CHAPTER 2

Literature Review of Transport Economic Feasibility

2.1 Introduction

The feasibility study of a transport project in its wide rang definition is the evaluation of value of money for the implementation of the project (Litman, 2013). The evaluation then should be based on the identification of a lot of project options and predicting their impacts. Such options could include, among others, alternative transport modes, route locations, and management technologies. This statement implies many questions: assessment by whom, for whom, and from which viewpoints. One of the features of the decision making is the typical project impacts on many parties (stakeholders); e.g. transport operators, individual transport users, local residents and businesses, land and property owners. Each of these stakeholders will seek to evaluate the impacts of the project from the perspective of own interest (De Brucker, Macharis, & Verbeke, 2013).

Otherwise, the word economic feasibility of a transport project can be defined as the degree of economic satisfaction of a wide range of well-defined project options to cover successfully expected transport demands (Sayers, Jessop, & Hills, 2003). An economic feasibility study investigates the costs and benefits of project options based on technical and economic analysis, and compare project options among each other to select the preferable option; i.e. the cost-effective solution. Most economic feasibility studies of transport projects are primarily concerned with direct market prices. Economic justification has historically been a product of feasibility studies.

Such a traditional feasibility study is focused largely on economic analysis (benefits and costs) taking into consideration some performance measures related to traffic and transportation impacts of each option. The most important costs are typically the capital costs, and associated stream of maintenance and operating costs. Similarly, benefits indicate the improvement of the transportation efficiency; such as saving travel time, reducing user and public costs, as well as decreasing accident damage costs.

Moreover, a feasibility study may also include an investigation of the impacts of each alternative on the environment, primarily air pollution, but sometimes also noise and water pollution, as well as land use impacts (De Brucker et al., 2013).

A traditional feasibility study of a transportation project has two general components: an economic analysis in monetary terms, and non-monetary but quantifiable considerations (Sinha & Labi, 2011). To the extent possible, all impacts should be translated into monetary equivalent terms. However, non-monetary can sometimes be an important part of the economic justification, such as air quality, social, and land use impacts.

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Feasibility studies, by nature, provide imprecise results; therefore, it is vital to present the information in a manner that allows researchers to understand exactly what is being assumed in the base condition, and how the final results would be affected by variations in such assumptions (Shakhsi-Niaei, Torabi, & Iranmanesh, 2011). This is accomplished by performing various sensitivity tests and comparing the results with those based on the various assumptions of the base condition.

This Chapter describes basically different aspects related to economic feasibility of transportation projects. It presents and reviews also in detail the various tools commonly used in economic feasibility studies. In addition, it identifies the practical applications of each approach and provides an overview of their strengths and weaknesses. Finally, it draws some conclusions and analyses about the implications of these tools for policymakers.

2.2 Costs and Benefits in a Feasibility Study

Evaluation of a transportation project in the framework of a feasibility study lies at the interface between technical activities (engineering – planning - economics) and political decision-making. The evaluation should not only be technically sound, but it must also be capable to present several explanations to the decision makers. The explanation may include (Odgaard, Kelly, & Laird, 2006):

- The initial objectives of the project.
- The project scale and its target lifetime.
- Screening a lot of possible projects or project options which are subjected to full evaluation.
- The indicators and the assumptions used in the evaluation.
- Project selection or prioritization ranking of project options.
- Financial analysis (possibilities, options, arrangements, and plan).
- Expected direct and indirect subsidies and taxes.

The evaluation needs to respect capital budgeting rules, and to represent risks and uncertainties regarding variations in inflation, foreign exchange, and interest rates over the entire project lifespan (Shuh Liang, 2013). Thus, a feasibility study evaluates the project options based on a detailed investigation of the impacts of each option. The impacts can be classified into costs and benefits.

2.2.1 The Costs

The costs of a transportation project include:

1. Initial Costs (also capital or investment Costs),
2. Maintenance costs, and
3. Operating costs.

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2.2.1.1 Initial Costs

A project's initial costs are those that are incurred during the design and construction process. They can include any of the following (Button, 2010):

- Planning, preliminary engineering, and project design
- Project-related staff training
- Final engineering
- Land costs (value of the land needed for the project)
- Construction costs, including improvements to existing facilities
- Equipment and vehicle purchases (also maintenance vehicles, if needed)
- Equipment required for project operation (for example, signaling system)
- Disruption costs (costs of disruption from construction, e.g. delays to private traffic, delays to public transport, effect on neighbours "noise, dust etc.", changes in risk of accidents, etc.)
- Decommissioning costs for facilities that are no longer needed.

For the estimation of the capital costs of a project, the lifetime of the infrastructure and its sub-components should firstly be determined and fixed (Nellthorp, Laird, & Mackie, 2005a). The time horizon of the project should consider the lifetime of each component of the infrastructure in order to capture the full life-cycle costs of the project. This means that during the whole lifetime of a project, some of its components could be replaced, and thus, the capital costs will be purchased at different times (initial costs and replacement investments of components with service time shorter than the whole project lifetime). In this case, the evaluation of the project option should be based on the present value concept using discount rates that recount future values of money to current values.

