A COST - BENEFIT ANALYSIS:
BOLU MOUNTAIN TUNNEL PROJECT EXAMPLE

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Approval of the Graduate School of Social Sciences

Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science/Doctor of Philosophy.

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science/Doctor of Philosophy.

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ABSTRACT

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BOLU MOUNTAIN TUNNEL PROJECT EXAMPLE

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This thesis analyzes the concepts and theories related to the cost – benefit analysis. The definition of cost – benefit analysis, its historical perspective and economic concepts of cost – benefit analysis is introduced. The applications of cost – benefit analysis to transportation projects and the literature related to this concept is also reviewed. An empirical research to assess the feasibility of Bolu Mountain Tunnel project by using cost – benefit analysis is also conducted. The costs related with this project (construction costs and maintenance costs) are gathered. The benefits of the project (vehicle operating cost savings, accident cost savings and travel time savings) are estimated. Internal Rate of Return concept is used as a decision rule to asses the net benefits stream of the project. According to the results, Bolu Mountain Tunnel project is economically feasible. Net Present Value of the project is positive at % 12 discount rate level and Internal Rate of Return of the project is found to be % 22.

Keywords: cost – benefit analysis, internal rate of return, discount rate, net present value, Bolu Mountain Tunnel, transportation projects

ÖZET

FAYDA – MALİYET ANALİZİ: BOLU DAĞI TÜNELİ PROJESİ ÖRNEĞİ

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Tez Yöneticisi: Prof. Dr. İsmail Bulmuş

Ocak 2008, 68 sayfa

Bu çalışma, fayda – maliyet analizi kavramını ve teorilerini içermektedir. Çalışmada, fayda –maliyet analizinin tanımı, tarihsel perspektifi ve fayda – maliyet analizi ile ilgili iktisadi kavramlar sunulmaktadır. Fayda – maliyet analizinin ulaştırma projelerine uygulanması ve bununla ilgili literatür taraması çalışmaya eklenmiştir. Ayrıca, Bolu Dağı Tüneli Projesi'nin iktisadi değerlendirmesi, fayda maliyet analizi yöntemi kullanılarak ampirik olarak ölçülmüştür. Projenin maliyetleri (inşaat, bakım)elde edilmiş, projenin beklenen faydaları (taşıt işletme giderlerindeki azalma, kaza maliyetlerindeki azalma, zaman tasarrufları) tahmin edilmiştir. Fayda – maliyet analizi sonuçlarına göre, Bolu Dağı Tüneli iktisadi olarak yapılabilirdir. Analiz sonuçlarına göre, Bolu Dağı Tüneli Projesi'nin Net Bugünkü değeri, % 12'lik indirgeme oranında pozitiftir. Ayrıca, projenin İç Verimlilik Oranı % 22 olarak bulunumuştur.

Anahtar Kelimeler: fayda – maliyet analizi, iç verimlilik oranı, indirgeme oranı, net bugünkü değer, Bolu Dağı Tüneli, ulaştırma projeleri

To My Oldest Friend
Cenk Hasinger….

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TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Cost benefit analysis (CBA) is the most widely used project evaluation method by both public and private sectors for comparison of the projects according to their costs and benefits in order to take any investment decision. The present value of a project's costs and benefits are calculated then compared. If the comparison will be made among several projects, the project which is the most beneficiary is chosen. If the decision will be made for one project, the project is concluded worthwhile if the net benefits exceed the net costs.[1]

The purpose of using CBA for public sector is to maximize social benefit by allocating resources efficiently among the projects which will have positive effect on social welfare. CBA is used especially for the evaluation of the education, health, environmental, transport and other infrastructure projects which are mostly provided by public sector for the reason that these services are mostly in the characteristics of public goods.

While conducting CBA all relative cost and benefit items should be monetized then included in the analysis in order to make the benefit and cost streams comparable. The following step is to discount these streams by an appropriate discount rate to compute the net present value of the costs and benefits.

[1] Hilmi Ünsal, "Kamu hizmetlerinin planlanmasında fayda-maliyet analizi ve uygulanabilirliği", *Gazi Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, No:1(2004),p.1

Although CBA has its roots back to 19th century when it had firstly introduced by a French engineer Arsene-Jules-Etienne-Juvenal Dupuit in 1844[2] it did not commonly used until 20th century. CBA is redefined in mid-1950's corresponding to economic standards. In 1950's and 60's the modern welfare economists supported by U.S and other governments to set the formal principles of CBA. The popularity of CBA in 1960's had declined in 1970's because the theorists and agencies using CBA began to question the method. After that period, there has been a rapid increase both in literature and practical use of CBA. Today, CBA is widely used and required by EU and other countries as well as USA.

This thesis consists of five chapters. In the first chapter a brief definition of cost benefit analysis, the historical evaluation of the method and the steps which have to be followed in conducting CBA is given. Understanding the basic features of the method is important for the implementation of the technique to the projects. The first chapter covers the general framework of the analysis method.

In the second chapter, economic concepts related to cost benefit analysis is presented. The first section identifies the consumer surplus concept and the relation between CBA and consumer surplus is clarified. As the consumer surplus is one of the most critical economic concepts of CBA the demand curve from which it should be derived is considered as well. The second section deals with the producer surplus which is as important concept as consumer surplus in understanding theoretical background of cost and benefit valuation. The third section is devoted to compensating and equivalent variation measures which are crucial for analyzing

[2] Thayer Watkins, "An Introduction to Cost Benefit Analysis", *San José State University Department of Economics,* Silicon Valley & Tornado Alley USA.

welfare effects of price changes in view point of individual's preferences. In corporation to CV and EV measures willingness to pay and willingness to accept approaches are mentioned as well.

Third chapter is about the identification and measurement of costs and benefits which is the most critical point of the evaluation of a project. In the first section, classification and identification of costs and benefits as; "real vs. pecuniary", "direct vs. indirect", "inside vs. outside" effects are detailed. The second section deals with the measurement of costs and benefits. For the analytical purpose, firstly the market conditions as first-best and second-best environment are determined. Then, shadow price approach which is used for the valuation when the markets are distorted and market prices are no longer reflects the real social value of the goods is determined and derivation of shadow prices for wage rate and foreign exchange rate is given. The second section deals with the valuation of non-marketed inputs, namely; value of life and value of time are discussed in detail.

In the fourth chapter decision rules used for the project selection are presented. In the first section, decision criteria of cost- benefit analysis which are net present value, benefit-cost ratio and internal rate of return are depicted. In the second section, the choice of appropriate discount rate is discussed which is one of the critical points for the reliability of the analysis.

The fifth chapter is the application of cost-benefit analysis. Firstly, some examples of the application of CBA to transport projects in literature are considered and then limitations and critiques to the technique are mentioned. In the second section, costs and benefits which are specific to transport investments are identified. In the third section Bolu Mountain Tunnel Project is presented and the related costs*;* *construction costs* and *maintenance costs,* and benefits; *accident cost savings, vehicle operating cost savings* and *travel time savings* are calculated by using the which are gathered from GDH and other institutions.

CHAPTER I

1. THE DEFINITION OF CBA AND HISTORICAL PERSPECTIVE

1.1. Definition

Cost benefit analysis (CBA) is the most widely used project evaluation method by both public and private sectors for comparison of the projects according to their costs and benefits in order to take any investment decision. The present value of a project's costs and benefits are calculated then compared. If the comparison will be made among several projects, the project which is the most beneficiary is chosen. If the decision will be made for one project, the project is concluded worthwhile if the net benefits exceed the net costs.[3]

The purpose of using CBA is different for public and private sectors. While the private sector uses the method only for profit maximization, the public sector uses it to maximize social benefit. The aim of public sector for using CBA can be stated also as to allocate resources efficiently among the projects to raise the social welfare. As the purpose is stated as to maximize social welfare the standard of CBA is the Potential Pareto Condition or in other words Kaldor-Hicks Rule which has its roots from Pareto Optimality theorem of welfare economics[4].

CBA used by public sector especially for the evaluation of education, health, environmental, transportation and other infrastructure projects. These services provided by public sector because they can be defined as public goods in sense that they produce externalities and their usage cannot be excluded from some parts of the

[3] Hilmi Ünsal, "Kamu hizmetlerinin planlanmasında fayda-maliyet analizi ve uygulanabilirliği", *Gazi Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, No:1(2004),p1.
[4] Tevfik Nas, *Cost Benefit Analysis Theory and Application,*California: Sage Publications,1996,p.57.

society and another reason is the high investment costs required for the production which are non-profitable for private sector.

The CBA can be used for both ex-ante and ex-post analysis. While the ex-ante evaluation is for the selection of a project among the alternatives, the ex-post analysis is for the measurement of economic effects of an intervention.[5]

While conducting the CBA for any project all costs and benefits should be measured with a common unit which is “money”. The reason for converting all costs and benefits into monetary units is to promote the basis for comparison. Then these streams are discounted and present value of net benefits (benefits-costs) is compared.

1.2. History

The idea of CBA as an economic accounting method is first introduced by a French engineer Arsene-Jules-Etienne-Juvenal Dupuit in 1844[6].

Although CBA had been introduced at 19th century, it didn’t commonly used until the U.S Army Corps of Engineers started to use the method. After 1902, Congress accepted the water projects which are found efficient and beneficial by the Corps. Another important turning point of CBA usage is after The Flood Control Act of

[5] Evaluating socio economic development,sourcebook2:Methods& technics of cost benefit analysis,2003

[6] Thayer Watkins, “An Introduction to Cost Benefit Analysis”, *San José State University Department of Economics,* Silicon Valley & Tornado Alley USA.

1936 which allowed Congressional authorization to undertake the projects only which meet the requirements of Corps[7].

Corps' decision rule can be simply stated as the acceptance of the projects that benefits exceeds costs. Although CBA was firstly used by engineers, its economical aspects needed to be defined. CBA is redefined in mid-1950's corresponding to economic standards. In 1950's and 60's the modern welfare economists supported by U.S and other governments to set the formal principles of CBA. One of the earliest welfare economists Wilfredo Pareto (1848-1923) defined the rule of optimal reallocation of resources as the situation; "no one can be made better off without making someone else worse off". If someone in an economy becomes better off without making anyone else worse off this is called "Pareto Improvement".[8] Although Pareto optimum rule had been the standard of the selection of projects it is very strict and the application to real-world situations is rather difficult. For the most real world situations welfare improves by at least making one person worse off[9].Because of this strictness of the Pareto optimum rule in project selection, another decision standard named "Potential Pareto Improvement" or "Kaldor-Hicks Rule" developed by J.R.Kaldor and Nicholas Hicks in 1930's. Potential Pareto Improvement indicates that a project is worth to apply if its beneficiaries become better off that they could compensate those made worse off by the project [10].In other

[7] History of Benefit Cost Analysis
www.chicagoasa.org/downloads/CostBenefitConference2006/benefit%20cost%20history.pdf
[8] Matthew D.Adler and Eric A.Posner, "Rethinking Cost-Benefit Analysis", *The Yale Law Journal*, No.109(Nov, 1999), p. 165.
[9] Nas, p.11.
[10] History…

words "a project is desirable if money measure of gains exceeds the money measure of losses".[11]

The popularity of CBA in 1960's had declined in 1970's because the theorists and agencies using CBA began to question the method. The problem was about the practical use. The difficulty arises in the foundation of the relevant data especially for environmental effects, human life and other goods that are hard to measure.[12] After that period, there has been a rapid increase both in literature and practical use of CBA. Today, CBA is widely used and required by EU and other countries as well as USA.

