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Economic appraisal of the Bosphorus Tube Tunnel and İstanbul Metro alternative and their environmental impacts

Cevat Karataş*

Boğaziçi University, Faculty of Economic and Administrative Sciences, Department of Economics
80815 Bebek, İstanbul

Abstract

The purpose of this paper is to provide a detailed analysis of the Bosphorus Tube Tunnel and a number of alternative İstanbul metro systems. An attempt is made to compare economically the Bosphorus Tube Tunnel with an İstanbul Metro system via Taksim and combined alternative which comprises both the Bosphorus tube Tunnel and the İstanbul metro system by refering to a future no-build baseline alternative. In the analysis, the Little-Mirrlees appraisal method is adopted that requires the estimation of national parameters and conversion factors for the primary inputs. Economic analysis is first based on market prices and then accounting prices. The economic appraisal system includes calculations of the internal rate of return, benefit-cost ratios and the discounted net present value (NPV) of each alternative. In the final section, the environmental impacts of each project are identified and taken into account in order to provide a more complete evaluation.

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* The author is Professor of Development Economics at the Department of Economics, Boğaziçi University, İstanbul, Turkey. At the time of writing (1998/99) the author was a visiting Fellow at the Development and Project Planning Centre (DPPC), University of Bradford, West Yorkshire, UK. An earlier version of this paper was presented at the Seminar Series of DPPC, Bradford University on November 22, 1998. The author is indebted to David Potts, Ian Lomas, Hossein Jalilian, Behrooz Morvaridi and P. B. Anand for their constructive comments during the preparation of this paper.

1. Introduction

The purpose of this paper is to provide a detailed analysis of the Bosphorus Tube Tunnel (which retains its popularity) and a number of İstanbul Metro systems as separate alternatives. More specifically, in the following sections, an attempt will be made to compare economically the Bosphorus Tube Tunnel with an İstanbul Metro System via Taksim and a combined alternative which comprises both the Bosphorus Tube Tunnel and the İstanbul Metro systems, by referring to a future no-build baseline corresponding to Alternative 1, which includes existing facilities plus committed improvements. However, it should be noted that in 1998, the former İstanbul Municipality Authority was pressing for the establishment of a Third Bosphorus Bridge as another alternative to the metro systems in order to alleviate the notorious congestion and traffic problems in the İstanbul Metropolitan area.[1] After a brief description of the characteristics of the Tube Tunnel and metro alternatives and capital costs of these projects, the paper will focus on an estimation of the total benefits. These will include the value of travel time, vehicle operation and maintenance costs (including auto-taxi, buses and trucks), roadway maintenance costs, accident costs and freight time costs. In the middle section, based on 1990 constant prices and the above considerations, the economic appraisal system will include calculations of internal rate of return (IRR), benefit-costs ratios and discounted net present value (NPV) of these alternatives. Depending on the results, an appropriate selection and ranking will be recommended.

In the analysis, the Little-Mirrlees appraisal method (1974) is adopted, which is based on the estimation of national parameters and conversion factors for the primary inputs. Economic analysis is first based on market prices and then accounting prices. In the final part of the paper, the environmental impacts of these alternatives are identified and taken into account in order to provide a more complete evaluation. In this context, the environmental effects resulting from the metro systems will be discussed by referring to air pollution, the vibration effects from the operation of metro rail vehicles and tunnels, and noise effects all of which will adversely affect the residential areas and passengers.

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1 For details and analysis of the third Bosphorus bridge, see Karataş (1989).

The IRTC (İstanbul Rail Tunnel Consultants)[2] considered a number of metro alternatives or combinations of alternatives to resolve the public transport problem in the İstanbul Metropolitan area. A brief summary and outline are given below of the Bosphorus Railroad Tube Tunnel (Alt.8), the North-South/Topkapı Metro system via Taksim (Alt.9B) and the Combined Alternative (10B) which includes both the Bosphorus Tube Tunnel and Metro System via Taksim. The Light Rail System (LRT) and the North-South/Topkapı Metro via Dolapdere (9B) have not been included in the following analysis. An extensive evaluation and analysis of the last two metro alternatives were demonstrated in several earlier studies.[3]

2. Bosphorus railroad Tube Tunnel (Alt. 8)

The alignment for the Bosphorus Rail tunnel is in a bored tunnel for 6.5 km under the land portions of alignment, a sunken tube tunnel for 2 km under the Bosphorus and at grade for a total of 2.5 km both ends where the alignment connects to the existing commuter railroad tracks. The system includes two new and two modified commuter rail stations as well as the existing station at Söğütlüçeşme (Asian side). The new stations will include Kocamustafapaşa (modified), Yenikapı (modified), Sirkeci and Üsküdar. The IRTC Report (1987) indicates that all commuter rail stations along the new Bosphorus Railroad route would be provided with pedestrian and bus feeder access. It is noted that at Yenikapı station rail transit transfer to the north-south and east-west metro line would also be provided. It is also expected that transfer to the 23 km municipal light rail line would be ensured at Yenikapı (see, Figure 1).

The Sirkeci to Üsküdar (Harem) section of the alignment would involve construction of a railroad tube tunnel. This would be built as a segmented, prefabricated sunken tube tunnel. The sunken Bosphorus tube construction which would place the tube below the bottom surface of the Bosphorus is expected to be between two ventilation buildings which would be placed on the east and west sides of the Bosphorus close to the shorelines (IRTC Report: 1987, 4-23). Accordingly, the Üsküdar

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2 The IRTC group was a consortium of Parsons Brinckerhoff International Inc. in association with Kaiser Engineers International Inc. and PB-TSB Consulting and Engineers Co. Ltd, Temel Engineering AS and Tumas Engineering AŞ.