2.2.1.2 Maintenance Costs

The maintenance costs cover periodic maintenance (regular servicing of equipment and facilities, cleanup, and urgent repair), as well as rehabilitation (infrequent major repairs of facilities). Rehabilitation does not typically include reconstruction, which is treated as a project in its own right.

Maintenance is often an overlooked component in the evaluation of transportation projects. However, the effective treatment of maintenance within project evaluation is fundamental to informing the decision regarding the optimum investment strategy (Laird, Mackie, & Nellthorp, 2005c). This is because the nature of the maintenance strategy can have direct inferences on operating costs and other benefits (e.g. travel time savings).

Even as maintenance costs present only a small fraction of the initial investment costs, they can very often represent a vital component of the investment strategy for whole life costing. Maintenance costs are to be estimated during the operating life of the project infrastructure. This is because a maintenance strategy can have a direct influence on the value of user costs and operating costs, as well as the quality of service. The economic cost of poor maintenance can negatively affect the users and service providers. An effective maintenance strategy can therefore increase the economic benefit of a project through reductions in user costs, and can ensure cost savings in the long term (Nellthorp, Laird, & Mackie, 2005b).

There are two significant aspects by the project evaluation of whole life costing (Button, 2010). Firstly, there is a trade-off between the initial investment cost and future maintenance costs. That is there is a choice between developing a transport project of a high design standard that will be quite costly in the first instance, but will require little future maintenance, or developing a project of a lower standard that will require significant maintenance expenditure in the future. Secondly, the optimum investment strategy of a transportation project is the one which will be determined by the combination of whole life costs and whole life benefits. Whole life benefits would accrue through say vehicle operating cost savings and time savings.

In developing countries with tightly constrained budgets, maintenance can sometimes be delayed from one year to another. Such delays do not have an immediate effect but their cumulative impact can be disastrous. The delays can vary in scale from slight delays to the significant disruption that can be caused through the complete closure of the infrastructure for scheduled repairs (Laird, Mackie, & Nellthorp, 2005a).

Therefore, it is recommended that local country data on maintenance costs should be available. It is an absolute necessity when estimating future maintenance cost levels. Otherwise, when evaluating alternative investment and maintenance strategies, it is important to include the impact of delays imposed on the users and operators; such lump sums "emergency estimations" (Nash, 1979).

2.2.1.3 Operating Costs

The operating costs include the expenses needed for traffic management, public transport and terminal operations. Typical elements and examples of these costs are (Nellthorp, Laird, & Mackie, 2005c):

- Labor (public vehicle drivers, operation and traffic control personals, technical workers, administration staff)
- Materials and supplies (e.g. fuel and tires)
- Utilities (electricity, gas, telephone, other communications services)
- Rent and lease payments (building and land rent)
- Depreciation (it may not be included in certain short-term projects).

Local country specific data should be utilised wherever possible (Nash, 1979). Operating costs are far more generic and transferable between countries, as they are influenced by climate and the transport infrastructure maintenance level. If transport infrastructure is not well maintained operating costs can increase significantly.

Operating costs for road transport comprise of those incurred by road owner (e.g. the government) and road users. The costs borne by the road owner are the maintenance costs described above. The principle components of road vehicle operating costs include fuel, lubricating oil, spare parts, maintenance (labour), tires, depreciation, crew costs (for trucks, and

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drivers of some private cars), and overheads. These costs fluctuate according to vehicle type, speed, age, as well as vehicle, fuel, and maintenance price. They also vary by road layout and road surface condition. Road vehicle operating costs are also affected by traffic flow and road congestion (through speed).

The operating costs for an urban public transport system are those incurred by the service provider. These costs vary by the length of the journey, route alignment, and quality of service. The Operating costs for urban public transport systems include time-dependent costs, which do not vary with distance travelled (standing costs or fixed costs), and distance-dependent costs (White, 2008). The standing cost components are depreciation (time-dependent share) and administration. The distance-dependent components include personnel costs (i.e.; costs associated with transport mode drivers and operation staff), repair and maintenance costs, depreciation (distance-related share), energy, insurance, and overheads.

2.2.2 The Benefits

The benefits of a transportation project can be derived from its objectives, and may include (ZHOU & NIE, 2011):

- Save Time
  There is always a way to get from one place to another, by some means. A new or expanded facility allows the travel to be made in less time.
- Reduce User, Public and External Costs
  User (capital and operating) costs, public (capital and operating) costs, and external costs (pollution, noise) can be reduced by a capital improvement
- Improve Safety
  Improved safety reduces the risk of accidents that result in fatalities, injuries, damage to vehicles, and other property damage.
- Improve Transport Quality
  A transportation improvement may result in greater comfort, security, convenience, and reliability for passengers or less damage to goods for shippers. Quality changes for the user can often be represented as changes in the opportunity cost (value) of travel time.

All of the above benefits can be broadly grouped as reducing the cost of transport and increasing travel mobility.

