APPRAISAL FRAMEWORK FOR TRANSPORTATION INFRASTRUCTURE PROJECTS BY USING CBA AND WLCC

إطار تقييم ومقارنة مشاريع المواصلات من خلال تحليل التكاليف والفوائد على امتداد دورة حياة المشروع

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ZAID MURAD AL DABBAG

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Prof. Halim Boussabaine

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Abstract

The decision process related to the budgeting and selection of transportation infrastructure projects is considered one of the most complex tasks due to its dynamic interrelation with other Social, Economic, Environmental, Political, and Technological life aspects (Veryard, D., 2016).

In this paper, we will explore the key literature and best practices worldwide related to the appraisal of transportation infrastructure projects, and develop a framework that includes all the related cost and benefit components along with the required parameters.

The framework will then be used to build a Microsoft Excel© model and examples will be examined within this model to illustrate its capability and flexibility in producing the required reports and charts to support decision makers in prioritizing and selecting the projects and its alternative which have the best value.

ملخص الأطروحة:

يعتبر اتخاذ القرارات المتعلقة بتحديد مشاريع المواصلات والمفاضلة بينها عملية معقدة، وتحتاج لوقت وجهد كبير لتحديد العوامل التي ستلعب دور في هذه القرارات، وتعتبر طريقة تحليل التكاليف والفوائد المتوقعة للمشاريع على كامل مراحل دورة حياتها من أنجع الطرق في تحديد قيمة المشروع وتأثيراته من النواحي الفنية والمالية والبيئية والمجتمعية والسياسية، والمفاضلة بينه وبين المشاريع والبدائل الأخرى المتاحة، ووضعه ضمن إطار مناسب لاتخاذ القرار.

سنقوم من خلال هذا البحث بجرد واسع لأفضل الأبحاث والدراسات والممارسات العالمية في هذا المجال، وإعداد اطار منهجي موحد لمشاريع المواصلات المختلفة، واستخدام هذا الإطار لبناء نموذج رياضي باستخدام برنامج Microsoft Excel © وايضاح كيفية العمل به والقيام بإعداد التقارير والرسوم البيانية اللازم لدعم مستخدمي القرار.

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1.Chapter 1 - Introduction

In this chapter, a brief explanation will be given on the topic and its importance, in addition to a theoretical background that will introduce the later chapters.

Chapter 1 will also include the paper problem statement, research questions, aim and purpose, and the study objectives, concluding with a paper methodology.

1.1. Background

The paper in general discusses the appraisal of transportation projects, which involves comparing project alternatives, or prioritizing projects based on their costs, benefits and value.

The paper topic covers one of the most important areas that governments of all countries need to consider to ensure economic growth, maintain the wellbeing of its society and strengthen its infrastructures.

The importance of the paper comes from the knowledge it may bring, which could provide economists and transportation planners with tools which will enable them to justify investments in transportation infrastructure and in selecting the projects and their alternative that will deliver the best economic, social, and environmental return. It will also help governments to make better decisions on financing and funding those projects.

At the time of writing this paper, the UAE government have put a VAT tax law (Value Added Tax) in action. The tax came after lifting the subsidization and deregulation of petrol prices in August 2015, and several years after implementing the Salik tollgate system in Dubai in July 2007. The VAT tax law was implemented a year after the introduction of law 6 for year 2006 (cost sharing law): the law that regulates and enforces a property tax to support the funding of transportation infrastructure requirements around the new developments.

In parallel, Dubai roads have improved significantly and have won the global best roads award for years 2015, 2016 and 2017, which is increasing the need for well-governed improvement to its transportations systems to maintain its reputation and to sustain is growth.

Most OECD countries and other developed countries have developed their own CBA frameworks, which was built based on their country's needs. As a member of the International Transport Forum (ITF), and a leader in Transportation quality internationally and regionally, the UAE needs to develop its own CBA framework and standardize the transportation projects appraisal process in order to keep its leading position ("Member Countries" 2018).

The better the standard of living, the more access to products and services is required. In turn, governments need a transportation network with greater capacity, faster routes and better urban design in order to cope with the growing demands.

However, resources are not available indefinitely to cover the growing demands; therefore, governments should develop strategies on where to invest, and how these strategies will improve their citizen's standards of living.

Increasing transportation cost and fees is not an easy solution, as it could affect the low-income user's access to essential goods and services and could limit their ability to improve their income and life standards. This may increase inequality, and negatively affect the whole country's economy.

It is important to develop this framework on national scale in order to provide the necessary knowledge that could enable the private sector to contribute more into the development of the country infrastructure.

A transportation project is usually considered feasible if its expected benefits (social, environmental and economic for example) exceed its costs over its life span, including the cost of borrowing money needed to implement it. The decision to build it or not, and when to do so is what to be discussed in this paper.

A simple (commercial) cost benefit analysis could conclude recommending the development of roads network for rich areas rather than for areas of low income. This paper will consider all the factors and procedures that could eliminate such bias, as it could be more beneficial for governments to invest in transportation infrastructure for those areas to encourage the growth and improve the life quality of those areas by providing cheap and reliable transportation options.

In the following paragraphs, we will explain the purpose and objectives of this paper in further detail and outline the contents of the next chapters.

1.2. Problem Statement

Transportation projects comparison and prioritization is a complex, and time/ effort consuming process as it involves multiple qualitative and quantitative variables that needs to be calculated/ estimated for 20 to 50 years ahead.

Calculating and estimating quantitative variable maybe easy, as they can be derived from previous projects or from the market, while qualitative variables require large-scale studies related to the country's economy, environmental and social aspects in order to produce reliable results.

Most of OECD countries and other developed countries have developed their own CBA frameworks, which was built based on their country's needs. UAE as a member of the International Transport Forum (ITF), and a leader in Transportation quality internationally and regionally needs to develop its own CBA framework and standardize transportation projects appraisal process in order to keep its leading position ("Member Countries" 2018).

1.3. Research Questions

This paper is an attempt to answer questions related to decision-making processes related to transportation infrastructure projects, and it concentrates on the Cost Benefits Analysis (CBA). Below are some of those questions that the paper will attempt to answer:

Is CBA the best method to evaluate and compare transportation projects?

What is Cost Benefits Analysis and how/ why is it used with transportation projects?

How governments can use CBA to set priorities for its transportation portfolio of projects?

What are the main costs and benefits components that may affect transportation projects throughout its life cycle?

What are market and non-market components? In addition, what are the available methods to measure the impacts of non-market components for transportation projects?

What are the key issues that needs to be considered in order to make the CBA more reliable?

How to interpret Cost Benefit Analysis results?

Why Cost Benefits Analysis for transportation projects is important? Moreover, why it should be automated?

How can Cost Benefit Analysis process be simplified and optimized?

1.4. Purpose and Aim

The key purpose of this paper is to provide a broad knowledge related to the transportation projects appraisal process namely the “Cost/Benefit Analysis CBA” which is considered a key decision-making tool internationally in the transportation field.

This paper also identifies key decisions, which the CBA can support, and how to calculate the costs and benefits components for each stage of a transportation project, and for its whole expected life cycle.

In addition to the issues and pitfalls that may influence the accuracy of the analysis outcomes, the paper will also provide a brief explanation on quantifying (monetizing) non-market cost and benefit components.

Furthermore, the paper will develop a standard CBA framework for transportation project, based on all possible cost and benefits components that may be involved in transportation projects during the whole life cycle. Then we will develop a simplified practical CBA framework that could make CBA an acceptably simple task by reducing the components based on their impact magnitude and availability of data at the level of local transportation agency rather than the government.

Those frameworks, if developed and applied correctly, would promote rational government and private sector investments decisions in transportation infrastructure projects.

This paper is **not** intended to show how to estimate each cost of benefit component, nor to discuss travel modeling. rather to listing them and indicate how to combine them into components and indicators like (NPV, IRR, B/C etc…) that can provide a decision supporting knowledge.

This paper is promoting the application of a standardized CBA framework, and is an attempt to pave the path for developing related studies that could lead to adopting an assessment policy or manual to be use in Dubai and the UAE.

Finally, an excel model(s) would be initiated as an outcome of this paper for other scholars or agencies to use or develop further.

1.5. Study Objectives

The paper is structured to achieve its aim and purpose through the following objectives:

- Identifying the possible costs and benefits in transportation projects (components), and its key stakeholders throughout the whole project lifecycle through an extensive literature review of the recent and key research papers in the transportation field.
- Explaining the process of establishing CBA framework and its prerequisites
- Listing possible methods for estimating related variables and Calculating CBA measure.
- Identifying issues and pitfalls that may impact CBA measures' calculation.
- Provide examples of CBA calculation, and advice on ways to simplify the process and optimize the benefits.
- Building a Microsoft Excel model, that can be used in the simplified CBA process.
- Simulating some projects with the Excel model, and performing sensitivity analysis
- Reviewing the importance of applying the CBA for transportation projects, and where to concentrate in the future studies

1.6. Methodology

The research method employed in this paper is a mixed quantitative and qualitative method. The **qualitative part** consists of an extensive literature review of the key literature resources related to: Transportation Economics, Project’s Appraisal, Cost/ Benefits Analysis, Whole Life Cycle Costing, and Economic Sustainability for Transportation Infrastructure Projects.

The paper builds on the key literature to produce a framework which combines Cost Benefit Analysis (CBA) along with Whole Life Cycle Costing (WLCC) for transportation projects. Through the literature review, the paper will list all the related components that may have an impact on the Cost Benefit Analysis for transportation projects including Transportation Projects Types, Transportation Projects stages, Transportation Projects Key Stakeholders, Cost Components, Benefit Components, Cost Benefits Analysis Measure, and other elements like interest rates, Market and Non-Market resources, Joint & sunk costs, and Uncertainty.

The **quantitative part** of this paper will be demonstrated by using the proposed theoretical framework to model the Cost Benefit Analysis process in Microsoft Excel, then the model will be tested with multiple scenarios based on the purpose and the data availability of the tested projects to demonstrate the application of the developed excel tool.

Methodology structure

The paper methodology is structured to combine the results of the literature review with modeling to promote the use of CBA framework as a reliable decision-making tool.

The literature review will provide information of the evaluation methods, then collect all possible factors that may impact the process, then build the framework and compare it with exposing frameworks.

The proposed framework will be utilized to models based on agency’s requirements, then those models will be tested against examples.

Those examples were collected from confidential resources for the exploring the framework and the model capability, and to show how easy it can be to develop the model and customize it based on the agency requirement and the available data.

Similar method has been used before like the work of (Li, Z., & Madanu, S., 2009) and (Jiang, Y., Zhao, G., & Li, S., 2013)

The results of testing the model will not be used to generalize any project specify findings, however they will be used to show how those results can support more informed decisions.

Furthermore, the modeling and simulation will explain more some of the used and available tools and techniques that can be used in modeling the CBA framework processes.

questionnaire was omitted from the scope of this paper due to the time and effort limitation of this paper, although it would have given more significance to its outcome especially to the importance of each and every cost or benefit components, especially in the UAE.

In the next chapter, key recent literature related to transportation infrastructure will be explored, to identify its characteristics, and the methods are being used to assess them.

1.1 Dissertation Outlines

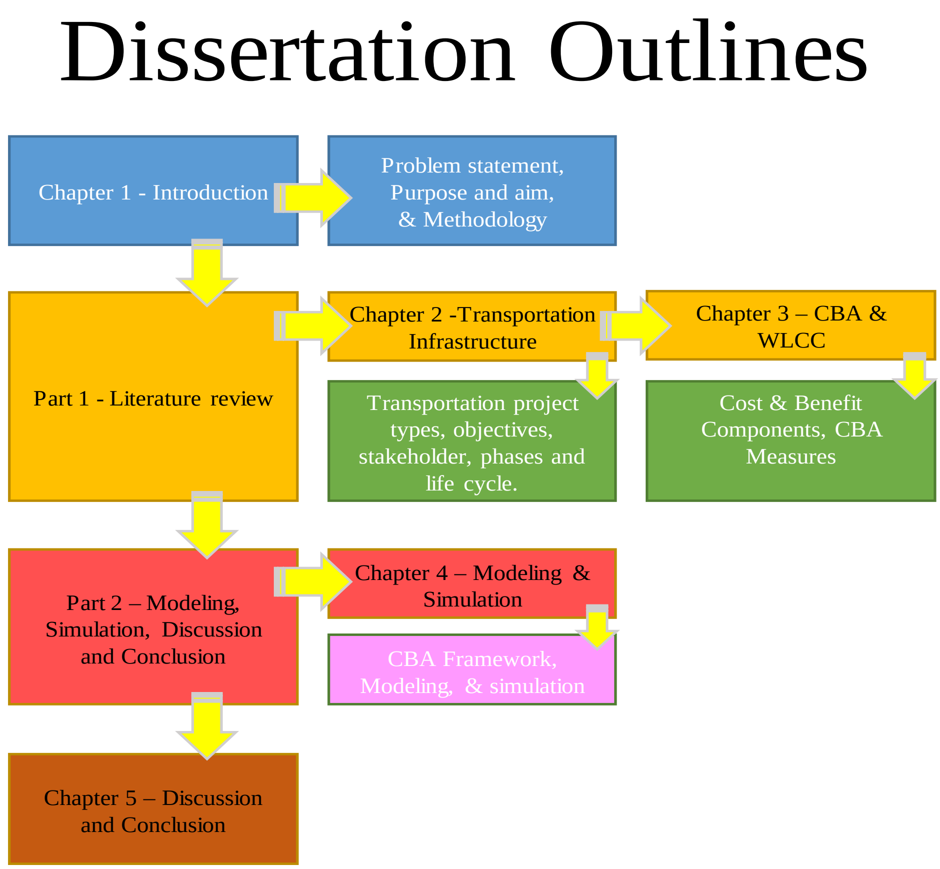


Figure 1 Dissertation Outlines

2.Chapter 2: Transportation infrastructure

2.1 Introduction

In this chapter, aspects of transportation infrastructure projects will be explored in the recent literature to: indicate the importance of developing an evaluation framework; define the elements and parties which may have an impact/ impacted by the evaluation process; and the currently used evaluation methods and procedures.

2.2 Importance of Transportation infrastructures:

Transportation infrastructure are economic and social tools that enables society to be more productive, through supporting its economic activities. They are usually built to enable the economy to create value by moving resources including people and goods locally, regionally and internationally, Although transportation facilities do not directly generate revenue (even in the case of toll systems) but without a reliable and efficient transportation other infrastructure will not perform efficiently (Litman, T., 2009).

It is every government's aim to make sure that transportation means are efficient and utilized at their optimal capacity (reduce mobility and accessibility time and cost, etc…), in order to reduce any value wasted while using them (congestion, time, money, accidents, etc…), also to make sure that their disadvantages (noise, accidents, pollution, etc…) are compensated, reduced or eliminated.

In Todd Litman (2009), John Whitelegg states, "*It is the ease of access to other people and facilities that determines the success of a transportation system, rather than the means or speed of transport. It is relatively easy to increase the speed at which people move around, much* *harder to introduce changes that enable us to spend less time gaining access to the facilities that we need*."

A transportation project is usually considered feasible if its expected benefits (Social, Environmental, Economic….) exceeds its costs over its life span, including the cost of borrowing money needed to implement it. The decision to build it or not, and when to do so is what to be discussed in this paper.

A simple (commercial) cost benefit analysis could conclude recommending the development of roads network for rich areas rather than for areas of low income. This paper will consider all the factor and procedures that could eliminate such bias, as it could be more beneficial for governments to invest in transportation infrastructure for those areas to encourage the growth and improve the life quality of those areas by providing cheap and reliable transportation options.

According to Litman (2010) and (2017), the above objective could also be categorized into three main categories Economic, Social and environmental as show in the below table:

Sustainable Transport Goals	
Goal	Definition
Economic	
Efficient mobility	Fast and affordable transport of people and goods
Local economic development	Progress toward local economic goals, such as increased productivity, employment, business activity, income, property values and tax revenues
Operational efficiency	Maximize efficiency of providing transport facilities and services
Social	
Human safety and health	Increased travel safety, public fitness and health
Affordability	Ability of households to afford basic transport

Social equity	Supports equity objectives including fair distribution of impacts (benefits and costs), progressivity with respect to income, and basic mobility
Community cohesion	Increased quantity and quality of interactions among community members
Cultural preservation	Preservation of artifacts and activities valued by a community
Environmental	
Pollution reductions	Reduced air, noise and water pollution
Resource conservation	Reduced and more efficient use of scarce resources such as petroleum and land
Open-space preservation	Preservation of farmlands, parks, and natural habitats

Table 1 Sustainable Transport Goals (Litman (2010))

Publicly funded transportation projects usually consider all the possible economic, social and environmental costs and benefits for all the previously mentioned stakeholders (with only few exceptions) that could relate to external parties, unless those costs and benefits are of small negligible impacts.

2.3 Transportation Projects Objectives

This paper will focus on publicly funded transportation projects, for which the main objectives would typically be as follows (according to Litman (2009, 2010, and 2017) and Transportation Benefit-Cost Analysis. (2018)):

1- Provide accessibility to new areas,

2- Reduce mobility costs (cost saving), by reducing travel distance and time, accidents and congestion and improve all society safety,

3- promote equality in transportation and mobility rights and improve transportation affordability to low income household,

4- Improved mobility for non-drivers,

5- Reduce parking costs, in land occupation and operational costs, 6- Energy conservation,

7- Reductions in air, noise and water pollution,

8- Reduce energy consumption,

9- Wild life habitat protection,

10- Support for local economic development,

11- Improved public fitness and health, by increased walking, cycling, reduction of accidents, pollution and stress,

12- Improve the wellbeing of all society members,

13- Improve people productivity and reduce the stress and health related issues related to transportation.

2.4 Types of transportation projects

According to Litman (2009, 2010, and 2017) and Transportation Benefit-Cost Analysis. (2018) website, Transportation project usually involves one or more of the following key types of activities:

- Roads and highways projects, including small improvements and temporary works,
- Bridges/ tunnels/ underpass projects,
- Rails/ metro/ tram projects,
- Public transportation projects like HOV (High-Occupancy Vehicle lanes) lanes, HOT lanes (High-Occupancy Toll lanes), dedicated bus lanes & routes, new fares zones, integration with other modes, Bus depots, bus stop shelters etc.…
- Cycle tracks, jogging tracks and walkways routes,
- Park and ride facilities, Transportation Hubs projects, on street parking, parking lots and

multistory parking buildings,

- Policies related to Transportation like Tolls, Taxation laws, vehicles ownership etc.…
- Related utilities projects (Storm water and street lighting enhancement projects)
- Trucks routes and accessibility management,
- Other major projects related to sea ports, airports
- ITS (Intelligent Transportation Systems) including integrated control centers and intelligent information signs and traffic signals,
- Maintenance and rehabilitation projects
- Transportation related studies like monetization studies, TMPs (transportation master plans), TISs (traffic impact studies), EcIA (Economic Impact Analysis), EnIS (Environment Impact Assessment), and CIA (Community Impact Assessment).

2.5 Transportation project stakeholders

Based on the extensive literature provided in Transportation Benefit-Cost Analysis. (2018) website, Jonsson, B. (2010), and Khraibani, R., De Palma, A., Picard, N., & Kaysi, I. (2016) to identify the possible stakeholders for transportation projects are:

- Government and local councils, and their tax collection agencies,
- Legal authoritarian bodies,
- Federal and local Military, security, police,
- Emergency response authorities, like civil defense, ambulance and hospitals,
- Related state and federal authority bodies like water, electricity, storm water drainage, sewerage, communication, environmental, city municipalities, urban planning,
- Project owner/ their representatives and sub entities,

- Project operators, their representatives and sub entities,
- Financing bodies, their representatives and sub entities
- Project manager, Project Engineer (consultant), their representatives and sub entities,
- Contractor, Suppliers, and their representatives,
- Local and federal Public transport agencies and companies,
- Surrounding air and sea ports and their owners and operators,
- Passengers, private car owners, residents, household owners, communities, business owners, freight companies and their trucks drivers, cyclists, and petrol stations.
- Tourism authorities and agencies
- Media channels
- Essential services providers like Schools, health and recreational facilities,
- International, regional and local rating organizations.

Those stakeholders may impact and be impacted by the transportation projects in terms of costs or benefits, economists and transportation planners involved in the evaluation process should identify those costs and benefits, and check if may influence the assessment outcomes.

2.6 Transportation projects phases and Life Cycle

According to PMI PMBOK (Snyder, C. S., 2014), any project can be broken down into 5 phases: Initiation, Planning, Execution, Monitoring and controlling, and closing as shown in the below figure.

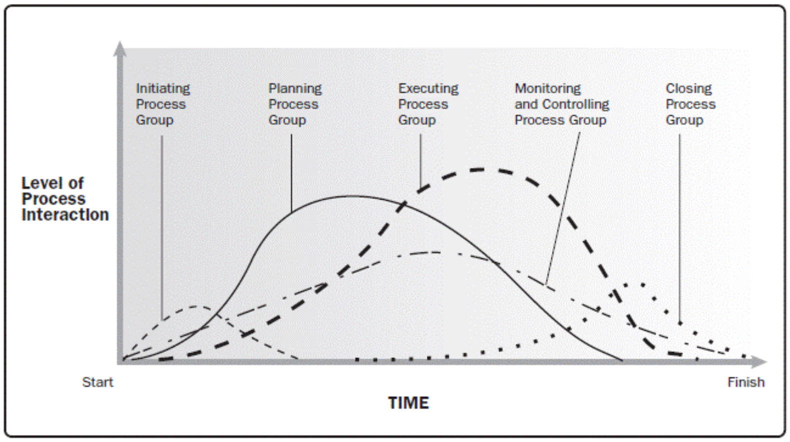


Figure 2 PMI Project Life Cycle

However, for transportation construction projects and even policies we can adapt the following project stages:

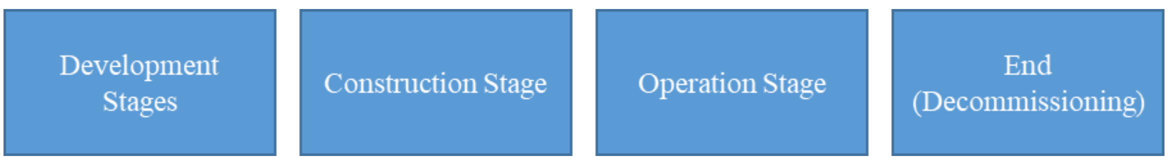


Figure 3 Standard construction project stages

The evaluation process should be done at the development stage, and should be used for monitoring and controlling the project during later stages. It should also have a feedback sub-process to ensure the continuous development of the evaluation framework processes.

Costs and benefits should be calculated for all project stages, which in general are, Development stage (concept, feasibility, planning and design), Construction Stage (construction, testing and commissioning), Operation, Rehabilitation and Maintenance Stage, and Project end stage (Decommissioning).

Adapting standard stages for the projects to be evaluated will provide guidance for the costs and benefits identification process.

Furthermore, a transportation infrastructure asset life cycle was developed and adapted for this paper based on the standard life cycle to demonstrate the importance of continuously managing the transportation projects in order to make sure that the evaluation process generate benefits and cash that will cover the operation and maintenance costs along with the cash required to build new assets to fulfill the growth needs.

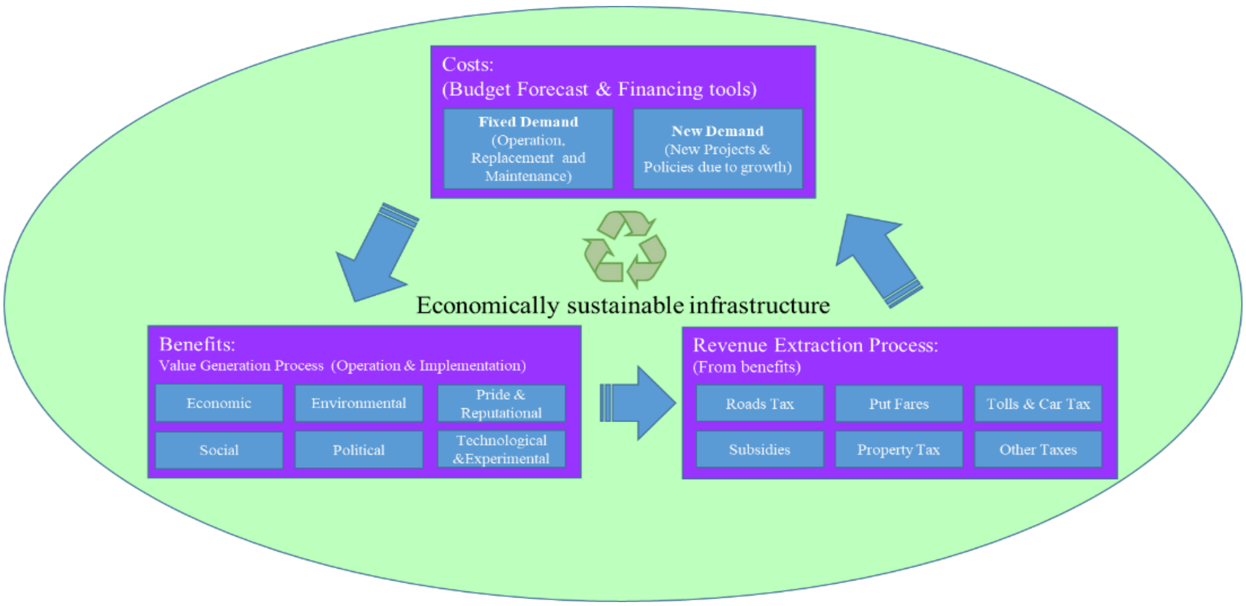


Figure 4 Transportation Infrastructure Full Life Cycle Analysis

This figure shows the three interrelated components: Expenditure (Costs), Benefits, and Cash revenue generation.

The above life cycle was extracted from asset management literature related to transportation infrastructure assets life cycle.