1.3. The Core

In literature and practice different writers and application agencies identify the steps which must be followed in CBA. Although the classification seems to be differing, main idea remains same for all. One of the classifications, made by Boardman (1996) suggests nine steps as following[13] :

1) Decide whose benefits and costs count
2) Select the portfolio of alternative projects
3) Catalogue potential (physical) impacts and select measurement indicators
4) Predict quantitative impact over the life of project
5) Monetize all impacts
6) Discount for time to find present values

[11] History of Benefit Cost Analysis
www.chicagoasa.org/downloads/CostBenefitConference2006/benefit%20cost%20history.pdf
[12] History of Benefit Cost Analysis
www.chicagoasa.org/downloads/CostBenefitConference2006/benefit%20cost%20history.pdf
[13] Theodore Panayotou, "Basic Concepts and Common Valuation Errors in Cost-Benefit Analysis", *International Development Research Centre,Ottowa*,(september,2000),p.2.

7) Add up benefits and costs

8) Perform sensitivity analysis

9) Recommend the alternative with the largest net social benefits

A broader classification is done by Florio (2002). The structure of CBA consists of seven steps:

1) Objectives definition

2) Project identification

3) Feasibility and options analysis

4) Financial analysis

5) Economic analysis

6) Multicriteria analysis

7) Sensitivity and risk analysis

The broadest classification is the Nas's. The stages are as follows:

1) Identification of costs and benefits

2) Measurement of costs and benefits

3) Comparison of costs and benefits streams accruing during the lifetime of the project

4) Project selection

CHAPTER II

2. ECONOMIC CONCEPTS OF CBA

2.1. Consumer Surplus

One of the most critical economic concepts of CBA is the consumer surplus. Consumer surplus is used as a measurement unit of the welfare change of the society from a price change generated by a project. Consumer surplus in other words, is used to determine the "cost savings" of a project. Cost savings refer to the benefits generated by a project which is aimed to reduce the cost of a product. The cost reduction serves as a benefit to society[14].

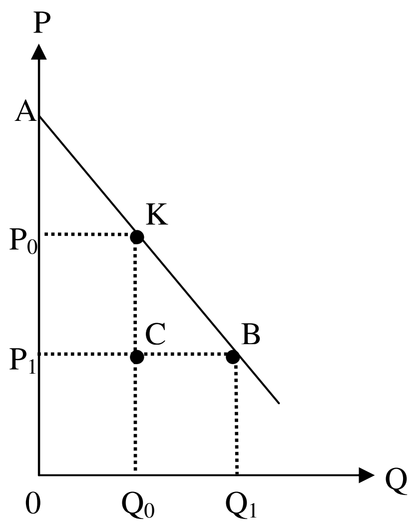

Figure 1 Consumer Surplus

When a new project is implemented and if this implementation reduces the costs of a particular good which will in turn lead a price decrease and an increase in quantity demanded. If the price was P_0 before the project the consumer surplus was the area

[14] E.J.Mishan, Cost-Benefit Analysis; *An Informal Introduction,*London: Gresham Press, 1975,2nd edit,p.27.

AP_0K. After the project, the new consumer surplus becomes the area AP_1 B. The increase in the consumer surplus is the area P_0 KP_1B. This increase can be divided into two parts. The rectangular part P0 KP_1C is the cost-saving component. By multiplying P_0 P_1 (reduced cost) with the initial quantity demanded the cost saving component is derived. The second part is the triangular area CKB which represents the increase in consumer surplus arisen with the additional users of the good (Q_0Q_1).

Consumer surplus is defined by Alfred Marshall (1925) as;" the maximum sum of money a consumer would be willing to pay for a given amount of the good, less the amount he actually pays". This definition is valid for the market demand curve derived under the ceteris paribus condition. The ceteris paribus assumption means that, holding other factors that effect the demand of a good constant, deriving the demand curve only as a function of its own price. The other factors that affect the demand of a good are the prices of complementary and substitute goods, technology, income, tastes and preferences.

As the *ordinary* demand curve (Marshallian) reflects both the income and substitution effects, the use of ordinary demand curve can be misleading to obtain the exact measure of welfare change arising from a price change[15]. To obtain a more accurate measure of welfare change the *compensated* (Hicksian) demand curve is preferred. Holding real income constant, the compensated demand curve reflects only the substitution effect of a price change. The assumption of the constant real income is important because if the money income is held constant instead of real income, a fall in the price of a good will result an increase in real income and if the

[15] Nas,p.69

income effect is positive this will lead to an increase in the demand of the good, thus the assumption of the consumer surplus is derived from compensated demand curve will be violated as the demand curve reflects both income and substitution effects[16].

2.2. Producer Surplus

Producer surplus is the difference between the actual price and the amount of the good that the supplier is willing to accept to provide that good. If the supply curve is drawn for a specific factor of production it then represents the opportunity cost of employing one more unit of the factor. If this is the case, the producer surplus can be renamed as "economic rent"[17].

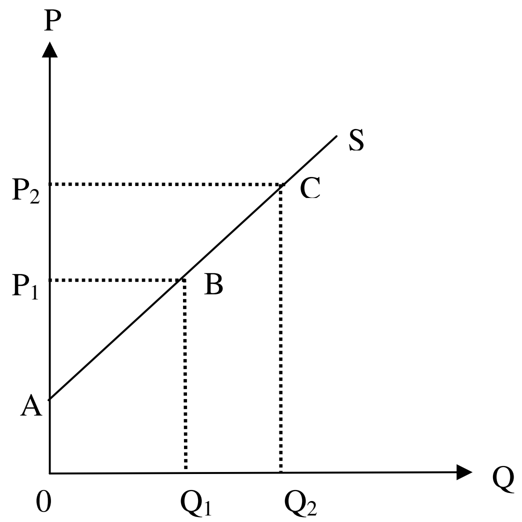

Figure 2 Producer Surplus

This is an ordinary supply curve under the assumption of increasing marginal cost and every point on the curve represents the MC = P points corresponding to each output level. To consider the figure, the initial price which is equal to marginal cost

[16] Mishan,p.30
[17] Nas, p.76

at Q_1 output level is P_1 and at that price, supplier gains the sum of respective marginal costs up to $Q_{1.}$ This is represented by the area P_1AB which is called producer surplus. When the price rises to P_2 this leads to an increase in production until the new price will be equal to marginal cost at the new quantity level $Q_{2.}$ In this case, the increase in producer surplus is the area of P2CB $P_{1.}$

If producer surplus is estimated as the economic rent of factors, these rents can always be included into the analysis as benefits. But this measure of a rent of factors used in a project should be distinguished from the rents derived from a firm's or industry supply curves[18].

2.3. Compensating and Equivalent Variation

Compensating and equivalent variation are used as the measurement units of the welfare change resulting from the price change after the application of a project. The broadest definition of Compensating Variation (CV) is given by Mishan as the measure of money transfer to keep the individual at the initial utility level after a price change created by the implication of any project or policy. Another definition which is narrower but more commonly used can be stated as: one's willingness to pay for a price decrease to maintain the preprice total utility level[19]. If there is a price increase which means a welfare reduction, CV is the minimum amount of money that an individual is willing to accept to not to be worse off.

The other measure, Equivalent Variation (EV) is defined as the minimum amount of money that an individual is willing to accept to be compensated for a price reduction

[18] Mishan, p.60.
[19] Nas, p.70.

or the maximum amount that an individual is willing to pay to be given up the price increases and remains at the post-price change income level[20].

The difference between CV and EV can simply be stated as; CV is measured at new prices and original utility level while EV is measured at initial prices and new utility level. CV and EV are also the measures of one's willingness to pay (WTP) or willingness to accept (WTA) for a change[21]. To summarize the differences and circumstances at which EV and CV are appropriate measures to be used, the following scheme can be helpful:

Table 1 Summary of EV and CV measures

Results of the project		
Welfare gain	CV(WTP)	EV(WTA)
Welfare loss	CV(WTA)	EV(WTP)

Before continuing with the discussion of which measure is more appropriate, an important point should be emphasized. The point is selection of the demand curve which can give the exact value of CV or EV. Although it is accepted with a great consensus among the analysts that the Hicksian demand curve gives the exact value of CV for price changes and true WTP of an individual to avoid the change, as it reflects only substitution effect, in practice Marshallian demand curve is more commonly used because of its availability[22]. Although it is used more commonly, the Marshallian demand curve is misleading because it reflects both substitution and

[20] Nas, p.71
[21] Panayatou, p.7
[22] Panayatou, p.8

income effects thus it overestimates WTP for price decline and underestimates it for a price increase.

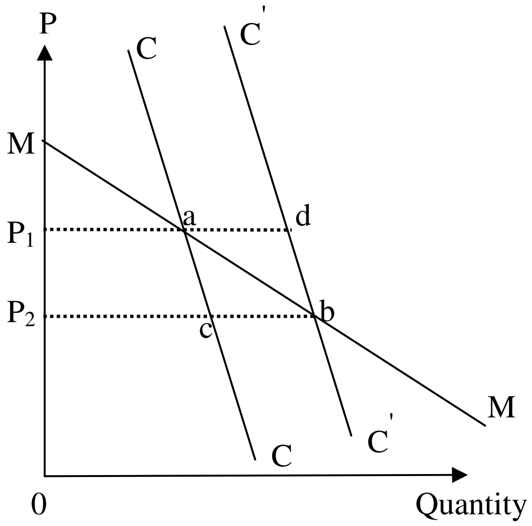

Figure 3 Marshallian and Hicksian Demand Curves

In this figure, while MM is representing a Marshallian demand curve, CC and C' C' represent the Hicksian demand curves. When there is a decrease in price (from P_1 to P_2) the area P_1abP_2 reflects the change in price and income. Thus the accuracy of using compensated demand curve in order to measure the welfare change of a price change can be seen more clearly. When there is a decrease in price, the area under the compensated demand curve P_1acP_2 represents CV and P_1dbP_2 represents the EV and when there is an increase in price, the CV and EV becomes just the opposite[23].

The most crucial question is which measure should be used. There are various views for the choice of the right measure but almost none of them recommend any of the measures as superior to other. Varian (1992) suggests CV if the desired measure of compensation is more applicable at new prices. But he suggests EV as a reasonable WTP measure for the reasons stated by him as ; the welfare is measured at original

[23] Nas,p.70

prices thus it becomes easier to compare the values at current prices and the other reason is that as the original prices are held constant EV is more suitable for the comparison of the projects. As well, Freeman suggests EV as a more appropriate measure than CV because for numerous project proposals CV submits different rankings while EV provides same rankings for different proposals[24].

[24] Nas, p.72

CHAPTER III

3. IDENTIFICATION AND MEASUREMENT OF COSTS AND BENEFITS

3.1. IDENTIFICATION OF COSTS AND BENEFITS OF A PROJECT

Identification of costs and benefits of a project is another crucial part of CBA. The difficulty arises mostly in the decision of which costs or benefits should be included or not to be included in the analysis. There are various classifications made by the researchers but the most generally used distinction in the identification of costs and benefits can be summarized as; "real vs. pecuniary", "direct vs. indirect", "inside vs. outside" effects generated by the project.

Most commonly the costs and benefits are classified as follows:

Direct vs. Indirect Effects: Direct costs arise as the investment take place and these costs are born by the investors of the project. As well, direct benefits affect the consumers of the output of the project. Indirect costs and benefits which can be stated rather as externalities are the effects of the project outcome on the secondary parts. These effects are which the users do not pay for.

Real vs. Pecuniary Effects: Real costs and benefits can also be stated as technological effects of the project. While real costs have negative effect on social welfare, real benefits increases the social welfare as a result of a change in production possibilities. Contrary to real costs and benefits, pecuniary costs and benefits have no effect on social welfare they only indicate distributional effects thus the pecuniary effects that are only the price changes in relative markets should not be included in the analysis in order to avoid double counting.