Almost all developed countries basically utilize variations of economic analysis tools and manuals for predicting the benefits of transportation projects (Browne & Ryan, 2011). These tools and manuals can also serve as guidelines in ranking the feasibility of the projects and/or the project options. The nearly common main criteria of economic analysis to the all developed countries are time saving, traffic safety, and impact to the environment.

However, each country has its own biases to the designation of weight among the evaluation criteria. For instance, UK put more weight to time savings and accident reduction way above all other impact criteria, while France tends to put more significance to the impact on local development of urban investments. Further, Japan, includes qualitative and quantitative consideration of global and local environmental impact. On the other hand, Germany further assesses regional political impacts. Depending on the criteria and its relative significance, evaluation results of each country on similar projects may therefore vary differently (Hayashi & Morisugi, 2000).

Basically, predicting the benefits of transportation projects should be established on forecasting future transport demand. The conventional stepwise method, which is composed of generation, attraction, distribution, modal split and assignment, is widely utilized for this purpose.

2.2.2.1 Time Saving

Because the primary purpose of most transportation projects is to reduce the transport time from one place to another, the valuation of time saving is certainly a central issue in project evaluation. Time saving value is the production of travel time saving multiplied by the value of time. Within some developed countries they can often account for up to 80% of overall benefits (Laird, Mackie, & Nellthorp, 2005c).

Two methods, namely, the wage rate-approach, and the stated preference (SP) or revealed preference (RP) analysis are basically used in developed countries to measure the value of time (Laird et al., 2005c). The wage rate approach is used to estimate the value of working time while SP or RP analysis is used to estimate the value of non-working time.

SP and RP methods are established on empirical model concepts; such as utility function and Logit models. These concepts are differentiated on trip purpose, transport mode (auto, taxi, public transport, etc.), and waiting time (park place searching and multi-modal transfer). More recently, theory has been refined and attention focused on more fundamental features (travel comfort, trip length, and traveler's willingness to pay). Values of time should also regard worker income classification, and socio-economic status in the study area.

In particular, most manuals for economic evaluation of transportation projects in developed countries specify the value of time by vehicle type and by trip purpose (working trips and non-working trips). Almost all countries adopt a uniform hourly value for each category. The time values are based on average national wages adjusted by the results of empirical models. This means that the manuals present two national standard values of time; a single value for work trips and a single value for non-work trips (Lee, 2000); (Bickel et al., 2006). However, in Japan the value of time is specified by vehicle type and by day of week including holidays (Morisugi, 2000).

The formulation of these concepts is based on a lot of information and observations, as well as household, opportunity and business interviews.

In developing countries, the lack of data regarding the economic value of time obstructs the estimation process and makes it difficult to a large extent (Gwilliam, 1997). The time value estimation faces several problems; such as:

- Immense differences of wages; i.e. numerous time value estimations.
- Complexity by predicting time value by income group, socio-economic group, trip purpose, and transport mode.
- Hug difficulties by valuating time for employees and non-employees, for car users and public transport travelers, work trips and leisure trips, for poor people and good income groups, etc.
- Challenges by predicting the willingness to pay for time savings (ignorance, poverty, and the inability to imagine the future).
- Unexpected sudden changes in inflation rates and currency price.
- Uncertainty of data quality.

In such instances time value can be omitted from appraisals, or may be directly related to national average wage rate.

As the travel time value of work trips is directly related to the wage rate, the World Bank recommends that the national average wage rate appears to be a prober solution for evaluating time in developing countries in the absence of other data (Laird et al., 2005c). This approach can avoid the doubt that public money might be directed at saving rich people's time at the expense of the poor. The value of such trips will therefore grow over the lifespan of the considered project with the projected wage rate, which is typically assumed to equal the growth in Gross Domestic Product (GDP) per capita. In addition, it is recommended that 30% of household income per hour (per head) being used for the valuation of non-work trip time (Hess, Bierlaire, & Polak, 2005).

2.2.2.2 Traffic Safety

The World Health Organization has estimated that nearly 25% of fatal injuries worldwide are a result of road traffic crashes, with 90% of the fatalities occurring in low and middle income countries (Peden et al., 2004). Road accidents cause significant social and economic costs (typically between 1 and 3 percent of Gross National Product "GNP").

Accident costs are often thought about as a combination of items, some of which are resource costs incurred by society as a consequence of the accident (emergency services, medical aid, etc.), some of which represent a part of the individual's expected contribution to production which is no longer possible due to their injuries and some of which represents the individual's personal human costs. These human costs are sometimes characterized as "pain and suffering" (Kunreuther, Slovic, & MacGregor, 1996).

Developed countries' manuals for evaluation of transportation projects take traffic safety into account. The traffic safety is estimated as the reduction in total accident cost, defined as the summation of the cost per accident, multiplied by the traffic accident occurrence. Traffic accident occurrence is calculated by multiplying accident probability "accidents/vehicle.km" and traffic volume "vehicle.km" (Litman & Fitzroy, 2009).