The below figure by Jonsson, B. (2010). Shows the sources of direct roads infrastructure costs:

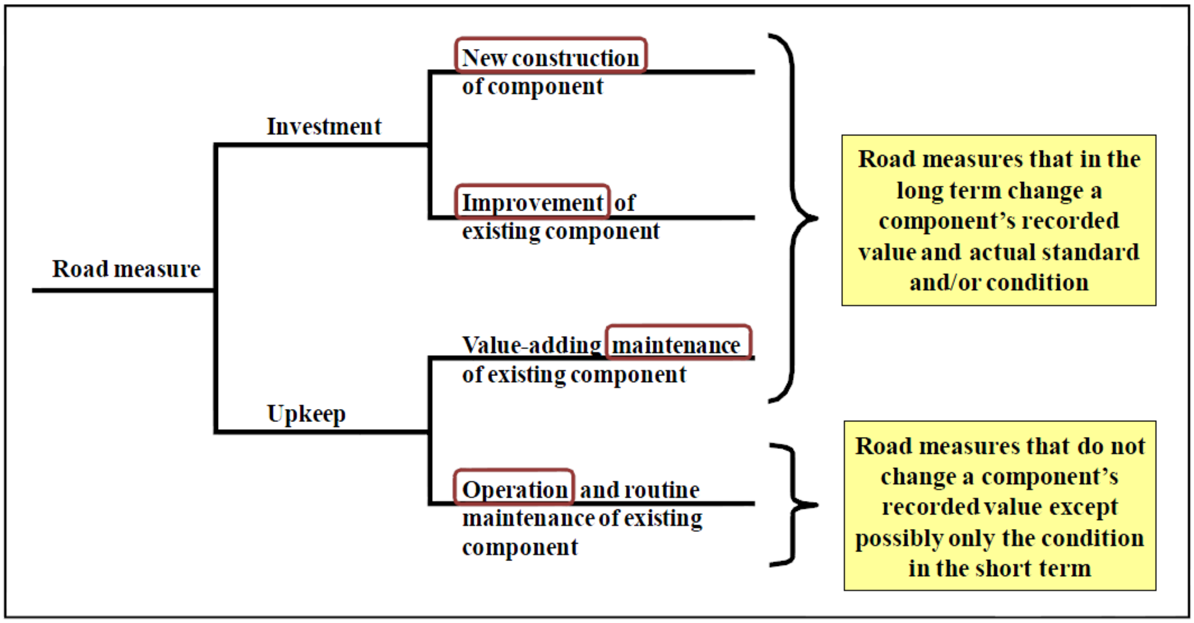


Figure 5 Highways Infrastructure costs elements (Jonsson, B. (2010))

The Costs and Benefits components in the previously suggested life cycle will be covered in this paper; however, the revenue extraction process will only be covered briefly in the next paragraph.

2.7 Source of transportation projects funds & financing tools

Transportation projects are usually funded by local and federal government's bodies and in some cases by private investors.

According to Slack, N. E. (2009), governments and private developers usually fund their transportation projects from one of the following sources:

- Taxes on cars imports and usage,
- Cars registration, insurances, and driving license fees,
- Fright fees,
- Traffic fines,

- Toll gates,
- Public transportation and parking fares,
- Tax on fuel,
- Property prices and taxes,
- Community fees,
- Other taxes (income tax, corporate taxes, import and export tax, etc…)

Moreover, the fund is delivered by using one of the following financial tools:

- Federal or local government direct budgeting,
- Governments Bonds,
- Public Private Partnerships and its sub-models,
- Direct Private fund,
- International funds.

The evaluation framework should provide the necessary documentation to support any of the above financial tools at the project appraisal stage along with any other related asset performance data.

2.8 Assessment of transportation projects

All developed countries have developed their own transportation projects evaluation and appraisal policies and frameworks, which consists of qualitative and quantitative tools (Khraibani, R., De Palma, A., Picard, N., & Kaysi, I., 2016).

However, the cost benefit analysis is considered the most used methods in transportation projects appraisal due to its flexibility and ability to include quantitative and qualitative variables, if it is combined with total life costing and monetization procedures.

The wide use of CBA, did not eliminate the need for other related studies related to the interrelation between transportation projects and the other economic, social, environmental, political, legal, and security aspects.

Accordingly, high level studies like Economic Impact Analysis, Environment Impact Assessment, and Community Impact Assessment are still required to support governments in their key decisions.

Considering the above, developing a comprehensive CBA framework that consider and overcome the previous limitation, will serve as a tool to optimize the selection of the right projects and their alternatives to achieve the required economic, social, environmental, political, legal, and security goals.

In the below figure Veryard, D. (2016) shows how CBA and EcIA are interconnected.

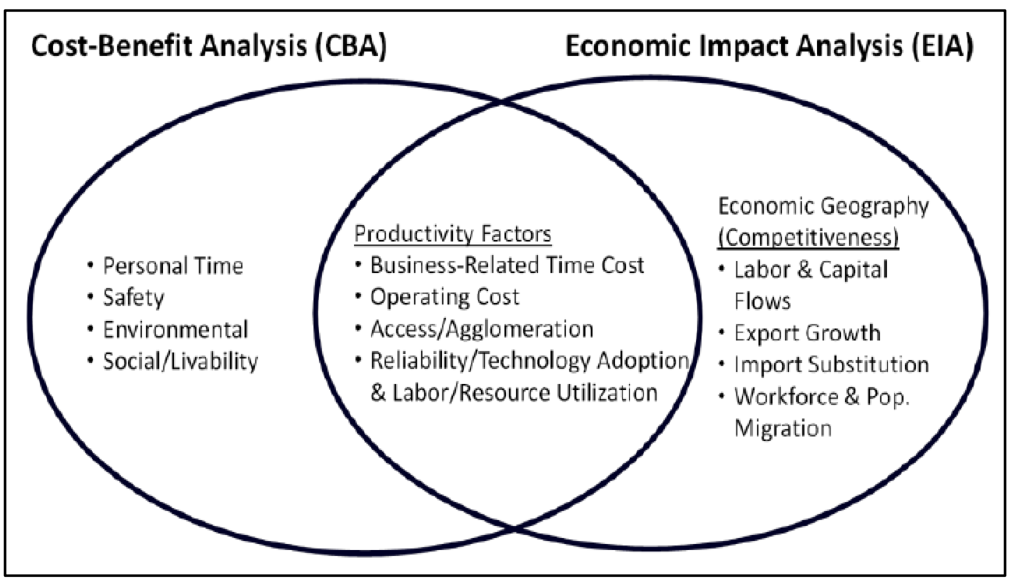


Figure 6 Scope of CBA versus EcIA

2.9 Assessment Framework for Transportation Projects

A framework will be developed and presented in later chapters, based on the findings in the literature related to CBA in transportation projects, which is similar to the frameworks presented in the work of Veryard, D. (2016) and in Jiang, Y., Zhao, G., & Li, S. (2013). Works.

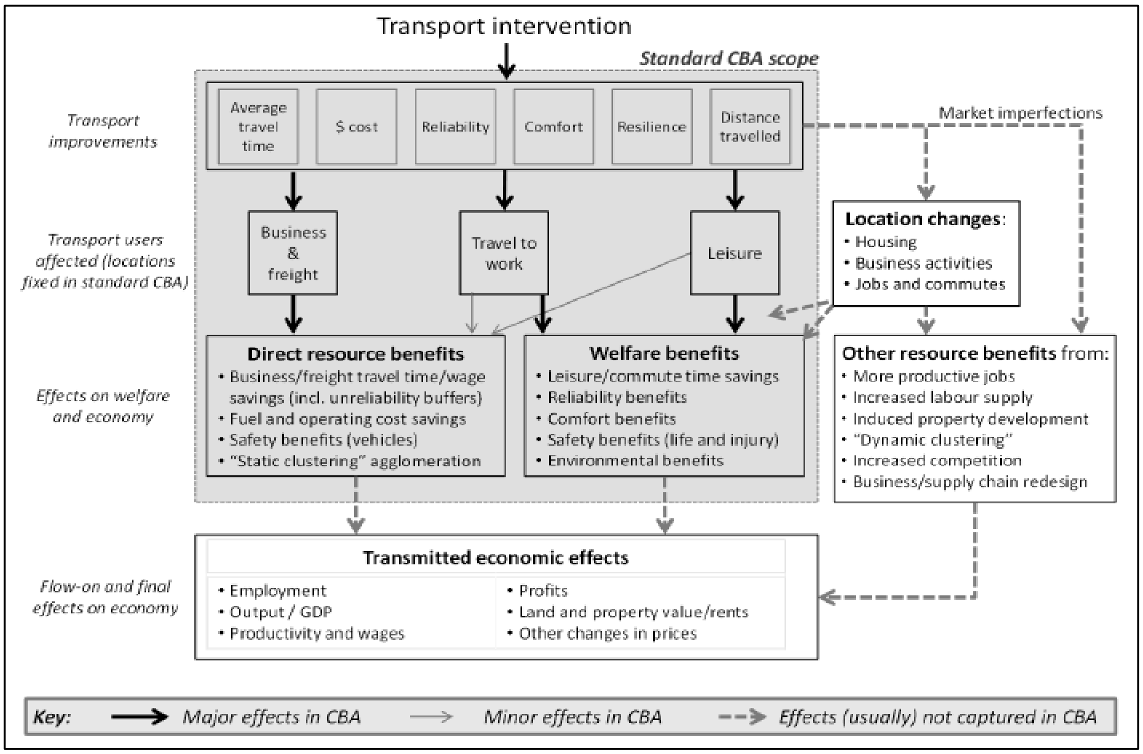


Figure 7 Veryard, D. (2016) CBA Framework

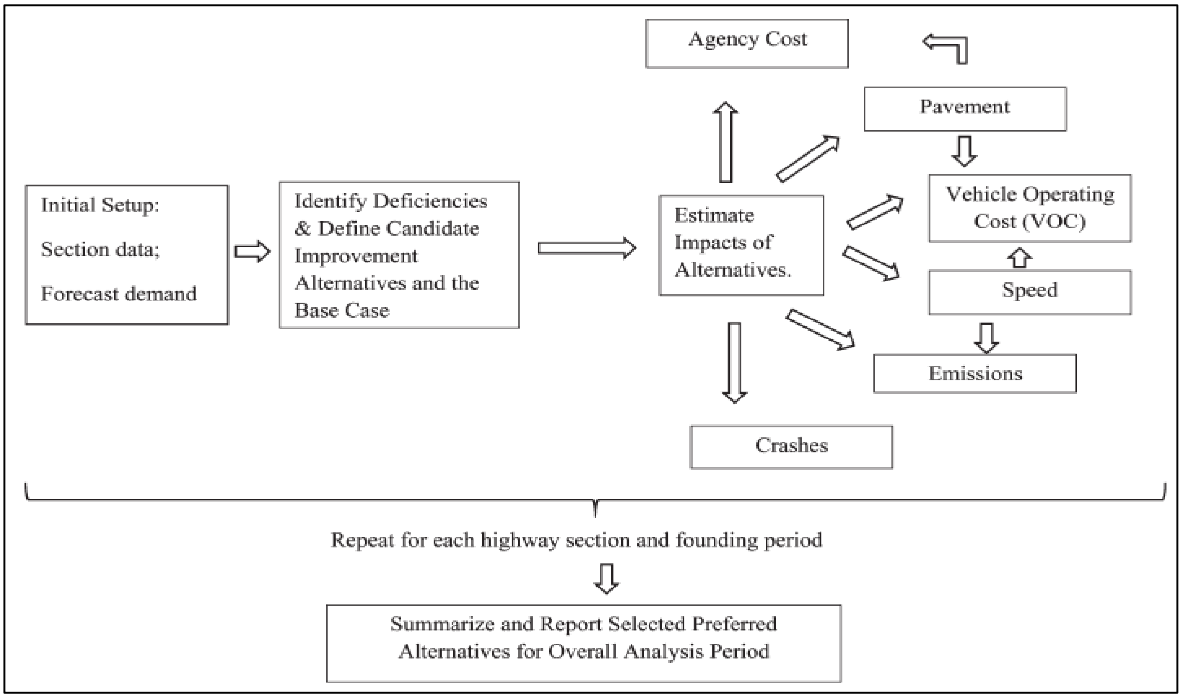


Figure 8 Jiang, Y., Zhao, G., & Li, S. (2013)." HERS Framework

We can see from the previous frameworks that all literature are recommending adding the social costs and benefits and to consider any possible cost or benefits that may be borne by the possible stakeholders, however they also recommend not to consider them in the modeling and calculation if they are of not big importance and will not affect the final assessment outcomes.

The next chapter will provide detailed information on Cost Benefit analysis method and its components.

3. Chapter 3: Cost and Benefit Analysis and whole life cycle costing for Transportation Project

3.1 Introduction

In this chapter, we will review the most recent notable literature related to cost benefit analysis and whole life cycle costs evaluation methods, and will extract all the possible cost and benefits components and any other parameter, which may affect the evaluation results throughout any transportation project life cycle.

Furthermore, the review will identify the most used CBA measures, and the methods used for valuating (monetizing) qualitative cost and benefits components.

This chapter will also provide a brief description on the new PMI publication related to benefit realization management (BRM) which is being introduced recently.

At the end of this chapter, we will provide a theoretical about the probabilistic approach which will also be used in the Excel model for the sensitivity analysis exercise.

Cost Benefit Analysis (CBA):

According to Transportation Benefit-Cost Analysis. (2018), Cost Benefit Analysis (CBA) is a systematic process to calculate and compare a project cost and benefits, either to determine/ justify the investment, or to enable decision makers to prioritize or check the best alternative for projects.

CBA is considered one of the most widely used methods used for comparing, selecting and prioritizing transportation projects (Nogués, S., & González-González, E. (2014)).

CBA is simply calculating all the discounted cost components and all the discounted benefits over the whole life cycle of the project or for each of its alternatives and compare them in one of those measuring methods:

- Is the project benefits value exceeding costs value?
- Is the Net present value (NPV) greater than zero?
- Is Benefits / costs rate more or less than one?
- Internal Return Rate (IRR) > or < (other investment return rate)
- What is the Payback period? In addition, is it better than other alternatives?

The key difference between CBA and other comparison methods (like value engineering) is the extensive use of monetization for the quantitative costs and benefits components over the whole life cycle of the project alternatives, which could yield better decision supporting results if was based on a reliable monetization studies and statistics. In the same context, CBA requires much more effort to conduct monetization studies especially if there is no statistical and economic data available.

Whole Life Cycle Costing "WLCC" is an investment & procurement appraisal tool, which is used in business to model investments, business cases, and procurement options, to help decision makers to assess and select the best option based on its profitability and value for money.

It involves applying discount rate to the provided forecasts of each of the options' costs and revenues over the whole life cycle of the project/ investment, to make sure that the project in profitable and that it revenue surplus its costs within an acceptable investment-payback period (Boussabaine & Kirkham 2008).

The below figure shows how CBA can be combined with WLCC to produce a cash flow that can be used for modeling.

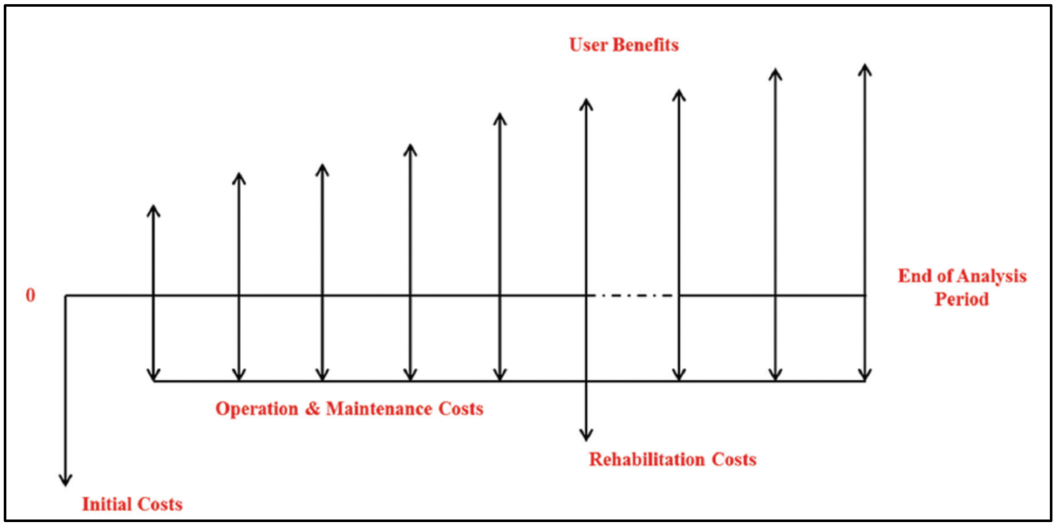


Figure 9 Simple Cash Flow Diagram (Jiang, Y., Zhao, G., & Li, S. (2013))

The above figure shows steady costs during the operation stage without considering the effect of discount rate, as the value of money should decrease by time.

3.2 Advantages and Disadvantages of CBA in Transportation Projects

The key advantage of applying CBA for transportation projects is providing a reliable and flexible decision-supporting tool for decision makers to be used for assessing projects and their alternatives in a way that will make it easy to compare them and priorities them based on their value, and provide a documented justification for selecting specific projects and their alternatives. CBA is considered as the best methods of assessing transportation projects due to its flexibility to include multiple qualitative or quantitative components for the whole life cycle of the project. However, according to Beukers, E., Bertolini, L., & Te Brömmelstroet, M. (2014), advantages of applying CBA can be summarized in the following four categories:

- Prioritizing projects in an unified framework based on their economic, social, environmental, political, pride & reputational, and technological & experimental overall value, in order to define budget forecasts, and filtering out low or negative value projects to optimize the use of available funds,

- Identifying best alternative for a project based on its overall value and cost effectiveness, in a unified and agreeable framework,
- Evaluating policies and their impact and optimizing their value, and testing those policies prior to their implementation to reduce and unexpected risks,
- Benchmarking and creating knowledge based on previous CBA studies and their outcomes during the project's stages, and building transportation business models that can be used for assessment that is more reliable.

Applying a well-documented and a transparent CBA framework based on international standards could also support government's policies to attract private investment locally, regionally and internationally, and provide clear information for the public on government's decisions that will lead to more public support.

Outcomes of CBA could be also used for quality assurance and project management activities during project development, construction/ implementation, operation and closure stages by monitoring costs and benefits realization and driving the project to achieve its planned objectives in terms of ultimate costs and benefits.

Benchmarking and knowledge creation are amongst the most important indirect advantages of applying CBA analysis for transportation projects. Because it may answer important questions related to government's investments in different sectors other than transportation like education and health, this knowledge could also be used for setting strategies and to do a high-level estimation and forecasts, below are some questions that CBA benchmarking could answer:

How much is the cost of moving goods for 1 km around the country and in the cities, and how does it compare with other countries regionally and internationally?; What is the percentage of transportation costs for goods?; What is the current transportation cost percentage compared to average wage, and how does it compare with other cities and countries?; How can a government improve its economic competitiveness?; What is the value of roads as an asset vs its cost, are they value generating asset or a liability?; Should a government keep on building new roads to resolve congestion? Or should the government invest in mass public transportation systems?; At what point investment in new roads will not be cost effective?; Is a single road an asset or the aggregated network is more profitable?; When is to invest in transportation infrastructure rather than other infrastructure like education, health, housing, power, manufacturing, etc…?; Should a country privatize its transportation infrastructure?; Should a country/ state/ city subsidize its public transportation infrastructure? And how to calculate transportation taxes?; How much budget should we reserve yearly for transportation infrastructure maintenance, replacement and rehabilitation?; Should the government invest in long lasting transportation infrastructure with high forehead costs or with cheap short term solutions?; How much extra budget is required to keep up with the current population growth ratio? Should the government invest in transportation projects with B/C less than 300% for the next 5 years? At which NPV& B/C should the government consider investing in public transportation projects and policies rather than building new roads?.

In addition, many more questions that are needed to develop clear and reliable strategies countrywide.

Applying CBA and monitoring its application its benefits realization and providing the required feedback to its policy makers will guarantee the continuous development of the proposed framework and its related models.

3.3 Components of CBA

Generally, costs and benefits are also categorized into market and non-market components based on how their values are estimated, for which market components are estimated directly from the market or through an easy to manage process, while the non-market components valuation require detailed studies.

It is recommended to have separate estimate model for each of the market and non-market cost/ benefit components that could be developed over time.

Calculation and modeling for each individual market and non-market components will not be covered in this paper. Due to the time and scope limitation of this paper, whose main purpose is to build a governing framework to guide the process of CBA and to identify the possible components from the latest literature, which are required to produce a reliable analysis to support the appraisal of transportation projects.

Cost and benefits will be listed below based on the general project stages, which are project planning and development stage, construction & commissioning stage, Operation/ Maintenance/ Rehabilitation stage, and the end of project stage when the project facilities will be decommissioned or totally replaced.

Calculation of costs and benefits for a project and its alternatives depends on the purpose and the perspective of the owner and his partners or sub entities, to whom costs and benefits could be considered internal or external throughout the project life cycle.

The below cost and benefits components were extracted from all the literature listed in the references.

3.3.1 Cost Components

Cost components of transportation projects may vary based on the project's type, however all transportation projects can share the same life cycle stages.

For cost benefits analysis, costs components that would not have an impact the analysis needs to be filtered in order, accordingly current transport planning, economists and investment decisions tend to focus on direct market costs. Indirect and nonmarket costs tend to be undervalued because they are more difficult to measure.

Main cost components related to transportation projects (which were extracted from the key literatures) will be listed in the next paragraphs according to the standard transportation project's stages. Also, those costs components will be given codes to simplify the CBA equations that may be used in this paper, as well as in the excel sheet.

3.3.1.1 Development Stage Costs (DC)

This component consists of the Planning, preliminary engineering, project design, and agencies costs:

- Consultancy services cost for (planning, project management and final design) (DC1)
- Agencies and authorities' costs (DC2)
- Environmental and transportation impact reports and soil investigation reports (DC3)
- Project related training (DC4)

Some of those costs could be considered as joint costs, as they are shared with too many other projects and cannot easily segregated using reasonable ways.

Those costs will not be used in the modeling exercise, which will be developed alongside this paper as all of them are constant for all options and it is in the range between 0.1 to 2% of the direct construction cost.

3.3.1.2 Construction Stage Costs

Construction stage cost are categorized into two sub-categories, construction direct costs and construction dis-benefits costs.

i) Construction Direct Costs (CDC)

Those costs can be represented by one variable or can be separated based on the level of effort and accuracy required for the analysis, and most of the agencies have formulas to estimate those cost based on project types and attributes.

It will be a challenge to model all the possible items in the CBA model and it is better to build a separate model for the construction direct costs that could include all of the possible items from all probable disciplines (Roads, Bridges, Tunnels, Rails, Marin, Utilities, etc…).

In addition, those costs are market costs, which could easily be estimated from the market through contractors or suppliers,

Usually those costs are:

- Construction and standard operation equipment and vehicles,
- Material, labors, supervision and site offices costs,
- Special material stocks and inventory costs (special street lighting, special bridges mechanical parts, etc…),
- Land acquisition and clearance costs,
- Other agencies fees and direct costs like police, services diversion, protection, and new

networks

- Temporary works costs,
- Demolishing of existing facilities,
- Cost of disposal and recycling of waste materials,
- Impact on public transportation cost,
- Insurances, warranties and accidents,

ii) Construction Dis-Benefits Costs (CDBC)

This component can have great impact on alternatives' selection for construction methods and construction duration.

Those costs can be estimated based on the same methods used for the benefits components through monetization process, as they are usually none market items/ resources,

Agencies should develop a database and models for quick simplified estimation of those costs, more details will be provided in the benefits components section in regard to None-Market components estimation.

The possible sub components of the Construction dis-benefit costs are:

- Traffic delays (vehicle added hours, vehicles added kilometers, and its resulting stress),
- Construction noise costs,
- Construction pollution costs,
- Impact on businesses costs,
- Impact on community costs,
- Impact on essential community services (schools, hospitals, police, civil defense, ambulance),
- Emission costs,

- Aesthetics impact costs,
- Safety costs,
- Cost of impact on pedestrian, cyclists, parking,
- Reputational costs,
- Remaining value of existing facilities that will be demolished or replaced,

3.3.1.3 Operation, Maintenance, Rehabilitation and Replacement Stage Costs

Those costs are referred to as continuing costs, and it refers to the costs, which incur after the transportation facility is completed and is in use. Those costs are categorized into four main types:

1 **Operational Costs (OC)**

Street lighting and traffic signal power costs, traffic monitoring and management, buses fuel and tires, metro power, toll collection, buildings/ facilities bills, staff (managers, drivers, technicians…), software license, police and ambulance costs. This component can be estimated based on previous statistics from existing similar facilities.

This component could include all subsided costs like PUT fares, land rental etc…

2 **Maintenance Cost (MC)**

This cost includes routine preventive maintenance and inspection costs including small repairs like pavement inspection and repairs, bridges and tunnels periodically inspect and joint cleaning, vehicles/ equipment maintenance, accidents and adverse weather repairs, traffic diversions, traffic delays during maintenance, etc… this component could also include short term maintenance contracts (3 to 5 years). This component also can be estimated based on previous statistics from existing facilities based on roads/ bridges/ underpass areas or lane kilometers, except for the traffic delays that should be calculated based on a monetization method.

This component needs a considerable effort especially when the compared alternatives involve different transport modes. Jiang, Y., Zhao, G., & Li, S. (2013).

3 Rehabilitation and Replacement Costs (RRC)

These costs are usually considered major repairs or replacement of transportation facilities elements or part of it, like resurfacing of pavement, replacement of bridge mechanical parts. This component can be estimated from the previous statistics of existing facilities and suppliers Jiang, Y., Zhao, G., & Li, S. (2013).

Maintenance, rehabilitation and replacement are very important in extending the life expectancy of any infrastructure as well as making sure that the facility will keep on delivering benefits for the whole analysis period at the planned capacity.

4 Operation, Maintenance and Rehabilitation Dis-Benefits (ODBC)

Those costs can be environmental, economic and/ or community costs, like the impact on animal habitat areas, the noise and pollution that a new highway could cause in a residential area, the impact on local accessibility and walkability and emission costs, etc.