Inside vs. Outside Effects: Another important point of estimating costs and benefits is to define the target area of the project clearly. As the projects have external effects, the boundaries of the project target's importance can be understood more clearly. Outside effects represents the externalities occur out of the project's boundary but as they are the results of the project involving them in the analysis will have significant effect depending on the size of the effects. Thus, inclusion or omission of the spillovers arising from the project depends on the identification of the project's target area definitely.

The costs and benefits are most commonly classified as summarized above. Besides these definitions and in addition to that Nas makes a more complex and comprehensive classification of costs and benefits of a project. The distinguishing parts of Nas's classification are explained as below:

Real Direct Effects: The increased real outcome is the expected "real direct benefits" of the project. The real direct benefits and costs can be depicted by using the consumer surplus measure.

External effects are divided in two parts either of them should be clearly defined and should not be confused in order to make a robust analysis.

Technical (Real) External Effects: Technical external effects are those which create a change in the production possibilities of the society and have an effect on social welfare. The difference between real direct effects and real external effects can be stated as; real external effects are the costs and benefits affecting the third parties while real direct effects are the costs and benefits that are born by the consumers or the suppliers of the project outcome. The technical externalities should be included in the analysis if they have not been initialized by the price mechanism. If these external effects are not included in the analysis this will cause the underestimation of costs and benefits in the cases of external costs or external benefits.

Pecuniary External Effects: Pecuniary effects are relative price changes in commodity or factor markets. These effects are only redistributive thus they should not be included in the analysis but they should clearly be defined and their importance should be mentioned by the analyst in order to avoid double counting. These effects can be explained as; a price change occurring in the market of the substitute or complementary of the inputs used in the project. In a competitive environment these price changes in secondary markets will omit each other so as a total there will be no change in social welfare.

3.2. MEASUREMENT OF COSTS AND BENEFITS

3.2.1. VALUATION OF MARKETED INPUTS

3.2.1.1.Shadow Prices

Shadow prices are used instead of market prices whenever the analysts realize that the market prices are inappropriate to reflect the real (social) value of costs and benefits. As well, shadow prices are needed to be derived for the non-priced goods and externalities, time savings, value of life, etc. Shadow prices can also be stated as the assumed real market value of goods when the markets are distorted thus perfectly competitive market conditions are no longer valid. Nas considers three circumstances which make the valuation of costs and benefits difficult thus need for shadow pricing arise. These conditions are[25];

- the non-existence of price of some goods, namely; public goods,
- distorted prices because of market failures or government intervention
- the significant effect of project on demand or supply of goods even the prices were non-distorted.

For analytical purposes, market conditions are determined as first-best or second-best environment. Before continuing with the derivation of shadow prices and for which goods it must be applied, market structures will be mentioned to state the theoretical background.

3.2.1.1.1. First-Best Environment

The first best environment can basically be defined as the economy where there are no market imperfections. The assumptions of the first best environment which is fundamentally connected with the perfect market conditions are shortly stated as below[26];

- perfectly informed individuals about all possible allocation options
- clearly defined property rights
- perfectly competitive market conditions consistently designed institutions

The first best environment is the highest possible point attainable on the social utility frontier which is representing all Pareto optimal allocation points. As long as

[25] Nas, p.91
[26] Nas, p.92

government interventions are non-distortionary, first best environment conditions would prevail.

Market prices can be used adequately for the evaluation of a new project as they represent the Pareto optimal resource allocation values in the first best environment.

When the projects have non-marginal effects on prices market prices are no longer appropriate even in the first best environment. Non-marginal project effects can be defined as the increase in demand of a project input which leads a decrease in the consumption of it by private sector. This effect would result in a price change, thus the true social cost (new price) can be derived by taking the average of the changes both in supply and demand sides[27].

3.2.1.1.2. Second-Best Environment

When there are market imperfections because of distortionary policies, market prices can no longer be used as appropriate measures to reflect the real social costs or benefits. In these circumstances, for the reliability of the analysis shadow or adjusted prices should be derived and the source of distortions with their effects on efficiency of resource allocation should clearly be defined.

Some of the main sources of distortions can be stated in a broad sense as follows. One of the important distortions arises due to market imperfections. Imperfection of the market condition can be the result of scale economies which causes the market price to be above the marginal cost due to market power. Another source of

[27] Nas, p.93

distortion is the any kind of externality created by the use of a commodity and when these externalities are not initialized in prices this will cause a gap between marginal social costs and benefits. The third one is the asymmetric information between market agents. The last one is the government policies such as taxes, subsidies etc. which have distortinary effects on markets[28].

One of the most encountered distortions is the taxes imposed on any good. For that reason an example of shadow price derivation in the case of distortionary tax will be enlightening.

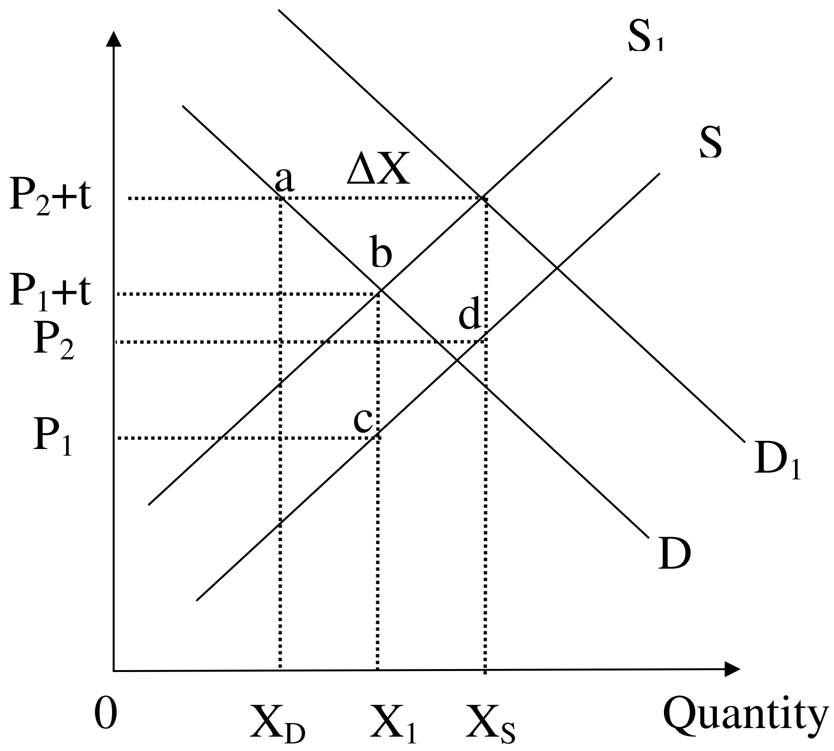

Figure 4 Derivation of Shadow Price (taxation case)

In this figure, P_1 and P_2 represent production prices (P_P), P_1 + t and P_2 + t represent the consumption prices (Pc). When a new project is implemented this will cause an

[28] Robin Boadway, "Principles of Cost-Benefit Analysis", *Public Policy Review*, Vol.2, No.1(2006),p.8

increase in the demand of the good and as the demand increases, the price (tax-inclusive) of the good will increase. The increase in the demand of good ΔX comes from the increase in supply ΔS and reduced demand ΔD elsewhere in the economy. To be more clear; when a tax imposed on price of X the price rises from P1 to $P_1 + t$. As the implementation of the project shifts the demand by the required amount of X (ΔX) the price of the good rises to $P_2 + t$ which cause a decrease in quantity demanded by the amount of ΔD which is the reduced consumption. The supply of X rises by the amount of ΔS.

The derivation of shadow price due to these effects is given by the formula below;

$$P^* = P_p.\Delta S / \Delta X + P_C.\Delta D / \Delta X$$

The formula represents the average of producer and consumer prices weighted by the proportion of ΔX.

Shadow prices of some critical inputs will be discussed in the following part.

3.2.1.2.Shadow Wage Rate

Theoretically market wage rate represents the cost of labor if employed in perfectly competitive market. In reality, labor markets are most oftenly distorted by taxes, unemployment and wage rigidities. In the light of this, shadow wage rate should be derived in order to find the true social cost of labor needed by proposed projects.

In the case of taxation as the only source of distortion, shadow wage rate can be calculated by taking the weighted average of before-tax wage rate and after-tax wage rate[29]. The weights are the ratio of number of workers withdrawn from elsewhere in the economy to the number of workers entered to the labor force.

Another and more complicated case is the existence of involuntary unemployment in the labor market as a source of distortion. In this case, workers needed by the project can be provided from three sources; some of the workers can be withdrawn from other parts of the economy, some of them entered to the workforce from voluntary unemployed and others which are involuntarily unemployed. The shadow wage rate is derived as the weighted average of opportunity cost of each which is represented by the formula below;

$$W^* = W_D.\Delta E / \Delta L + W_S.\Delta U / \Delta L$$

The opportunity cost of involuntary unemployed can be smaller than after-tax wage rate but be greater than the value of leisure as they presumably ready to work at the current wage rate but are not able to find a job[30]. The involuntary unemployment means that there are number of people who are willing to work but cannot find jobs therefore labor markets suffer excess supply of labor. If the competitive market conditions existed equilibrium wage rate would fall until it eliminates excess supply. But as the labor market is distortioned, the mechanism does not work in this way. Another one of the distortion is the unions which do not allow workers to take a job under a wage rate which is determined above market clearing rate.

[29] Boadway, p.19
[30]Boadway, p.20

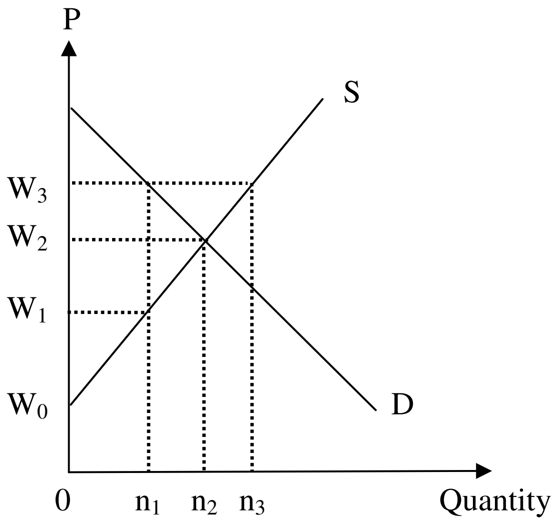

Figure 5 Shadow Wage Rate

If the wages are fixed at W_3 there will be an excess supply of workers $n_3 - n_1$. This situation is a basic example of involuntary unemployment where there are number of workers willing to work and the number jobs is not enough. The optimal shadow price of labor can be derived by assuming a situation; if n_1 workers were demanded they would accept to work at W_1 and an efficient allocation of jobs would be able[31].

3.2.1.3.Shadow Exchange Rate

When a project's input is an imported good, this leads an increase in demand for that good as well it will increase the demand for foreign currency in order to purchase that good. Under the assumption of fixed world price foreign exchange instead of commodity itself can be taken as a good and the exchange rate as the price of it. In competitive market conditions or at floating exchange rate regime the value of foreign exchange is determined at the equilibrium point of demand and supply of foreign currency. But in reality and especially for the developing countries the foreign exchange markets are distorted by tariffs, quotas, exchange rate controls.