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Theoretically there should be a change in the accident avoidance behavior, depending on the condition of routes. In practice, however, it seems that there are no considerations on this point since its value relative to the users' benefit is quite small.

Estimation methods on physical damage are different among countries. Monetary valuation of material damage is commonly based on the market price. Every developed country uses the insurance statistics for the valuation of physical damage, and estimates the accident occurrence probability based on accident statistics. The value of human life is likewise different for each country. The largest value is 2.6 million US dollars as used in the US while the smallest value is 0.27 million US dollars as used in Japan (Hayashi & Morisugi, 2000).

Empirical studies of the costs of accidents have been conducted and standard unit costs for fatalities (the value of life), serious and slight injuries, and property damage have been published (Li & Poon, 2013). However, these values are of less significance than those for travel time. One reason is that safety often does not vary much between alternatives, and there is no explicit willingness to trade off safety for money. Another reason is that the relationship between physical design and accidents is not especially strong.

2.2.2.3 Environmental Impacts

For calculating the environmental impacts, country-specific values should be used taking into account local population density and regional climate. The treatment of environmental impact is different among developed countries (Hayashi & Morisugi, 2000).

For air pollution, Cost factors are measured in unit price per ton of pollutant emitted in different environments (urban areas, outside built-up areas).

For air pollution, the environmental impacts in the European countries and Japan are taken into consideration in monetary terms. France and Germany first convert the different exhausts into equivalent CO units before converting it into monetary terms, while Japan take into account global warming as an item for evaluation (nitrogen oxides "NO_x"). The unit damage cost of CO or NO_x is estimated by an investigation considering material damage costs, human health damage costs. The cost factors are measured in unit price per ton of pollutant emitted in different environments (urban areas, outside built-up areas).

In UK, the environmental impacts are not evaluated in monetary terms (Hayashi & Morisugi, 2000). The impacts are included in wider context both quantitatively and qualitatively measures, including parameters such as tons of CO_2. In the USA, even if environmental impacts are often evaluated in monetary terms, these impacts are only infrequently included in the project feasibility.

For damage cost due to noise, the European countries and Japan estimate its value based on the amount of investment for noise reduction (Odgaard et al., 2006).

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2.3 Evaluation Techniques

Several evaluation methods can be employed for the evaluation the economic feasibility of transport related projects (Browne & Ryan, 2011). Three common used evaluation methods can be identified, namely the Cost-Benefit Analysis (CBA), the Cost Effectiveness Analysis (CEA), Lifecycle Cost Analysis (LCCA).

The Cost-Benefit Analysis (CBA) takes the pure financial cost and benefits of the project into account. It compares total benefits with total costs of each project option. It is being executed from the point of view of the private or public investor and does not take more broad objectives into account.

The Cost/Effectiveness Analysis (CEA) looks at the effectiveness of the measure in terms of the costs that government puts in. It compares the costs of various options for achieving a single specific objective. The CEA has thus a one criterion perspective.

Lifecycle Cost Analysis (LCCA) is a cost-benefit analysis that incorporates the time value of money. This allows comparisons between alternatives that provide benefits and costs at different times. For example, one option may cost more but be quicker to implement than another.

In conclusion, the Cost-Benefit Analysis (CBA), the Cost/Effectiveness Analysis (CEA), and Lifecycle Cost Analysis (LCCA) are not interesting to include stakeholders into the analysis.

2.3.1 Cost-Benefit Analysis

Cost-benefit analysis (CBA) compares total benefits with total costs. It is not limited to a single objective or benefit. CBA is often used to determine whether (i) a particular project option is cost-effective and (ii) which option provides the greatest overall benefits (Litman, 2009). CBA is the most widely used tool for evaluating proposed projects. It involves estimating, where possible, the full direct and indirect costs and benefits associated with a possible project in monetary terms, and calculates the ratio of total benefits with respect to total costs, i.e. the Benefit-Cost Ratio (BCR).

$$\mathrm{BCR} = \frac{\mathrm{Benefits}}{\mathrm{Costs}} \qquad (1)$$

By estimating the costs and benefits, different other objectives can be taken into consideration; such as congestion, air pollution, noise damage and accident costs. Any possible project option with a BCR value greater than 1 for can be considered as a feasible option. The higher the ratio, the greater is the benefits relative to the costs.

An alternative to BCR, the net benefits can be calculated; i.e., subtraction costs from benefits:

$$\text{Net Benefits Value} = \text{Total Benefits} - \text{Total Cost} \qquad (2)$$

If the net benefits are negative, they are stated to as net costs.
The primary benefits of CBA for the evaluation of transport policies and programmes are that (a) it can be used to compare costs and benefits of project options in a clear and transparent manner and (b) it can be used to quantify all impacts in the form of real indicators.

However, CBA also has a number of weaknesses (Litman, 2003). Firstly, CBA may dominate some direct impacts, such as travel time saving, and underestimate or ignore other direct and indirect impacts, such as environmental and health impacts. Secondly, it is difficult to monetise all impacts; in particular the socio-economic or political impacts such as quality of life.