Those adverse impacts should be acknowledged and mitigated by providing solutions (sound barriers, pedestrian bridge, and grade-separated animal crossing facilities, in order to avoid inconsistency in calculation of different projects alternatives.

Another issue to acknowledge is the extra-generated traffic due to the creation of transportation, which is called "Induced Travel" which will have also adverse impact on the environment and cause more demand.

Other costs to be considered are the ones related to the dis-benefits during maintenance and rehabilitation of the transportation facilities and the utilities within the ROWs over the duration of the analysis period due to the proposed improvements and the required traffic diversions if applicable, along with the cost of the resulting traffic disturbance.

Economic dis-benefits costs represents the adverse impact on local/ regional/ national and even international businesses due to transportation projects those impacts could affect people jobs and income as well as properties value, like the impact of upgrading a collector road into a highway on local coffee shops or the impact of trucks prohibition zones on ports.

Those costs are usually non-market costs and cannot be easily mitigated; accordingly estimating them requires special studies.

Those cost components could include the following:

- Health impact (hearing, stress, sleeping)
- Pollution impact on the environment
- Accidents
- Pedestrians and cyclist’s accessibility
- Nearby Property value impact

i) End of Project Costs (EPC)

It is also referred to as the decommissioning costs, which involves the decommissioning and demolishing costs of the facilities and reinstating the site condition to its original conditions, and the lost value of the remaining service life in case of early decommissioning.

It is usually consisting of the flowing elements:

- Residual value: which is equal to the value of the assets at the end of the analysis period in case its condition allows it to continue functioning at an acceptable level of service.

This value should also be considered in case of early closure/ termination of the project in case of failure or requirement for upgrade.

- Salvage value: it is the value of the working assets if it is to be sold, like the value of buses or any other equipment or materials if it could be sold.

Jiang, Y., Zhao, G., & Li, S. (2013).

3.3.1.4 Costs with varying or no-specific time line

There are some costs which does not have a clear time of occurrence, which their value is realized at the full and successful operation of the project, like the following costs:

Political and National Security Costs (PNSC)

Transportation infrastructure projects could have negative impact on the country security, for example, opening new roads between countries could impose security concerns related to smuggling and trafficking.

This component needs to be considered for projects that may impose such concerns.

Campaigns and awareness costs (CAC)

Those costs are usually high in policies type of projects, like the cost of preparation of a safety campaigns or the announcement for opening of a new road.

Usually those costs are not easy to estimate since policies have big uncertainty in achieving their goals and objectives.

Reputational Costs (RPC)

This component refers to the cost of the damage that the agency could suffer from due to considering a new controversial project or an alternative. For example, if the agency is considering the demolishing of a bridge that was built recently due to a mistake or due to unexpected traffic growth, then the impact on the agency reputation should be considered while assessing the alternatives.

Experimental Costs (EXC)

This cost is related to works that is done for testing a solution or a new technology, which can be adopted or discarded based on its outcomes, those costs should not be included as they are considered as joints costs as their value, which is mainly in the knowledge, is shared in many other future projects.

3.3.2 Benefit Components

Usually transportation projects main objective is to reduce transportation costs, however improving transportation and reducing its costs has plenty other benefits (and dis-benefits). Subsequently, transportation projects benefits can be categorized into two main categories, cost saving benefits and Non-cost saving benefits, which includes community, economic, political and national benefits.

The term cost saving is used to refer to the currently incurring costs that could be saved if the proposed project is to be implemented, during the analysis period.

3.3.2.1 Development Stage Benefits (DSB)

It consists of the value created by building knowledge and risk reduction during the development stage of the project.

3.3.2.2 Construction stage benefits

There has been no recorded benefit in the literature that incur during the construction stage other that the economic benefits which will be mentioned later on in this chapter, but its time of occurrence is not clear.

3.3.2.3 Operation, Maintenance, Rehabilitation and Replacement Stage Benefits

i) Travel Time Benefits (Cost Savings) (TTB)

This component refers to the saving in passenger's and driver's time that is spent on transportation through reducing the travel distance, increasing travel speed and/ or reducing congestions or stop cycles.

Estimating this benefit value requires the Value of Time (VoT) for each group category and the Vehicle Hours Travel saving (VHT) (in the case of surface transportation) for each passenger type. Calculating this benefit requires great effort especially when it involves multiple travel modes, as it needs separate studies/ surveys to estimate vehicles occupancy rates, also in addition to other studies/ surveys to estimate the time value for each passenger/ driver type.

$$TTBx = \sum (VHTi * VoTi)$$

Macro Modeling software are capable of calculating VHT time saving, while the value of time and other variables and multipliers like occupancy rates still require further economic and traffic studies.

ii) Vehicle Usage Benefits (Cost Savings) (VUB)

This component is related to the saving in kilometers travelled by vehicles or public transits due to the introduction of new roads, improving capacity or travel conditions on other surrounding roads networks, introducing new transit policies or services, new HOV (High occupancy vehicle) or carpooling lanes etc…

This value is calculated based on the number of kilometers saved by each vehicles group multiplied by the cost of a kilometer traveled of that vehicles group.

Although this cost is supposed to be considered external to governments, but it should be considered in the CBA as it highly contributes to the cost of travel, and reducing it contributes to governments main objectives.

Vehicle travel costs are usually impacted by the vehicle type, vehicle age, its running speed, number of stop (change is speed cycles), road gradient, fuel and oil costs, tires, curvature and road surface conditions.

Vehicle kilometer costs includes some fixed costs like its price, financing, registration fees, insurance, residential parking, maintenance and repairs.

Similar to the time cost saving the vehicle usage saving will be calculated by multiplying the number of saved kilometers (VKT) by the cost of traveling a kilometer for each vehicle group (value of kilometer VoK).

$$VUBx = \sum (VKTi * VoKi)$$

Calculating VKT can be done through Macro modeling software, although calculating VoK requires a lot of time and effort to establish the required variables and database.

This saving can have multiple nesting benefits related to change of travel modes from private cars to cycling or walking, but due to its complexity and small impact, then it will be ignored.

According to Litman, T. (2009), motor vehicle costs are categorized to internal and external, and subcategorized to variable and fixed costs, which also could be market and non-market as shown in the following table:

	Variable	Fixed
Internal (User)	Fuel	Vehicle purchase
	Short term parking	Vehicle registration
	Vehicle maintenance (part)	Insurance payments
	User time & stress	Long-term parking facilities
	User crash risk	Vehicle maintenance (part)
External	Road maintenance	Road construction
	Traffic services	Subsidized parking
	Insurance disbursements	Traffic planning
	Congestion delays	Street lighting
	Environmental impacts	***Land use impacts***
	Uncompensated crash risk	***Social inequity***
(Bold & Italics = Non-market)		

Table 2 Motor Vehicle's cost (Litman, T. (2009))

iii) Travel Time Reliability Benefits (TTRB)

To include this benefit component, two studies should be carried out, one is to establish a valuation methodology for the travel time reliability, and the other is to estimate the changes in travel time reliability.

Both studies require a lot of time and effort to be reliable for the analysis purpose, accordingly it is not recommended to include it in the CBA unless it has big impact on the decision.

In most of the models used worldwide, the travel time reliability is derived from the same monetization method used to calculate the value of time (VoT) and some countries calculate it by multiplying it with specific multiplier based on the travel modes.

iv) Parking Benefits (Cost Saving) (PB)

Some projects/ policies may reduce the need for more parking spaces, due to increase the Public Transportation (PUT) share or walkability/ cycling environment or HOV lanes.

Parking costs consist of the price/ rent cost of the land, construction costs, operation and maintenance costs.

Parking availability usually adds value to any destination for private car drivers but at the same time attracts more traffic; usually policy makers encourage the use of PUT through altering the availability of parking spaces or changing the parking costs.

Usually the parking costs and benefits are not included in the CBA due to their small impact if compared with other components.

v) Tolls, Fares and Taxes Benefits (TFTB)

Tolls and other taxes components benefits are considered internal/ transfer, and whether to be considered them or not depends on the purpose of the analysis and its extents.

Including such components will add to the complexity to the process and may not add real value to the overall benefits of a country/ state transportation agency unless it could be applied for external parties only. However, those components are considered essential regulatory elements in the economic sustainability of the transportation infrastructure system.

vi) Safety Benefits (Cost Savings) (SB)

Travel accidents are usually categorized into three major types based on its impact on road users: which are fatal, with casualties, and properties damage only.

The cost of accidents consists of the following items:

- Cost of properties damage (cars and road's furniture)
- Cost of traffic disturbance and police services
- Cost of emergency services
- Cost of medical treatment and rehabilitation
- Impact on productivity of the injured people,
- Cost of pain, grief and suffering in case of death

All those items can be estimated from the market except for the last two items, which require special monetization exercise especially for the cost of human life as it is not acceptable to be considered as a commodity.

This benefit is calculated by multiplying the anticipated difference in accident numbers (ADiAN) by the cost of its corresponding type of accident (CoA),

SBx = ∑ (ADiANi * CoAi)

Estimation of the difference in accidents can be linked to a separate variable (single or multiple) like the number of conflict points, the density of conflict points, trucks percentage, speed variation, speed and/ or volume, then calibrates the model with local accidents record for the same area.

A special model should be established to estimate the costs of type of accidents.

Agencies should establish a method to estimate accidents cost based on fatality, injury, and property damage types of accidents, which require another sub-model to measure the safety improvement based on statistics, number of conflict points, VMT, and road classification.

Jiang, Y., Zhao, G., & Li, S. (2013) provide a simple flow chart for safety benefits estimation in the below figure:

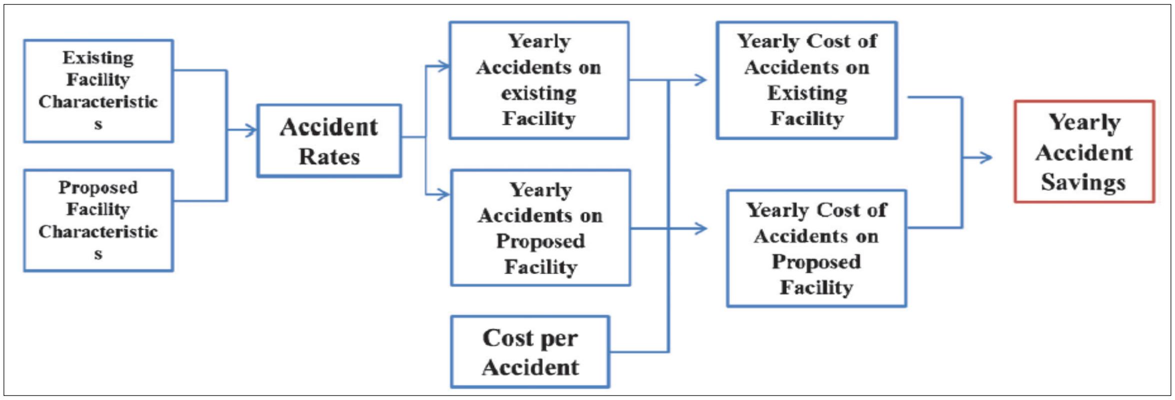


Figure 10 Computation steps of crash reduction savings, Jiang, Y., Zhao, G., & Li, S. (2013)

vii) Environmental Benefits (Cost Savings) (EVB)

According to a research conducted by the United Nation Transportation activities contributes to one fifth of the global energy consumption, and to one quarter to energy related global greenhouse emissions, and this percentage is projected to rise to 50% by 2030 ("Commitment to sustainable transport mobilized at UN Climate Summit - UN Climate Summit 2014" 2018).

The impact of transportation on the environment can be one of the following:

- Noise pollution,
- Gas emission and air quality,
- Water quality,
- Animal habitats.

The first three impacts can be linked directly with the VKT and VHT for each type of vehicle but it needs detailed study and calibration based on actual tests, also in relation to the selection of each unit and the valuation of its cost. However, the impact on animal habitat can be estimated by the cost of its mitigation because it cannot be considered as a commodity that could be sold or evaluated.

viii) Economic Benefits (ECB)

Investment in transportation projects have great benefits on the economy.

And a well-developed transportation infrastructure is supposed to improve productivity, employment rates, investment, business activities, property values, access to education and health facility, walkability, equity and affordability to all income groups, country Gross domestic product (GDB), public income, tourism, tax revenue and overall wellbeing of household owners, cities, regions, countries and even the entire world.

That is because it reduces the cost of transporting people and the services that they provide and the products and goods that they produce locally, and internationally.

Investing in transportation infrastructure also creates liquidity in the construction market, which is considered an indicator of country economic conditions.

Economic and community benefits /dis-benefits of transportation projects are so difficult to capture and estimate and that it mainly due the difficulty to predict their time of occurrences, and their occurrences are dependent on other economic factors.

Transportation networks (Roads, Airports, see ports and rails) are connected locally, regionally and internationally, and a benefit to a group of people may be considered dis-benefits to another.

For example, improving accessibility to a particular community may improve the supply for more quality products, but at the same time increase the competition for local business owners.

Another example is that upgrading the road network in a particular area may reduce the transportation cost and increase the speed for one group of users, but at the same time could limit the walkability environment within that area for other groups.

Those benefits are usually not considered in the CBA as they are only important to compare different investment types like investment in transportation or education or maybe other infrastructure like power or water, usually those advantages are addressed in Economic Impact Analysis (EIA) s. Those impacts are also referred to as “Economic Development Impacts” Another reasons why economic and communities impact should not be included in CBA is that it would be double counting of transportation benefits, as those are the results of reducing transportation costs.

ix) Community Benefits (COMB)

Community benefits are the components that makes the community more attractive and livable like:

- Community walkability,
- Health, safety and security,
- Cycling and recreational facilities,
- Beautification,
- Community cohesion,
- Sunshine, Skyline and scenery views,
- Landscaping,
- Cost effective accessibility to basic services,
- Property value,
- Equity impacts (equal distribution of transportation services and facilities)
- Country reputation
- Civic pride
- Recognized monuments and landmarks

Community impacts could be considered part of economic impacts but usually are evaluated separately as community impacts are more localized and limited to the subject community geographic limits.

Community benefits and costs are very difficult to estimate and are not recommended to be included in the CBA as they may be considered double counting and they are extremely subjective.

At the same time, those cost/ benefits should be done separately in different supportive appraisal studies.

x) Social Benefits (SOB)

Cheaper transportation makes social activities more affordable and create more face-to-face interaction between society members and between firms and their possible clients, which will improve social health and relation between businesses and their society members, which in return helps in creating more jobs and adds to the wellbeing of all society members.

This component is usually not included in cost benefit analysis for transportation projects due to its complexity and the uncertainty of its outcomes (Federing, D., & Lewis, D., 2017).

3.3.2.4 End of Analysis Value Benefits - Residual Value (EAVB)

This component is similar to the "End of Project Costs (EPC)" component, the only difference here is that we calculate this benefit when comparing two projects or alternatives with different life span for an analysis period less the than either of the alternative life span (Bailly, H., & Brinckerhoff, P., 1999).

3.3.2.5 Benefits with varying or no-specific time line

As in costs, there are also some benefits with no clear time of occurrence, which their value is realized at the full and successful operation of the project, like the below benefits:

Political and National Security Benefits (PNSB)

Transportation infrastructure can be used as economic and political tools to influence political relationships between countries in both positive and negative ways.

Transportation has major impact on every country's economy, and it plays a major role in the countries security especially in regards to country's essential goods supplies, for that governments tend to build some routes due to political risks, even when costs may exceed the return on investment and even if it is not warranted by traffic volumes.

Furthermore, transportation networks can also play important roles during wars and troubles, and governments could also develop separate transportation facilities like roads and airports for military usage only, however those types of projects are not included in the scope of this study.

It is recommended to consider this component in the Costs benefits analysis, due to its impact on the decision, which could be key differentiator especially in turbulent times.

However, considering it is not easy due to the non-market feature of this component.

Reputational Benefits (RPB)

It refers to the value that is assigned to a project or one of its alternatives that could have positive impact or prevent a negative impact on the organization/ agency.

For example, agencies could undertake projects or invest in developing a new technology just to maintain its place a leader in some field of transportation, although those projects could have low ranking in terms of its CBA measures.

Quantification of the reputational benefits is subjective, and is usually assessed by using the risk assessment methods, literature does not recommend adding this component to the cost benefit analysis especially that it is not clear at which stage and year this component would occur.

Experimental Benefits (EXPB)

This component refers to the knowledge and experience that is expected to be collected throughout the projects stages from the development stage until the decommissioning stage. Although this component could be bought or rented through the market, however monetizing it is not an easy task, and it is usually ignored to reduce the complexity of the CBA process for transportation projects.

The below table lists all the possible cost and benefits components for a tranpsortation project, along with its st

Ge and importance based on the liteature review above:

Component	Code	Type	Stage	Included in CBA	Estimation difficulty	Objective / Subjective	Estimation method	Issues	Impact
Costs									
Development stage Costs	DC	Cost	Planning	No	Easy	Objective	empirical	Joint/ Sunk cost	Low
Construction direct costs	CDC	Cost	Construction	Yes	Easy	Objective	empirical		High
Construction dis-benefits costs	CDBC	Cost	Construction	Varies	Difficult	Subjective	Monetization		medium
Operational costs	OC	Cost	O&M&R	Yes	Easy	Objective	empirical		High
Maintenance cost	MC	Cost	O&M&R	Yes	Easy	Objective	empirical		High
Rehabilitation and Replacement costs	RRC	Cost	O&M&R	Yes	Easy	Objective	empirical		High
O&M&R dis-benefits	ODBC	Cost	O&M&R	Varies	Difficult	Subjective	Monetization		High
Political and national security Costs	PNSC	Cost	O&M&R	yes	Difficult	Subjective	Monetization		High
Campaigns and Awareness Costs	CAC	Cost	Varies	No	Difficult	Objective	empirical		low
Reputational Costs	RPC	Cost	Varies	Yes	Difficult	Subjective	Monetization		High
Experimental Cost	EXC	Cost	Varies	No	Difficult	Subjective	Monetization		low
End of project costs	EPC	Cost	Decomissioning	Yes	Easy	Objective	empirical		low
Benefits									
Development Stage Benefits	DSB	Benefit	Planning	No	Difficult	Objective	empirical	Joint Benefit	Low
Travel Time Benefits	TTB	Benefit	O&M&R	Yes	Difficult	Objective	Monetization		High
Vehicle Usage Benefits	VUB	Benefit	O&M&R	Yes	Difficult	Objective	Monetization		High
Travel Time Reliability Benefits	TTRB	Benefit	O&M&R	No	Difficult	Subjective	Monetization	Double Counting	Low
Parking Benefits	PB	Benefit	O&M&R	No	Easy	Objective	Monetization		Low
Tolls, Fares and Taxes Benefits	TFTB	Benefit	O&M&R	Yes	Easy	Objective	empirical	Transfer benefits	Low
Safety benefits	SB	Benefit	O&M&R	Yes	Difficult	Objective	Monetization		High
Environmental benefits	EVB	Benefit	O&M&R	Yes	Difficult	Subjective	EnvIA		High
Economic benefits	ECB	Benefit	O&M&R	No	Difficult	Subjective	EIA	Double counting	High
Community benefits	COMB	Benefit	O&M&R	Varies	Difficult	Subjective	Monetization		High
Social Benefits	SOB	Benefit	O&M&R	No	Difficult	Subjective	Monetization	Double counting	High
Political and national security benefits	PNSB	Benefit	O&M&R	Varies	Difficult	Subjective	Monetization		High
Reputational Benefits	RPB	Benefit	Varies	Yes	Difficult	Subjective	Monetization		High
Experimental Benefits	EXPB	Benefit	Varies	No	Difficult	Subjective	Monetization		Low
End of Analysis Value Benefits	EAVB	Benefit	Decomissioning	Yes	Easy	Objective	empirical		High

Table 3 Transportation projects list of possible Costs and Benefits during its life cycle

3.3.3 Contextual determinants

Calculating all the above costs and benefits for the whole project life cycle duration requires special attention to the assumptions and variables that could affect the results.

Analysis purpose and calculation perspective is essential in order to differentiate between the internal and external costs/ benefits.

Usually all external components will be excluded, which also depends on the geographic scope of work, for example, if analysis is done for a local agency's project, then all components that belong to private parties which are outside the agency jurisdiction should be excluded from the calculation.

Another important item that needs to be considered is the level of effort available/ required for the CBA task, according to which cost and benefits components that have small negligible impact can be excluded from the analysis like the parking costs and benefits.

Other factors that could affect the calculation are analysis timeframe, discount rate, inflation rate, depreciation rate, transfers, double counting, joint costs, sunk costs, uncertainty impact, sensitivity analysis, and most important factor is the reliability of the valuation method (monetization) which will be explained in later paragraph.

Analysis Period

It refers to the analysis period, which usually covers the whole life cycle of the project or at least one of its alternatives, to capture all its costs and tangible benefits.

When CBA is used for comparing options or prioritizing projects with different analysis periods, then adjustments should be applied to make sure that the comparison is done correctly, those adjustments could include calculating residual value for each option that have longer life span than the analysis period. In addition, the analysis period should not extend beyond scenarios that traffic model's results are not reliable.

Discount Rate, Financing Costs, Inflation, and Depreciation Rates

Money that is available today worth less in the following years, as it can be used to generate profits (benefits) in the future years, accordingly future costs and benefits are discounted to reflect the decreasing value of money over the life cycle of the investment. In addition, the discount rate should be used to cover the cost of lost opportunity, which is calculated based on profit that could be generated if the money is to be invested in other available opportunities. Discount rates usually includes three components: inflation, which reflect the decrease in the purchasing power; a risk component; and a real interest rate, which captures the productive value of available money for investment.

Usually public investments analysis ignores the first two components, as inflation impact is negligible and public borrowing comes with small risks, however the real discount rate needs to be obtained from each country central bank or similar agencies to ensure reliable analysis outcomes.

Financing costs can also be ignored for public investment projects, since it is already counted for in the discounted rates, unless the subject project required special investment arrangement.

It is recommended to ignore applying depreciation in the CBA to avoid double counting of its costs with the maintenance and rehabilitation costs, as the CBA assumes that the analysis infrastructure will be able to maintain its optimal functionality through the regular preventive and corrective maintenance and rehabilitation that are already included in the cost components.

Furthermore, benefit-cost analyses typically ignore inflation because the prediction of future prices introduces unnecessary uncertainty into the analysis

Source of transportation project funds:

Transportation projects are usually funded by local and federal government's bodies and in some cases by private investors.

Usually governments and private developers fund their transportation projects from one of the following sources:

- Taxes on cars imports and usage,
- Cars registration, insurances, and driving license fees,
- Fright fees,
- Traffic fines,
- Toll gates,
- Public transportation and parking fares,
- Tax on fuel,
- Property prices and taxes,
- Community fees,
- Other taxes (income tax, corporate taxes, import and export tax, etc…)

Moreover, the fund is delivered by using one of the following financial tools:

- Federal or local government direct budgeting,
- Governments Bonds,
- Public Private Partnerships and its sub-models,
- Direct Private fund,

- International funds.

At last, CBA framework would provide the necessary documentation to support any of the above financial tools at the project appraisal stage along with any other related asset performance data

Transfers, Double Counting, Joint, and Sunk Costs

Transfer, double counting, join costs and sunk costs are the main pitfalls that makes CBA difficult to apply and are somehow adds to its complexity, they are unavoidable so it is better to identify their occurrence and eliminate their impact at the start of the analysis.

Transfer costs and benefits are transactions without real value that may only affect the project economics like the impact of a project on public transit fares, tolls, parking fees, taxation etc… Since those components goes to the government and they are usually subsidized and calibrated to serve the same government purpose; which is to reduce the cost of transportation, and there is supposed to be no real competition within transportation authority's projects.

Double counting issue is the most common pitfall that impact the results of CBA, and especially when transportation specialists tends to add economic and community impacts (impact on jobs, business activities, etc…) to the project's basic benefits related to reduce mobility costs.

In order to avoid double counting it is required to make sure that every monetary unit (dollar for example) benefit or cost is count once only.

Joint costs represent the money spent to allocate resources to more than one project but are counted as a whole for during CBA, like counting the cost of land acquisition for road ROW and ignoring that this ROW include rail corridor and major service lines are not related to the main function of the new road.

Joint costs should be calculated properly in order to avoid overloading projects or one of its alternatives.

Sunk costs are the costs that have been already spent or already committed in a way that cannot be recovered, like the cost of an existing ROW, and the cost of existing roads, or existing service utility that can be utilized in the project. According to Eschenbach, T. (2003) those costs should not be included in the CBA.

Uncertainty Impact and Sensitivity Analysis

Every cost and benefit value could have some uncertainty especially that most of those values would be calculated for a long-time period ranging between 10 to 75 years. For example, traffic model's prediction can vary which will affect VHT and VKT and eventually change the cost saving benefits overall value.

Usually sensitivity analysis will provide a good indicator to which component will have the greatest impact on the CBA to refine its estimation method and to provide results that are more reliable or reduce uncertainty impact.

To conduct a sensitivity analysis, costs and benefits components with the biggest values should be identified, an optimistic/ most likely/ pessimistic value should be then identified, and CBA will be calculated based on all those values and identify the components that have the biggest impact in order to enhance its value estimation.

Further information related to the benefits of sensitivity analysis will be provided in the optimization section.

CBA and Total life cycle costing requires assumptions and forecast of the variable values in the future; all those variables values have some degree of uncertainty. In order to calculate the impact of this uncertainty on the appraisal process literature recommends applying sensitive analysis and risks assessment and there are several frameworks that explain this process.

In general, the process involves looking at different combinations of numbers for the subject variables, and to explore how the change in one variable or two could influence the other variables values and the assessment results.