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[31] Robert Sugden and Alan Williams, *The Principles of Practical Cost-Benefit Analysis,*Britain:Oxford University Press,1978, p.103

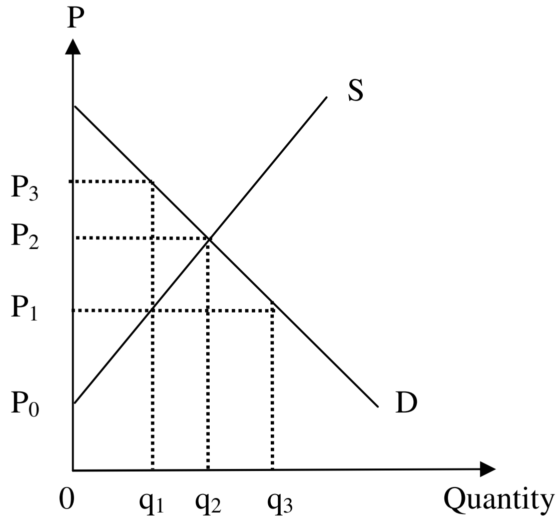

Figure 6 Shadow Exchange Rate

In the competitive market conditions price of a foreign currency or the exchange rate would be P_2 where the demand and supply of foreign exchange intersects. But sometimes government (especially of poorer countries) sets an exchange rate below the market exchange rate. This means the overvaluation of domestic currency. When the domestic currency is overvalued by the exchange rate restriction the shadow exchange rate should be used. The question that arises here is what will be the shadow exchange rate? From one point of view; willingness to pay criteria, when the exchange rate is fixed below market exchange rate (P_1) quantity of foreign exchange available is q_1 whereas quantity demanded is q_3. In this case there are number of consumers which are willing to pay P_3 for q_1. Therefore, the efficient allocation of foreign exchange would prevail at P_3 which can be used as shadow price[32].

When the distortion is a tariff imposed on imports the shadow exchange can alternatively be derived by weighted average of imports and exports.

32 Sugden and Williams, p.100.

$$S_e = e\frac{\Delta S}{\Delta Y_e} - (1+t)e\frac{\Delta D}{\Delta Y_e}$$

When a common tariff (t) is imposed on imports, the domestic price of imports will be (1+t)e. To derive the shadow exchange rate(S_e) as the above formula import and export prices are weighted by the ratio of imports (ΔD) (demand for foreign currency) and exports (ΔS) (supply of foreign currency) to the net demand for foreign currency(ΔY_e).

When the foreign exchange is taken as a single commodity, the above suggestions of shadow exchange rate are valid. But when the analysis is preferred to be made with commodity prices, the process of shadow pricing differs as it can be expected

If the domestic markets are distorted with tariffs or any kind of exchange restriction, world price of the imported goods can be taken as an appropriate shadow price which reflects the true opportunity cost of these inputs. The rationale of taking world price is explained by Mishan with the facts that; everything produced and consumed domestically has an effect on balance of payments and because of substitution possibilities any good can be compared with foreign exchange, in addition, world prices reflects the real cost or benefit to a country in terms of foreign exchange[33].

[33] Mishan, p.85

3.2.2. NON-MARKET VALUATION

3.2.2.1. Value of Life

One of the most difficult and disputatious issues in project analysis is to put a value on human life in order to monetize the benefits and costs generated by the project.

At first, it should be emphasized that valuing life is morally problematic. Besides, technically there are various methods that have been argued so far in the economic literature. In the Paretian point of view, which is suggested by Mishan; the value of a person's life can be computed by summing the minimum compensation value of increased probability of death. An alternative to that measure is to take the maximum sum of money that a person is willing to pay to prevent from death[34]. As the derivation of a single value for 'prevented death' is quite impossible, some other social objectives have been set by the economists. One of them is to take the present value of expected future earnings of an individual as the value of prevented death[35]. The social objective of this measure is to maximize GNP. Another one is to measure the value of life of an individual as the financial loss that would be imposed on others if he died.

For practical purposes with the identification of statistical lives saved by safety improvements, willingness to pay for additional safety measures can be adopted. This method is more commonly used in real-world applications. Willingness to pay

[34] Mishan, p.309
[35] Sugden and Williams, p.173

measures can be obtained by revealed preference and questionnaire methods incorporately[36].

3.2.2.2.Value of Time

When the market environment is ensuring competitive market conditions, hourly wage rates can be used as an appropriate measure for value of time as it reflects the choice of workers between an additional hour of work and leisure. But when the market conditions are not perfectly competitive, in other words in a second-best environment, market wages can no longer be used as an appropriate measure for value of time. Instead, shadow wage rate should be preferred. Another problem is the heterogeneity of time which means that an individual may value the time differently at different times in a workday, as well time values can differ for each person. Considering these limitations, an estimate for the value of time suggested by Nas as the valuing time saved at work by gross tax wage rate and valuing time saved for leisure by net of tax wage rate[37].

Value of time measurement is consequential especially for the transport project appraisals because almost every transport project is designed to reduce travel time or to provide more comfortable travel conditions. In this aspect, compensating variation can be taken as the maximum sum of each individual's willingness to pay to save that amount of time for the time-saving projects[38]. The appropriate measure suggested by Mishan is marginal social product of labor if the saved time were to be used for additional output. But the limitation to that suggestion is the unavailability

[36] Nas, p.108
[37] Nas, p. 110
[38] Mishan, p. 273

of the information whether this saved time will be used in production or consumption.

In general, it is implicitly assumed that traveling activity produces disutility for the traveler but this assumption can be inconvenient as the value of journey time can vary. Thus, for the evaluation of the value of reduction of travel time, the sort of travel and the alternatives available for the travelers must be noticed[39]

[39] Mishan, p.277

CHAPTER IV

4. INVESTMENT CRITERIA AND PROJECT SELECTION

In literature and practice three decision rules; net present value, internal rate of return and benefit/cost ratio are used widely in project selection. The main point of the decision is the comparison of cost and benefit streams in a time dimension. The decision depends upon whether the benefits generated by the project exceed the costs. The most important point in the evaluation of the costs and benefits in a time dimension is the choice of an appropriate discount rate which will be discussed in detail in the following parts.

4.1. Net Present Value

Net present value (NPV) is the most widely used method as a decision rule of project selection. NPV is the difference between the present values of benefits and costs. NPV can be calculated in two ways as; taking the difference of total of the present values of costs and benefits which are discounted separately or discounting the net benefits to find the present value. For the chosen period, the project with the highest net present value can be selected as the most beneficiary one. Or if the analysis is done only for one project, the project is worthwhile as the NPV is positive for the chosen discount rate. The most important issue here is the choice of the right discount or interest rate which is commonly chosen as the social time preference rate. The general formula is given as below:

$$NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+i)^n}$$

4.2. Benefit-Cost Ratios

The benefit cost ratio can be derived by two ways; one is to calculate present value of benefits over the present value of costs (including investment and annual operating costs) or the present value of net benefits over investment costs. The project should be selected if the B/C is greater than 1.

$$B/C = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+i)^n}}{\sum_{t=0}^{n} \frac{C_t}{(1+i)^n}}$$

Yet another B/C measure can be stated as net benefit/cost ratio which is the ratio of NPV over the present value of costs. In this case the project with B/C greater than one should be selected.

4.3. Internal Rate of Return

Internal rate of return is the discount rate which equates NPV to zero. When this method is used the project is chosen if the IRR exceeds the market interest rate or any other discount rate selected as a social discount rate. To calculate IRR, the following equation is solved for IRR.

$$NPV = 0 = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+IRR)^n}$$

4.4. The Choice of Discount Rate

The choice of an appropriate discount rate is an important and the most argued part of CBA. For the determination of social discount rate there have been various issues debated in economic literature which are; the market interest rate, government borrowing rate, social opportunity cost rate and social time preference rate.

Under the assumption of perfectly competitive capital markets and if there are no externalities arisen from household saving and when the value of consumption is taken as numeraire, market interest rate can be used as an appropriate discount rate. Under these conditions when there are taxes on capital income after tax returns to savings can be used as the consumption discount rate[40].

Social opportunity cost rate assumes that as the capital funds are scarce an investment in public sector would withdraw resources (funds) that would be placed in private sector investments. Therefore, appropriate rate of interest should be the one which reflects the opportunity cost of capital. For that, two methods have been established to determine the SOCR; i) rate of return on a comparable project in private sector, ii) the reciprocal of capital output ratio[41].

Social time preference rate is the investment decisions taken in order to increase future consumption thus a sacrificed present consumption. As the markets are distorted (second best environment) decision of which rate to be used becomes complicated as the market interest rate(r), consumption rate of interest (q) and rate of return to investment (i) diverges. To overcome this complexity some methods have been developed.

[40] Boadway, p.29
[41] Erhun Kula, "The Social Discount Rate in Cost-Benefit Analysis: The British Experience and Lessons To Be Learned", *Milan European Economy Workshops Working Paper*, (2006), p.2

One of these methods is the weighted average approach. When some proportion of loanable funds are withdrawn from increased savings and some from reduced investment elsewhere in the economy, additionally where a tax on funds is assumed, a shadow discount rate is derived with weighted average approach[42].

$$r^* = i(\Delta D / \Delta I) + q(\Delta S / \Delta I)$$

In this formula, r^* is the shadow discount rate whereas ΔD is the reduced investment, ΔS is the increased savings and ΔI is the amount of capital required by the new project.

Another method is the shadow price of capital approach in which the rate of time preference and investment rate of return are combined in a different way than weighted average approach. In this approach all future costs and benefits are converted into consumption measures then discounted at the rate of time preference. The conversion function (v) is the ratio of i/p where p represents the time preference rate. Public costs are the future stream of consumption which would be expected from private investment.

$$NPV = -C.V + B / p \Rightarrow -c(i / p) + B / p$$

[42] Nas, p.137

CHAPTER V

5. APPLICATION OF CBA TO TRANSPORT PROJECTS

5.1. Literature Review

Cost benefit analysis is the most widely used appraisal technique by public authorities. The method is especially used for infrastructure and transport projects. Transport infrastructure can be regarded as 'public goods' because of the high fixed costs which are not beneficial for public investors. The main rationale that lies beneath the use of CBA is that it gives opportunity of ranking numerous projects that will be selected to be undertaken. As the CBA is conducted for almost every infrastructure project especially for transport projects, some specific examples of transport project evaluation will be given throughout the section. Although the literature is very wide and it can be seen as limited the purpose is giving a broad idea of how CBA is used and to enlighten how can the measures can vary.

The aim of public sector is to maximize social welfare instead of profit maximization as private sector, thus CBA is a preferred method because it takes into consideration the social costs and benefits which are the subjects of public investor units.

Despite its some weaknesses the advantage of CBA is that its ability of monetizing all impacts (although some effects cannot be monetized CBA also mentions about their significance) so projects can be ranked on a standard measure.

The use of CBA as an appraisal technique for transport projects had been risen in late 1960's and early 1970's. Although practical use of CBA has its roots from USA, it is required by EU for the funding of the projects in the enlargement process. In the enlargement process new regulations are made by EU commission, to provide efficiency for the development in the light of regional policy objectives. The objective of regional policy of EU is the convergence of regions and it will be provided by Structural Funds, Cohesion Fund and ISPA. For that purposes to evaluate the proposed projects objectively some standards have been generated which must be met by project proposers. In that sense, CBA is required for the projects with budgets more than 50, 10, 5 million Euros. In the work of Florio & Vignetti (2003) 240 projects (2/3 of them are environmental and remaining is the transportation projects) have been analyzed by means of ISPA co-financing rates and determinants of CBA as financial rate of return (FRR) and economic rate of return (ERR). One of the foundations of the paper which are crucial measures for project appraisal of EU commission is that expected financial returns vary in a wide range before and after EU grant as well as the variability of co-financing rates amongst countries. The benchmarks have been found out as; for FRR / C as – 2.5 on average which is a measure for financial sustainability. Another benchmark is FRR / K as around %7 on average with high standard deviation. And the relevant benchmark ERR which considers the externalities and shadow prices a positive ERR is expected and it's argued that ERR < %5 should be considered low priority by commission services.[43]

An example of CBA for tunnel construction is the work of Proost(2005) in which proposal of constructing a new tunnel alternative to the existing one in Antwerp under Sheldt River in order to reduce congestion. The expected cost of tunnel is more

[43] Massimo Florio and Silvia Vignetti, "Cost-Benefit Analysis Of Infrastructure Projects İn An Enlarged European Union: An İncentive-Oriented Approach", (May,2003)

than € 1 billion. For the analysis three alternative tolling schemes comparing to do-nothing alternative have been conducted. With the % 5 discount rate and 20 years time horizon it is concluded that the tunnel is worthwhile[44].