Finally, it could also be noted that (i) many cost estimates have significant variation and uncertainty; (ii) some transportation costing studies provide insufficient details of assumptions; and (iii) estimates may reflect average costs, which tend to vary, depending on time, location and other factors.

As transportation projects involve several objectives, usually in conflict, and several criteria that can hardly be translated into monetary terms, then, the optimal selection among project options under CBA cannot be reached (Sayers et al., 2003).

2.3.2 Cost/Effectiveness Analysis (CEA)

Cost/Effectiveness Analysis (CEA) is generally used to assess the efficiency of a number of project alternatives to achieve a single specific objective; such as abatement of GHG emissions (Povellato, Bosello, & Giupponi, 2007). Units of effectiveness are simply a measure of any quantifiable outcome; e.g. cost per ton of GHG emissions reduction. It is typical to focus on the trade-off among project options based on the comparison of cost/effectiveness ratios. These ratios can be calculated according to the following equation:

$$\text{Cost/Effectiveness Ratio} = \frac{\text{Cost of Option A} - \text{Cost of Option B}}{\text{Benefit of Option A} - \text{Benefit of Option B}} \qquad (3)$$

In terms of strengths as a method for evaluation, CEA is particularly useful for ranking transportation policy options using a real objective. With the use of CEA, decision-makers can, therefore, make decisions between options and ensure that goals will be met at the least possible costs.

However, CEA also has a number of disadvantages. One of the key limitations of CEA is that it compares different options for achieving only a single objective. Obviously, only one objective does not satisfy the whole goals of a transportation project. Thus, ranking options on the basis of Cost/Effectiveness without considering other objectives may not give an accurate evaluation picture (Kampman, de Bruyn, & den Boer, 2006). CEA is limited to identifying the best option for achieving a single, narrowly defined objective and it is, therefore, not suitable for evaluating project options with a variety of potential benefits.

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Secondly, there are challenges associated with estimating the monetary benefits of a transport project. The benefits that a society gains from a transport system arise through the usage of transport project and the associated social or economic benefits realised through increased accessibility, social cohesion, employment opportunities and mobility. These benefits are difficult to quantify and monetise.

Thirdly, a particular transportation project involves fixed costs in the short-term, whereas many of the benefits are likely to be realised in the longer-term. The focus on Cost/Effectiveness also disadvantages many other projects, which become more cost-effective when the timescale of the impacts is taken into consideration (Anable, 2008). Furthermore, similarly to CBA, the monetised value of costs and benefits is often uncertain and is subject to assumptions.

2.3.3 Life Cycle Cost Analysis (LCCA)

Life Cycle Cost Analysis is an economic evaluation technique that has been particularly valuable when there is a need to compare competing project alternatives involving costs and benefits that stretch over long spans of time (Ozbay, Parker, & Jawad, 2003). LCCA is particularly suitable for the evaluation of project alternatives that satisfy certain transport requirements, but that may have different initial investment costs; different operating, maintenance, and repair costs; and possible different lives. Figure 1 presents the conceptual cash flow diagram over the lifespan of a typical transportation project which includes in monetary terms the costs for the different needed activities and timing for each activity.