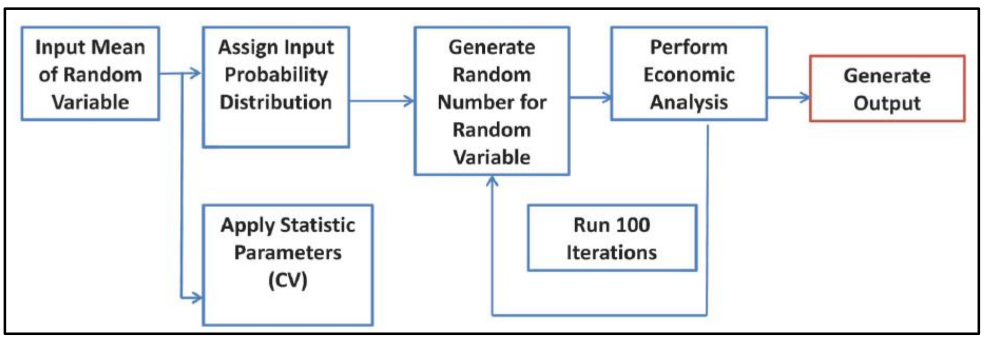


Figure 11 Probabilistic analysis process (Jiang, Y., Zhao, G., & Li, S. (2013))

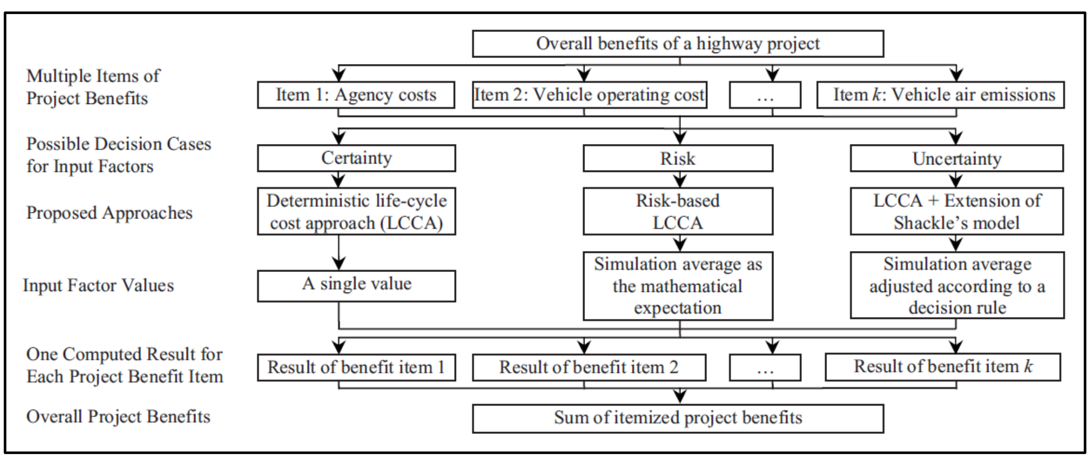


Figure 12 Framework for estimating project benefits under certainty, risk, and uncertainty (Li, Z., & Madanu, S. (2009))

However, in this paper we will use the developed Microsoft Excel © models to perform the sensitivity analysis.

Cost of Uncertainty Due to Risks, Opportunities, Complexity and Reliability

Those costs should cater for the uncertainty in achieving the project's benefits and ultimate goals in the future due to risks, complexity and reliability of the selected alternative or some of its components.

To include this cost in the CBA process, a special monetization model should be developed. Existing risk management framework and procedures could be used to develop the monetization model.

This cost component should not be included within the CBA, but to be carried out based on the outcome of the CBA as it should consider all the risks in each cost and benefit component. Monte Carlo simulation and sensitivity analysis can also be utilized for the estimation of those costs.

3.3.4 Valuation Methods (Monetization) Quantification of Qualitative Aspects

Monetization is the process of measuring value in equivalent monetary unit, in order to rank values of services/ functions/ resources like time, health, environment etc… Usually those resources are called non-market items, as their value cannot be obtained, bought or rented from the market, does not yet exist, benefit others or may never been used like wilderness area or reservation.

Those values are usually subjective and vary based on time, location and user attributes.

Below is a list of the non-market resources that could be included in the CBA:

- Noise impact,
- Air quality and emission impact,
- Aesthetics impacts,
- Stress, pain and grief impact,
- Time value,
- Time reliability impact,
- Civic pride impact,
- Some community impacts (equity, walkability, cycle tracks, etc…),
- Political and national impacts,

The impact of the above resources can be excluded from CBA and evaluated separately by using other methods like the weighted scoring and CBA outcomes could be considered one of the comparison criteria factors, but it is recommended to monetize those elements and include them in the CBA in order to obtain more reliable and agreeable results.

However, there are two main methods to do monetization, Hedonic Pricing method and Contingent method.

Hedonic method uses some relevant values (Usually real estate value), and other characteristics to evaluate some other transportation related costs or benefits.

For example, comparing house prices between unites impacted by the highway noise and others that are facing local neighborhood after considering all the other factors that could affect the prices like house size and distance to schools and other community facilities etc… Boardman et al (2017), Uyeno et al (1993).

While the **Contingent method** is more detailed, and it uses surveys and other statistical tools to establish the value based of all possible population groups by asking users questions related to how those users valuate the non-market components by using the following questions technique: What is the price you are "Willing to accept" or "Willing to pay"? In order to establish its value, and then apply sensitivity analysis and other uncertainty methods to refine the outcomes and evaluate the possible contingencies.

Each county/ agency should have their own valuation methods and records as the results for each item/ resource could vary extremely from area to area based on multiple characteristics (Diamond & Hausman 1994) and (Mitchell, R. C., & Carson, R. T. 1989).

Below is an example of the values that have been extracted from a monetization study for the value of the required values like time and cost of emission for Stockholm Metro project in Sweden.

Some of the parameters used in Swedish transport-related CBAs. Source: (SIKA, 2008)

Value of time	Private trips <10 km	5.1 €/h
	Private trips >10 km	10.2 €/h
	Business trips	27.5 €/h
Value of human life and injuries	Life	2.23 M€
	Severe injury	0.415 M€
	Slight injury	20 k€
Emissions[a]	Carbon dioxide	0.15 €/kg
	Particles	1 149 €/kg
	VOC	6.8 €/kg
	SO2	33 €/kg
	NOx	3.6 €/kg
General parameters	Discount rate	4%
	Marginal cost of public funds	1.21

[a] Values depend on geographical area (except for carbon dioxide), among other things on exposure rates. The values relate to the inner city of Stockholm.

2014 An ex-post CBA for the Stockholm Metro

3.4 CBA Measures

This section explains how the final output of CBA can be used in project's appraisal, and how decision makers can use CBA to make informative and reliable decisions in selecting best project's alternatives or best projects portfolio based on the available budget, those measures are called capital budgeting techniques in the business field

After calculating all the discounted cost (C) and benefit (B) components for the whole project life cycle then we can calculate one or more of the following values: Benefit/ cost ratio (B/C), Net present value (NPV), internal rate of return (IRR), Payback period and Cost effectiveness.

Benefit/ Cost Ratio (B/C) & Net Present Value (NPV)

B/C is calculated by dividing the total discounted benefits value by the total discounted costs value, projects with B/C greater than 1 are having benefits exceeds the costs and the greater the ratio the better the project or a specific alternative.

This measure is not a good indicator if used by itself, as it is not sensitive to the project magnitude and may favor projects with small cost over big projects, using B/C measure along with Net Present Value (NPV) could remove the expected bias.

B/C and NPV are calculated as follows:

Considering:

(n+1) are the number of years according to the set analysis period,

Bi is the value of benefits for year i (i from 0 to n)

Ci is the value of costs for year i (i from 0 to n)

(d) is the discount rate

After calculating Bi and Ci for all the years 0 to n, then B would be the sum of the discounted benefits ($\Sigma(Bi/(1+d)^i)$), and C would be the sum of discounted costs ($\Sigma (Ci/(1+d)^i)$) for all the years, and accordingly: B/C would be the benefits to cost ratio and NPV = B – C.

Selecting the projects/ alternatives with the best value for money and with optimal over all advantage would be then by ranking them according to their B/C and NPV values and selecting the ones with the highest NPV and B/C respectively.

Internal Rate of Return (IRR)

Internal rate of return is the discount rate that will make the net present value equals to zero, this rate gives an indication on how profitable (beneficial) the project is.

This rate should be compared to other alternatives rate, and the higher the rate the better the alternative in terms of return on investment, and it is calculated as below:

IRR = d when NPV= $\Sigma (Bi / (1+d)^{i)} - \Sigma (Ci/ (1+d)^{i)}$ =0 (i from 0 to n)

Payback Period

The Payback Period is the number of years at which accumulative benefits will be equal to the accumulative costs, and the alternative with the lowest Payback Period is considered the best.

Payback period is calculated as below:

Payback period = m (m from 0 to n) when NPV= $\Sigma (B_m / (1+d)^m)) - \Sigma (C_m / (1+d)^m))$ =0.

Cost Effectiveness / Value Engineering

Cost effectiveness is used when the benefits are difficult to be measured, and when a specific benefit/ function is required to be achieved, then projects or alternatives will be compared against their costs.

This measure is similar to Value Engineering techniques, with small difference is that Value Engineering usually gives simple ranking (Weighted Scoring method) to measure qualitative benefits then divide the scores by the total discounted cost ($C = \Sigma (Ci/ (1+d)^i)$) to rate the compared alternatives.

3.5 CBA Framework

The CBA framework will provide a simplified flowchart showing the main processes and some of the sub-processes, along with factors/ elements that may influence the inputs and outputs of the whole process. The literature is full of frameworks and processes related to CBA and transportation projects appraisal, but most of them are optimized to simplify the process. Veryard, D. (2016) shows in his framework the main elements that he deemed important to the assessment process along with its interface with the economy without considering the other aspects like the environmental and social aspects.

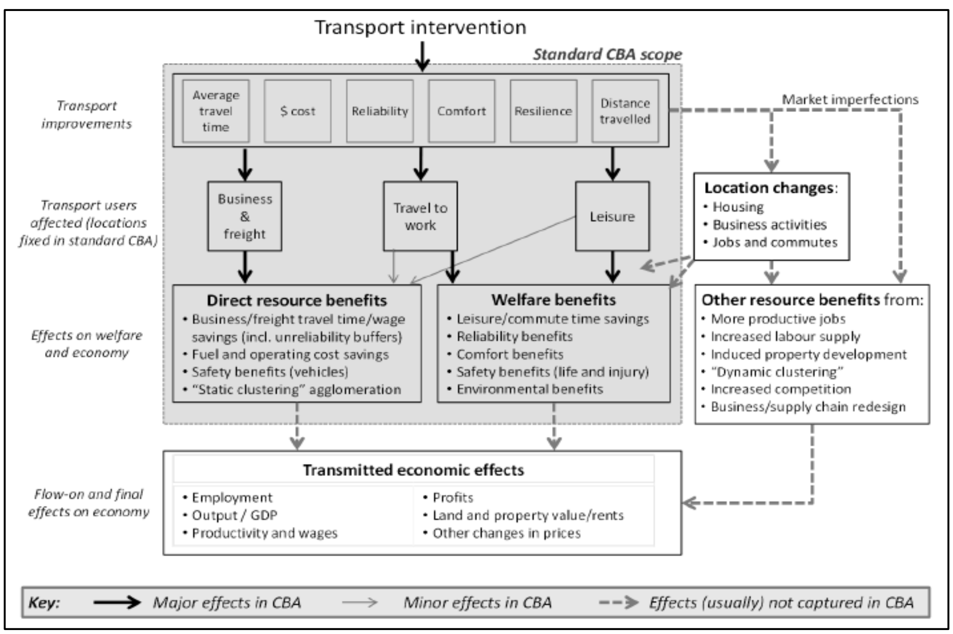


Figure 13 Veryard, D. (2016) CBA Framework

(Li, Z., & Madanu, S. (2009)) have proposed a CBA framework which considers some of the previous components, and is also ignoring others like the environmental and social components, and that is due to the complexity of adding them, as shown in the below figure.

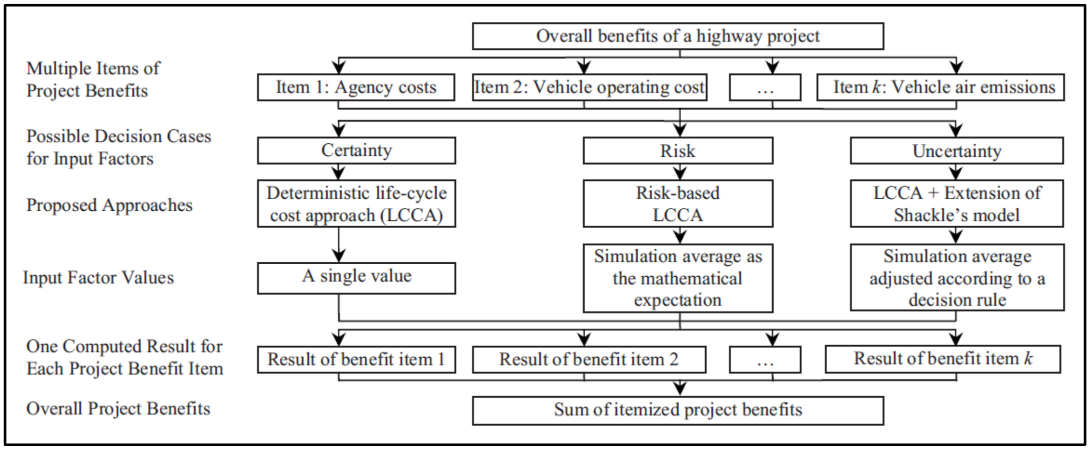


Figure 14 Framework for estimating project benefits under certainty, risk, and uncertainty (Li, Z., & Madanu, S. (2009))

Below are some other frameworks, which are all focusing on the direct costs and cost saving elements of the appraisal process, and the main reason is that other aspects are mainly subjective non-market aspects that require huge effort to estimate them with high degree of risk and uncertainty.

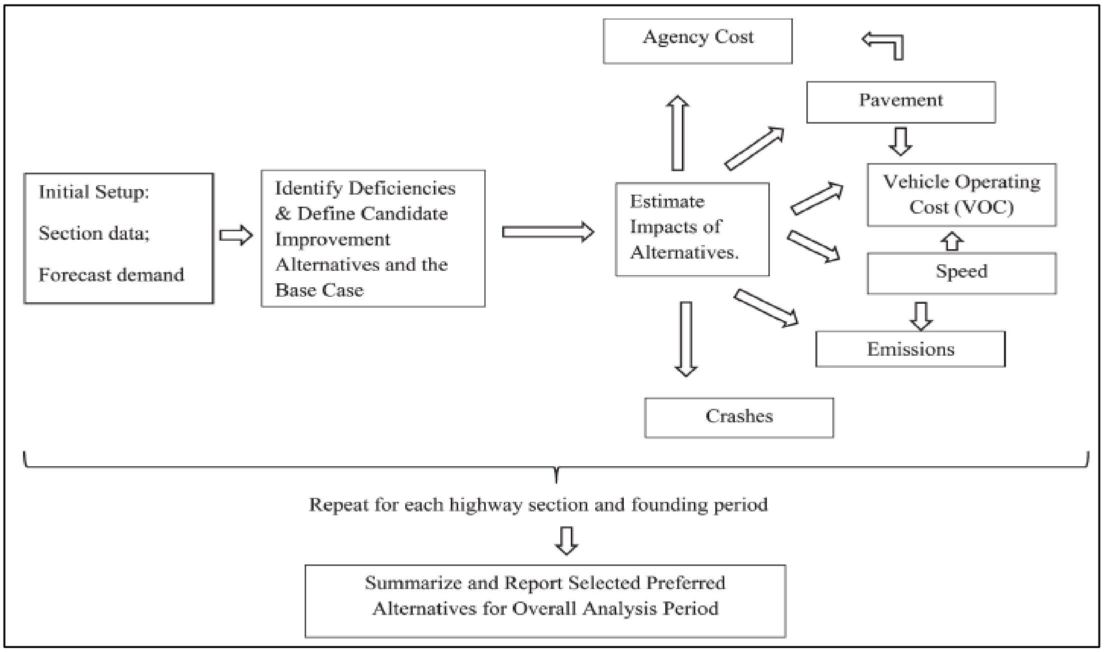


Figure 15 Jiang, Y., Zhao, G., & Li, S. (2013)." HERS Framework"

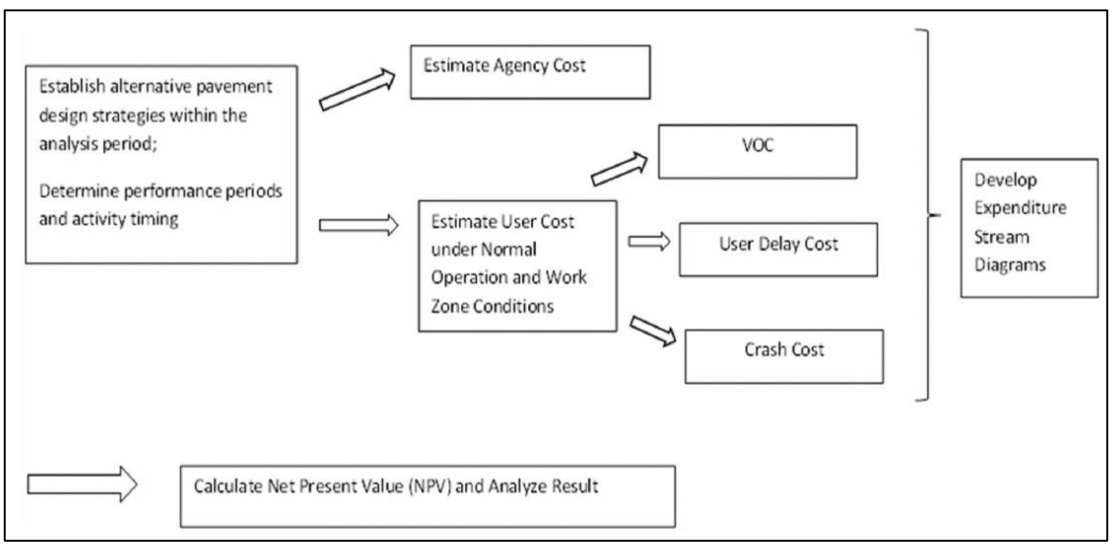


Figure 16 Jiang, Y., Zhao, G., & Li, S. (2013)." RealCost Framework"

The below framework, which is proposed in this paper and based on the previous literature, it suggestes deviding the CBA process into 4 stages.

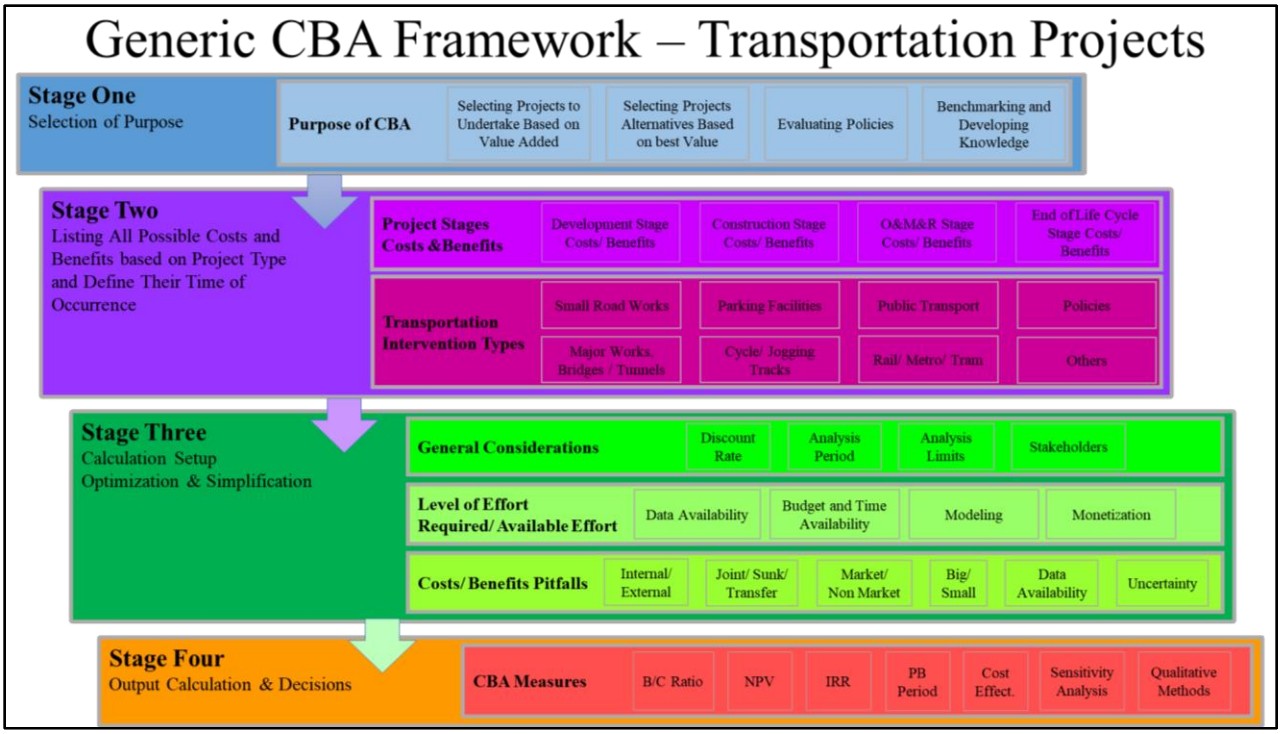


Figure 17 Generic CBA Framework "this Paper"

The proposed framework explains how to establish the CBA process within an agency whom concerned in transportation projects. The framework devides the process into four main stages as follows:

- Stage One: in which the purpose of the analysis is selected from four options, the selection of the purpose will imply set of rules into the next stage.
- Stage Two: at this stage and based on the previous stage outcomes and the project type, the analyst will define all the costs and benefits components and their time of occurance which will be included in the analysis.
- Stage Three: at this stage all the calculation variables should be set, like the analysis period and discount rate for the future years. Also, cost and benefits componenets will be tested for their relevance, signification and reliability.

- Stage Four: at this stage data should be entered into the model, and the CBA measures should be calculated for each project or alternative, ad sensitivity analysis should be carried out to cater for any uncertainity in the provided data.

The final output of the analysis depends on the set purpose at the begening of the study.

3.6 Benefit Realization Management (BRM)

PMI in 2016 released multiple papers related to Benefits Realization Management (BRM), claiming that benefit management is as important as time, budget, scope, and quality management.

PMI also pointed out that lack of knowledge, practice frameworks and difficulties in measuring the intangible qualitative benefits are the key barriers for an affective BRM.

PMI papers discussed business benefits in general, however for transportation projects, benefits cannot be simply considered as pure business benefits, especially that most of transportation projects are undertaken by governments, and that transportation projects benefits/ returns comes indirectly in the form of economic/ environmental/ community and social benefits even in the case of tolls. Accordingly, a special BRM framework should be developed to suit transportation projects benefits.

Usually the main aspects of benefit management are implemented through active maintenance, asset management and infrastructure resilience policies. Those policies are supposed to maintain the functionality of transportation infrastructure at an acceptable level of service for their intended life span.

What CBA framework can add to Benefit Realization Management is providing a clear benefits baseline to measure against, and to use for maintenance budgeting and future planning through knowledge management.

3.7 Probabilistic Approach

CBA and Total life cycle costing requires assumptions and forecast of the variable values in the future; all those variables values have some degree of uncertainty. In order to calculate the impact of this uncertainty on the appraisal process literature recommends applying sensitive analysis and risks assessment and there are several frameworks that explain this process.

In general, the process involves looking at different combinations of numbers for the subject variables, and to explore how the change in one variable or two could influence the other variables values and the assessment results.

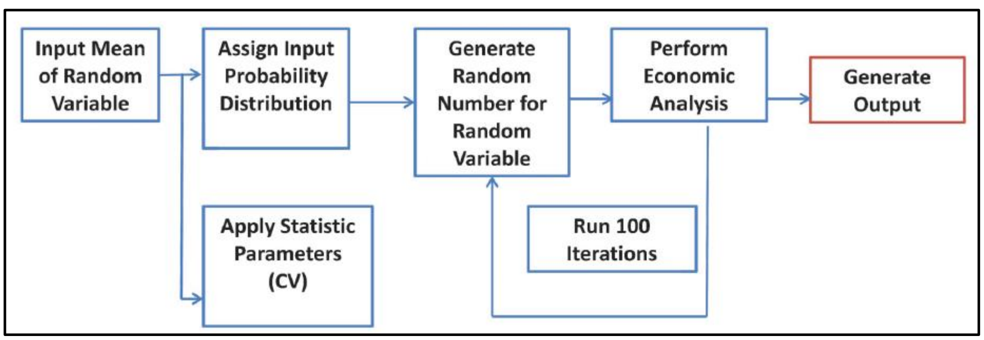


Figure 18 Probabilistic analysis process (Jiang, Y., Zhao, G., & Li, S. (2013))

4.Chapter 4 – Modeling & Simulation

4.1 Introduction

After identifying the possible purposes of performing the assessment, types of transportation projects and its standard stages, the possible stakeholders and their costs and benefits, and all the other factors that might affect the assessment, an Excel Model will be developed to calculate the set CBA measure as discussed in previous chapters.

This chapter will show how the CBA and WLCC are combined to produce Microsoft Excel Models capable of performing the CBA calculation and produce the required outcomes. Then three examples will be tested, each one of them is based on different set of information to show that modeling CBA is flexible, and it can be customized based on data availability and available/ required level of effort.

However, prior to go through the modeling process, it is worth mentioning that there is several software in the market with comprehensive CBA capabilities, some of them were developed by transportation agencies, and others have been developed by software companies for commercial use.

4.2 Available Software

Most of the developed countries and especially OECD countries have developed their own CBA frameworks for their transportation infrastructure projects, even some cities and states have published their own frameworks to suit their needs. They have even developed their own models and software to automate the process.

In this paragraph, a list of the available software and Excel models that have been developed for the same purpose with a brief description.

