifying Impacts

3.3.1 General

A number of U.S. studies have been directed at measuring the impacts of PT at the local or regional levels for specific geographical areas, such as: Skolnik and Schreiner (1997); Maimed and Lomax (1989); Cambridge Systematics (1995b) and Urban Institute/Cambridge Systematics (1991).

Skolnik and Schreiner (1997) measured the impact of a small urban area PT in the Housatonic Valley Regional Transit District, Connecticut in the U.S. The study, which found that PT provided significant net benefits to the local community, estimated the following impact categories if PT was withdrawn:

(a) *User costs* for those moving from PT to car, walking or cycling. (The value of cost given to walking and cycling trips, was the equivalent bus fare on the assumption that is what PT users were prepared to pay to avoid walking or cycling).

(b) *Costs of foregone trips*. PT trips no longer being made were assumed to bring a loss to the local economy in terms of lower consumption expenditures and associated wages.(average values of expenditures by trip purpose were estimated from PT users surveys. These values were then factored to account for the economic multiplier effects).

(c) Impacts on congestion;
(d) Accidents; and
(e) air pollution

The additional car usage included an estimate for induced trips from those individuals who purchase cars as in the absence of PT.

3.3.2 Mobility/Accessibility

Accessibility is an indicator of the potential for people to access one or more types of activities. It can be seen as being made up of two components, namely: the ease of getting from a to b (expressed as the generalized cost of travel); and the amount of opportunities available at b for the type of activity of interest. There have been several definitions of accessibility put forward and Zhang et al.(1998) and handy and Niemeier (1997) provide useful summaries of the literature in this area. If employment opportunities are being assessed, then the most commonly used accessibility index is that proposed by Hansen (1959), namely:

$$A_a = \sum_b E_a f(C_{ab})$$

Where: A_a = the accessibility from area *a* to employment opportunities in the whole study area;

E_b = Number of jobs in area *b*;

C_{ab} = The generalized cost of travel from *a* to *b* (this includes travel time and out-of-pocket expenses); and

$f(C_{ab})$ = is a deterrence function which can be obtained through the calibrated gravity models for the study area and for the trip purpose being considered. This function can have the form:

$f(C_{ab}) = \alpha (C_{ab})^{\beta}$ where α and β are calibrating parameters.

This definition of accessibility index is preferred in practice mainly because it is the same expression as the denominator term of the gravity model which is widely used for the trip distribution stage of conventional transportation studies.

Allen et al.(1993) provide an application of the concept of accessibility indices in some U.S. cities, whilst Zhang et al. (1998) use the Hansen (1959) definition to measure the social welfare or equity impacts of a rail project in the San Juan urban area.

In order to obtain a monetary value for accessibility, Niemeier (1997) used the results of a mode-destination choice logit model. The model was calibrated with a.m. trip to work data for the Puget Sound Region in the Washington State. The coefficients of the mode-destination choice model were modified to yield measures of consumer welfare that can be equated to the worth of accessibility to the relevant group of travelers. In this way, the results of mode-destination demand modeling can be used directly in a cost-benefit analysis of transport options.

Most PT investments and operating subsidies are usually justified on the basis of two main objectives, namely: economic efficiency and equity. The latter can be represented by the concept of mobility or transport related accessibility. This involves providing a basic level of mobility to all members of a community regardless of income, car availability or age. PT induced mobility increases, which are closely tied to access to employment, education and other essential activities, can be a major component of total project benefits, Litman (2000). Lewis And O'Conner (1997) estimated that the consumer surplus benefits to PT riders was of the order of 0.89 $US per passenger mile in 1993.

According to Litman (2000) there are four main types of mobility benefits, namely:

- economic (access to jobs and education and services);
- personal (career benefits, access to social events, financial benefits through access to a wider range of services);
- equity (inadequate mobility compounding social and economic inequities); and
- increased travel options in case of emergencies or altered conditions.

3.3.3 Efficiency Gains

Most past work in this area assumes that PT replaces private car trips on the basis of the same distance. This may understate PT benefits since Neff (1996) found that, in the US, PT replaces car trips on a 1: 7 distance ratio.