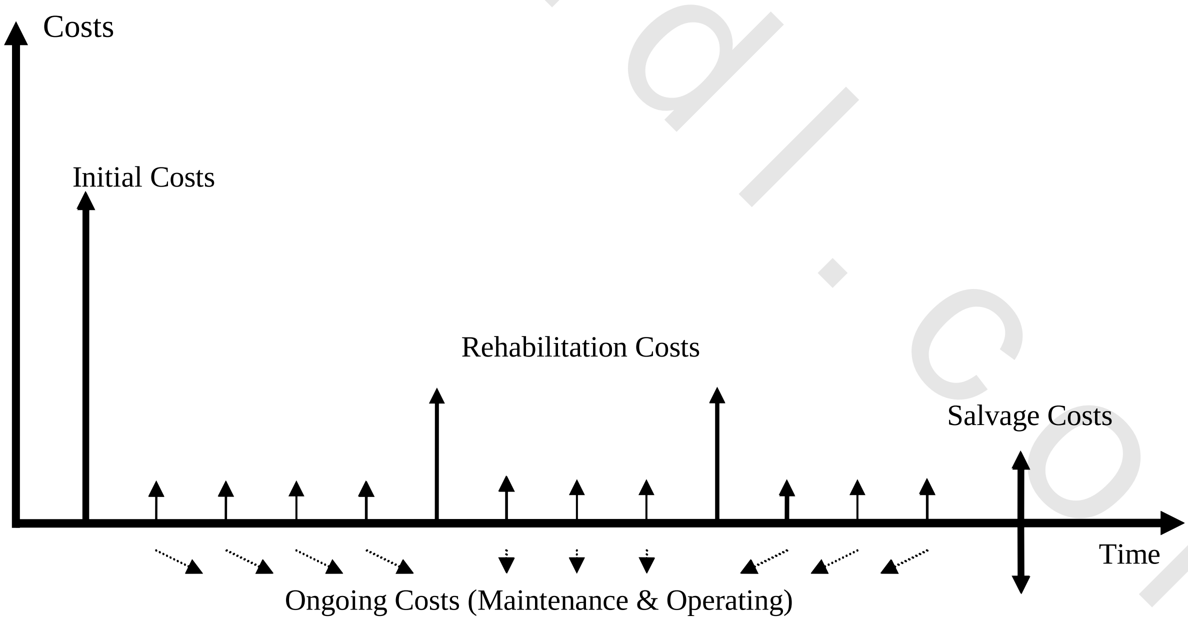

Figure 1: Conceptual Cash Flow of a typical Transportation Project

For road transport, the costs consist of the costs of initial construction, rehabilitation and upgrading, periodic maintenance, engineering, and other overheads. For public transport the costs include infrastructure (permanent way, stops and stations, garages and workshops, etc.), rolling stock as well as system modifications and modernization over the lifetime of the project. Other public transport costs could contain administrative costs in terms of public funding and subsidies.
The ongoing costs (maintenance and operating costs) of the transportation projects cover the periodic maintenance and repair, the costs of material, labor, machinery, signal control, energy and tires (for public transport), as well as any other unforeseen activities. These costs can be estimated from recent bids and historic records, provided that inflation is taken into account.

The salvage value is another cost component that is considered so often as part of the owner costs (Fuller, 2010). The salvage value is the value of the project at the end of a project or the analysis period. The salvage costs may be either:
(a) Selling price; it is the estimated value of the project assets at the end of the period of analysis, representing their expected value in continuing use; it is a negative cost since it is income, or
(b) The costs of future demolition and removal at the end of the project's operation to put the project "to bed," assuming the analysis period matches with the project's operation period; it is an asset with a positive cost.

In principle, economic evaluation is performed by accounting costs and benefits, taking into account their respective times of occurrence. Discount factors are applied to benefits and costs for each period to convert all values to a base year (Ozbay & Jawad PhD, 2006).

LCCA aims at establishing the economic feasibility of the project options; if the anticipated benefits of some options cover the estimated costs, these options are worthwhile in principle. The results of the analysis determine also the prioritization and rank of the selected options.

There are several techniques of LCCA (Ozbay & Jawad PhD, 2006). The most common techniques are Net Present Value (NPV), Payback Period (PP), Internal Rate of Return (IRR), and Equivalent Uniform Annual Costs (EUAC).

Lifecycle Cost Analysis (LCCA) is an important evaluation method that can be used in Cost-Benefit Analysis to incorporate the time value of money. Discount factors are applied to benefits and costs for each period to convert all values to a base year. In addition, it can also be used in cost-effeteness analysis to take account of the costs arising over different points in time in the future.

The choice of the appropriate procedure depends largely on the level and context of the analysis. It may also depend on the degree of uncertainty in some parameters. For example, when projects are evaluated in developing countries where the discount rate is highly uncertain, the IRR format is the preferred indicator. On the other hand, when the analysis period of the project is unknown or the project is expected to last indefinitely, then EUAC is considered to be the better format since EUAC equations are derived with the assumption that the project will last indefinitely (Douglas & Brooker, 2013).

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2.3.3.1 Net Present Value (NPV)

NPV is an evaluation method that is applied to determine which investment is best when different project options are compared among each other's. This technique allows projects with costs and benefits occurring at different times (cash flow) to be compared. An example is where one project option with high capital costs and low operating costs needs to be compared with an alternative option that has lower capital costs and higher operating costs.

The first step in calculating the NPV is to decide on a discount rate to use (Grant-Muller, Mackie, Nellthorp, & Pearman, 2001). The discount rate recounts future values of money to current values. For example, 100 EGP benefits received or expenses paid one year in the future are only worth 90.91 EGP today with an annual discount rate of 10 percent.

The term discount rate is often used for the interest rate when comparing alternative projects. If costs and benefits accrue equally over the life of a project, the selection of discount rate will have little impact on the estimated cost-benefit ratios. However, most benefits and costs occur at different times over the project life cycle. Thus, costs of constructing will be purchased early in contrast to benefits, which will accrue over the life of the project. The discount rate then has a significant impact on measures such as benefit-cost ratios, since the higher the discount rate, the lower the present value of future benefits. In view of the uncertainty concerning appropriate discount rate, analysts frequently use a range of discount rates. This procedure indicates the sensitivity of the analysis to variations in the discount rate (Shrieves & Wachowicz Jr, 2001).

The equation that represents Present Value is:

$$\text{Present Value (PV)} = C / (1 + r)^t \quad (4)$$

Where,
C = amount of future cash flows (benefits – ongoing expenses),
r = discount rate, and
t = number of years
The net present value can then be calculated by subtracting the present value of the initial capital investment from the future cash flows (benefits – ongoing expenses). The formula is:

$$\text{NPV} = \text{PV} – \text{Initial Costs} \quad (5)$$

To obtain the net present value across all the years, the calculation of the ongoing costs and benefits should be carried out year by year and the running accumulation until the end of the life time of the project operation in a cash flow table.