HDM-4 (By World Bank): The Highway Development and Management Model (HDM-4) is a software system, which is developed by the World Bank to help governments and its highways agencies worldwide in making decisions related to evaluating road infrastructure investments. The HDM-4 model is most commonly used as a basis for feasibility studies, in which a road project is evaluated in terms of its economic viability.

TREDIS (http://www.tredis.com/benefit-cost-analysis): the software was developed by private company, and it is capable of doing CBA and Financial Impact Analysis (FIA) for all transportation projects, it can even provide analysis for multiple transportation modes.

BCA.Net https://hwbca.net/BaseLogin/LoginReg3.aspx: the web application was developed by USA Federal Highway Administration FHWA, to support decision making for federal and local Highways projects.

Cal-B/C (By Caltrans): it is an excel sheet model developed by California Department of Transportation for evaluating highways and public transport projects and policies in the state of California, USA.

MicroBENCOST: is a model designed to assess multi-modal urban transportation investment and policy alternatives at the regional and corridor levels

STEAM: A comprehensive software, which is capable of calculating all the possible cost and benefits components, including the environmental and social impact.

The software includes a probability module that is capable of performing risk assessment and sensitivity analysis.

HERS-ST: is a comprehensive software developed by FHWA, to manage its highways assets from planning until decommissioning stage.

Furthermore, there are several risk and sensitivity analysis software available to perform probabilistic complex calculations like Monte Carlo simulation, and to produce more reliable and standardized report probabilistic results like **@risk, Invantive Control for Excel, Oracle Crystal Ball, TUKHI, ModelRisk, Risk Solver,** and many more other commercial software.

4.3 Model elements: Inputs, Equations and Outputs

In general, any model should have the following essential elements:

4.3.1 Inputs and Assumptions:

- **Analysis period** and limits.
- **Time schedule** with the following minimum milestones and duration (starting date, construction period, operation & maintenance period, major rehabilitation dates, decommissioning date)
- **Costs** schedule, showing costs for each year (Ci), of the analysis period, for each of the previously mentioned cost components, and for each project or alternative.
- **Benefits schedule** showing benefits for each year (Bi) of the analysis period, for each of the previously mentioned benefit components, and for each project or alternative.
- Discount rate for the analysis period,
- Ranges of values for sensitivity analysis
- **Comparison and prioritization criteria,** which should be developed and customized by the agency, to suit its requirement.

- **Assumptions:** As the purpose of the analysis, or that the discount rate will be fixed throughout the whole project life cycle, or the bridge structure will not require major rehabilitation for the next 25 years, etc…

4.3.2 Equations:

The mathematical relationships that convers inputs to outputs, and other equation that is required for monetization, or to calculate costs or benefits inputs.

4.3.3 Outputs:

CBA measures: B/C, NPV, IRR, Payback Period, and Nominal Profit Rate.

Charts: Cash flow charts (Cost, Benefits, and accumulative NPV), Sensitivity analysis Charts

Comparison and prioritization results based on the agency's criteria.

4.4 Optimization and Simplification of CBA framework

As discussed before, modelling the CBA process will be based on the proposed framework, and this paper will provide three models, each one will represent different scenario with different set of assumptions and datasets.

But prior to proceeding with the models, optimization and simplification to the CBA framework will be done to show how we is required to reduce some of the variables that will not be required based each agencies requirement.

According to the previously stated CBA measures, the basic method to optimize CBA results is to reduce cost and increase benefits, although that it is still debatable which measure to be used to compare projects or their alternatives.

Some researchers would even ignore all the Environmental, Political, and Community costs and Benefits components, and consider only the following:

- Construction costs,
- Operation, maintenance, and replacement/ rehabilitation costs
- Cost-Saving benefits components namely: Time Cost Saving, Kilometers Cost Saving, and Safety Cost Saving

As shown in the below figure extracted from Jiang, Y., Zhao, G., & Li, S. (2013) paper.

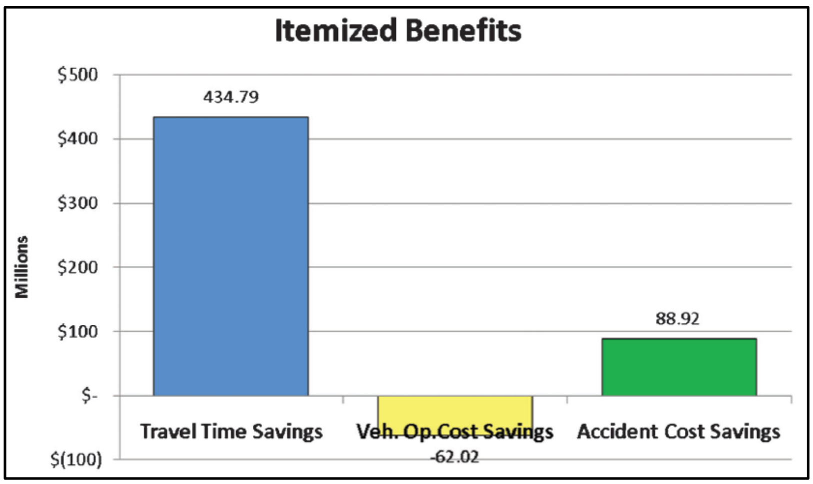


Figure 19 Itemized Benefits (Jiang, Y., Zhao, G., & Li, S. (2013))

Simplification of CBA could be achieved by reducing the number of variables while not affecting the accuracy and the goal of the analysis.

For example, if a transportation agency is to carry out the CBA for comparing its project alternatives or for selecting and optimizing its projects portfolio budget forecast, then components like environmental, community and economic, which could be the scope of other specialized agencies can be ignored at the selection stage. Although the economic value of those ignored components could be major and may affect the selection choices but for a transport agency, the most important goal is to deliver mobility and accessibility at the lowest costs.

A simplified CBA framework was prepared based on the original CBA framework shown previously, which reduces the purpose of the analysis to two options, and to limit the types of projects to include to only the major ones. In addition, the process will consider impacts on few key stakeholders only. In the proposed simplified CBA framework, cost and benefit components were reduced as in the following:

- No development stage components
- Construction stage components: Capital costs and key construction Dis-advantages costs,
- Operation Stage Components: O&M&R costs, key O&M&R Dis-advantages costs, All Cost Saving benefits, and Key Environmental/ Political/ Community Benefits,
- End of life cycle components: Decommissioning Costs, Lost Benefits, and Salvage Value.

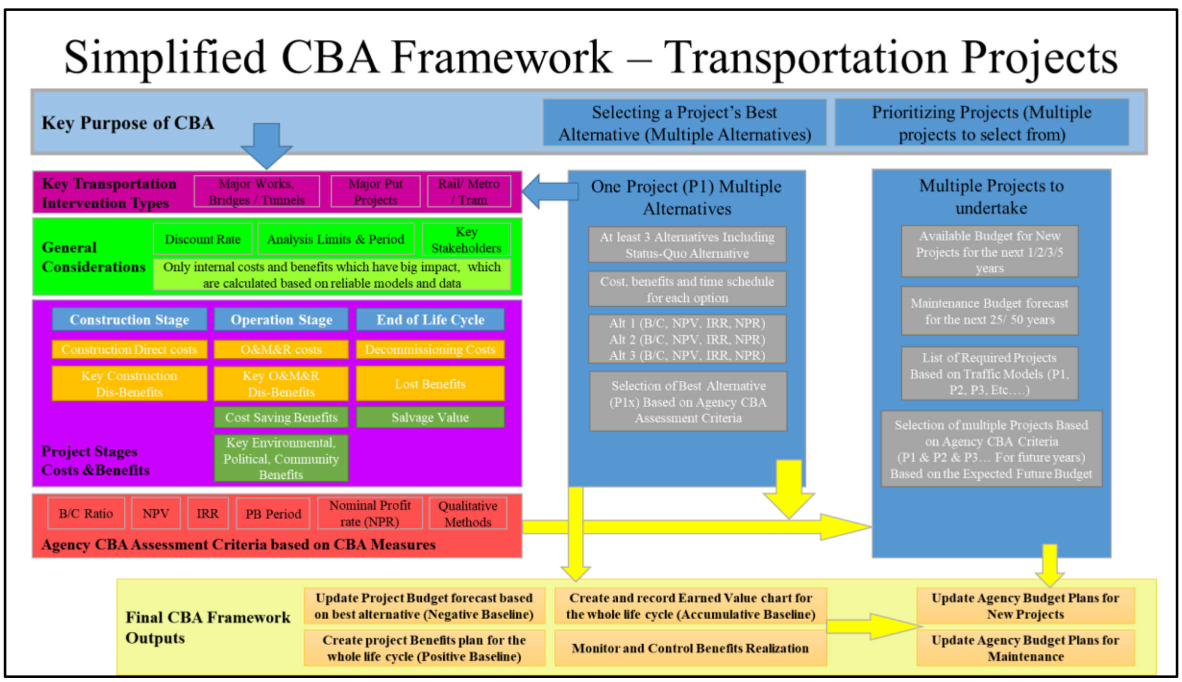


Figure 20 Simplified CBA Framework "this Paper"

4.5 Modeling & Simulation for Example 1

In this example, an agency is comparing three alternatives for on transportation projects that is aimed to improve the level of service (LOS) of an area to an acceptable level.

Modeling of this example is considered the easiest, because the costs and benefits were provided and there is no monetization effort required.

Inputs and Assumptions:

According to the simplified CBA framework, the analysis purpose is to select the best alternative; the project Type is a major works; the analysis period is 15 years; and the discount rate to be used is 3%, however, we will test all alternatives for their sensitivity to changes in the discount rate for the range between (0 to 20%).

Cost and benefits for the whole life cycle were estimated by a specialized consultant based on previous experience, benefits were calculated based on the cost saving components only.

The input for the model are as shown in the below table:

	Discount Rate	3.00%		Inflation	0												
Project 1 (Alt 0) status que																	
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Costs	5	2	2	2	2	5	2	2	2	2	5	2	2	2	2	5	44
D. Costs	5	2	2	2	2	4	2	2	2	2	4	1	1	1	1	3	36
benefits	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D. Benefits	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Net Value	-5	-2	-2	-2	-2	-5	-2	-2	-2	-2	-5	-2	-2	-2	-2	-5	-44
Net Dis Values	-5	-2	-2	-2	-2	-4	-2	-2	-2	-2	-4	-1	-1	-1	-1	-3	-36
Accum Dis value	-5	-7	-9	-11	-12	-17	-18	-20	-22	-23	-27	-28	-30	-31	-32	-36	
Project 1 (Alt 1) New roads and small intersections																	
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Costs	-150	-150	-2	-2	-2	-2	-2	-2	-2	-2	-3	-2	-2	-2	-2	-5	-332
D. Costs	-150	-146	-2	-2	-2	-2	-2	-2	-2	-2	-2	-1	-1	-1	-1	-3	-320
benefits	0	0	20	30	40	50	50	50	50	50	30	50	50	50	50	20	590
D. Benefits	0	0	19	27	36	43	42	41	39	38	22	36	35	34	33	13	459
Net Value	-150	-150	18	28	38	48	48	48	48	48	27	48	48	48	48	15	258
Net Dis Values	-150	-146	17	26	34	41	40	39	38	37	20	35	34	33	32	10	139
Accum Dis value	-150	-296	-279	-253	-219	-178	-138	-99	-61	-24	-4	31	64	97	129	139	
Project 1 (Alt 2) only two interchanges																	
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Costs	-200	-200	-20	-4	-4	-10	-4	-4	-4	-4	-10	-4	-4	-4	-4	-50	-530
D. Costs	-200	-194	-19	-4	-4	-9	-3	-3	-3	-3	-7	-3	-3	-3	-3	-32	-492
benefits	0	0	20	30	40	50	60	70	80	80	50	80	80	80	80	600	1400
D. Benefits	0	0	19	27	36	43	50	57	63	61	37	58	56	54	53	385	1000
Net Value	-200	-200	0	26	36	40	56	66	76	76	40	76	76	76	76	550	870
Net Dis Values	-200	-194	0	24	32	35	47	54	60	58	30	55	53	52	50	353	508
Accum Dis value	-200	-394	-394	-370	-338	-304	-257	-203	-143	-85	-55	0	53	105	155	508	
Project 1 (Alt 3) Ptu policy																	
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Costs	-10	-10	-2	-2	-2	7	-2	-2	-2	-2	-7	-2	-2	-2	-2	-7	-49
D. Costs	-10	-10	-2	-2	-2	6	-2	-2	-2	-2	-5	-1	-1	-1	-1	-4	-41
benefits	5	5	10	20	20	15	20	20	20	20	15	20	20	20	20	15	265
D. Benefits	5	5	9	18	18	13	17	16	16	15	11	14	14	14	13	10	209
Net Value	-5	-5	8	18	18	22	18	18	18	18	8	18	18	18	18	8	216
Net Dis Values	-5	-5	8	16	16	19	15	15	14	14	6	13	13	12	12	5	168
Accum Dis value	-5	-10	-2	14	30	49	64	79	93	107	113	126	138	151	163	168	

Table 4 Example 1 Inputs

Equations:

The model will utilize the following equations to calculate the discounted costs & Benefits:

Discounted costs (for Years i) = Costs (for Years i)/ (1 + Discount Rate) ^(i).

Discounted benefits (for Years i) = Benefits (for Years i)/ (1 + Discount Rate) ^(i).

Total Discounted costs = Sum of all discounted costs for the whole analysis period.

Total Discounted benefits = Sum of all discounted benefits for the whole analysis period.

Net Value (for Years i) = Benefits (for Years i) - Costs (for Years i).

Net Discounted Values (for Years i) = Discounted benefits (for Years i) - Discounted costs (for Years i).

Accumulated discounted values (NPV until year i) = Sum of all Net Discounted Values (until Years i).

Calculation of CBA measures (B/C, NPV, IRR, NAP, and payback period) will utilize the following equations:

B/C = Total Discounted benefits / Total Discounted costs %

NPV = Accumulated discounted values for the whole life cycle.

IRR = the Discount rate that will make NPV = 0; which can be calculated automatically in Excel with the Function IRR (array of Net Values)

Payback Period = the period in years that will make accumulated discounted values = 0.

Nominal Annual Profit rate = (Total Discounted benefits - Total Discounted costs)/ (Total Discounted costs).

Summary, output, and simulation of Example 1:

Alternative 1 consists of several at-grade modifications for intersections around the community, with initial capital of 300 AED million to be constructed in two years.

Alternative 2 consists of construction of two flyovers to link the community directly to the freeway with initial cost of 400 million AED to be constructed in two years.

Alternative 3 introduces new bus routes with dedicated bus lanes throughout the community. This alternative includes extensive campaign and policies to promote its ridership along with other benefits like subsidized fare and discounts on other public facilities.

The initial cost of this alternative is 20 AED million for the first two years; those results did not consider the cost impact of uncertainty.

Applying the previously stated CBA framework resulted in the following: Alternative 2 is the best in terms of NPV (more than 3 times bigger that alternative 3). However, alternative 3 in the best in terms of all other measures as B/C is almost 2 times and IRR is more than 7 times of that in alternative 2; 9 years less in the payback period. The inputs and outputs of Example 1 are summarized in the below table:

Project 1 (Alt 1) New roads and small intersections (AED Millions)							
	Total	**B/C**	**NPV**	**IRR**	**IRR/n**	**Payback Period**	**Nominal Annual Profit rate**
Costs	332	143%	139	8%	1%	10	= (NPV/ (Discounted costs)/n)% = 3%
Discounted Costs	320						
benefits	590						
Discounted Benefits	459						
Net Value (not discounted)	258						
Net Discounted Value	139						
Project 1 (Alt 2) only two interchanges (AED Millions)							
	Total	**B/C**	**NPV**	**IRR**	**IRR/n**	**Payback Period**	**Nominal Annual Profit rate**
Costs	530	203%	**508**	12%	1%	11	= (NPV/ (Discounted costs)/n)% = 7%
Discounted Costs	492						
benefits	1400						
Discounted Benefits	1000						
Net Value (not discounted)	870						
Net Discounted Value	508						
Project 1 (Alt 3) PTU policy (AED Millions)							
	Total	**B/C**	**NPV**	**IRR**	**IRR/n**	**Payback Period**	**Nominal Annual Profit rate**
Costs	63	**394%**	156	**88%**	6%	2	= (NPV/ (Discounted costs)/n)% **= 20%**
Discounted Costs	53						
benefits	265						
Discounted Benefits	209						
Net Value (not discounted)	202						
Net Discounted Value	156						

Table 5 Project's alternatives – Example 1 (inputs & outputs)

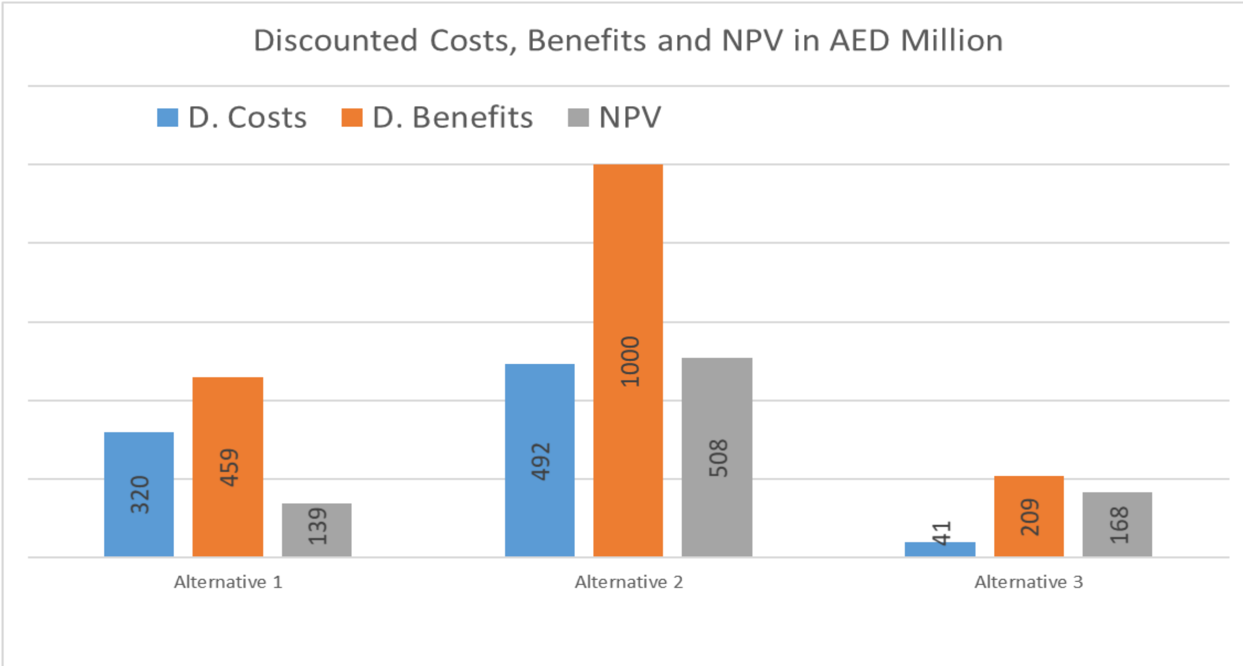


Figure 21 Example 1- Costs, Benefits and NPV Results

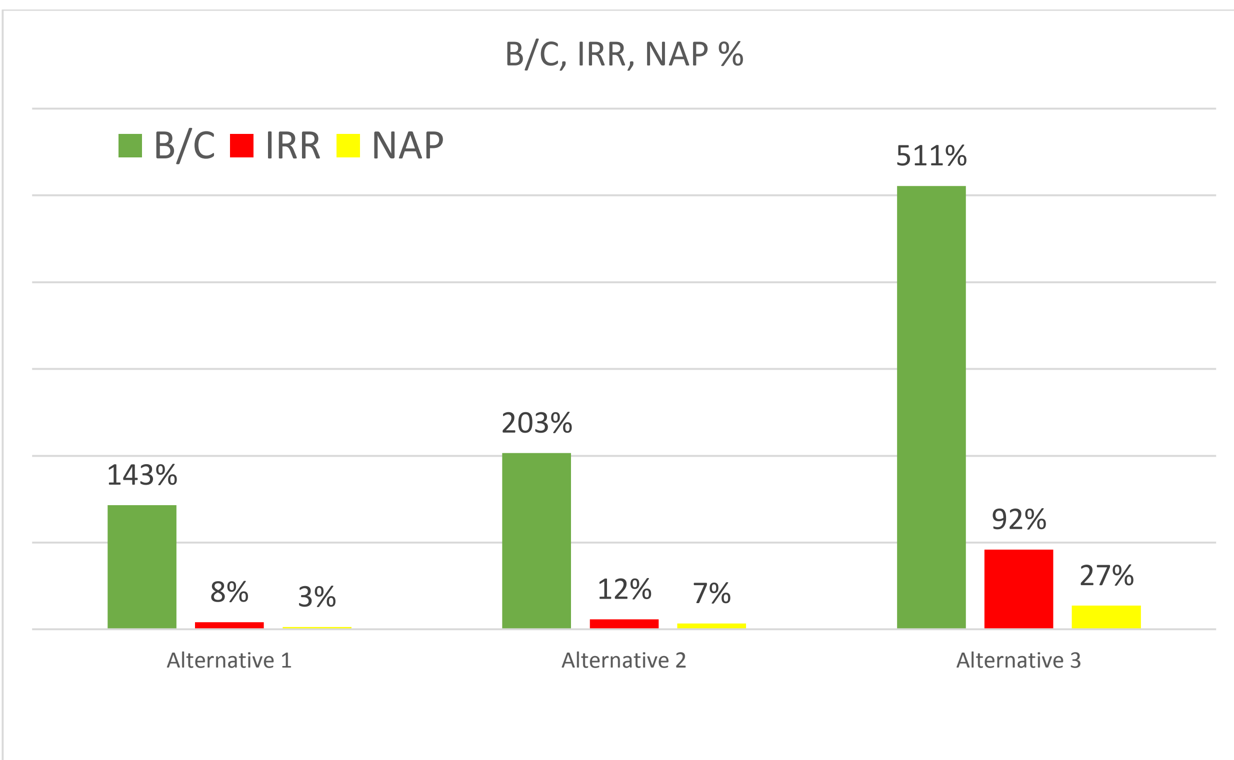


Figure 22 Example 1- B/C, IRR & NAP Results

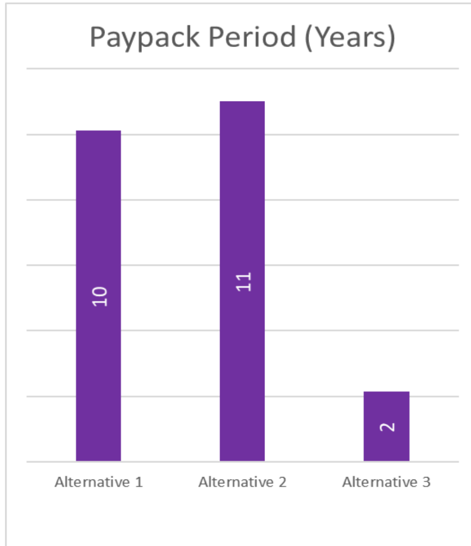


Figure 23 Example 1- Payback Period Results

Below figures show the cash flow graphs extracted from the Excel model for the three alternatives discussed above.

