# A Conceptual Framework of Cost and Benefit Analysis on Airport Road Access Wayfinding

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***Abstract*— The inclusion of cost and benefit analysis (CBA) on the airport road access wayfinding design is important. Standard CBA was used to determine the additional costs incurred and benefits from airport road access wayfinding development. This concept paper explains the willingness to trade-off between the social benefits and the cost comparison of airport road access wayfinding design. The importance of airport cost and benefit structures and their influence on the decision-making process for the provision of airport road access wayfinding was considered. The key issues were then analysed and presented; costs (i.e. investment, operating, maintenance, and fuel consumption costs); benefits (i.e. travel time, accident reduction savings, and airport road advertising revenue). The CBA is an appropriate technique for the airport road access wayfinding appraisal. It has an explicit normative basis and was performed for the purpose of guidelines of informing airport management and road sign design professionals that the alternative airport road access wayfinding with the largest positive Net Present Value (NPV) and Benefit-Cost Ratio (BCR) exceeding 1.0 would be given primary consideration as the preferred course of action.**

***Keywords*—** *Road; navigation; driver; airport terminal; CBA analysis*

## 1. Introduction

The standard cost and benefit analysis (CBA) on the airport road access wayfinding design is important to determine the additional costs incurred and benefits from airport road access wayfinding development. This paper examines the willingness to trade-off between the social benefits and the cost comparison of alternative airport road access wayfinding design. The importance of airport cost and benefit structures and their influence on the decision-making process for the provision of airport road access wayfinding was considered. The key issues were then analysed and presented; costs (i.e. investment, operating, maintenance, and fuel consumption costs); benefits (i.e. travel time, accident reduction savings, and airport road advertising revenue).

Standard cost and benefit analysis (CBA) was applied in airport road access wayfinding research Figure 1). Standard CBA is a systematic process for calculating and comparing costs and benefits of a project or decision [1]–[3]. Standard CBA evaluates the value of the project from a social view rather than commercial perspective (Mackie, 2010). Litman [4] stated the cost (i.e. money, time, and loss of an opportunity) is a concept of trade-offs between the uses of resources against a benefit. For example, increases in fuel prices and parking fees lead to additional traveling expenses [4]; which could affect drivers' decision to drive to the airport. Benefits are commonly interpreted as travel time, delay reductions, vehicle cost savings, accident reductions and promoting road safety [3], [5], [6]. Corlett, Manenica and Bishop [7] agreed that simple signage placement at a decision point plays an important role in reducing travelling time. Harding [8] and ACRP [9] agreed that fewer signage placements increased wayfinding performance. Wener and Kaminoff [10] state that the addition of signage at decision points helps to reduce stress and improves wayfinding performance. O'neill [11] claimed that the effectiveness of signage resulted in a 13% increase in the rate of travel, a 50% decrease in wrong turns (i.e. drivers did not miss the exit to the airport), and a 62% decrease in backtracking during road navigation.

The first step of the CBA process is defining alternative projects that can meet the aim of the research. CBA was used to evaluate the economic advantages (benefits) and disadvantages (costs) of each airport road access design. It is important that the definition of an alternative project is broad in order to probe the reasonable alternative solutions. For example, the conventional drivers preferred to have a traditional wayfinding system (i.e. aid of map, architectural clue and signage) to find the distinctive direction to airport. In contrast, the modern wayfinding navigation (i.e. built-in Sat. Nav.) is useful as an alternative tool to reduce the


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travelling time and fuel cost. As a result, combined traditional and modern wayfinding systems should be taken into consideration as alternative tools to navigate to the airport. Modelling the flexibility of wayfinding design is proposed at step two.