Efficiency gains are in the form of:

- user cost changes (monetary): car trip costs including parking charges; potentially, fewer cars owned per household or delays in vehicle replacement; and
- travel time changes (converted to monetary values through value of time factors).

[For example, the value of time is distinguished by different categories throughout the European Union, including: by person or vehicle; journey purpose; mode; distance; class of travel; and type of vehicle. A range of 6.3-23 euro/hr for working travel by car and 2.4-5.3 euro/hr for non-wok time was identified.]

3.3.4 Land use and Economic Development Impacts

Urban and regional development benefits have been one of the main gains from major PT projects, particularly new urban rail projects. The benefits are seen in terms of faster economic growth rates, increases in higher land values around PT stations and along the PT corridor in general. The measurement of such land-use benefits have been the subject of several studies, Al-Mosaind et al. (1993); Berick and Cervero (1994); Cervero (1994); Knight and Trygg (1977) and Shaw (1993).

Urban sprawl increases the costs of providing infrastructure services and transportation. PT can reduce sprawl by encouraging higher densities around stations and by reduced need for additional road space. Gains can be significant if development is oriented specifically towards PT.

Macroeconomic modelling can be used to estimate effects on regional employment, income and business productivity effects. Factors to be included are:

- Additional spending during construction and maintenance;
- Added consumer spending through savings on travel costs;
- Increased amenity value; and
- Additional employment attracted to the area.

This type of analysis accounts for employment and income impacts. It takes into account benefits to business and individuals in terms of the impacts on wages. There is no account taken of social, environmental and quality of life impacts, Weisbrod and Grovak (1998).

There is a large degree of uncertainty attached to some of the estimates in this approach, such as the impact of projects on business growth and employment. This is due mainly to model specification errors, as well as data reliability problems.

As a labour intensive service industry PT tends to create jobs and benefit the local and regional economy. Miller et al. (1999) found that in Texas, a 1% shift in travel from car to PT resulted in a $US2.9million gain in regional income (226 additional regional jobs). Kenworth et at. (1997) also found that PT can increase regional productivity, whilst car dependency reduces regional economic development. This argument is based on the premise that cars and associated infrastructure are more capital intensive than PT and hence funds are diverted to car based facilities rather than being used more productively elsewhere. PT can also improve land values around stations/stops and hence attract economic activity and stimulate the local and regional economies. Land values reduce with increased distance from PT stations/stops to reflect the additional access travel time requirement.

The fact that PT may increase economic activity in an area is not sufficient to identify such impact as an economic benefit to a project. If the additional economic activity generated by the project is a result of a transfer in either time or space, there is a danger of double-counting the benefit. For example, the additional income spent in an area through a new PT project needs to be new income generated by the project, rather than existing income diverted from elsewhere.

3.3.5 Congestion Costs

Estimates of congestion costs in the U.S. average around 0.1 to 0.3 $US per mile for urban peak trips, Levinson (1995). The alternatives to the use of PT to reduce congestion include the use of demand management strategies or increases in road capacity. The latter option tends to be effective in the short to medium term only. The additional induced traffic as a result of the new road space tends to reduce average speeds in the long term.

3.3.6 Parking Provision and Costs

Reduced parking may bring benefits in terms of: user cost savings; avoiding the need for parking supply increases in high parking demand areas; and releasing high premium land for other uses.

3.3.7 Safety

PT travel has significantly lower accident rates than car trips. Some Canadian data suggests that the number of fatal accidents per transit vehicle km is 5% of the corresponding rate for car travel, Litman (2000).

3.3.8 Road Space and Facilities Savings

Comparisons of road infrastructure cost per vehicle km point to a doubling of unit costs for car versus bus travel, Litman (2000). However, these savings are only achieved if there is a significant shift from car to PT since the provision of road space is a step function in steps of 2000 vehicles/hr (1 lane). U.S. estimates suggest that buses require 1.6 times the road space of an average car, Litman (2000).