Another example of CBA for transportation projects is the work of Murty which implements CBA for Delphi Metro Project which consist of two parts costing totally 144320 million Rs. Two kinds of approaches have been used for economic analysis one of which assuming a sub-optimal level of saving which leads social time preference rate to be lower than the rate of return on investment and a social premium on investment. The other one assumes optimal saving level and non-distorted capital markets therefore rate of return on investment can be taken same as the social time preference rate. Regarding these approaches IRR has founded % 23.86 and % 23.88 respectively. And with discount rates % 8 and % 10 NPV's are 43238.5 and 232050.7 millions[45].

Although literature on CBA in Turkey is not wide enough there are a few examples for transport projects which should be mentioned here and also guided for the analysis part.

One of these studies is the publication of Çakır's (1999) in which a comparison of Kınalı-Sakarya toll way and E-80 state road made by using CBA which includes social and private costs and benefits. In this work, treasury bond annual interest rate of % 73.88 had been used as a discount rate and NPV was found a positive value.

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[44] S.Proost, S. Van der Loo, A.de Palma and R. Lindsey, "A Cost-Benefit Analysis of Tunnel Investment and Tolling Alternatives in Antwerp",*Katholieke University Of Leuven Center For Economic Studies Working Papers*, (September,2005)
[45] M.N Murty,Kishore Kumar Dhavala,Meenakshi Ghosh and Rashmi Singh, "Social Cost-Benefit Analysis of Delphi Metro", *MPRA,*No.1658 (October,2006)

IRR had been founded as % 78.71 and NPV had been calculated for different discount rates up to %80, beyond that rate NPV became negative. It had been concluded that toll way is economically more efficient than E80 state road[46].

Another detailed study is the Özkan's(2000) classical cost benefit analysis and a Simple Multi Attribute Rating Technique (SMART) has been conducted. Here, only Cost benefit analysis's results will be mentioned as they are related. CBA conducted for different highway projects already ongoing by GDH which are important from different aspects. For all projects discount rate have been taken as % 12. Then projects have been ranked according to their benefit/cost ratios which are mentioned as follows. For the first case study in which Afyon- Sandıklı, Mekece- Adapazarı, Gazipaşa- Alanya highway projects analyzed B/C ratios are 1.76, 1.06 and 0.51 respectively. For the second case study in which Balıkesir-Susurluk- Karacabey, Bornova-Turgutlu-Salihli, Yalova- Topçular- Altınova and Samsun- Çorum highway projects analyzed and B/C ratios are 2.2, 2.16, 1.38 and 1.36 respectively. After the cost-benefit analysis SMART approach have been applied and it have been concluded that while for the first case study the ranking of the projects remained same, for the second case study the rankings have been changed by incorporating social effects. The rationale for the changes in rankings is that as the range between B/C ratios becomes smaller the inclusion of the social effects causes a difference[47].

From the analysis mentioned above an interesting point seems to be conspicuous that the great difference between ERR (or IRR) and the discount rates used. While for

[46] Tufan Çakır, *Türkiye'de Kamu Ekonomisince Üretilen Karayolları Hizmetlerinde Fayda-Maliyet Analizi Tekniğinin Uygulanabilirliği*, Eskişehir:Anadolu Üniversitesi Yayınları, 1999
[47] Nilhan Özkan (Erdal), "Refinement of Benefit Cost Analysis Results for Highway Projects", (Thesis, METU Department of Civil Engineering,2000)

EU the highest acceptable ERR is between % 8- % 10 for India case % 22-23 becomes acceptable. As well for Turkey the rates are relatively high. In the logic of CBA it is an expected issue of fact for the rates to differentiate amongst countries as the interest rates, inflation rate and other relevant determinants are various. From the view point of developed and developing countries, higher rates are expected for developing countries due to volatility, inflation, higher interest rates, etc.

5.1.1. Critiques and Limitations

Although cost benefit analysis is the most widely used project evaluation method for over 40 years, it is also widely criticized. In this section, limitations and critiques will be discussed especially for the transportation project applications.

The main criticism or the weakness of the technique is the monetization of costs and benefits especially of those which are non-marketed and the externalities created by the project. This argument can also be stated by a more generalized way as the valuation problem. One side of this criticism states that although everything has a value they cannot and should not be monetized. In this aspect, value of life and time attract the attention of analysists. The difficulty in valuing life is discussed in the preceding chapter but the critique mentioned here is beyond the difficulty of valuing it states that there is no statistical life and human life cannot be measured and this method of willingness to pay to avoid the risk of death is paradoxical and confused with the value of risk[48]. The other side of the criticism arises for the decision of where to use the values before or after the project implementation. While the drawback of using the values after project implementation is the overestimation of

[48] Lisa Heinzerling and Frank Ackerman, "Pricing the Priceless: Cost-Benefit Analysis of Enviromental Protection",*Georgetown Enviromental Law and Policy Institute*(2002)

the project effects, using the values before project would underestimate these effects[49].

Referring to monetization critique, measurement of accident cost saving which depends on valuing life and travel time savings which also depends on another controversial issue, valuing time are the most problematic but also indispensable items of transportation projects. For the evaluation of accident cost saving, GDH uses a method which estimates years of productive life lost as the result of accident and adds the direct costs which includes medical care and other related legal services[50]. Although this method seems useful and practical, besides the moral and ethical issues of valuing life, there are problems special to Turkey as the unavailability of direct cost data and the underestimated causality and injury numbers because the victims of the accident are not followed after the accident so it is not known that if the person is died or not. Another problematic issue is the measurement of travel time savings which is on of the most important benefits of transportation improvements. Although GDH provides a basis for calculation of passenger and driver time values for different kinds of vehicles, GDH itself does not include this item into the analysis but recommend that it should be included. The problem here, again for Turkey conditions, is the inconvenience of using average wage rate and unavailability of classification of trips due to purposes as leisure or business[51].

Another mostly criticized issue of cost benefit analysis is valuation of environmental effects. The application of CBA to environmental projects is a wide literature and far beyond the scope of this analysis. But the environmental issues arise as the external

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[49] Panayatou, p.10
[50] Özkan, p. 75
[51] Özkan, p. 76

costs or benefits as expected reduction of pollution is the part of transportation project evaluation. In broadest sense, environmental costs subject to transportation are; air pollution from emissions, global warming and ozone depletion. In most of CBA environmental impacts are hard to be monetized thus, they are evaluated separately and concluded as complementary.

Another main criticism is the uncertainty problem which arises from the two sides of the analysis. First, benefit and cost streams for a given period in future are needed to be estimated and secondly the right discount rate should be chosen to convert these future streams into present values to make them comparable. Although benefit and cost streams are estimated by using some appropriate indicators, the valuation for unknown future conditions leads uncertainty and the analysis can be considered as suffering a great bias.

The last important critique to be mentioned is that the cost benefit analysis does not take into account the distributional effects. As the CBA serves within a partial equilibrium model, it is assumed that the overall surplus is distributed to whom benefits from it but in general equilibrium process, these benefits are distributed to other economic agents[52]. Thus, the partial equilibrium assumption fails to consider the distributional effects, thus a further analysis is needed to be made in general equilibrium framework.

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[52] Emile Quinet, "Transport Cost Benefit Analysis in France: Recent Changes, Progress and Shortcomings", Milan European Economy Workshops Working Paper, (October, 2006),p.13

5.2. Identification of Costs and Benefits of Transport Projects

For the evaluation of transport project analysis the first step is the identification of costs and benefits of the project. Specific costs and benefits of a transport project are determined by the General directorate of highway turkey and by literature are stated as follows.

5.2.1. Costs

Cost items of a transport project are separated as the costs accruing to the project holder and the costs on the users. Main cost items of a transport project are as below:

5.2.1.1.Construction Costs

Construction costs are the largest part of a highway investment. Construction cost can either be named as capital or investment cost. The estimates of the construction cost items are predetermined and in many countries a system is developed in order to standardize the construction of particular highways with the given type of terrain, the volume and the nature of the expected traffic[53] then, by using these standardized values the distribution of the expenditures during construction period is derived. The main construction cost items are; earthwork, pavement, drainage, site preparation and superstructure.

[53] Özkan, p.18

5.2.1.2.Maintenance Cost

Within the lifetime of a highway, some repairments (patches, drain cleaning, reshaping of slopes etc..) and maintenance services should be implemented in order to keep the quality of the highway at the desired level. Maintenance cost consist of three parts; routine maintenance, periodical, extraordinary. Routine maintenance is the maintenance of roads provided annually while the periodical maintenance is conducted at some years defined by GDH that differs for the type of the road. Extraordinary maintenance appears in the cases of snow fighting, flood and landslides.

5.2.2. Benefits

Benefits which are directly related with the transport system are included in the analysis as they can be monetized. The benefits of a highway project are generally arisen in the form cost reduction. The main benefits of a highway project are travel time saving, reduction in vehicle operating cost and accident cost saving.

5.2.2.1.Vehicle Operating Cost

When a new highway is constructed the main benefit expected from this new application is to reduce the vehicle operating cost. Vehicle operating costs are derived separately for different types of vehicles; car, bus, truck, trailer. Costs are calculated due to roughness factor of the current and project roads[54]. Tables of standard operating costs for each type of vehicle are established by GDH for Turkey, as well the official institutions of transport of other countries. The VOC figures of

[54] kgm

GDH are given in Table 2. VOC savings are calculated by multiplying the saving per km with the distance of the improved road and the number of vehicles[55].