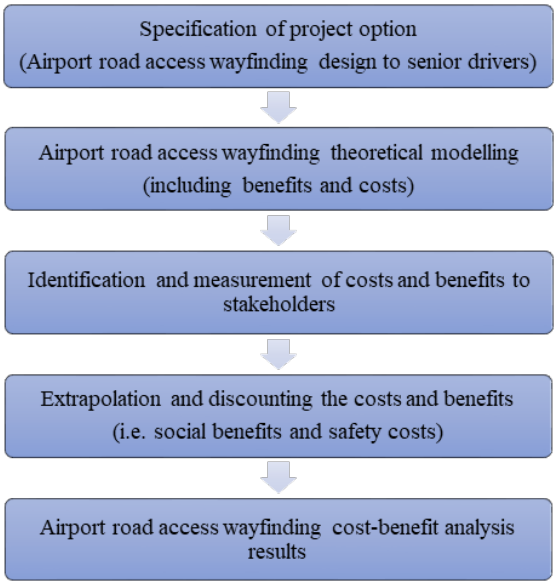


**Figure 1.** Cost and benefit analysis process of airport road access wayfinding design (Source: Turnbull, 2010; FAA, 1999)

The CBA model has been developed to evaluate the changes in travelling time, transportation costs (fixed and variable), benefits to society, and signage costs. The model is used as a tool for evaluating and comparing different airport road access projects. Step three focuses on identification and measurement of CBA wayfinding modelling to stakeholders. According to Turnbull [12], the identification of costs and benefits related to the possible impact on different stakeholders as follows:

1. Possible impacts may include flexibility in travel times, fuel cost, crashes, congestion, safety, and reliability to drivers;
2. Possible impacts may include changes in investment costs, operating costs, and revenues to airport management and road planners;
3. Possible impacts may indicate subsidies, taxes, grants, competitiveness on labour markets as well as government policy and regulation.

The fourth step of CBA is to focus on extrapolating and discounting the costs and benefits over the life of the project. Costs of transportation investments are incurred in the initial years, while benefits are accrued over few years in the future [13]. Discounting converts future costs and benefits that occur in different years into a value for a common year; i.e. present value [14].

The final step is to calculate cost and benefit, which indicates summary statistics (i.e. figures, percentage) and report presentation (Table 1). CBA results were used to evaluate both monetised and non-monetised effects and impact of the projects. Litman [4] defined market costs as traded goods involved in a competitive market, such as vehicles, land and fuel. The goods that are not regularly traded in markets such as travelling time, clean air, driver stress and crash risk were known as non-market costs.

**Table 1.** Market and non-market cost distribution criteria (Source: Litman, 2009)

| Factor | | Cost | Variable | Fixed |
|---|---|---|---|---|
| **Internal (user)** | • Time<br>• Expense<br>• Safety<br>• Reliability<br>• Quality | Market cost | • Fuel<br>• Short term parking<br>• Vehicle maintenance (part) | • Long term parking facilities<br>• Vehicle maintenance (part)<br>• Insurance payment |
| | | Non-market cost | • Driver time<br>• Driver stress<br>• Driver crash risk | |
| **External** | • Environment<br>• Health<br>• Community<br>• Mobility | Market cost | • Road maintenance<br>• Traffic services | • Road construction<br>• Traffic planning<br>• Street lighting |
| | | Non-market cost | • Congestion<br>• Environmental impacts<br>• Uncompensated crash risk | • Social inequity |

## 2. Cost and benefit analysis (CBA) of airport road access wayfinding design

Cost and benefit analysis (CBA) of airport road access wayfinding is defined as a systematic process for calculating and comparing benefits and costs of the research. CBA works by defining the project and any alternatives; and then identifying, measuring, and valuing the benefits and costs of each. CBA has two purposes; to determine the possibility of investment and decision (justification and feasibility) of the intended project, and to provide a basis for comparing alternative projects.