If the NPV of a project is positive or zero then the project should be considered. If the NPV of a project is negative then the project should not be rejected. While comparing two or more exclusive projects having positive NPVs, the one with highest NPV is accepted.

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However, if the total investment of a project is distributed over a long time (also during its operating time), the general NPV formula which can be used is as follows (Yang, Talbot, & Patterson, 1993):

$$\mathrm{NPV} = \sum_{t=0}^{\mathrm{T}} \frac{\mathrm{B^t} - \mathrm{C^t}}{(1+\mathrm{r})^{\mathrm{t}}} \tag{6}$$

Where,
$\mathrm{B^t}$ = anticipated benefits at time t,
$\mathrm{C^t}$ = total costs at time t (capital investment and ongoing expenses),
t = time of incurrence, and
T = lifetime of the project.

2.3.3.2 Payback Period (PP)

Payback is a method to decide the point in time at which the initial investment is paid off. The calculation of the payback period considers the initial investment and net benefits (that is, benefits minus operating costs) in the cash flow table. The year when the value of the net benefits becomes positive is the year in which payback occurs. The formula used for determining the payback period can be described as follows (Blank, Tarquin, & Iverson, 2005):

$$\text{Payback Period} = \mathrm{A} + \frac{\mathrm{B}}{\mathrm{C}} \tag{7}$$

In the above formula:
A = the last period with a negative cumulative cash flow
B = the absolute value of cumulative cash flow at the end of the period A
C = the total cash flow during the period after A

This formula can only be used to calculate the soonest payback period; that is, the first period after which the investment has paid for itself. If the cumulative cash flow drops to a negative value sometime after it has reached a positive value, thereby changing the payback period, this formula can't be applied. This formula ignores values that arise after the payback period has been reached.

Additional complexity arises when the cash flow changes sign several times; i.e., it contains outflows in the midst or at the end of the project lifetime. The modified payback period algorithm may be applied then. First, the sum of all of the cash outflows is calculated. Then the cumulative positive cash flows are determined for each period. The modified payback is calculated as the moment in which the cumulative positive cash flow exceeds the total cash outflow.

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2.3.3.3 Internal Rate of Return (IRR)

IRR is the interest rate at which the net present value of all the cash flows (both positive and negative) from a project equal zero. The formula for IRR is (Blank et al., 2005):

$$\mathrm{NPV} = \sum_{t=0}^{T} \frac{\mathrm{B}^{\mathrm{t}} - \mathrm{C}^{\mathrm{t}}}{(1 + \mathrm{IRR})^{\mathrm{t}}} = 0 \tag{8}$$

A project should only be accepted if its IRR is not less than the target internal rate of return. When comparing two or more mutually exclusive projects, the project having highest value of IRR should be accepted.

2.3.3.4 Equivalent Uniform Annual Costs (EUAC)

Net present value analysis is applied to determine investments by summing the present value of all future incomes and expenses, but that does not verify the annual payment over the life of the project. A common engineering tool for this sort of evaluation is called the equivalent uniform annual costs (EUAC) method. EUAC is the cost per year of owning and operating a project over its entire lifespan. It is often used as a decision making tool when comparing investment projects of unequal life spans (Sahin, Yilmaz, Ust, Guneri, & Gulsun, 2009).

EUAC works best when the evaluation of project alternatives may have different investment costs, different operating, maintenance, and repair costs; and different useful lives.

For calculating $EUAC_{C0}$ of an initial cost C_0 the following formula is used (Blank et al., 2005):

$$EUAC_{C0} = C_0 * APFt,i \tag{9}$$

Where,
$APF_{t,i}$ = Annuity payment factor

$$\mathrm{APF_{t,i}} = \left[\frac{\mathrm{i} \cdot (1 + \mathrm{i})^{\mathrm{t}}}{(1 + \mathrm{i})^{\mathrm{t}} - 1}\right] \tag{10}$$

Where,
i = discount rate
t = analysis period in the future (number of years)

If it is expected an asset will be to need to be rebuilt, maintain, or upgrade the project in the year n of its life period t with a cost of P (EGP). The single present value $SPV_{n,i}$ of the payment P with a discount rate i can be calculated as follows:

$$\mathrm{SPV_{n,i}} = \mathrm{P} \cdot \left[\frac{\mathrm{i}}{(1 + \mathrm{i})^{\mathrm{n}} - 1}\right] \tag{11}$$

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For calculating the equivalent uniform annual costs $EUCA_{SP}$ for this single payment maintenance cost P at time n over the whole life of the project t with a discount rate i, the following formula is used:

$$EUAC_{SP} = SPV_{n,i} \cdot \left[\frac{i \cdot (1 + i)^t}{(1 + i)^t - 1}\right] \tag{12}$$

The Equivalent Uniform Annual Value of the salvage income $EUAC_S$ that occurs at the end of the service life (t years) of the project with a discount rate i can be calculated with the help of the following equation:

$$EUAC_{S,t,i} = E \cdot \left[\frac{i}{(1 + i)^t - 1}\right] \tag{13}$$

It should also here be noted that the $EUAC_S$ may have a negative value (as a selling price), or a positive value (as removal expenses).