Table 2 Vehicle Operating Costs

TYPE OF PAVEMENT	TERRAIN TYPE	AUTOMOBILE	BUS	TRUCK	TRAILER
Asphalt Concrete (R=2)	FLAT ROLLING MOUNTAIN	0.1948 0.1927 0.1935	1.2565 1.3607 1.6171	0.8756 1.0402 1.3547	1.5181 1.7745 2.2792
Old Asphalt Concrete (R=2,5)	FLAT ROLLING MOUNTAIN	0.1987 0.1966 0.1974	1.2770 1.3813 1.6383	0.9137 1.0781 1.3934	1.5660 1.8222 2.3289
New Surface Treatment (R=3)	FLAT ROLLING MOUNTAIN	0.2029 0.2008 0.2015	1.2982 1.4026 1.6602	0.9513 1.1155 1.4316	1.6136 1.8696 2.3783
Old Surface Treatment (R=3.5)	FLAT ROLLING MOUNTAIN	0.2073 0.2052 0.2059	1.3201 1.4248 1.6829	0.9883 1.1525 1.4694	1.6609 1.9169 2.4273
Old Surface Treatment (R=4)	FLAT ROLLING MOUNTAIN	0.2120 0.2099 0.2106	1.3428 1.4479 1.7064	1.0248 1.1893 1.5068	1.7082 1.9642 2.4762
Stabilized Under Well Conditions (R=5)	FLAT ROLLING MOUNTAIN	0.2235 0.2219 0.2252	1.4057 1.5208 1.7805	1.0961 1.2677 1.5852	1.8362 2.0828 2.5937
Stabilized Under Bad Conditions (R=10)	FLAT ROLLING MOUNTAIN	0.3020 0.3003 0.3028	1.7116 1.8268 2.0866	1.4517 1.6246 1.9465	2.3193 2.5433 3.0732

5.2.2.2.Travel Time Saving

Travel time saving is the major benefit generated by highway improvements. The savings can be stated as the difference of travel time between project and alternative road. The estimation of travel time saving depends on the vehicle-hours traveled including the driver and passenger time values for different types of vehicles[56]. Even though travel time saving is an important part of the benefits of a highway improvement because of the difficulties and shortcomings of the estimation of value

[55] Özkan, p.41
[56] Benefit Cost Analysis for Transportation Projects, Mn/DOT Benefit cost Analysis Guidance, June 2005, http://www.oim.dot.state.mn.us/EASS/

of time which have been discussed on previous chapter, some analysts prefer to exclude the travel time saving from the analysis. With keeping in mind these shortcomings, as a major benefit, time saving should be included in the analysis with a proper estimation method. For that purpose a standard value of time measure is estimated by GDH for passengers and drivers of different kind of vehicles. By the help of this standard value a general estimation can be conducted.

5.2.2.3.Accident Cost Saving

Another important benefit of a highway improvement is the expected reduction of the accidents. As the highway standards are improved statistics show that roads become safer. Although calculation of value of life or the costs of rehabilitation are controversial some common measures can be given to evaluate the benefits due to decline in the accidents.

5.3. Bolu Mountain Tunnel

Bolu Mountain Tunnel is located on the motorway which starts from Ankara stretches up through Istanbul to Kapıkule Border Gate. The (Gerede-Ankara) Junction–Istanbul–Kapıkule Motorway is also designated as a road numbered as E 80. Bolu Mountain passage is in the mountainous area where severe winter conditions prevail, constitutes 25,5 km motorway and 1,6 km link road. The motorway has been designed as 2x3 lanes and link road has been designed as 2x2 lanes and the project consist of earthwork, tunnel, and some superstructure works. Bolu Mountain passage starts from Kaynaşlı which locates at the 30th km of Gümüşova-Gerede highway, passing Bolu mountain with a tunnel ends at the Yumrukaya. This road project includes 2871 meter long two tubbed tunnels, 4644 meter long four viaducts, 917 meter long three bridges, 76 meter crossover bridge and 682 meter long twelve underpass bridges.

After the earthquake in 1999 the tunnel was affected and damaged, this obliged to a change the itinerary of the project. The total length of the tunnel is about 2954 m. The project is completed in 2006 and opened to the traffic.

Project had been financed by equity capital and external loans. The total estimated cost of the project is 686 267 689 $.

5.3.1. Evaluation of the Bolu Mountain Tunnel Project

Bolu Mountain Tunnel has been constructed for about seventeen years and cost of the tunnel is relatively high considering the other highway projects implemented in Turkey. Bolu Mountain Passage is an important link between Istanbul and Ankara. The rationale for a tunnel construction is to provide safer transport conditions than the current passage of Bolu Mountain (D100 highway). Bolu Mountain passage had been the most dangerous part because of hard winter conditions. Heavy snow and dense fog during the winter time lessens the safety of the road. For these reasons a tunnel construction seemed to be an efficient way of improving the road safety and time saving. As the tunnel construction had not finished at the deadline planned by the earliest project appraisal the necessity of tunnel construction became controversial among the society as it requires high investment costs which are withdrawn from other resources of the economy.

Although Bolu Mountain Tunnel had finished and opened to the use the project itself is gripping to conduct a cost benefit analysis. The analysis is therefore an ex-post analysis as the project had been implemented thus it investigates the future benefit streams expected to be generated and the internal rate of return has been used as the criteria to conclude if the project worth to be implemented. As an alternative and a base-case D100 highway Bolu Mountain Passage part has been used. For the comparison and to check the consistency of the IRR result net present value has been calculated for the discount rate of % 12 which is a proposed rate by DPT for infrastructure projects.

The computation of costs and benefits of the project are stated in the section below.

5.3.1.1.Construction Costs

Construction cost items consist of the earthwork, superstructure, major and minor artworks. The data has been derived from the GDH progress certificate of January 2006. Cost data includes the payments made to the contracting firm during the project implementation period starting from the contract date of 1987 to January 2006. Payments are made annually through 1987 to 1994 and the last payment is made on 2006. The data is used in the analysis after subtracting the VAT payments since the tax items are excluded in benefit and cost analyses. Then for consistency, dollar values of cost items are converted to TYR by using the annual exchange rate values gathered from CBTR. Construction costs due to years are given in Table 3.

Table 3 Investment Costs of Bolu Mountain Tunnel

YEARS	PAYMENTS (USD)	EXCHANGE RATE (USD/TRY)	COSTS (TRY)
1987	$1,369,072	0.00086	1177.40
1988	$2,342,686	0.00143	3350.04
1989	$2,650,140	0.00212	5618.30
1990	$1,321,241	0.00261	3448.44
1991	$1,395,226	0.00418	5832.04
1992	$427,919	0.00687	2939.80
1993	$517,376	0.01104	5711.83
1994	$185,070	0.02979	5513.24
2006	-$2,648,362	1.4311	-3790097.34

5.3.1.2.Maintenance Costs

Maintenance costs are the costs that accrue during the lifetime of the highway. This cost item is derived from GDH web site. These cost items are assumed to be constant over years. Since the data gathered from GDH is the maintenance cost for one kilometer of highway, the calculation process of this cost item includes multiplication of the length of the project road (27.2 km) with the maintenance cost per kilometer. The same calculation is also made for the D100 highway section.

As the maintenance costs gathered from GDH includes toll collection costs for the newly constructed Anadolu Otoyolu (Anatolian Highway), which the Bolu Mountain Tunnel is one of its sections, revenues received from toll payments, which are included in the analyses, is a cost reducing item.

Derivation of the maintenance costs are given in the below table, in which project 1 is the D100 highway as an alternative and project 2 represents the Bolu Tunnel.

Table 4 Maintenance Costs of Bolu Mountain Tunnel

Years	Project 1 (TRY)	Project 2 (TRY)	Toll Payments (TRY)	Total (TRY)
2006	391,440	2,071,280	318,157.60	-1,361,682.40
2007	391,440	2,071,280	337,247.06	-1,342,592.94
2008	391,440	2,071,280	357,481.88	-1,322,358.12
2009	391,440	2,071,280	378,930.79	-1,300,909.21
2010	391,440	2,071,280	401,666.64	-1,278,173.36
2011	391,440	2,071,280	425,766.64	-1,254,073.36
2012	391,440	2,071,280	451,312.64	-1,228,527.36
2013	391,440	2,071,280	478,391.39	-1,201,448.61
2014	391,440	2,071,280	507,094.88	-1,172,745.12
2015	391,440	2,071,280	537,520.57	-1,142,319.43
2016	391,440	2,071,280	569,771.81	-1,110,068.19
2017	391,440	2,071,280	603,958.11	-1,075,881.89
2018	391,440	2,071,280	640,195.60	-1,039,644.40
2019	391,440	2,071,280	678,607.34	-1,001,232.66
2020	391,440	2,071,280	719,323.78	-960,516.22
2021	391,440	2,071,280	762,483.20	-917,356.80
2022	391,440	2,071,280	808,232.20	-871,607.80
2023	391,440	2,071,280	856,726.13	-823,113.87
2024	391,440	2,071,280	908,129.69	-771,710.31
2025	391,440	2,071,280	962,617.48	-717,222.52
2026	391,440	2,071,280	1,020,374.52	-659,465.48

5.3.1.3.Accident Cost Savings

One of the most important benefits of highway improvement is the expected reduction in the number of accidents. In the Bolu Mountain Passage case, this expectation plays a more important role since this part of the road has suffered from high number of accidents until the tunnel started to operate. The main causes of the accidents were the bad weather conditions especially in winter, the structure of the mountain road which has lots of hairpin bends and the congested traffic as a result of being the main stream road between Ankara and Istanbul.

Accident cost saving valuation is crucial because it is hard to express the costs of personal injuries or death in monetary terms. According to an approach in the literature relating to the evaluation of accident costs, a monetary value cannot and also should not be attached for a human's life. According to this approach, the number of personal injuries and death should be assessed and evaluated as a separate evaluation criterion. But in this thesis, the evaluation of personal injuries and death is included in the accident cost savings item in monetary terms. To express these items in monetary terms the "loss of production" approach is used.

To calculate the loss of production, minimum wage is taken as the base rate. In case of fatalities, the loss of production is accepted as 35 years. In case of injuries, it is assumed that of all injured people, % 40 for 1 month, % 30 for 3 months, % 20 for 6 months and the rest during 35 years cannot do their work[57]

In Turkey, accident direct cost information is unavailable therefore this item is excluded in some analysis while computing accident costs. Also accident victims are not followed after the accident, therefore accident cost values of Turkey are very low compared to developed countries which cause the underestimation of accident costs.

As the accident cost saving is a benefit in the form of cost reduction, the values are calculated for the D100 highway with the assumption of the new constructed tunnel

[57] Özkan, p.63

will decrease number of accidents by % 60. The accident numbers have been derived from the Bolu Police Department.

Table 5 Accident Cost Savings

accidents	**421**	cost of labor	**380 TRY**						
damaged	**842**	casualty	**159600 TRY**						
causality	**5**	repairment	**2388 TRY**						
injuries	**128**	% decrease of Accident: 60%							
years	**accident**	**damaged**	**casualty**	**injuries**	**cost acc (TRY)**	**cost cas. (TRY)**	**cost inj. (TRY)**	**Total (TRY)**	**benefits from ADR (TRY)**
2006	421	842	5	128	1,005,348.00	798,000.00	2,164,480.00	3,967,828.00	2,380,696.80
2007	446	893	5	136	1,065,668.88	845,880.00	2,294,348.80	4,205,897.68	2,523,538.61
2008	473	946	6	144	1,129,609.01	896,632.80	2,432,009.73	4,458,251.54	2,674,950.92
2009	501	1003	6	152	1,197,385.55	950,430.77	2,577,930.31	4,725,746.63	2,835,447.98
2010	532	1063	6	162	1,269,228.69	1,007,456.61	2,732,606.13	5,009,291.43	3,005,574.86
2011	563	1127	7	171	1,345,382.41	1,067,904.01	2,896,562.50	5,309,848.92	3,185,909.35
2012	597	1194	7	182	1,426,105.35	1,131,978.25	3,070,356.25	5,628,439.85	3,377,063.91
2013	633	1266	8	192	1,511,671.67	1,199,896.95	3,254,577.62	5,966,146.24	3,579,687.75
2014	671	1342	8	204	1,602,371.97	1,271,890.76	3,449,852.28	6,324,115.02	3,794,469.01
2015	711	1423	8	216	1,698,514.29	1,348,204.21	3,656,843.42	6,703,561.92	4,022,137.15

Table 4 Accident Cost Savings (continued)

years	**accident**	**damaged**	**casualty**	**injuries**	**cost acc (TRY)**	**cost cas. (TRY)**	**cost inj. (TRY)**	**Total (TRY)**	**benefits from ADR (TRY)**
2016	754	1508	9	229	1,800,425.15	1,429,096.46	3,876,254.02	7,105,775.63	4,263,465.38
2017	799	1598	9	243	1,908,450.66	1,514,842.25	4,108,829.26	7,532,122.17	4,519,273.30
2018	847	1694	10	258	2,022,957.70	1,605,732.78	4,355,359.02	7,984,049.50	4,790,429.70
2019	898	1796	11	273	2,144,335.16	1,702,076.75	4,616,680.56	8,463,092.47	5,077,855.48
2020	952	1904	11	289	2,272,995.27	1,804,201.36	4,893,681.39	8,970,878.02	5,382,526.81
2021	1009	2018	12	307	2,409,374.99	1,912,453.44	5,187,302.28	9,509,130.70	5,705,478.42
2022	1069	2139	13	325	2,553,937.49	2,027,200.64	5,498,540.41	10,079,678.54	6,047,807.13
2023	1134	2267	13	345	2,707,173.73	2,148,832.68	5,828,452.84	10,684,459.26	6,410,675.55
2024	1202	2403	14	365	2,869,604.16	2,277,762.64	6,178,160.01	11,325,526.81	6,795,316.09
2025	1274	2548	15	387	3,041,780.41	2,414,428.40	6,548,849.61	12,005,058.42	7,203,035.05
2026	1350	2700	16	411	3,224,287.23	2,559,294.11	6,941,780.59	12,725,361.93	7,635,217.16

5.3.1.4.Vehicle Operating Costs

Vehicle operating costs (VOC) are the costs which are borne by the road users for vehicle operating and depreciation. This cost item is of crucial importance for the evaluation of road projects along with construction and maintenance costs. Vehicle operating cost savings occur due to expected reductions in roughness of pavements as a result of pavement improvements.