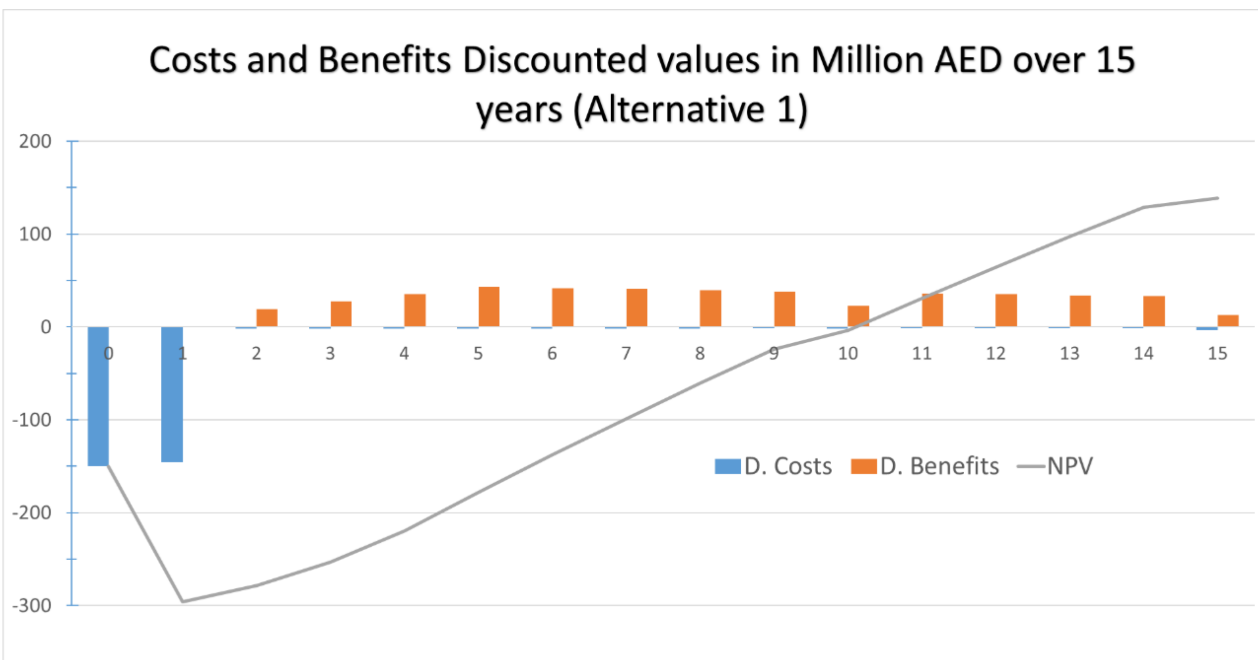


Figure 24 CBA results for Alternative 1

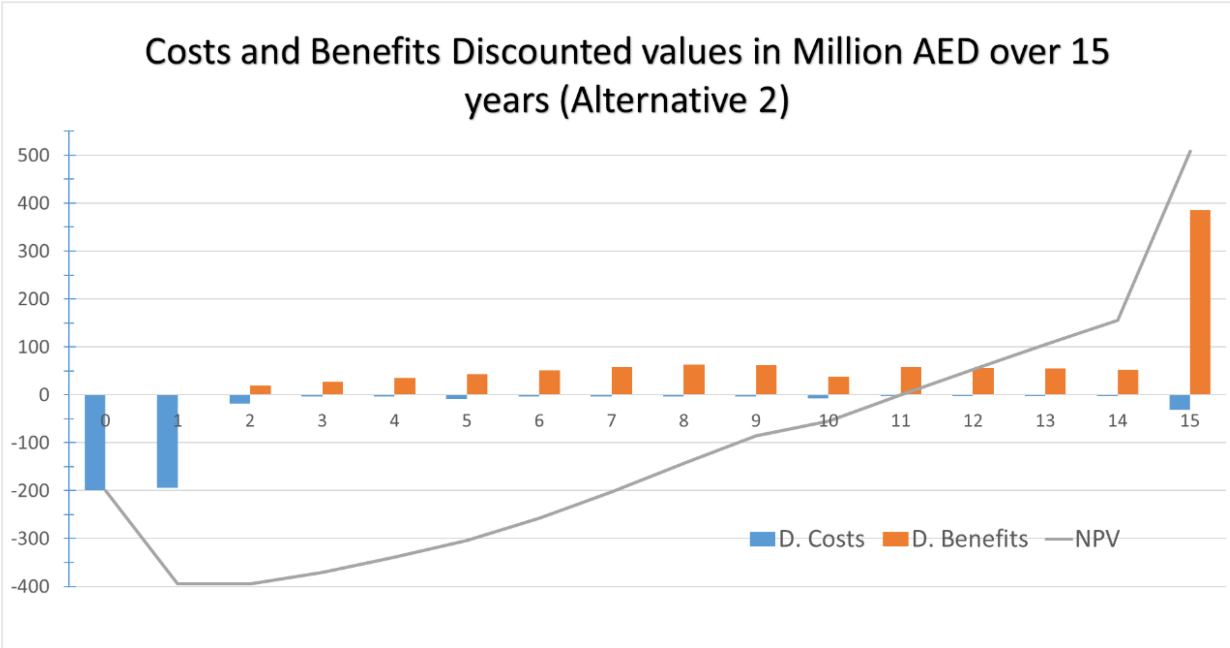


Figure 25 CBA results for Alternative 2

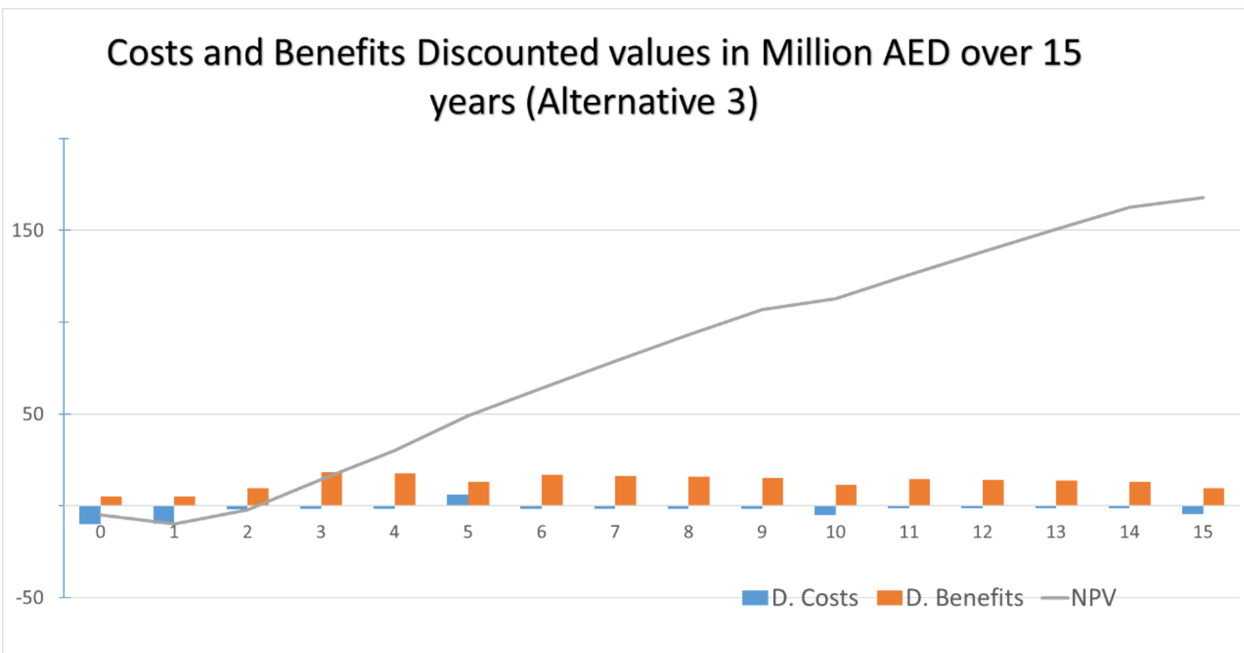


Figure 26 CBA results for Alternative 3

The above results could be difficult to read for non-experienced decision makers, since it does not indicate the most cost-efficient option, and that it is not clear, which one of the measures is the best to use, for that the agency should set its comparison criteria prior to carrying out the analysis to avoid any bias.

Some researcher recommends consider NPV first and then IRR, because NPV they consider it more reliable as it changes with the change of the discount rates, while IRR does not change with the discount rate, considering the fact that discount rate is changing with time during the analysis period.

However, other researchers may recommend B/C, IRR, or payback period, the point is that each measure has its advantages and disadvantages, then the analyst should select the best measure, or a combination of two or more based on the purpose of the analysis and based on the results as shown in the table.

For the above example, we can see that alternative 2 is the best in terms of NPV, which is due to the size of investment in that option, and due to the long-life span of bridges structure.

To eliminate the impact of the investment size, a new measure was introducing (Nominal Annual Profit rate) which considers the flat profit rate based on the overall discounted costs, benefit over the analysis period, and is calculated based on the following formula:

Nominal Annual Profit rate = (NPV/ (total discounted costs) / (no of years) %

The results show that alternative 3 is the best with almost three times the rate of alternative 2.

Sensitivity analysis

By using the built-in capabilities of Microsoft Excel “What if –Data Tables“ function, the below table was produced which is showing how changing the discount rate will affect the NPV values of each alternative. The below table and chart show that alternative 2 will remain the best option (in terms of NPV) as long as the discount rate is less than 8%, and that alternative 3 will be the option if the discount rate in above 8 %.

Discount Rate	0%	1%	2%	**3%**	4%	5%	6%	7%	8%	9%	10%	14%	15%	16%	19%	20%
Alternative 1 (NPV)	258	214	174	**139**	107	78	52	29	8	-10	-28	-82	-92	-102	-127	-133
Alternative 2 (NPV)	870	732	612	**508**	417	337	266	205	151	103	60	-66	-90	-111	-161	-175
Alternative 3 (NPV)	216	198	182	**168**	155	143	132	123	114	106	99	76	71	67	56	52

Table 6 Example 1 – NPV V.S. Discount Rate

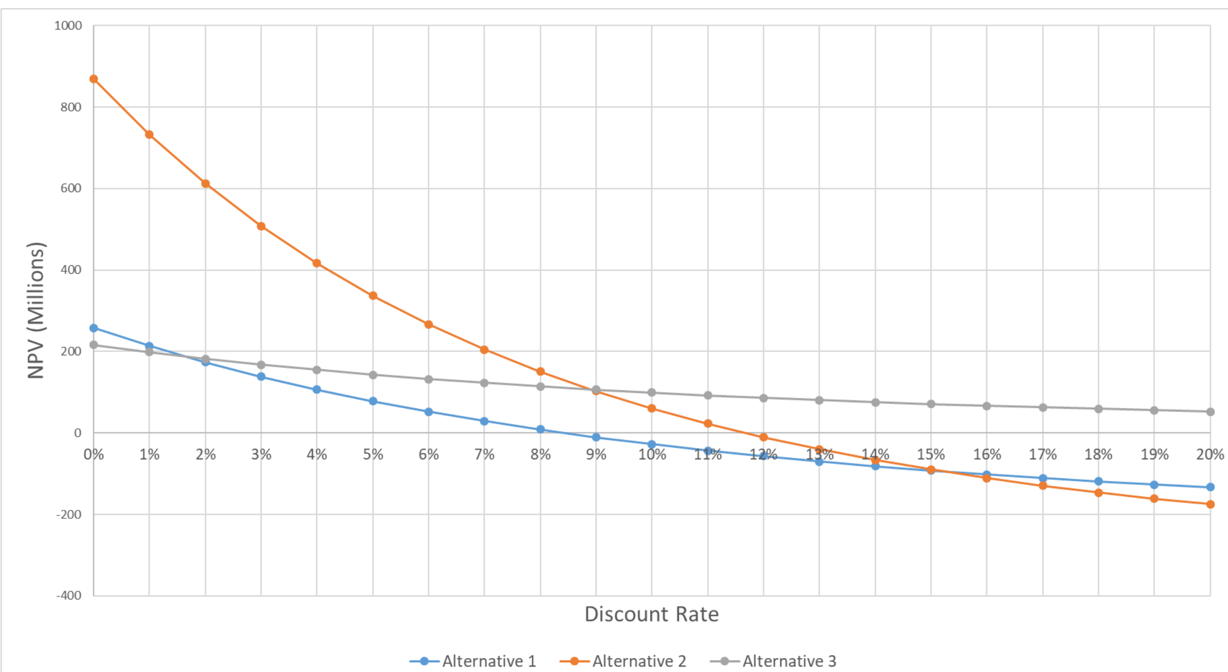


Figure 27 Example 1- Sensitivity analysis (NPV V.S. Discount rate for three alternatives)

The above results of CBA analysis for Example 1, shows the need for developing an agency specific criterion for the final decision making, by utilizing the CBA results and combining it with other supporting tools.

4.6 Modeling & Simulation for Example 2

In this example, an agency has selected a project's alternative to undertake, which consist of developing multiple interchanges on a major highway in the state.

Inputs and Assumptions:

The purpose of the analysis is to select the best alternative, and to optimize it by using sensitivity analysis for multiple inputs, like the initial costs, the construction duration, etc…

The project scope is to replace two signalized junctions into full cloverleaf interchanges and some improvements to the surrounding roads with a cost of AED 600 million, and a construction period of three years.

The project Type is a major works; the analysis period is 20 years; Discount rate to be used is 3%, however, and sensitivity analysis ranges are:

- (0 to 20%) for the discount rate
- (1 to 16 years) Construction duration
- (75 to 1,200 million AED) Construction Costs

Several costs and benefits components were calculated including environmental as shown in the table below:

Project 1 Optimal Alternative (Bridge with 40 years effective life span)																											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**B/C**	**NPV**	**IRR**	**IRR/n**	**Payback Period**	**N. A. Profit rate**
Development stage Costs	10	0	0	0																		**252%**	**1448**	**13.07%**	**1.31%**	**11 years**	**13%**
Construction direct costs	200	200	200	0																							
Construction dis-benefits costs	10	10	10	10																							
Operational costs					5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	100						
Maintenance cost					5	5	5	5	5	5	10	5	5	5	5	10	5	5	5	5	200						
Rehabilitation and replacement costs								10								10											
O&M&RR dis-benefits								2			2					2											
End of project costs																					25						
Total Costs	220	210	210	10	10	10	10	22	10	10	17	10	10	10	10	27	10	10	10	10	325						
Total Discounted Costs	-220	-204	-198	-9	-9	-9	-8	-18	-8	-8	-13	-7	-7	-7	-7	-17	-6	-6	-6	-6	-180						
Travel time benefits	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	1000						
Vehicle usage benefits					30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	600						
Safety benefits						15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	300						
Environmental benefits						2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	40						
Community benefits					10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	200						
Total Benefits	0	0	0	0	90	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	2140						
Total Discounted Benefits	0	0	0	0	80	92	90	87	84	82	80	77	75	73	71	69	67	65	63	61	1185						
Net Value	-220	-210	-210	-10	80	97	97	85	97	97	90	97	97	97	97	80	97	97	97	97	1815						
Net Discounted Values	-220	-204	-198	-9	71	84	81	69	77	74	67	70	68	66	64	51	60	59	57	55	1005						
Accumulated Discounted value	-220	-424	-622	-631	-560	-476	-395	-326	-249	-175	-108	-38	30	96	160	212	272	331	388	443	1448						

Table 7 Example 2 – Inputs & CBA measures

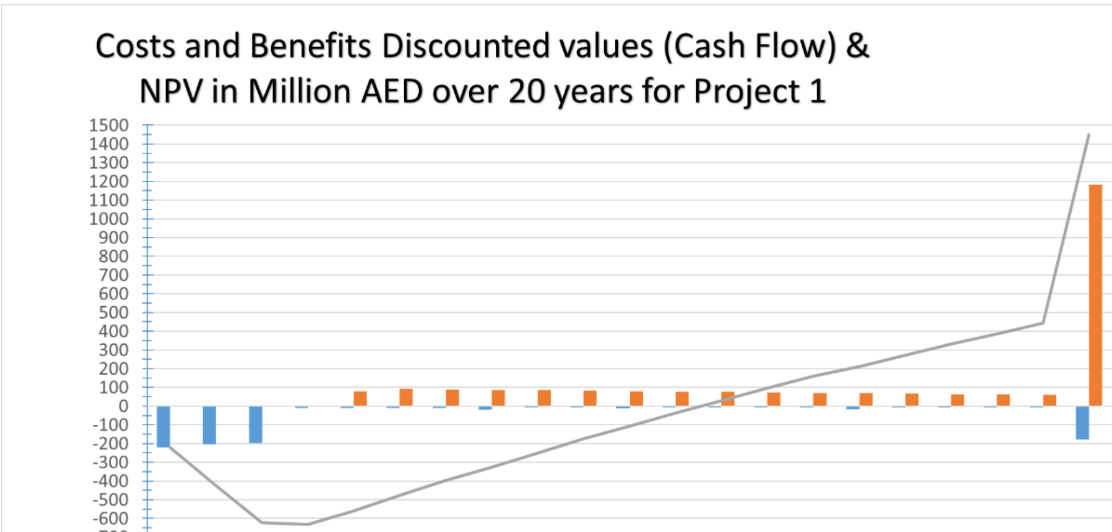
Equations:

Example 2 uses the same equations used in Example 1 model, with minor difference that the yearly Costs/ Benefits net values were calculated by summing the values of the yearly Costs/ Benefits components.

Summary, output, and simulation of Example 2:

Calculation of CBA measures shows that the project is cost effective, with positive NPV of 1,488,000 AED, and B/C of 252%, NAP = 13%, and a payback period of 11 years.

The below graph shows the cash flow, costs, benefits and the NPV of the project.



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15					
Discounted Costs	-220	-204	-198	-9	-9	-9	-8	-18	-8	-8	-13	-7	-7	-7	-7	-17	-6	-6	-6	-6	-180
Discounted Benefits	0	0	0	0	80	92	90	87	84	82	80	77	75	73	71	69	67	65	63	61	1185
NPV	-220	-424	-622	-631	-560	-476	-395	-326	-249	-175	-108	-38	30	96	160	212	272	331	388	443	1448

Figure 28 Example 2 - Cash flow and NPV for 20 years

Sensitivity analysis

In Example 2, a two-dimension sensitivity analysis was carried out, by using the “What if” function in Excel, which shows how a specific CBA measure could change based on the changes of two other input variables.

Accordingly, NPV was tested against discount rate and construction duration according to the previously mentioned ranges and the results are as shown in the below table and chart:

NPV		Discount Rate															
1448		0%	1%	2%	**3%**	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%
Construction Duration (Years)	1	2768	2279	1873	1535	1252	1014	814	645	501	379	275	185	108	42	-16	-66
	2	2719	2232	1829	1493	1213	977	780	613	472	352	250	163	88	23	-32	-80
	3	2664	2181	1781	**1448**	1170	938	743	579	440	323	223	139	66	4	-49	-95
	4	2604	2125	1728	1399	1125	896	704	543	407	292	195	113	43	-17	-68	-112
	5	2538	2063	1671	1346	1075	850	661	504	371	259	165	85	18	-40	-88	-130
	6	2465	1996	1609	1288	1022	801	616	462	333	224	133	56	-9	-64	-110	-150
	7	2386	1922	1541	1225	964	747	567	417	291	186	99	25	-37	-90	-134	-171
	8	2298	1842	1467	1157	902	690	515	369	247	146	62	-9	-68	-117	-159	-194
	9	2201	1753	1386	1084	834	629	458	317	200	103	22	-45	-101	-147	-186	-218
	10	2095	1657	1298	1003	761	562	398	262	150	57	-20	-83	-136	-179	-215	-245
	11	1978	1551	1202	916	682	490	332	202	96	8	-65	-124	-174	-214	-247	-274
	12	1849	1435	1097	822	597	413	262	139	38	-45	-113	-169	-214	-251	-281	-305
	13	1708	1308	983	719	504	329	186	70	-25	-102	-165	-216	-257	-291	-317	-339
	14	1552	1169	859	608	404	239	105	-4	-92	-163	-220	-267	-304	-333	-357	-375
	15	1381	1017	724	487	296	142	17	-83	-163	-228	-280	-321	-354	-379	-399	-414
	16	1193	851	576	356	179	37	-77	-168	-240	-298	-344	-379	-407	-429	-445	-457

Table 8 Example 2 – NPV V.S. (Discount Rate & Construction Duration)

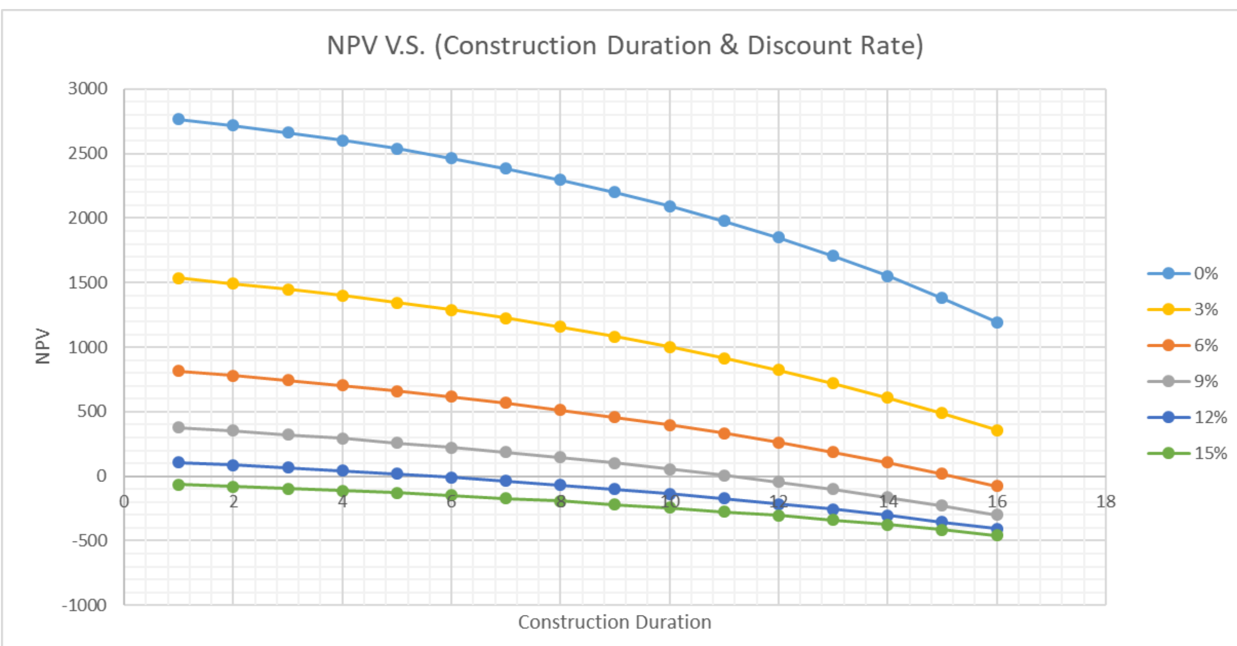


Figure 29 Example 2- NPV V.S. (Discount Rate & Construction Duration)

The next test was for NAP against Discount rate and Construction duration, as shown in the table and chart below:

NAP		Discount Rate															
13%		0%	1%	2%	**3%**	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%
Construction Duration (Years)	1	26%	22%	19%	15%	13%	11%	9%	7%	5%	4%	3%	2%	1%	0%	0%	-1%
	2	24%	20%	17%	14%	12%	10%	8%	6%	5%	4%	3%	2%	1%	0%	0%	-1%
	3	22%	19%	16%	**13%**	11%	9%	7%	6%	4%	3%	2%	1%	1%	0%	-1%	-1%
	4	20%	17%	14%	12%	10%	8%	6%	5%	4%	3%	2%	1%	0%	0%	-1%	-1%
	5	18%	15%	13%	11%	9%	7%	6%	4%	3%	2%	2%	1%	0%	0%	-1%	-1%
	6	16%	14%	11%	9%	8%	6%	5%	4%	3%	2%	1%	1%	0%	-1%	-1%	-1%
	7	15%	12%	10%	8%	7%	5%	4%	3%	2%	2%	1%	0%	0%	-1%	-1%	-2%
	8	13%	11%	9%	7%	6%	5%	4%	3%	2%	1%	1%	0%	-1%	-1%	-1%	-2%
	9	12%	10%	8%	6%	5%	4%	3%	2%	1%	1%	0%	0%	-1%	-1%	-2%	-2%
	10	10%	8%	7%	6%	4%	3%	3%	2%	1%	0%	0%	-1%	-1%	-1%	-2%	-2%
	11	9%	7%	6%	5%	4%	3%	2%	1%	1%	0%	0%	-1%	-1%	-2%	-2%	-2%
	12	8%	6%	5%	4%	3%	2%	1%	1%	0%	0%	-1%	-1%	-2%	-2%	-2%	-2%
	13	6%	5%	4%	3%	2%	2%	1%	0%	0%	-1%	-1%	-1%	-2%	-2%	-2%	-3%
	14	5%	4%	3%	3%	2%	1%	1%	0%	-1%	-1%	-1%	-2%	-2%	-2%	-3%	-3%
	15	4%	3%	3%	2%	1%	1%	0%	0%	-1%	-1%	-2%	-2%	-2%	-2%	-3%	-3%
	16	3%	3%	2%	1%	1%	0%	0%	-1%	-1%	-2%	-2%	-2%	-2%	-3%	-3%	-3%

Table 9 Example 2 – NAP V.S. (Discount Rate & Construction Duration)

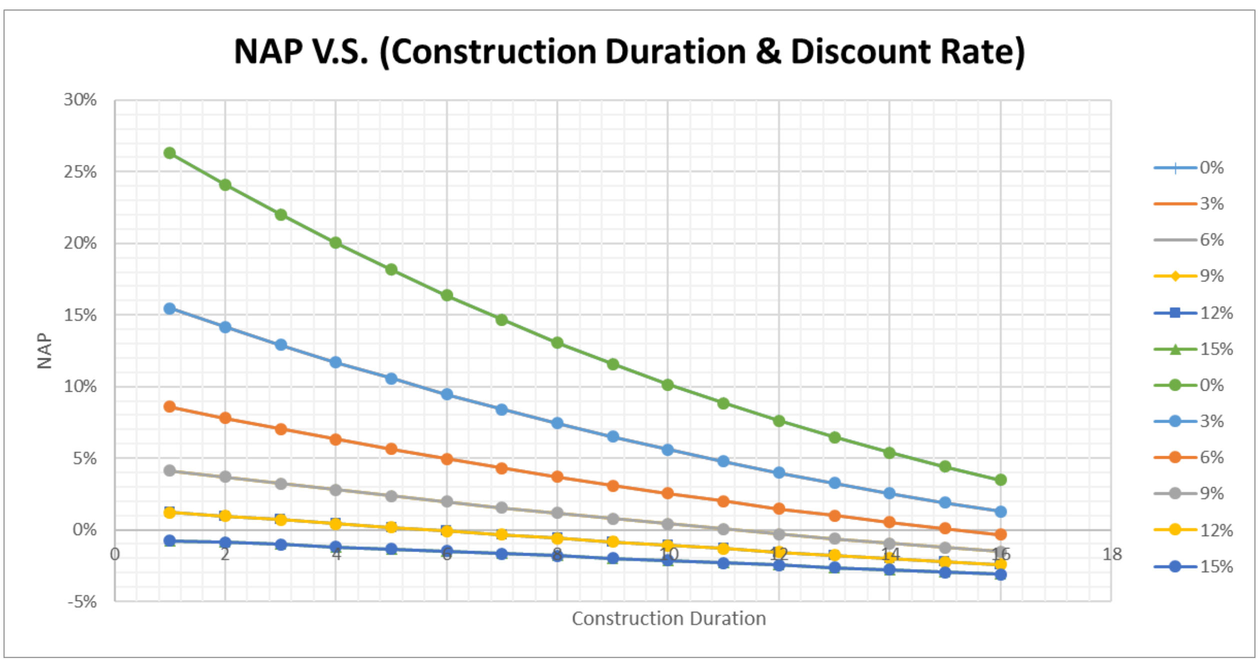


Figure 30 Example 2- NAP V.S. (Discount Rate & Construction Duration)

Below table and chart shows the sensitivity analysis for IRR against Discount rate and Construction duration:

IRR		Discount Rate															
13%		0%	1%	2%	**3%**	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%
Construction Duration (Years)	1	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%
	2	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%
	3	13%	13%	13%	**13%**	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%
	4	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%
	5	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%
	6	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%
	7	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%
	8	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%
	9	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
	10	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
	11	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%
	12	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
	13	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
	14	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%
	15	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%
	16	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%

Table 10 Example 2 – IRR V.S. (Discount Rate & Construction Duration)