CBA is commonly used as a prescriptive technique [15] that provides a set of standard inputs in decision making by determining whether the benefits of a proposed action justify its' costs [3], [5] in airport development. It has an explicit normative basis and is most useful in analysing a single program or policy to determine benefits and costs to society [16], [17]. CBA is used to determine whether a particular alternative airport road access wayfinding design is cost effective, and which option (stimulated driving scenario) offers the greatest overall benefits [5]. Conventional evaluation practices often exclude some impacts, which can result in solutions to one problem that exacerbate other problems. Elvik [18] highlighted five measures which are excluded from a formal transportation analysis of cost and benefit:

1. The effects of the measure on accidents or injuries were too badly known for meaningful quantification;
2. The measure was ineffective. It did not reduce the number of accidents or the severity of injuries;
3. The measure has already been fully implemented. For example, seat belts of car passengers were implemented years ago;
4. The measure overlaps another measure or is dominated by it. For example, general rehabilitation and reconstruction of existing roads was assumed to overlap both cross section improvements and changes in road alignment. To avoid double counting, only one of the measures was included; and
5. The measure was analytically intractable, such as land use planning was difficult to define its' level of use in a way that permits costs and effects to be calculated.

Figure 2 shows the Net Present Value (NPV) and Benefit-Cost Ratio (BCR) equations used for CBA calculation.

$$Net\ Present\ Value\ (NPV): NPV = PV_{benefits} - PV_{costs}$$

$$Benefit - Cost\ Ratio\ (BCR): BCR = \frac{PV_{benefits}}{PV_{costs}}$$

**Figure 2.** Net Present Value (NPV) and Benefit-Cost Ratio (BCR) equations (Source: ACRP, 2009)

The discount rate is used to convert all costs and benefits to 'present values' in order to make a comparison of each airport road access scenario. The proposed discount rate is 3.5% based on The Green Book [13]. The Green Book recommends that costs and benefits occurring in the first 30 years of a programme, project or policy be discounted at an annual rate of 3.5%, and recommends a schedule of declining discount rates thereafter[1] [13]. The NPV is the primary principle for deciding whether the alternative option and research objective can be justified. Therefore, the CBA justifies possible options for airport road access wayfinding design.

## 3. Cost and benefit analysis of airport road access wayfinding framework

Airport road access wayfinding cost and benefit analysis applied monetary units' values to compare total incremental benefits with total incremental costs [2]. The results of Benefit-Cost Ratio (BCR) were presented in ratio value, which is benefits divided by costs. Net Benefits are defined as the sum of all benefits minus the sum of all costs[2], which provides an absolute measure of benefits[3] (total in Pounds Sterling). CBA is most appropriate tool for evaluating airport road access wayfinding project that meets the following criteria:

1. The potential project expenditure is significant enough to justify spending resources on forecasting, measuring and evaluating the expected benefits and impacts; and
2. The project motivation is to improve the airport road access wayfinding system at serving travel and access-related needs, rather than to meet some legal requirement or social goal.

CBA has been widely used to evaluate transportation projects, and standardised methods have been developed, including software programs such as MicroBENCOST and HDM-4 [19]. These are generally designed to evaluate a particular type of transport improvement, such as highways or

[1] For instance, the declining long-term discount rate: [0-30 years (3.5%); 31-75 years (3.0%); 76-125 years (2.5%); 126-200 years (2.0%); 201-300 years (1.5%); and 301+ years (1.0%).

[2] Investment, operating, maintenance and fuel consumption costs.

[3] Travel time saving, accident reduction savings and airport road advertising revenues.

transit service. Therefore, taking account of the CBA calculation using Microsoft Excel, CBA was performed in this research. Taking WebTAG Databook [20] as a reference; the researcher used an Excel spreadsheet to calculate, analyse and perform CBA of airport road access wayfinding appraisal. The airport road access wayfinding framework (Figure 3) defined the basic evaluation process of airport road access wayfinding design. It is important to clearly define the framework because it allows stakeholders to understand the process, allows consistency between different evaluations, and defines the information that will be needed for airport road access wayfinding development.