The first stage of VOC savings calculation involves the forecasting of Annual Average Daily Traffic (AADT) over years. The forecasted AADT figures for D100 highway are given in Table 7. The AADT figures for Bolu Mountain Tunnel is estimated with the assumption of % 80 of the vehicles using D100 Highway will use Bolu Mountain Tunnel. The annual growth rate of the traffic has been estimated at % 8.

The vehicle operating costs of different types of surface conditions is published yearly by the Ministry of Public Works and Settlement for each kind of vehicle. Vehicle operating cost for each road (Bolu Tunnel and D100 highway) is calculated by multiplying the length of the road with AADT figures and the given VOC figures per vehicle. Then the total saving in vehicle operating cost is computed by taking the difference of the values of old and new roads which are presented in tables 8 and 9.

Table 6 Traffic Forecast for Bolu Tunnel

YEARS	CAR	BUS	TRUCK	TRAILER
2006	11630	1074	3334	2474
2007	12328	1139	3534	2622
2008	13068	1207	3746	2779
2009	13852	1280	3970	2946
2010	14683	1356	4209	3123
2011	15564	1438	4461	3310
2012	16498	1524	4729	3509
2013	17488	1616	5013	3719
2014	18537	1712	5313	3943
2015	19649	1815	5632	4179
2016	20828	1924	5970	4430
2017	22078	2040	6328	4696
2018	23403	2162	6708	4977
2019	24807	2292	7110	5276
2020	26295	2429	7537	5593
2021	27873	2575	7989	5928
2022	29545	2729	8469	6284
2023	31318	2893	8977	6661
2024	33197	3067	9515	7060
2025	35189	3251	10086	7484
2026	37300	3446	10691	7933

Table 7 Traffic forecast for D100 Highway

YEARS	CAR	BUS	TRUCK	TRAİLER
2006	14538	1343	4167	3092
2007	15410	1424	4417	3278
2008	16335	1509	4682	3474
2009	17315	1600	4963	3683
2010	18354	1696	5261	3904
2011	19455	1797	5576	4138
2012	20622	1905	5911	4386
2013	21860	2019	6266	4649
2014	23171	2141	6642	4928
2015	24562	2269	7040	5224
2016	26035	2405	7462	5537
2017	27597	2549	7910	5870
2018	29253	2702	8385	6222
2019	31009	2865	8888	6595
2020	32869	3036	9421	6991
2021	34841	3219	9986	7410
2022	36932	3412	10586	7855
2023	39148	3616	11221	8326
2024	41496	3833	11894	8826
2025	43986	4063	12608	9355
2026	46625	4307	13364	9916

Table 8 Vehicle Operating Costs for Project 2

		PROJECT 2		
YEARS	CAR (TRY)	BUS (TRY)	TRUCK (TRY)	TRAILER (TRY)
2006	22,492,895.86	13,402,637.18	28,978,840.79	37,281,349.20
2007	23,842,469.61	14,206,795.41	30,717,571.24	39,518,230.16
2008	25,273,017.79	15,059,203.14	32,560,625.51	41,889,323.97
2009	26,789,398.86	15,962,755.32	34,514,263.04	44,402,683.40
2010	28,396,762.79	16,920,520.64	36,585,118.82	47,066,844.41
2011	30,100,568.56	17,935,751.88	38,780,225.95	49,890,855.07
2012	31,906,602.67	19,011,897.00	41,107,039.51	52,884,306.38
2013	33,820,998.83	20,152,610.82	43,573,461.88	56,057,364.76
2014	35,850,258.76	21,361,767.46	46,187,869.59	59,420,806.65
2015	38,001,274.29	22,643,473.51	48,959,141.77	62,986,055.04
2016	40,281,350.74	24,002,081.92	51,896,690.27	66,765,218.35
2017	42,698,231.79	25,442,206.84	55,010,491.69	70,771,131.45
2018	45,260,125.69	26,968,739.25	58,311,121.19	75,017,399.33
2019	47,975,733.24	28,586,863.60	61,809,788.46	79,518,443.29
2020	50,854,277.23	30,302,075.42	65,518,375.77	84,289,549.89
2021	53,905,533.86	32,120,199.94	69,449,478.32	89,346,922.89
2022	57,139,865.90	34,047,411.94	73,616,447.02	94,707,738.26
2023	60,568,257.85	36,090,256.66	78,033,433.84	100,390,202.55
2024	64,202,353.32	38,255,672.06	82,715,439.87	106,413,614.71
2025	68,054,494.52	40,551,012.38	87,678,366.26	112,798,431.59
2026	72,137,764.19	42,984,073.12	92,939,068.24	119,566,337.49

Table 9 Vehicle Operating Costs for Project 1

	PROJECT 1			
YEARS	CAR (TRY)	BUS (TRY)	TRUCK (TRY)	TRAILER (TRY)
2006	35,937,390.83	27,744,301.71	72,115,320.85	90,029,083.76
2007	38,093,634.27	29,408,959.81	76,442,240.10	95,430,828.79
2008	40,379,252.33	31,173,497.40	81,028,774.50	101,156,678.51
2009	42,802,007.47	33,043,907.24	85,890,500.97	107,226,079.22
2010	45,370,127.92	35,026,541.68	91,043,931.03	113,659,643.98
2011	48,092,335.59	37,128,134.18	96,506,566.89	120,479,222.62
2012	50,977,875.73	39,355,822.23	102,296,960.91	127,707,975.97
2013	54,036,548.27	41,717,171.56	108,434,778.56	135,370,454.53
2014	57,278,741.17	44,220,201.86	114,940,865.28	143,492,681.80
2015	60,715,465.64	46,873,413.97	121,837,317.19	152,102,242.71
2016	64,358,393.58	49,685,818.81	129,147,556.23	161,228,377.27
2017	68,219,897.19	52,666,967.93	136,896,409.60	170,902,079.91
2018	72,313,091.03	55,826,986.01	145,110,194.17	181,156,204.70
2019	76,651,876.49	59,176,605.17	153,816,805.83	192,025,576.99
2020	81,250,989.08	62,727,201.48	163,045,814.17	203,547,111.61
2021	86,126,048.42	66,490,833.57	172,828,563.03	215,759,938.30
2022	91,293,611.33	70,480,283.58	183,198,276.81	228,705,534.60
2023	96,771,228.01	74,709,100.60	194,190,173.41	242,427,866.68
2024	102,577,501.69	79,191,646.63	205,841,583.82	256,973,538.68
2025	108,732,151.79	83,943,145.43	218,192,078.85	272,391,951.00
2026	115,256,080.89	88,979,734.16	231,283,603.58	288,735,468.06

5.3.1.5.Travel Time Savings

Another important benefit of a highway improvement is the expected savings generated in travel time due to improved road conditions. The net figure of travel time savings is a function of traveler's income, type of trip, day of the week etc… The estimation of value of travel time has some shortcomings. First of all, the value of travel time depends on trip purpose. For example, the value of a business trip is equal to the employee's wage rate. Second, the value of travel time varies from person to person according to their income level. But, according to this approach, travel time savings calculation of unemployed or people who are not in the labor force (retirees, housewives etc…) is problematic. Since deriving the income and other necessary data accurately for the users of the road to calculate travel time savings is practically impossible, some estimation are made in order to give an rough idea of travel time savings. The estimation is based on the value of time figures calculated by GDH for different types of vehicles as passenger and driver time values

The calculations of value of time by GDH are given in the table below:

Table 10 Value of Time

1-PASSENGER TIME		
Income per capita (2006) :		6749 TRY/year
		562 TRY/month
Assuming the monthly working hours as 176 hours;		
wage per hour :		562/176=3196 TRY/hour
Passenger Time Value :		**3196 TRY /hour**
2- DRIVER TIME		
BUS		
2 Drivers :	(2*1250)	2500 TRY/month
1 co-driver :	(1*600)	600 TRY/month
monthly wage :		3100 TRY/month
Wage per hour :		3100/176= 17614
Driver time value for bus :		**17614 TRY/hour**
TRUCK, TRAILER		
2 Drivers :	(2*1250)	2500 TRY/month
wage per hour :		2500/176=14205
Driver time value for truck and trailer :		**14205 TRY/hour**
3- PASSENGER PER VEHICLE (2006)		
Car	2.5	
Bus	28.3	

It is assumed that the new road will shorten the travel-distance time by 2.5 hours thus travel time savings have been accounted by multiplying the time values by the number of vehicles passing on the new road. The values entered the analysis as cost reduction in vehicle operating cost. The values can also be stated as a decrease in opportunity cost of using the new road by the reduction in time. Values are presented in table11.

Table 11 Time Savings

YEARS	CAR (TRY)	BUS (TRY)	TRUCK (TRY)	TRAILER (TRY)
2006	-232,317.24	-290,251.31	-118,384.47	-87,843.72
2007	-246,256.27	-307,666.39	-125,487.54	-93,114.34
2008	-261,031.65	-326,126.37	-133,016.79	-98,701.20
2009	-276,693.55	-345,693.95	-140,997.80	-104,623.28
2010	-293,295.16	-366,435.59	-149,457.67	-110,900.67
2011	-310,892.87	-388,421.73	-158,425.13	-117,554.71
2012	-329,546.45	-411,727.03	-167,930.63	-124,608.00
2013	-349,319.23	-436,430.65	-178,006.47	-132,084.48
2014	-370,278.39	-462,616.49	-188,686.86	-140,009.54
2015	-392,495.09	-490,373.48	-200,008.07	-148,410.12
2016	-416,044.79	-519,795.89	-212,008.56	-157,314.72
2017	-441,007.48	-550,983.64	-224,729.07	-166,753.61
2018	-467,467.93	-584,042.66	-238,212.81	-176,758.82
2019	-495,516.01	-619,085.22	-252,505.58	-187,364.35
2020	-525,246.97	-656,230.33	-267,655.92	-198,606.21
2021	-556,761.78	-695,604.15	-283,715.27	-210,522.59
2022	-590,167.49	-737,340.40	-300,738.19	-223,153.94
2023	-625,577.54	-781,580.83	-318,782.48	-236,543.18
2024	-663,112.19	-828,475.67	-337,909.43	-250,735.77
2025	-702,898.93	-878,184.22	-358,183.99	-265,779.92
2026	-745,072.86	-930,875.27	-379,675.03	-281,726.71

After calculating all benefit and cost items separately net benefit stream (benefits-cost) has been calculated and this stream has been deflated by using the deflator figures for the transportation projects published by State Planning Organization (SPO). Deflator conducted by SPO was lasting to 2010 but as the forecast period of the analysis continues to 2026 deflators through 2010 to 2026 have been estimated by assuming the growth rate as constant at %4 which is the figure used by SPO while estimating the deflators of years 2009 and 2010.