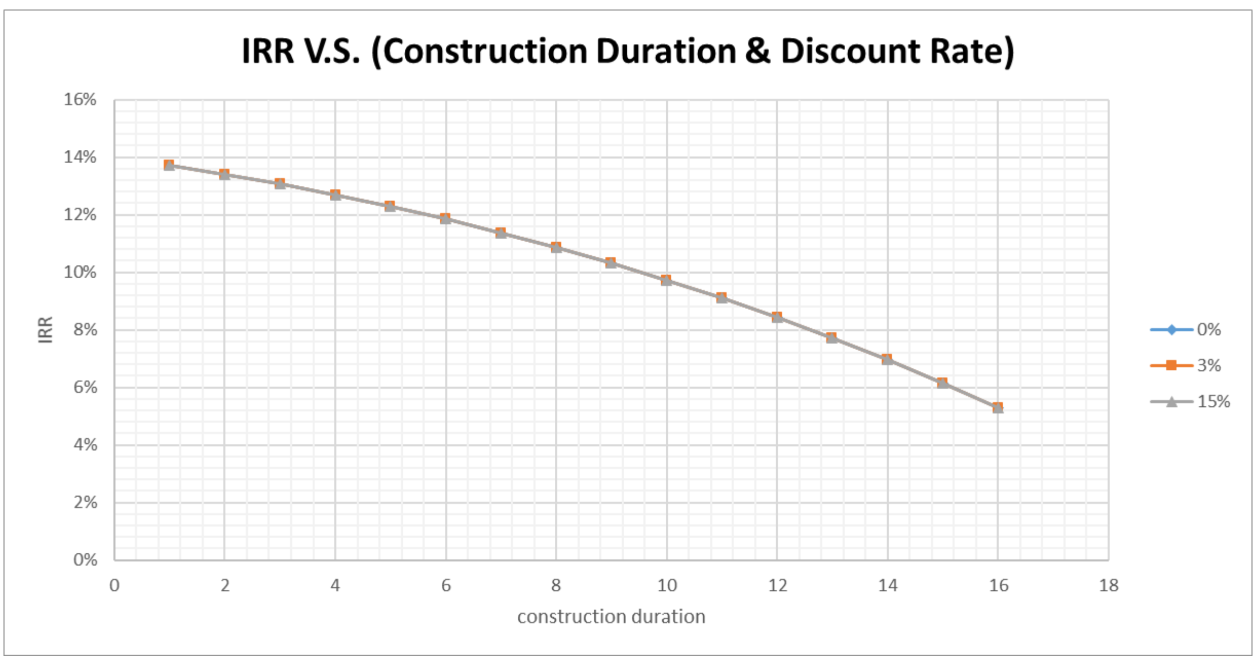


Figure 31 Example 2- IRR V.S. (Discount Rate & Construction Duration)

Below table and chart shows the sensitivity analysis for NPV against Discount rate and Construction Cost:

NPV		Discount Rate															
1448		0%	1%	2%	**3%**	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%
Construction Cost (Millions AED)	75	3189	2701	2296	1958	1675	1438	1239	1070	928	806	702	613	537	471	414	364
	150	3114	2627	2222	1885	1603	1367	1168	1000	858	737	634	545	470	404	348	298
	225	3039	2552	2149	1812	1531	1295	1097	930	788	668	565	478	402	337	281	233
	300	2964	2478	2075	1739	1459	1224	1026	860	719	599	497	410	335	271	215	167
	375	2889	2404	2001	1667	1387	1153	956	790	649	530	429	342	268	204	149	102
	450	2814	2330	1928	1594	1315	1081	885	719	580	461	360	274	201	137	83	36
	525	2739	2255	1854	1521	1243	1010	814	649	510	392	292	206	133	71	17	-30
	600	2664	2181	1781	**1448**	1170	938	743	579	440	323	223	139	66	4	-49	-95
	675	2589	2107	1707	1375	1098	867	672	509	371	254	155	71	-1	-63	-116	-161
	750	2514	2033	1634	1302	1026	795	601	439	301	185	87	3	-68	-129	-182	-227
	825	2439	1958	1560	1229	954	724	531	368	232	116	18	-65	-136	-196	-248	-292
	900	2364	1884	1487	1157	882	652	460	298	162	47	-50	-133	-203	-263	-314	-358
	975	2289	1810	1413	1084	810	581	389	228	93	-22	-118	-201	-270	-330	-380	-424
	1050	2214	1736	1340	1011	737	509	318	158	23	-91	-187	-268	-337	-396	-446	-489
	1125	2139	1661	1266	938	665	438	247	88	-47	-160	-255	-336	-405	-463	-513	-555
	1200	2064	1587	1193	865	593	366	176	17	-116	-229	-324	-404	-472	-530	-579	-621

Table 11 Example 2 – NPV V.S. (Discount Rate & Construction cost)

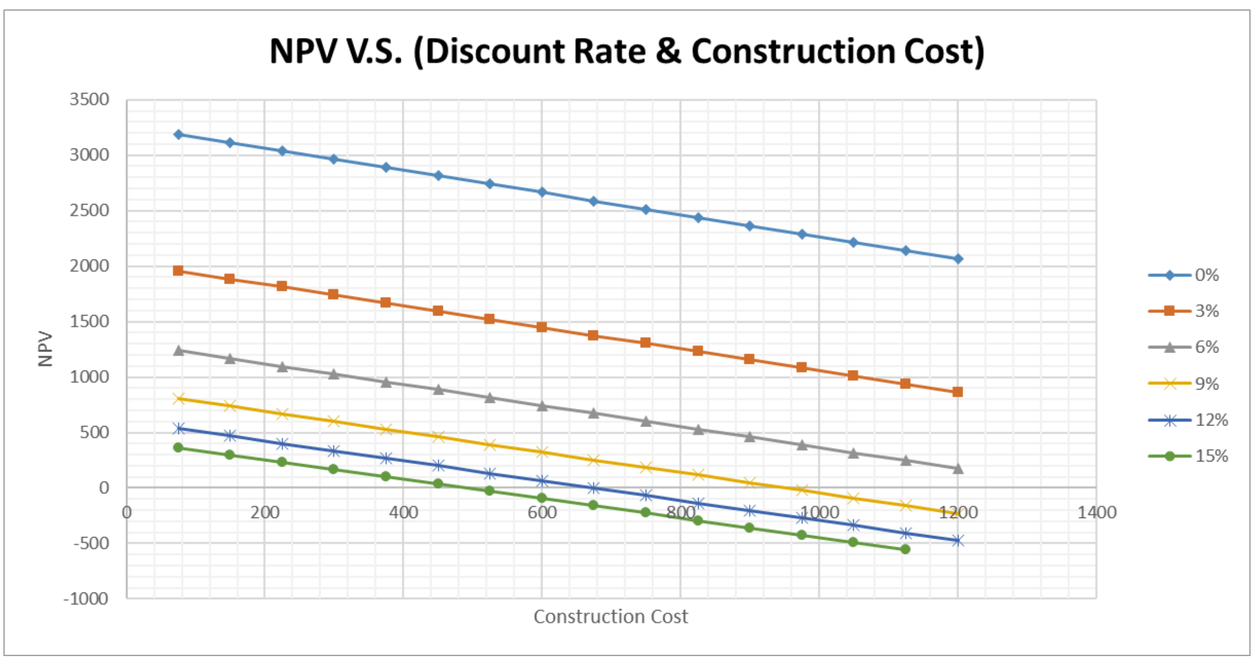


Figure 32 Example 2- NPV V.S. (Discount Rate & Construction cost)

Below table and chart shows the sensitivity analysis for NPV against Construction Duration and Construction Cost:

NPV		**Construction Duration (Years)**															
1448		1	2	**3**	4	5	6	7	8	9	10	11	12	13	14	15	16
Construction Cost (AED Millions)	75	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1967	1968	1969	1970
	150	1881	1883	1885	1887	1889	1891	1893	1895	1897	1899	1901	1903	1904	1906	1908	1909
	225	1806	1809	1812	1815	1818	1821	1824	1827	1830	1833	1836	1838	1841	1844	1846	1849
	300	1731	1735	1739	1744	1748	1752	1756	1760	1763	1767	1771	1774	1778	1781	1785	1788
	375	1656	1661	1667	1672	1677	1682	1687	1692	1697	1701	1706	1710	1715	1719	1723	1727
	450	1581	1587	1594	1600	1606	1612	1618	1624	1630	1635	1641	1646	1652	1657	1662	1667
	525	1506	1513	1521	1528	1535	1542	1549	1556	1563	1569	1576	1582	1588	1594	1600	1606
	600	1431	1439	**1448**	1456	1465	1473	1481	1488	1496	1504	1511	1518	1525	1532	1539	1546
	675	1356	1366	1375	1385	1394	1403	1412	1421	1429	1438	1446	1454	1462	1470	1477	1485
	750	1281	1292	1302	1313	1323	1333	1343	1353	1362	1372	1381	1390	1399	1407	1416	1424
	825	1206	1218	1229	1241	1252	1263	1274	1285	1296	1306	1316	1326	1336	1345	1354	1364
	900	1131	1144	1157	1169	1182	1194	1206	1217	1229	1240	1251	1262	1272	1283	1293	1303
	975	1056	1070	1084	1097	1111	1124	1137	1149	1162	1174	1186	1198	1209	1220	1231	1242
	1050	981	996	1011	1026	1040	1054	1068	1082	1095	1108	1121	1134	1146	1158	1170	1182
	1125	906	922	938	954	969	984	999	1014	1028	1042	1056	1070	1083	1096	1108	1121
	1200	831	848	865	882	899	915	931	946	961	976	991	1005	1020	1033	1047	1060

Table 12 Example 2 – NPV V.S. (Construction Duration & Construction cost)

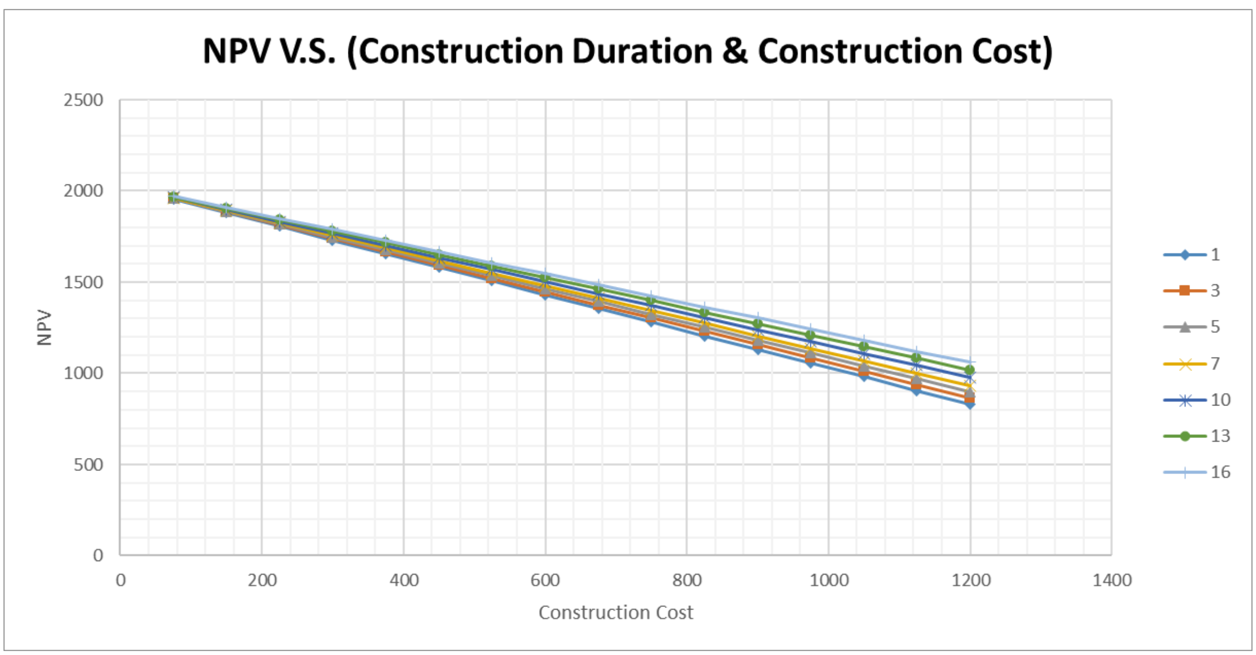


Figure 33 Example 2- NPV V.S. (Construction Duration & Construction cost)

Below table and chart shows the sensitivity analysis for the payback period against Construction Duration and Construction Cost:

PB Period		Construction Duration (Years)															
11 years		1	2	**3**	4	5	6	7	8	9	10	11	12	13	14	15	16
Construction Cost (millions AED)	75	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3
	150	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4	4
	225	6	6	6	6	6	6	6	5	5	5	5	4	4	4	4	4
	300	7	7	7	7	7	7	7	7	6	6	5	5	5	5	5	4
	375	8	8	8	8	8	8	8	8	8	7	6	6	5	5	5	5
	450	9	9	9	9	9	9	9	8	8	8	7	7	6	6	6	5
	525	10	10	10	10	10	10	10	9	9	9	9	8	7	7	6	6
	600	11	11	**11**	11	11	11	11	10	10	10	10	10	8	8	7	7
	675	12	12	12	12	12	12	12	11	11	11	11	11	10	9	8	8
	750	14	13	13	13	13	13	13	12	12	12	12	12	12	11	10	9
	825	15	15	15	14	14	14	14	14	13	13	13	13	13	13	11	10
	900	16	16	16	16	15	15	15	15	15	14	14	14	14	14	13	12
	975	18	17	17	17	17	16	16	16	16	16	15	15	15	15	15	14
	1050	19	19	18	18	18	18	17	17	17	17	16	16	16	16	16	15
	1125	19	19	19	19	19	19	19	18	18	18	18	17	17	17	17	16
	1200	19	19	19	19	19	19	19	19	19	19	19	18	18	18	18	17

Table 13 Example 2 – PB Period V.S. (Construction Duration & Construction cost)

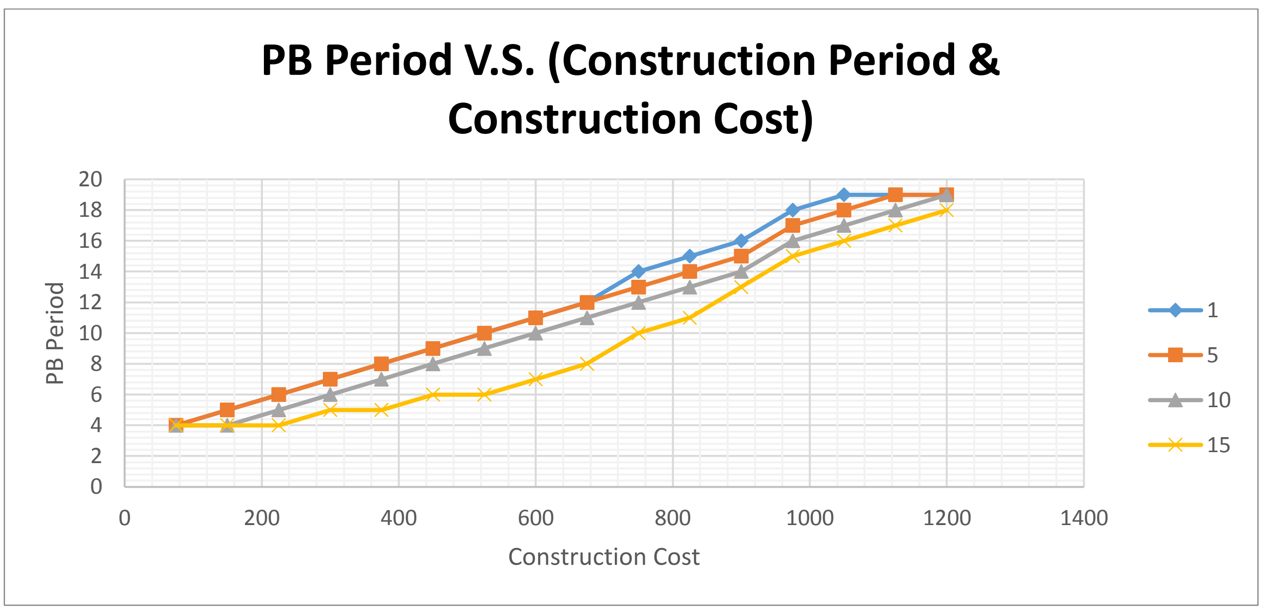


Figure 34 Example 2- PB Period V.S. (Construction Duration & Construction cost)

Below table and chart shows the sensitivity analysis for the payback period against Construction Duration and Discount Rate:

PB Period		**Discount Rate**															
11 years		0%	1%	2%	**3%**	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%
Construction Duration (years)	1	8	9	9	10	10	11	12	13	14	16	18	19	19	19	20	20
	2	9	9	10	10	11	12	13	14	15	17	19	19	19	19	20	20
	3	10	10	10	**11**	12	12	13	15	16	19	19	19	19	19	20	20
	4	10	11	11	12	12	13	15	16	18	19	19	19	19	20	20	20
	5	11	11	12	13	13	14	16	17	19	19	19	19	19	20	20	20
	6	12	12	13	13	15	16	17	19	19	19	19	19	20	20	20	20
	7	12	13	14	15	16	17	18	19	19	19	19	19	20	20	20	20
	8	13	14	15	16	17	18	19	19	19	19	19	20	20	20	20	20
	9	15	15	16	17	18	19	19	19	19	19	19	20	20	20	20	20
	10	16	16	17	19	19	19	19	19	19	19	20	20	20	20	20	20
	11	17	18	19	19	19	19	19	19	19	19	20	20	20	20	20	20
	12	18	19	19	19	19	19	19	19	19	20	20	20	20	20	20	20
	13	19	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20
	14	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20
	15	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20
	16	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20

Table 14 Example 2 – PB Period V.S. (Construction Duration & Discount rate)

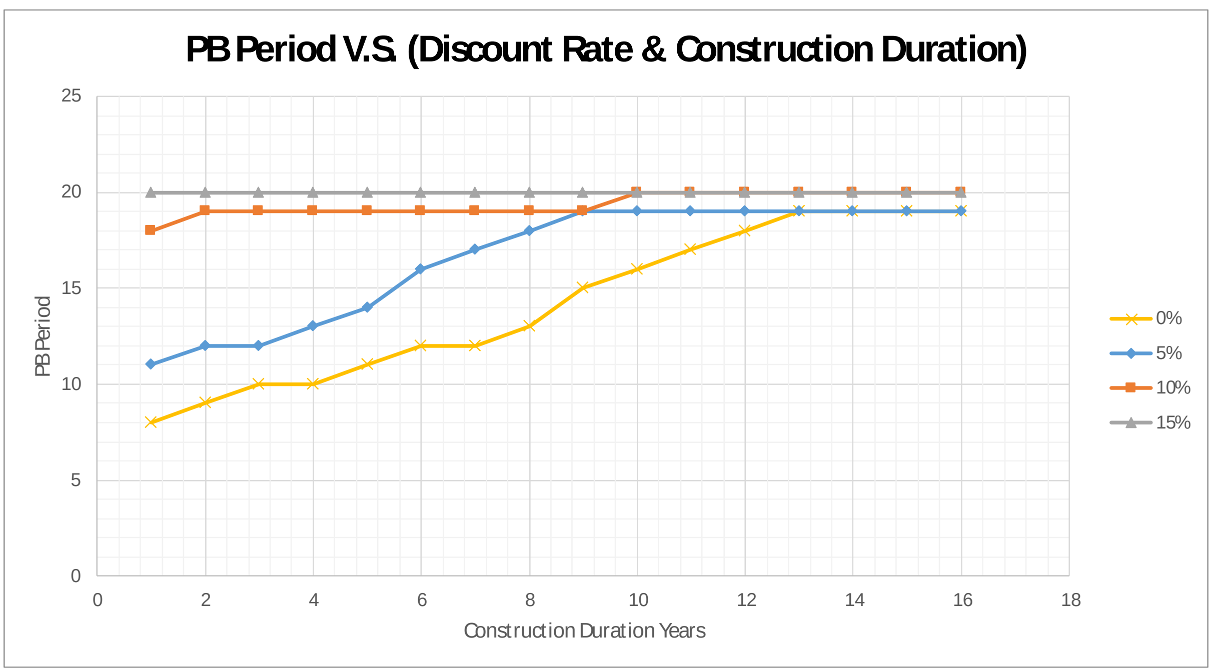


Figure 35 Example 2- PB Period V.S. (Construction Duration & Discount Rate)

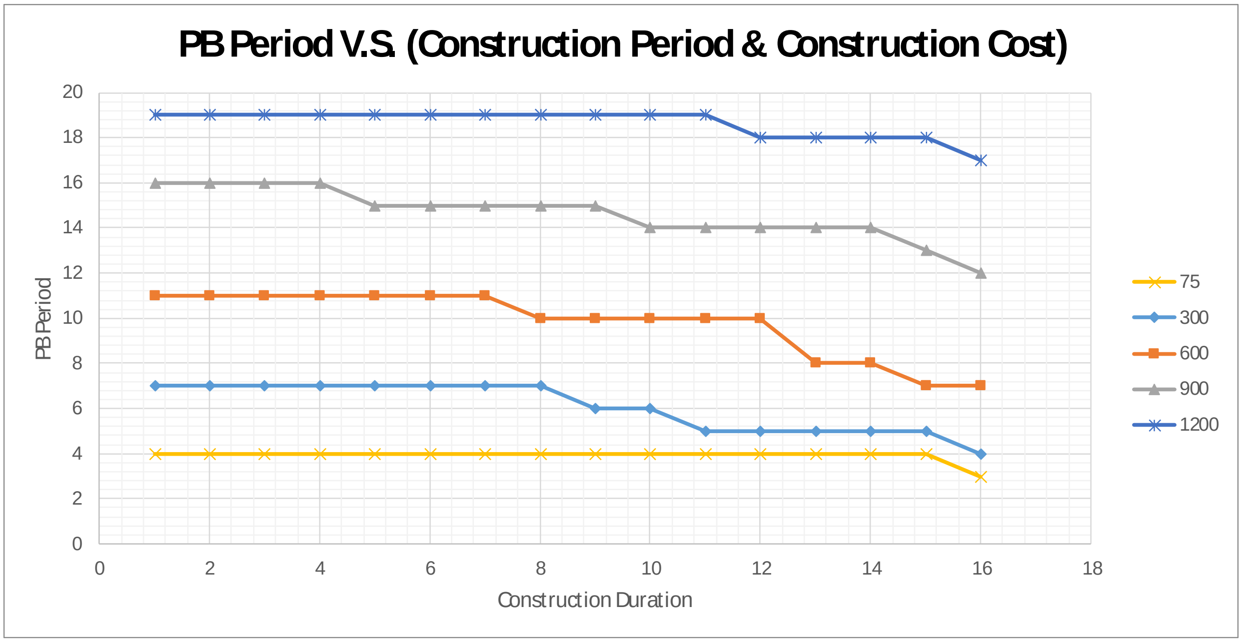


Figure 36 Example 2- PB Period V.S. (Construction Duration & Construction Cost) (reversed)

All of the above figures can be used to optimize the project value, and give guidance to decision makers on what should be the goals of the project in order to keep it cost efficient.

For example, the analysis clearly showed that IRR is not sensitive to the discount rate, accordingly IRR could be considered as a reliable CBA measure to compare projects or alternatives if all of them have NPV values and the analysis period is short.

Also, the payback period is not really sensitive to the construction duration but it is very sensitive to the construction costs. Agencies could obtain great knowledge if they invested the necessary effort and resources to build reliable models for their projects and develop them to generate tables and charts similar to the above in order to optimize the decisions.

4.7 Modeling & Simulation for Example 3

In this example, benefits will be calculated based on sub model, which involves monetizing the Travel Time (VHT) and Vehicle kilometers (VKT) cost savings benefits for a transportation project.

Inputs and Assumptions:

The purpose of the analysis is to build a model that can calculate and evaluate the CBA measures for the project and its alternatives based on the construction costs, the maintenance and operation costs, and VHT & VKT cost saving.

The project scope is to build new roads and improve few intersections in a congested area, the estimated construction cost is AED 800 million, and the construction period is four years.

The project Type is a major works; the analysis period is 20 years; Discount rate to be used is 3%, however, and sensitivity analysis ranges are:

- (0 to 10%) for the discount rate.
- (1 to 8 years) Construction duration.
- (0 to 100%) small car percentage of the whole traffic.
- (5 to 40 AED) average cost per car per hour.

The agency is carrying out this exercise to see if the proposed project will provide benefits that exceeds in its value the investment costs, and in order to do this assessment a comprehensive study involves surveys was done to estimate the following values:

- Key vehicles categories, their average occupancy factor, and their average percentages during the project lifecycle,
- The cost of an hour during travel per person,
- The cost per kilometer for each vehicle category

The below table shows the input parameters which will be used for the cost saving benefits.

	MOTOR CYCLE	SMALL CAR	VAN	BUS (DIESEL, GAS)	SUV/ TRUCK	MEDIUM TRUCK	HEAVY TRUCK	AVERAGE
Average occupancy	1	1.5	3	10	1.5	1.5	2	2.93
Cost Per Km (inclusive of all costs) (AED)	0.5	1	1.2	2	2	2	2	1.53
Cost per person per Hr (inclusive of all costs)(AED)	5	15	5	5	5	5	5	6.43
Cost per hour per vehicle (AED)	5	22.5	15	50	7.5	7.5	10	16.79
Percentage of vehicle types for the whole life cycle	5%	65%	10%	5%	5%	5%	5%	100%

Table 15 Example 3 – Inputs - Cost saving parameters

The project was modelled in a transportation planning software, and it is expected that the project will save 5 million travelled hours yearly, and will save 500,000 travelled kilometers yearly from the second year of its construction start.

The below table shows the cost and benefits throughout the project life cycle, along with its corresponding CBA measures.