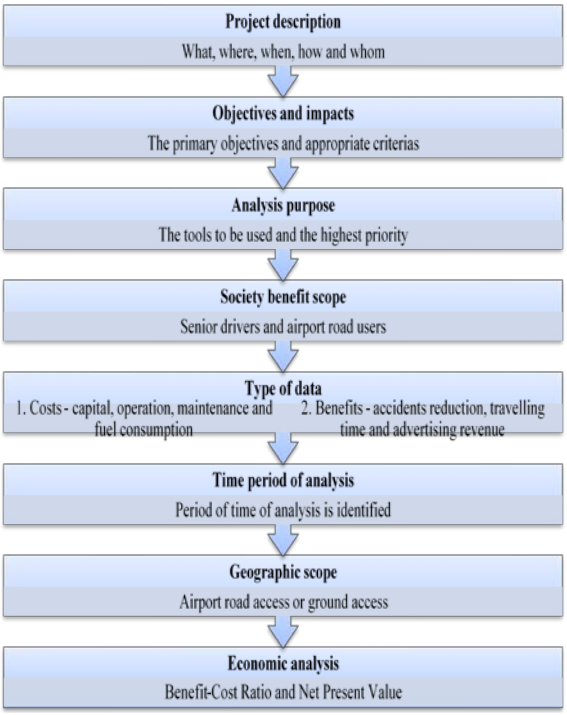


**Figure 3.** Airport road access wayfinding CBA framework

1. Where: The development of the airport road access wayfinding projects at propose location. The CBA calculation of airport road access wayfinding is developed using a self- designed excel spreadsheet.
2. How: Airport wayfinding efficiency decreased travelling time, fuel consumption, and promoted road safety to drivers. Benefits and costs of airport road access wayfinding is analysed in Economic Analysis stage.
3. By whom: Experienced airport planners, road planners, airport authorities and drivers.
4. When: The results of the airport road access wayfinding study will be beneficial to the drivers, airport road users, airport management and road sign design professionals.

The CBA objectives are to improve airport road access wayfinding design in order to promote airport roadway safety, reduction in traffic congestion and mobility of airport road drivers. The researcher attempted to maximise social benefits that would meet research objectives and questions. For instance, to evaluate the airport road access wayfinding efficiency, the additional costs incurred during the project development were also considered. All significant impacts (benefits and costs) were important in economic analysis. Many impacts can be quantified and monetised (measured in monetary values). Using the CBA could potentially reduce overall delays and improve safety by encouraging alternative routes and reduce travel time uncertainty.

The purpose of cost and benefit analysis is to determine the possibility of the airport road access wayfinding design being conducted with various transport improvement options, establish priorities of wayfinding projects and determine how the airport road access wayfinding research project should be done. Thus, by defining the purpose of airport road access wayfinding research, this will determine what costs and benefits to be included.

The airport road user benefits determine which impacts (costs and benefits) should be included [14], [20], [21] in the airport road access wayfinding design. Airport road access wayfinding CBA takes into account all costs and benefits that accrue into the development process which can highlight certain types of impacts.

The types of costs are identified as investment, operation and maintenance costs. Types of benefits are travel time, fuel cost saving and increasing road safety to be included in CBA.

The time period of airport road access wayfinding research started with the first project expenditures and extended through the useful life of the research or its most long-lived alternative, or some future time at which meaningful estimates of effects are no longer possible. MnDOT [14] suggested that the timeframe should be long enough to capture the majority of benefits, but not so long as to exceed capabilities to develop good traffic information. The airport road access wayfinding CBA timeframe is 10 years as an ideal comparison of feasible policies and interventions that could be implemented [22], [23].

The area of the analysis is the area over which the effects of the project and alternatives will be felt. MnDOT [14] suggested that an appropriate study area should be chosen by considering the majority of the effects on the logical geographical area; which travel mode will be affected by the investment alternative. In this research, the airport road access (i.e. airport roadway) was chosen as a geographic scope.