3.4 Valuing Externalities

Externalities are benefits or costs which are a result of the transport system but are external to it. That is, they are not felt by the transport users but by third parties who are not compensated (if it is a cost) or asked to pay (if it is a benefit). Examples of such external costs (borne by others) are:

- environmental impacts
    - air, water and land pollution
    - noise
    - visual intrusion
    - fauna and flora
- congestion costs not borne out fully by users
- accidents costs
- energy impacts (where the price paid for energy does not reflect the rate of resource depletion)

External impacts arise where a user affects other users and non-users production and consumption decisions.

The approaches used to evaluate the effect of externalities mostly relate to pricing negative technological external effects and can be categorised into the following (Blum, 1998):

- *The Resource Approach*: the value of the externality is defined by the corresponding resource price of the private market, which in most cases relates to prices for damage or repair;
- *The Avoidance Approach*: the value of the externality is defined by the possibility of substituting the resource, the technology of the good in question for a resource, technology or good without the external properties;
- *The Risk Approach*: the value of the externality is defied by the discounted expected monetary value based on an evaluation of risk; and
- *The Utility Approach*: the value of the externality is defined by the willingness to pay in order to reduce negative effects.

Tsamboulas and Mikroudis (2000) believe that converting environmental effects into monetary or non-monetary values is a task with serious methodological and philosophical difficulties. They assert that the basic requirements for a generic framework for environmental evaluation of transport projects are: combine environmental effects with monetary values; follow a network approach for the spatial variation of impacts; consider variation of impacts over time; handle uncertainty and be practical and understandable. The authors developed a framework for evaluating the environmental impacts from transportation projects, consisting of four steps:

- Structuring: constructing a decision tree for the environmental and monetary factors of the problem;
- Weighting: defining how the criteria, geographical regions and time zones are weighted against each other in the evaluation;
- Rating of alternative projects: ranking the alternatives using a combination of CBA and MCA; and
- Exploring the results: conducting sensitivity analysis and incorporating uncertainty.

Environmental Externalities

Considerable research exists on the valuation of externalities, Lee (1995), Delucchi (1996) and Litman (1995). Since there is no ready market for these impacts, the monetary valuation becomes open to debate. Several methods have been used to cost such impacts, namely:

- The cost to reduce or eliminate the impact (eg: anti-noise barriers); or the cost of the consequences of the impact (eg: productivity losses an health care costs from air pollution). Air pollution, for example has been costed in terms of damage to health, buildings and vegetation OECD (1994).

- The willingness to pay for a benefit (eg: reduction in air pollution) or the willingness to accept compensation for a negative impact.

    - Stated preference surveys are usually undertaken to derive values which reflect how much individuals are willing to pay to benefit from or to avoid an impact. This method is used for air and noise pollution valuations.

    - Hedonic prices are used to derive values for environmental impacts. For example, a change in the price of houses may reflect changes in noise levels in the area. Prices have been used mainly to value noise.

Some environmental impacts have both local, regional and global effects, as well as short and long term effects (eg: air pollution with its impact on local residents and on global warming). This makes it very difficult to arrive at valuations that capture these effects. Monetary estimates of such impacts have considerable uncertainty and are usually given in fairly wide ranges for each impact dependent on the type of approach used and the specific setting. However, past work in this area points to significant differences between modes for average values of impacts, Gastaldi et al. (1996). Therefore, economic evaluations of projects should include such impacts (either directly in dollar terms, or indirectly as trade-offs), so that efficient cross-modal resource allocation can take place.

Gastaldi et al. (1996) provide a review of actual monetary values used in some European countries. The following averages are given by those authors.

- In France environmental impacts are being costed for cost-benefit analysis purposes. Boiteaux (1994) proposed the following values:(1994 $A equivalent):

Noise: $128 per person affected

Air Pollution: Car (urban areas): 2 cents/pass-km
Truck (urban areas): 1.8 cents/tonne-km

- Inter-city average values from a number of European studies, (1992 values in cents/pass-km):

	Car	Bus
Noise	0.11	0.08
Air pollution	1.03	0.27
Greenhouse effect	0.65	0.4

Great care must be exercised when using such 'sensible averages' since they reflect average load factors and traffic flow conditions obtained from specific studies (OECD, (1994); Kageson (1992) and Ecoplan (1992).