The result of the analysis is as below:

NPV (with discount rate %12) = 117,861,967.59 TRY

IRR (which makes the NPV zero) = % 22

Although % 22 internal rate of return seems to be high it is an acceptable rate as the project size is high and by theory IRR which exceeds the discount rate means that the project is worth while. It can be said as well for NPV. As the NPV value is positive it means that the project benefits exceeding the costs thus appropriate for the implementation.

The benefits, costs and the net benefit stream are presented in the table 12.

Table 12 Benefits, Costs and the Net Benefit Stream

Years	Acc. Sav. (TRY)	VOC (TRY)	Maintenance (TRY)	Total (TRY)	Cost (TRY)	Benefit-Cost (TRY)	Deflator	Deflated Net Benefits (TRY)	Discounted Net Benefits (TRY)
1987					1,177.40	-1,177.40	0.0002908	-4,049,129.11	-3,615,293.85
1988					3,350.04	-3,350.04	0.0005471	-6,123,250.59	-4,881,417.88
1989					5,618.30	-5,618.30	0.0007910	-7,103,008.29	-5,055,781.00
1990					3,448.44	-3,448.44	0.0011720	-2,942,252.50	-1,869,854.65
1991					5,832.04	-5,832.04	0.0020073	-2,905,484.92	-1,648,650.17
1992					2,939.80	-2,939.80	0.0032313	-909,789.21	-460,927.53
1993					5,711.83	-5,711.83	0.0053707	-1,063,510.49	-481,078.13
1994					5,513.24	-5,513.24	0.0119082	-462,977.62	-186,988.90
1995					0.00	0.00	0.0205339	0.00	0.00
1996					0.00	0.00	0.0373058	0.00	0.00
1997					0.00	0.00	0.0676777	0.00	0.00
1998					0.00	0.00	0.1183358	0.00	0.00
1999					0.00	0.00	0.1799077	0.00	0.00
2000					0.00	0.00	0.2534504	0.00	0.00
2001					0.00	0.00	0.4490338	0.00	0.00
2002					0.00	0.00	0.6186928	0.00	0.00
2003					0.00	0.00	0.6853869	0.00	0.00
2004					0.00	0.00	0.7572576	0.00	0.00
2005					0.00	0.00	0.7621120	0.00	0.00

Table 12 Benefits, Costs and the Net Benefit Stream (continued)

Years	Acc. Sav. (TRY)	VOC (TRY)	Maintenance (TRY)	Total (TRY)	Cost (TRY)	Benefit-Cost (TRY)	Deflator	Deflated Net Benefits (TRY)	Discounted Net Benefits (TRY)
2006	2,380,696.80	124,399,170.84	-1,361,682.40	125,418,185.24	-3,790,097.34	129,208,282.59	0.8667832	149,066,437.62	15,453,235.37
2007	2,523,538.61	131,090,596.55	-1,342,592.94	132,271,542.21		132,271,542.21	0.9519277	138,951,255.10	12,861,274.21
2008	2,674,950.92	138,956,032.34	-1,322,358.12	140,308,625.15		140,308,625.15	1.0000000	140,308,625.15	11,595,457.02
2009	2,835,447.98	147,293,394.28	-1,300,909.21	148,827,933.06		148,827,933.06	1.0400000	143,103,781.79	10,559,335.52
2010	3,005,574.86	156,130,997.94	-1,278,173.36	157,858,399.44		157,858,399.44	1.0816000	145,948,963.98	9,615,424.73
2011	3,185,909.35	165,498,857.82	-1,254,073.36	167,430,693.81		167,430,693.81	1.124864	148,845,277.12	8,755,571.37
2012	3,377,063.91	175,428,789.29	-1,228,527.36	177,577,325.83		177,577,325.83	1.16985856	151,793,842.36	7,972,335.47
2013	3,579,687.75	185,954,516.64	-1,201,448.61	188,332,755.78		188,332,755.78	1.216652902	154,795,797.07	7,258,929.07
2014	3,794,469.01	197,111,787.64	-1,172,745.12	199,733,511.53		199,733,511.53	1.265319018	157,852,295.44	6,609,160.02
2015	4,022,137.15	208,938,494.90	-1,142,319.43	211,818,312.62		211,818,312.62	1.315931779	160,964,508.93	6,017,380.46
2016	4,263,465.38	221,474,804.60	-1,110,068.19	224,628,201.78		224,628,201.78	1.36856905	164,133,626.81	5,478,439.70
2017	4,519,273.30	234,763,292.87	-1,075,881.89	238,206,684.29		238,206,684.29	1.423311812	167,360,856.71	4,987,641.01
2018	4,790,429.70	248,849,090.44	-1,039,644.40	252,599,875.75		252,599,875.75	1.480244285	170,647,425.10	4,540,702.14
2019	5,077,855.48	263,780,035.87	-1,001,232.66	267,856,658.69		267,856,658.69	1.539454056	173,994,577.88	4,133,719.15
2020	5,382,526.81	279,606,838.02	-960,516.22	284,028,848.61		284,028,848.61	1.601032219	177,403,580.84	3,763,133.37
2021	5,705,478.42	296,383,248.30	-917,356.80	301,171,369.93		301,171,369.93	1.665073507	180,875,720.26	3,425,701.20
2022	6,047,807.13	314,166,243.20	-871,607.80	319,342,442.52		319,342,442.52	1.731676448	184,412,303.44	3,118,466.45
2023	6,410,675.55	333,016,217.79	-823,113.87	338,603,779.48		338,603,779.48	1.800943506	188,014,659.23	2,838,735.14
2024	6,795,316.09	352,997,190.86	-771,710.31	359,020,796.64		359,020,796.64	1.872981246	191,684,138.57	2,584,052.40
2025	7,203,035.05	374,177,022.31	-717,222.52	380,662,834.84		380,662,834.84	1.947900496	195,422,115.10	2,352,181.48
2026	7,635,217.16	396,627,643.65	-659,465.48	403,603,395.33		403,603,395.33	2.025816515	199,229,985.67	2,141,084.45

CONCLUSION

Cost benefit analysis (CBA) is the most widely used project evaluation method by both public and private sectors for comparison of the projects according to their costs and benefits in order to take any investment decision. The present value of a project's costs and benefits are calculated then compared. If the comparison will be made among several projects, the project which is the most beneficiary is chosen. If the decision will be made for one project, the project is concluded worthwhile if the net benefits exceed the net costs.[58]

The purpose of using CBA for public sector is to maximize social benefit by allocating resources efficiently among the projects which will have positive effect on social welfare. CBA is used especially for the evaluation of the education, health, environmental, transport and other infrastructure projects which are mostly provided by public sector for the reason that these services are mostly in the characteristics of public goods.

While conducting CBA all relative cost and benefit items should be monetized then included in the analysis in order to make the benefit and cost streams comparable. The following step is to discount these streams by an appropriate discount rate to compute the net present value of the costs and benefits.

This thesis consists of five chapters. In the first chapter a brief definition of cost benefit analysis, the historical evaluation of the method and the steps which have to

[58] Hilmi Ünsal, "Kamu hizmetlerinin planlanmasında fayda-maliyet analizi ve uygulanabilirliği", *Gazi Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, No:1(2004),p.1

be followed in conducting CBA is given. Understanding the basic features of the method is important for the implementation of the technique to the projects. The first chapter covers the general framework of the analysis method.

In the second chapter, economic concepts related to cost benefit analysis is presented. The first section identifies the consumer surplus concept and the relation between CBA and consumer surplus is clarified. Consumer surplus as the consumer surplus is one of the most critical economic concepts of CBA the demand curve from which it should be derived is considered as well. The second section deals with the producer surplus concept which is as important concept as consumer surplus in understanding theoretical background of cost and benefit valuation. The third section is devoted to compensating and equivalent variation measures which are crucial for analyzing welfare effects of price changes in view point of individual's preferences. In corporation to CV and EV measures willingness to pay and willingness to accept approaches are mentioned as well.

Third chapter is about the identification and measurement of costs and benefits which is the most critical point of the evaluation of a project. In the first section, classification and identification costs and benefits as ; "real vs. pecuniary", "direct vs. indirect", "inside vs. outside" effects are detailed. The second section deals with the measurement of costs and benefits. For the analytical purpose, firstly the market conditions as first-best and second-best environment are determined. Then, shadow price approach which is used for the valuation when the markets are distorted and market prices are no longer reflects the real social value of the goods is determined and derivation of shadow prices for wage rate and foreign exchange rate is given.

The second section deals with the valuation of non-marketed inputs, namely; value of life and value of time are discussed in detail.

In the fourth chapter decision rules used for the project selection are presented. In the first section, decision criteria of cost- benefit analysis which are net present value, benefit-cost ratio and internal rate of return are depicted. In the second section, the choice of appropriate discount rate is discussed which is one of the critical points for the reliability of the analysis.

The fifth chapter is the application of cost-benefit analysis. Firstly, some examples of the application of CBA to transport projects in literature are considered and then limitations and critiques to the technique are mentioned. In the second section, costs and benefits which are specific to transport investments are identified. In the third section Bolu Mountain Tunnel Project is presented and the related costs*; construction costs* and *maintenance costs,* and benefits; *accident cost savings, vehicle operating cost savings* and *travel time savings* are calculated by using the which are gathered from GDH and other institutions.

Bolu Mountain Tunnel which is evaluated in this thesis has been constructed for about seventeen years and cost of the tunnel is relatively high considering the other highway projects implemented in Turkey. Bolu Mountain Passage is an important link between İstanbul and Ankara. The rationale for a tunnel construction is to provide safer transport conditions than the current passage of Bolu Mountain (D100 highway). The analysis is therefore an ex-post analysis as the project had been implemented thus it investigates the future benefit streams expected to be generated and the internal rate of return has been used as the criteria to conclude if the project worth to be implemented. As an alternative and a base-case D100 highway Bolu Mountain Passage part has been used. After calculating all benefit and cost items separately net benefit stream (benefits-cost) has been calculated and this stream has been deflated by using the deflator figures for the transportation projects published by State Planning Organization (SPO). Deflator conducted by SPO was lasting to 2010 but as the forecast period of the analysis continues to 2026 deflators through 2010 to 2026 have been estimated by assuming the growth rate as constant at %4 which is the figure used by SPO while estimating the deflators of years 2009 and 2010. . For the comparison and to check the consistency of the IRR result net present value has been calculated for the discount rate of % 12 which is a proposed rate by SPO for infrastructure projects.

The result of the analysis is as below:

NPV (with discount rate %12) = 117,861,967.59 TRY

IRR (which makes the NPV zero) = % 22

Although % 22 internal rate of return seems to be high it is an acceptable rate as the project size is high and by theory IRR which exceeds the discount rate means that the project is worth while. It can be said as well for NPV. As the NPV value is positive it means that the project benefits exceeding the costs thus appropriate for the implementation.

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