Finally, the Equivalent Uniform Annual Value can also be calculated for an alternative with an infinite life with a discount rate i according to the next equation:

$$\text{EUAC for infinite period} = \text{Initial costs} \cdot i + \text{any other annual costs} \tag{14}$$

When comparing EUACs for competing projects, the analysis should avoid comparing projects with widely differing useful lives. Comparing EUACs for projects with lives differing by two or three years may be reasonable, but beyond that range, comparisons become problematic. It is also not recommend the use of EUAC by itself when the useful lives of alternative controls are very similar.

2.4 Financial Feasibility

Financial feasibility is the degree to which the construction and operation of an alternative facility or implementation of a strategy can be financed and managed. The feasibility study should quantify the resources required for the construction and operation, and identify the funding and sources that may be available to support such requirements. If a shortfall exists, new sources may be examined for use in financing the facility or strategy. These sources should be examined in sufficient degree to determine the probability of their availability. Such a product may be directly usable in financial planning documents developed for project implementation (Sayers et al., 2003).

2.5 Insufficiency of Traditional Economic Feasibility Studies

The literature review shows that there is no simple solution for a comprehensive evaluation of transport projects by applying economic feasibility technologies. Indeed, transport is by nature a

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very complex sector, and it is, therefore, difficult to find an uncomplicated tool that will adequately reflect the full impacts of transport projects, either quantitatively or qualitatively.

Conventional economic feasibility studies tend to focus on a limited set of criteria; such as infrastructure costs, vehicle operating costs, travel time saving costs, transport costs, and accident damage costs. Other impacts may receive less consideration. The economic feasibility studies overlook many other transport impacts.

Some of these undervalued impacts are difficult to quantify and others can be disregarded, depending on project size, how problems are defined, and the nature of the methods used to evaluate solution options. The ignored transportation impacts may include, among others, traffic impacts on non-motorized travel, non-users, parking costs, integration with other transport services, and accessibility to adjust land uses. These disregarded impacts become more obvious if long-term transport plan are considered.

The tools of an economic feasibility are varied, each of which has its application field, indicators, advantages and disadvantages. Table 1 presents a comparative analysis of the different economic feasibility techniques.

CBA is the most currently used in a variety of situations, particularly if total costs and benefits can be identified and monetised: (i) to assess the costs and benefits of transport infrastructure options such as roads and public transport; (ii) to estimate congestion and travel time impacts of transport projects; (iii) to compare different technology choices; and (iv) to assess the costs and benefits in scenario analysis.

CEA is becoming more widely used in policy analysis, but it should not be applied as a toll for evaluating the consequences of transportation projects as it tends to focus on a single defined objective such as GHG emissions reduction; excluding other impacts. Although CEA is particularly useful for comparing transportation policies, it may not be as useful when comparing a complete package of transport measures (Balana, Vinten, & Slee, 2011).

LCCA is an economic method of project evaluation that incorporates all costs arising from owning, operating, maintaining, and finally disposing to be potentially important to the decision making. It provides a significantly better evaluation of long-term project options rather than alternative methods. However, most of the LCCA input parameters are inherently uncertain, such as the discount rate, and the type and timing of future rehabilitation activities. In order to conduct LCCA in a reliable and trustworthy manner, a thorough understanding of the theoretical engineering and economics background must be acquired (FCM, 2002).

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Table 1: Comparative Analysis of Economic Feasibility Techniques

	Cost-Benefit Analysis (CBA)	Cost/Effectiveness Analysis (CEA)	Life Cycle Cost Analysis (LCCA)
Application	Project level evaluation	Evaluation of policy options	Economic evaluation of project options that stretch over long time span
Trends in Use	Widely used	Increasingly used	Increasingly used
Indicator	Benefit-Cost Ratio & Net Benefits	Cost/Effectiveness Ratio	Net Present Value & Payback Period & Internal Rate of Return Equivalent Uniform Annual Costs
Positive Impacts Considered	travel time savings, transport costs, congestion costs, and accident damage costs	GHG emissions reduction	Initial investment costs; operating, maintenance, and repair costs distributed over project life time
Less Considerate and disregarded Impacts	Non-monetised impacts	It deals only with a single defined objective	It deals only with cost analysis
Stakeholder Participation	Not required	Not required	Not Required
Ease of use	Difficult to monetise and quantify all impacts	Difficult to estimate costs	Difficult to estimate all costs
Disadvantages	• Overlooking indirect impacts • Uncertainty in estimating costs and benefits regarding variations in inflation, foreign exchange, and interest rates over project lifespan • Ignoring sustainable indicators that reflect community needs for its long term development • Insufficient for comprehensive evaluation of large-scale projects • Disregarding economic instability, budget constraints, and implementation priorities		