Economic analysis explains how to calculate several measures that are typically used to summarise CBA [(for example, Benefit-Cost Ratio (BCR) and Net Present Value (NPV)]. The purpose of the CBA analysis is to provide an economic assessment of the extent to which a project promotes safe driving and reduces the number of incidents on the airport roadway. The BCR analysis ultimately provides a means of selecting the most cost-effective countermeasure for any given project. The most important calculation in CBA is the NPV. Therefore, the NPV analysis gives the best indicator of CBA appraisal, which represents whether user benefits would be improved if the airport road access wayfinding project is implemented. Investment and maintenance costs were generated during this. The costs; investment, operating and fuel consumption costs were considered in the CBA of airport road access wayfinding. MnDOT [14] suggested that CBA results should be tested and compared to the potential volumes impacted on the transportation systems (e.g. cumulative changes in travel time to the airport as compared to the drivers' driving performances).

## 4. Analytical technique

CBA evaluates the following criteria as follows:

1. The potential airport road access wayfinding design expenditure which is significant enough to justify spending resources on forecasting, measuring and evaluating the expected net benefits to the society.
2. The airport road access wayfinding costs and its social benefits before and after the improvement project are implemented.
3. Airport road access wayfinding is designed to improve travelling efficiency at access-related needs, rather than to meet legal requirements or social goals. Litman [24] stated that transportation CBA is suitable for social benefits improvements and could be applied to a broad range of transport decisions, including analysis and planning policy. Transportation CBA incorporates a broader range of goals including social enhancement and environment [24]. It defines issues, benefits and costs, and identifies policies that achieve the project goals. The benefits (i.e. travelling time and accident reduction saving) included in an airport road access wayfinding CBA will be beneficial to drivers and airport users.

Objectives of the CBA are identified as follows:

1. Ease wayfinding for navigation, movement and accessibility through the placement and design of airport road access wayfinding elements to drivers.
2. Provide an optimal airport road access wayfinding solution based on sufficient funding (cost), wayfinding information and change of driving behaviour.

## 5. Conclusion

An airport road access wayfinding cost and benefit analysis is a systematic evaluation of the economic advantages and disadvantages to set investment alternatives. The objectives of CBA are to improve airport road access wayfinding design as well as to increase road safety, reduce traffic congestion and improve drivers' mobility at airport road access. Key points of alternative airport road access wayfinding CBA are the analysis stages, the basic inputs and the results [14]. The plans for the CBA for airport road access wayfinding design are summarised below.

1. Identification of 'base' case. Project of airport road access wayfinding design should be developed to be as realistic as possible to ease travellers and drivers drive to the airport. Different types and numbers of traffic and road advertising signs, road furniture, architectural design and traffic condition as part of the complexity of airport road access were considered.
2. Choice of discount rate used in airport road access wayfinding CBA is important to evaluate impacts that occur many years in the future. For example, in United Kingdom (UK), the recommended discount rate on airport road

access wayfinding project is 3.5% [13].

3. Estimation of airport road access wayfinding costs. The costs of airport road access wayfinding are defined as the resources that will be consumed to meet the research objective. Costs include all capital, labour, investment, operating, fuel consumption, maintenance, and natural resources necessary to undertake under each alternative project.
4. Distribution of airport road users' benefits. The drivers and airport would benefit from the airport road access wayfinding development. The benefits consist of travel time savings, drivers' safety and accident reduction savings. Airport management may benefit from road advertising revenues, increased safety awareness and a reduced traffic bottleneck on the airport roadway.
5. Risk analysis. The Costs and benefits analysis was finalised with a sensitivity analysis (i.e. optimism bias and risk-adjusted base cost), where variations in the results are observed by changing one or several input variables at a time. Sensitivity analysis with higher NPV, BCR exceeding 1.0 and lowest risk and economic losses is recommended, hence, proposed research objectives were attained. An ideal alternative to the airport road access wayfinding project is dependent on the measured benefits and costs, consideration of hard-to-quantify benefits and costs, and sensitivity of results to uncertainty.

This concludes that Cost and Benefits Analysis (CBA) is an appropriate technique for the airport road access wayfinding appraisal. It has an explicit normative basis and was performed for the purpose of guidelines of informing airport management and road sign design professionals that the alternative airport road access wayfinding with the largest positive Net Present Value (NPV) and Benefit-Cost Ratio (BCR) exceeding 1.0 would be given primary consideration as the preferred course of action.

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