	Project 1 (Alt 1) New roads and small intersections							B/C	NPV	IRR	Payback Period	N. A. Profit rate
Year	0	1	2	3	4	5	20	131%	311,179,766	7%	3 years	2%
VHT (Saving) per year (hours)				5,000,000	5,000,000	5,000,000	5,000,000					
VKT (Saving) per year (KM)				500,000	500,000	500,000	500,000					
Cost Saving in KM per year for Motor cycles		0E+00	0E+00	1E+04	1E+04	1E+04	1E+04					
Cost Saving in KM per year for Small Cars		0E+00	0E+00	3E+05	3E+05	3E+05	3E+05					
Cost Saving in KM per year for Vans		0E+00	0E+00	6E+04	6E+04	6E+04	6E+04					
Cost Saving in KM per year for Buses		0E+00	0E+00	5E+04	5E+04	5E+04	5E+04					
Cost Saving in KM per year for SUVs		0E+00	0E+00	5E+04	5E+04	5E+04	5E+04					
Cost Saving in KM per year for Medium trucks		0E+00	0E+00	5E+04	5E+04	5E+04	5E+04					
Cost Saving in KM per year for Heavy trucks		0E+00	0E+00	5E+04	5E+04	5E+04	5E+04					
Cost saving in time for Motor		0E+00	0E+00	1E+06	1E+06	1E+06	1E+06					
Cost saving in time per year for Small Cars		0E+00	0E+00	7E+07	7E+07	7E+07	7E+07					
Cost saving in time per year for Vans		0E+00	0E+00	8E+06	8E+06	8E+06	8E+06					
Cost saving in time per year for Buses		0E+00	0E+00	1E+07	1E+07	1E+07	1E+07					
Cost saving in time per year for SUVs		0E+00	0E+00	2E+06	2E+06	2E+06	2E+06					
Cost saving in time per year for Medium trucks		0E+00	0E+00	2E+06	2E+06	2E+06	2E+06					
Cost saving in time per year for Heavy trucks		0E+00	0E+00	3E+06	3E+06	3E+06	3E+06					
Total cost savings for VKT		0E+00	0E+00	1E+08	1E+08	1E+08	1E+08					
Discounted Total cost saving		0E+00	0E+00	9E+07	9E+07	9E+07	6E+07					
Construction direct costs	2E+08	2E+08	2E+08	2E+08	0E+00	0E+00	0E+00					
Operational & costs	1E+07	1E+07	1E+07	1E+07	1E+07	1E+07	1E+07					
Total Costs	2E+08	2E+08	2E+08	2E+08	1E+07	1E+07	1E+07					
Discounted Total Costs	2E+08	2E+08	2E+08	2E+08	9E+06	9E+06	6E+06					
Net Value	-2E+08	-2E+08	-2E+08	-1E+08	9E+07	9E+07	9E+07					
Discounted Net Value	-2E+08	-2E+08	-2E+08	-1E+08	8E+07	8E+07	5E+07					

Table 16 Example 3 – Cost and Benefits throughout the project life cycle & corresponding CBA measures

Equations:

In this example, we will use new equations to calculate the cost savings, however, the same equations used in examples 1 and 2 will be utilized to calculate the CBA Measure.

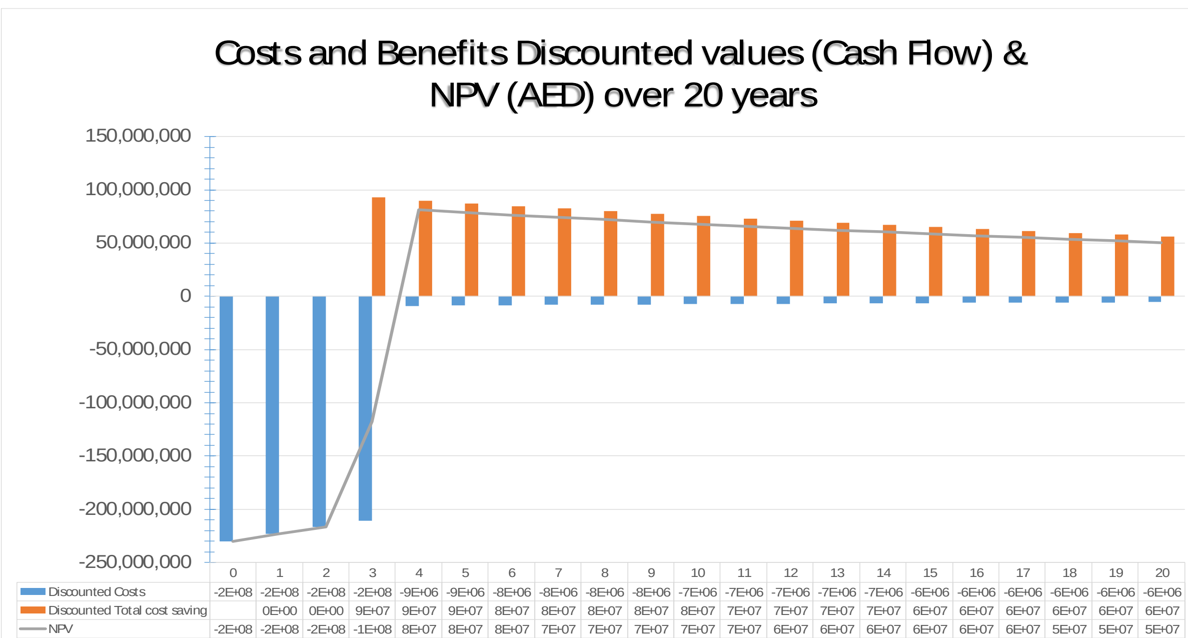
Cost Saving in KM per year for Category x for year i= Percentage of Category x* Cost Per Km for Category x * VKT (Saving) per year for year i

Cost saving in time for Motor Category x for year i = Percentage of Category x * Cost per hour per vehicle for Category x * VHT (Saving) per year for year i

Total Benefits (cost savings) for year I = the sum of all cost savings for VHT and VKT for all the categories for year i.

Summary, output, and simulation of Example 3

The CBA measure presented in the below chart shows that the project is cost efficient as follows: B/C =131%, NPV = 311 million AED, IRR = 7%, PB Period = 3 years, and NAP=2%.



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Discounted Costs	-2E+08	-2E+08	-2E+08	-2E+08	-9E+06	-9E+06	-8E+06	-8E+06	-8E+06	-8E+06	-7E+06	-7E+06	-7E+06	-7E+06	-7E+06	-6E+06	-6E+06	-6E+06	-6E+06	-6E+06	-6E+06
Discounted Total cost saving		0E+00	0E+00	9E+07	9E+07	9E+07	8E+07	8E+07	8E+07	8E+07	8E+07	7E+07	7E+07	7E+07	7E+07	6E+07	6E+07	6E+07	6E+07	6E+07	6E+07
NPV	-2E+08	-2E+08	-2E+08	-1E+08	8E+07	8E+07	8E+07	7E+07	7E+07	7E+07	7E+07	7E+07	6E+07	6E+07	6E+07	6E+07	6E+07	6E+07	5E+07	5E+07	5E+07

Figure 37 Example 3 - Cash flow and NPV for 20 years

Sensitivity analysis

In Example 3, a two-dimension sensitivity analysis was also utilized, to shows how a NPV value would change based on the changes of two other input variables.

Accordingly, NPV was tested against discount rate and construction duration according to the previously mentioned ranges and the results are as shown in the below table and chart:

NPV Million AED		Construction Duration (years)							
311 Million AED		1	2	3	4	5	6	7	8
Discount Rate	0	951	885	812	732	644	547	441	324
	1%	776	713	645	570	488	398	300	192
	2%	624	565	501	431	354	271	180	82
	3%	492	437	377	**311**	240	163	80	(11)
	4%	378	326	269	208	142	71	(6)	(89)
	5%	277	229	176	120	59	(7)	(78)	(154)
	6%	190	144	95	43	(14)	(74)	(139)	(209)
	7%	112	70	25	(24)	(76)	(132)	(191)	(256)
	8%	44	5	(37)	(82)	(130)	(181)	(236)	(294)
	9%	(16)	(53)	(91)	(132)	(176)	(223)	(273)	(327)
	10%	(70)	(103)	(139)	(176)	(216)	(259)	(305)	(354)

Table 17 Example 3 – NPV V.S. (Construction Duration & Discount rate)

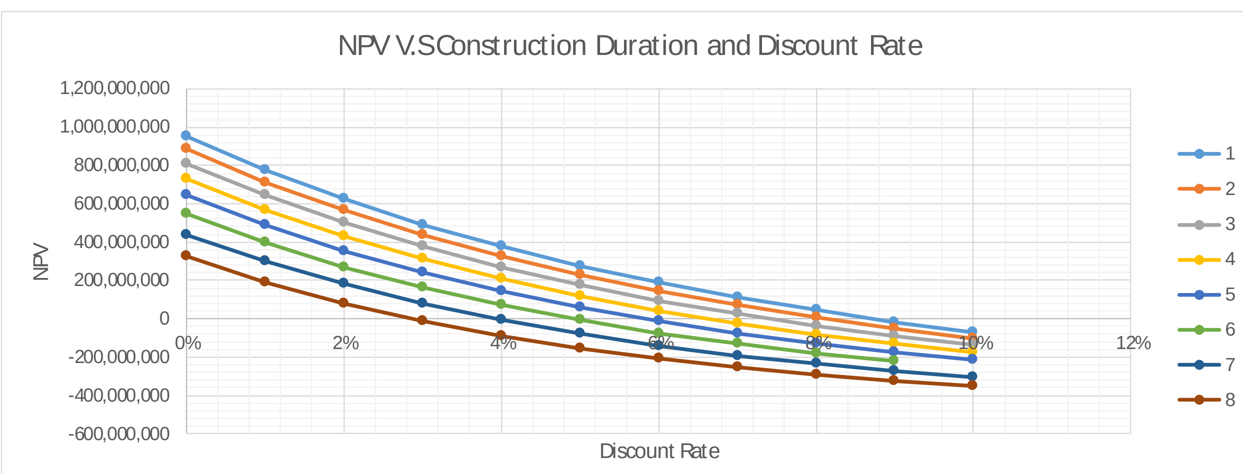


Figure 38 Example 3- NPV V.S. (Construction Duration & Discount Rate)

Below table and chart shows the sensitivity analysis for the NPV against Small Cars Percentage and Discount Rate:

NPV Million AED		Small Cars Percentage					
311 Million AED		0%	20%	40%	60%	80%	100%
Discount rate	0%	(590)	(183)	224	630	1,037	1,444
	1%	(611)	(248)	116	479	842	1,205
	2%	(628)	(302)	24	349	675	1,001
	3%	(641)	(348)	(55)	238	531	824
	4%	(651)	(387)	(122)	142	407	671
	5%	(659)	(420)	(180)	60	299	539
	6%	(665)	(447)	(230)	(12)	206	424
	7%	(669)	(471)	(272)	(74)	125	324
	8%	(672)	(490)	(309)	(127)	54	236
	9%	(674)	(507)	(340)	(174)	(7)	159
	10%	(674)	(521)	(368)	(214)	(61)	92

Table 18 Example 3 – NPV V.S. (Small Car Percentage & Discount rate)

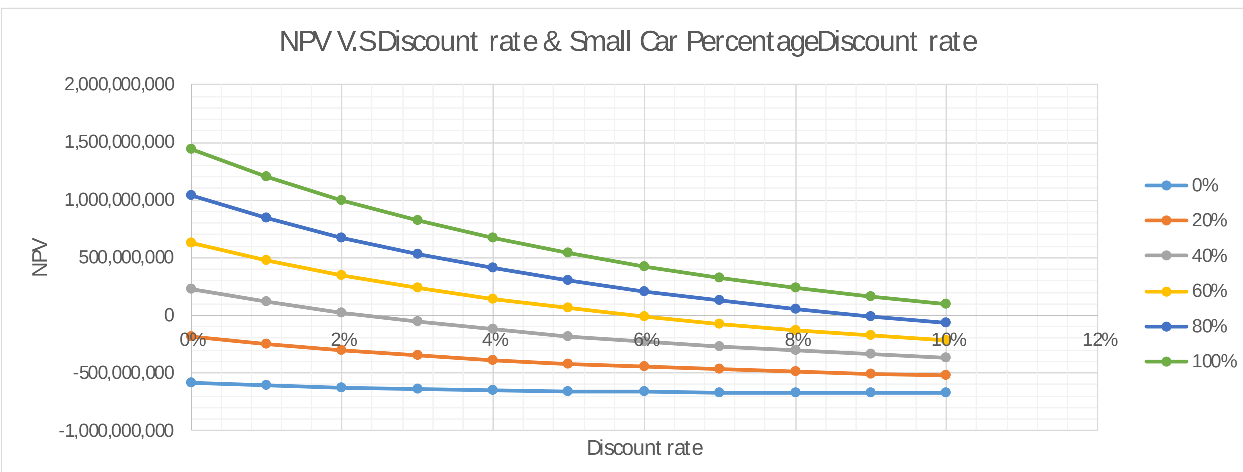


Figure 39 Example 3- NPV V.S. (Small Car Percentage & Discount Rate)

Below table and chart shows the sensitivity analysis for the NPV against Small Cars Percentage and the "Cost Per Car Per Hour":

NPV Million AED		Small Car Percentage					
311 Million AED		0%	20%	40%	60%	80%	100%
Cost Per Car Per hour	5	(641)	(575)	(509)	(443)	(377)	(310)
	10	(641)	(510)	(379)	(248)	(117)	14
	15	(641)	(445)	(250)	(54)	142	338
	20	(641)	(380)	(120)	141	401	662
	25	(641)	(316)	10	335	661	986
	30	(641)	(251)	139	530	920	1,310
	35	(641)	(186)	269	724	1,179	1,634
	40	(641)	(121)	399	919	1,438	1,958

Table 19 Example 3 – NPV V.S. (Small Car Percentage & Cost Per Car per Hour)

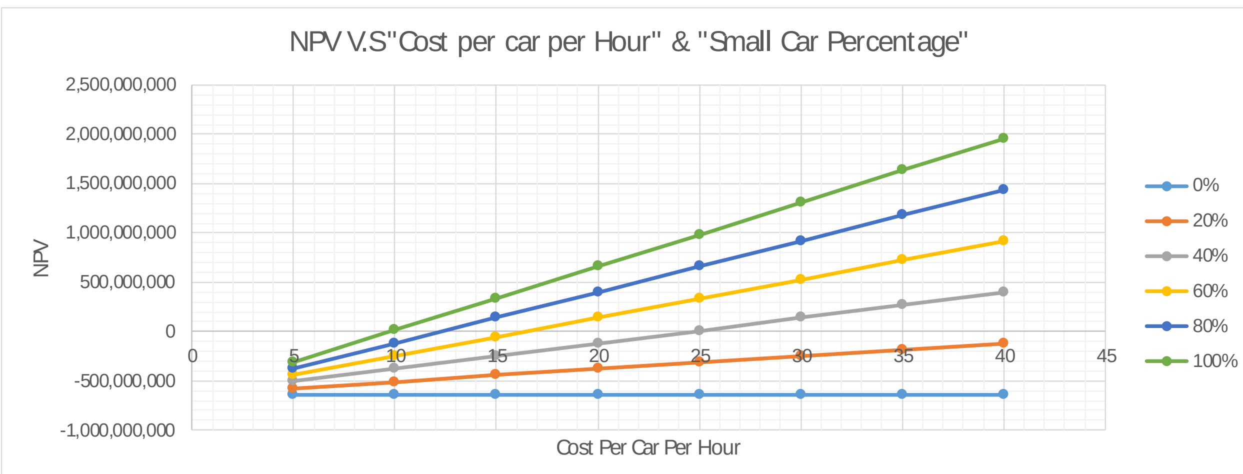


Figure 40 Example 3- NPV V.S. (Small Car Percentage & Cost Per Car per Hour)

The above tables and charts shows the project's NPV is very sensitive to the discount rate and to the changes in some of the cost saving parameters, for example the project will no longer be profitable if the discount rate will exceed 6%, or if the small cars percentage became lower than 44% etc…

Those figures can be used to calculate risks and contingencies, and make lead to discarding the project.

4.8 Summary of modeling and simulation results

The results of example 1 simulation show how the lack of selection criteria can make taking decisions difficult especially with all CBA measures are positive and no dominant option, the simulation shows also how important sensitivity in making the final decision, and how one parameter can affect CBA measures for all the alternatives at the same time.

While the results of example 2 and 3, shows how flexible the model can be to work with different inputs and level of complexity, and it also confirms the importance of sensitivity analysis in supporting the final decision.

5.Chapter 5: Discussion, Findings and Conclusion

5.1 Introduction

This chapter will explore the most important discussion points related to the literature review discussed in previous chapters, and review how paper have achieved its aim and objectives.

This chapter will also highlight how the paper have contributed to the knowledge related to transportation projects assessment, cost benefit analysis, and whole life cycle costing topics. And it will conclude with the research limitation and future improvements.

5.2 Findings and Discussion

5.2.1 Discussion

It has been observed in the literature review, that CBA is the most used methods for evaluating transportation projects (Nogués, S., & González-González, E., 2014), however most of the reviewed CBA frameworks does not include the environmental, economic, social, reputational, political, security, and experimental impacts (Veryard, D., 2016) & (Li, Z., & Madanu, S., 2009).

Transportation agencies sometimes take decisions based on some of those ignored components, like building and underpasses instead of bridges in residential areas to reduce noise and aesthetic impacts and to preserve resident’s privacy.

There are some reasons for not including them, like reducing the complexity of the analysis, not interfering with other agency’s or other sturdies scope like EvIA and EcIA, and the uncertainty and subjectivity nature of those components.

All Tod Litman literature agrees with the recommendation of this papers in including all the possible cost and benefit components, especially that most of the simple CBA assessments overstates transportation expansion solutions over effective utilization of existing resources that promotes public transport.

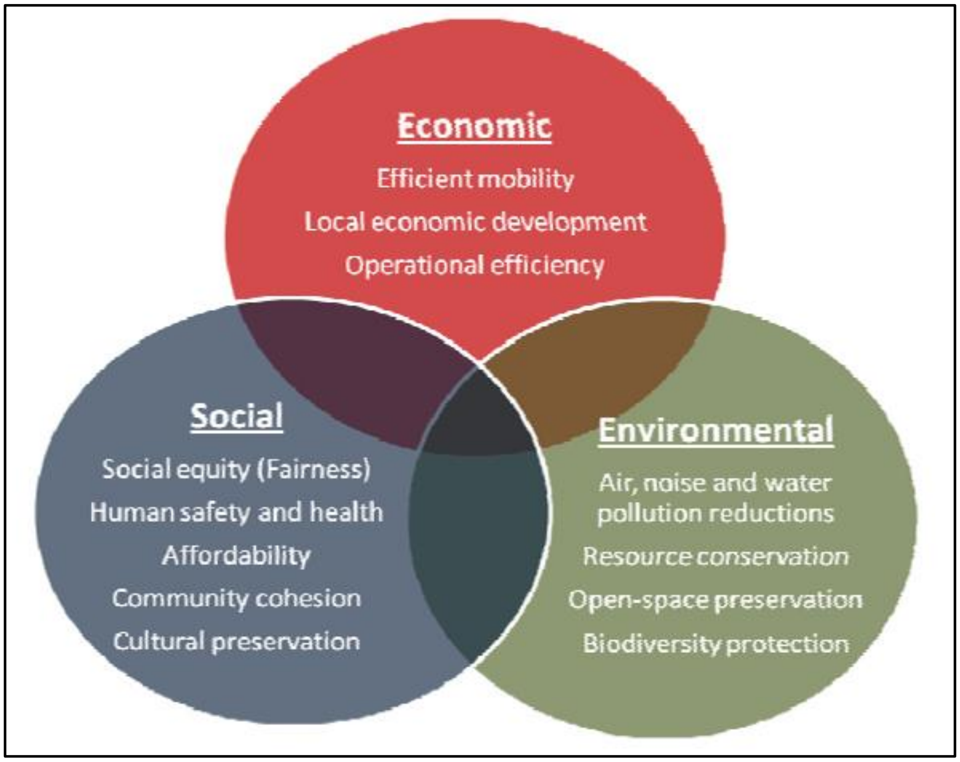


Figure 41 Sustainable Transport Goals – Litman, T (2010)

Furthermore, this study suggests carrying out full CBA scope for all the projects, as applying the full CBA framework and documenting its inputs and outputs creates knowledge, and helps in building database that can be used for a reliable benchmarking record for future projects planning, Beukers, E., Bertolini, L., & Te Brömmelstroet, M. (2014) agrees with this finding as they consider the assessment process an important learning process.

Another important discussion topic is the importance of including the probabilistic approach and the impact of uncertainty on the final decision-making process, which agrees with most of the reviewed literature especially Nogués, S., & González-González, E. (2014), although agencies do not comply with this requirements in their assessment process. The results of previous examples in chapter 5 shows how sensitivity analysis can provide very important information to decision makers, which can result of selecting the best project alternative, or optimize it for optimal return on investment.

This paper recommends automating the appraisal process and build comprehensive models, as the presented previous examples shows that carrying out CBA studies requires huge effort and time. Jiang, Y., Zhao, G., & Li, S. (2013) confirms the importance of modeling the appraisal process in providing reliable and fast method to provide the information required to support decision makers.

For example, calculating the time benefits (cost saving) only for a project for a period of 20 years require the following: Percentage (shares) and occupancy rate for each vehicle type and every transport modes for the analysis period (7 to 10 vehicle types and transport modes multiplied by 20 for the analysis period) which means between 140 and 200 variables. So, if an organization wanted to carry out CBA for a project with three alternatives, then they will have to deal with around 2000 variables for each alternative, which are coming from around 15 costs and benefits components, to be calculated for around 7 sub-user groups for an analysis period of 20 years, so in total around 6000 variables.

At last, and the most important finding is related to developing an agency specific selection/ priority/ winning criterion based on a combination of CBA measures and other qualitative methods outcomes/ component that may affect the decision-making process.

This is very important as each CBA measure (B/C, NPV, IRR, PB period, and NAP) have advantage over others, and agencies will have different criteria over time based on their financial status, and also based on government's specific requirements.

5.2.2 Key research findings

Below are the key findings of this paper:

- CBA is the best method to carry out transportation project assessment exercise as it can consider all the factors which may impact the project and its surrounding during the whole project life cycle from development stage till the decommissioning stage.
- CBA measures are not the ultimate answer to rely upon for the final decision, agencies should develop their flexible criteria based on CBA measure and other qualitative methods.
- Modeling CBA process and the agency's framework is simple, and could save plenty of time and can provide more fast and reliable decision supporting tool.
- Uncertainty can have huge impact on CBA measures and accordingly on the final decisions.

5.2.3 Generalization ability of the findings

The key findings of this paper can be applied to all transportation projects and policies, regardless of their size and location, especially that the proposed framework can be optimized and customized to suit the purpose and requirement of any transportation agency.

5.3 Fulfillment of paper's purpose and objectives

The research questions were answered, as the literature showed that the CBA is the best and most used assessment method for transportation projects, and in explaining its process, its components and how to estimate their values and calculate its measures.

The paper also identified the factors that makes using CBA so important and how to understand and optimize its outcomes.

The paper identified all transportation project types and its key stakeholders, and provided a generic reliable CBA framework that can be used for any transportation project or policy.

The framework provided a clear guidance to identify all the elements that are required to carry out a comprehensive assessment, and to help transportation planner and economics to make the right investment decisions for transportation projects.

The framework was also used to develop multiple Microsoft Excel Models that can simulate the assessment process. The models were tested with 3 examples. The results showed how easy and flexible modeling the CBA process is, and also showed how important and easy to include uncertainty in the assessment process.

this study shows how important it is to build a customized appraisal process for transportation projects, especially with the huge number of variables involved in the calculation process, and the huge effort required to setup the process and obtain the calculation parameters.

5.4 Knowledge contribution

This paper provides a comprehensive guidance on how to develop an assessment framework and the most important elements that may impact its outcomes, the key knowledge provided here is mainly coming from collecting all the related topics/ components/ factors/ variables in one place. And providing an easy framework that explain the relation between them, and how they can be modelled to produce a reliable outcome that can support decision makers for transportation projects. The paper may have not provided detailed information on each of its component, but it provided a comprehensive source for finding those components and evaluate them.

The outcomes of the provided examples which was presented in chapter 5 are not important by itself as it varies from project to project, however, the most valuable outcome is the framework and the process of building and customizing it to suit transportation agency's needs. This knowledge still has several areas that can be developed further which will be highlighted in the next paragraph.

5.5 Research Limitations & Further Improvements

This paper did not go into the details of estimating each cost and benefit components, or the details of monetization process, although it could have added more significance to its outcomes, because it would have distracted the reader from its main paper purpose.

The study also did not go through the different transportation infrastructures or modes like airports, seaports and rails, as the purpose of this paper is limited to explain the appraisal process using CBA framework, which can be applied to any project type even from other industries.

This study has highlighted many areas and gaps that needs to be researched further, like developing detailed frameworks and models for each of the cost and benefits components and link them to the main framework and its model, in addition to developing strategies and policies to extract cash from the qualitative benefits of transportation.

The study also indicated some areas that needs to be developed along with the appraisal process development in order to maximize the projects benefits, the main two areas are:

- Economic sustainability of transportation projects, and especially in terms of developing innovative methods to extract cash from the indirect benefits (Environmental, Economic, Social, Political, Reputational and technological), that can be used back in sustaining the transportation infrastructure operation and maintenance along with the growth requirements.
- Developing Benefits Realization policies and processes, to manage all the cost and benefits during the whole life cycle of the project, and provide reliable feedback that could enhance the appraisal framework and its models.

The study would have produced more significance if it were coupled with a questionnaire to assess the importance of each cost and benefit component from local expert's point of view, a survey or an investigation amongst local agencies and key transportation professionals to explore the existing methods that are used to perform project appraisals and budgeting processes.

This study could also have been coupled with other studies relating to benchmarking the relation between population, roads length, PUT shares, and GDB, to see if adding more roads or providing more PUT facilities is the solution to the congestion, and to set the target in relation to travel time for each person.

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