Wang et al. (1995) summarize several approaches used to estimate unit costs of air pollution. U.S. estimates of global warming range from $US20 to $US80 per tonne of CO_2, Litman (2000).

U.S. data suggests that bus noise can be 2 to 6 times higher than the average car and lower than motorcycles and trucks, Delucchi and Hsu (1996).

McRobert (1997) reports that even though the energy efficiency of various modes of public transport can be up to an order of magnitude greater then the automobile, these potential efficiency gains may not be realised. It was commented that often dual mode trips (car/rail/car) and low public transport occupancy levels will nullify the relative GHG emission benefits between public transport and personal car usage.

"Barrier Effect"

This is the impact of vehicle movements on other road users, such as pedestrian and cyclists. This potentially negative mobility and safety impact has been costed in some instances. Both Sweden and Denmark include such impacts in road project evaluation analysis. Gylvar and Steen (1983) estimated that the barrier effect represented around 15 percent of car induced externalities in Denmark.

Equity

CBA, which attempts to deal with economic efficiency of resource allocation objectives, is not well equipped to deal with equity related objectives, Khisty (1997), Lee (1978).

Equity (also referred to as distributive justice) in evaluation usually refers to the notion of insuring fairness in the distribution of benefits and in the avoidance of uncompensated losses. Equity can be defined by various criterial (eg: horizontal – treating similar groups equally; or vertical – treating different groups equally; and regional).

PT projects and strategies are often directed at serving specific groups in the general community or geographic areas (eg: non-car owning households; low accessibility areas; and low income groups). Therefore, the objectives in some cases may be related to redressing a perceived injustice. Since CBA is concerned with economic efficiency only, the evaluation of such projects will require an additional analysis of the distribution of benefits and costs.

Uncertainty

A number of methods have been used to help deal with uncertainty in the ability to predict impacts, as well as the judgement and vagueness involved in obtaining relative weights to be given to potentially conflicting objectives. The use of fuzzy logic based evaluation has been investigated by Austroads (1998), who compared it with a goals achievement matrix (GAM) approach for the evaluation of road projects. The latter method has seen widespread use in Australia, particularly in road project evaluation, Main Roads (1997). Austroads (1998) concluded that the use of fuzzy set theory for project evaluation, offered potential medium term promise. Fuzzy logic is well suited to applications which have uncertain outcomes and for which there is a lack of precision in some of the main input parameters. Uncertainty in forecasts can be dealt with through the assignment of a set of probabilities. However, fuzzy logic allows vagueness in the meaning of objectives and criteria to be dealt with mathematically. The application of fuzzy set theory to project evaluation is very limited to date, Avineri et al. (1997) and Nelson (1997).

4 CONCLUSIONS

Two methods are primarily used for in road and public transport project evaluation, namely: cost benefit analysis and multi-criteria analysis. For some impacts, such as equity, environmental effects and regional development, there is no consensus on their incorporation or quantification in money terms in an evaluation.

There is a consensus among the literature on evaluation methodologies for transport projects that the critical factor in the evaluation are the travel demand forecasts. Other aspects that require careful consideration in an evaluation include:

- The measure of public transport ridership should be carefully selected, as a number of the impacts are estimated on the forecast ridership figures;
- The term or life of the project should also be carefully selected as the benefits are long term and hard to quantify with certainty, resulting in the evaluation being less robust as the life of the project is extended;

- In selecting the most appropriate project, the risk factors in implementing each project are also very important. Therefore, some measures, such as the likelihood of successful implementation or difficulty of construction, should be considered;
- The definition of the base case and the geographic scope of the evaluation need to be carefully considered; and
- The evaluation method used should not focus on a final Net Present Value (NPV) or best solution. This may exclude: non-quantifiable benefits; uncertainty in the cost and benefit estimates; and alternative weighting of the project objectives.

Thus, an evaluation methodology needs to cater for sensitivity analysis, including the impact of changes in the weighting factors for each objective.

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