3 See IRTC Report (1986) Feasibility Study and Preliminary Designs, Bosphorus Railroad Tunnel and İstanbul Metro System Project., Task 109; also Karataş and Payaslıoğlu (1996: 191-226).

station would be built using a cut-and-cover technique. Meanwhile, the alignment east of Üsküdar station would be built as a bored tunnel to the port near the TCDD (State Railways) Haydarpaşa freight yards. The alignment would move eastward in order to connect with the existing commuter railtracks before the Söğütlüçeşme station[4]. It is estimated that the average speed would be around 60 km/hr in the Bosphorus Tube Tunnel and 47 km/hr along the rest of the track sections (IRTC Report, 1987: 4-24).

3. The North-South/Topkapı metro system via Taksim (9B)

The metro alternative via Taksim includes new north-south and east-west metro corridors, in addition to the Alternative 2 transport system improvements. Evidently the east-west metro corridor has been designed to terminate at Topkapı and includes the Cerrahpaşa Hospital area and Şehremini as well. Under this alternative, commuter rail express service improvements have also been envisaged. It has been indicated in the IRTC Report (1987) that the Taksim-Zincirlikuyu busways would not be undertaken under Alternative 9B. Apparently, the Taksim-Yenikapı, Topkapı-Aksaray, Taksim-Zincirlikuyu and Zincirlikuyu-4.Levent alignments have been considered separately. It should be noted that the Metro Alternative via Taksim (9B) has been under construction for almost seven years. The Taksim Square-Zincirlikuyu section of the alignment was put into operation in the year 2000 (see Figure 2).

4. The Bosphorus Tube Tunnel and North-South Topkapı Metro System (10 B)

This alternative is a “combined” one that includes the Bosphorus Tube Tunnel and the north-south/Topkapı Metro via Taksim, which has been expected to ensure a long term solution to the notorious traffic congestion and traffic problems in the İstanbul Metropolitan Area.

As outlined earlier, the Bosphorus Tube tunnel (railroad) was designed as an alignment, which would be in a bored tunnel for 6.5 km under the land and include a sunken tube tunnel for 2 km under the Bosphorus Straits. The proposed alignment is expected to connect to the

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4 The new Üsküdar station is on the Asian side of the tunnel and it would be within an existing major transit transfer centre. Ferries, minibuses, IETT and blue buses, and dolmuş cars are always converging at this location. IRTC Report (1987: 4-23).

existing commuter railroad tracks. Apparently, two new and two modified commuter rail stations are included in the system in addition to the existing station of Söğütlüçeşme. These new stations will include Kocamustafapaşa, Yenikapı, Sirkeci and Üsküdar (see Figure 3). The modified Yenikapı station will provide for rail transit transfer to the north-south/east-west metro lines. In addition, this metro system is expected to facilitate transfer to the 23 km municipal light rail line (LRT), which has been operational since 1995 between Yenikapı station and the Topkapı district on the European side.

5. Capital costs of the Bosphorus Tube Tunnel and Metro alternatives

The capital costs of the tube tunnel and metro alternatives include machinery and equipment and labour for the foreign component; and materials, machinery, energy and non-energy cost and land acquisition as domestic components of capital costs. For the purpose of conducting a social evaluation of capital costs, the Little-Mirrlees Appraisal Method (1974) is adopted that requires the estimation of national parameters and conversion factors for the primary inputs. The estimated capital investments of the tube tunnel and İstanbul Metro Alternatives based on market and social prices (resource-corrected prices) are presented in Table 1.

Table 1

Capital Cost Estimates of Tube Rail Tunnel and İstanbul Metro Alternatives

(million TL at 1990 prices)

Alternative	Capital Cost (market prices)	Capital Costs (social prices)
Alt 8 Bosphorus Tube Tunnel	2,993,142.2	2.556,492.7
Alt 9B İstanbul Metro System via Taksim	2,694,921.5	2.290,723.4
Alt 10B Bosphorus Tube Tunnel + Metro System via Taksim	4,896,552.0	4,190,195.0

Source: İstanbul Rail Tunnel Consultants (IRTC Feasibility Report): Conceptual Cost Estimates Report (1987: 1-14).

a) Alternative 8, 9B and 10B are the notations used in the IRTC Feasibility Studies Report (1987). The original 1985 prices are converted to 1990 prices by using the GNP deflator.

b) Total capital cost of the Bosphorus Tube Tunnel excludes revenue vehicles which comprise vehicles, installation fans, installation signals and installation radios. If these are included the capital cost will then amount to 3,338,693.3 million TL at 1990 prices.

6. Little and Mirrlees Model and conversion factors

The Little-Mirrlees Method (1974) and the World Bank approach (Mashayekhi: 1980) rests on the premise that conversion factors should be used in order to translate all costs and benefits into 'world prices'. As a common norm, the "numeraire" adopted by both methods is freely disposable uncommitted foreign exchange accruing to the government. What is utilised here is a foreign exchange numeraire, but expressed in terms of units of domestic currency (here Turkish lira) converted at the official exchange rate. Therefore bearing in mind the specific requirements of the Little-Mirrlees (and the World Bank) method, an attempt was made to estimate shadow prices and national parameters for Turkey to be used in the Bosphorus Tube Tunnel and Metro alternative projects. The conversion factors and national parameters estimated for the 1984-89 period in Turkey are given in Table 2. The national parameters and conversion factors have been adopted from an earlier study dealing with the third Bosphorus bridge and the Bosphorus tube tunnel (Karataş: 1989: 177-225).

7. Transportation model

It should be noted that in modelling the impacts of the alternative projects, the future geographic distribution and size of population, employment and commercial activity were considered as given (as exogenous to the model). Essentially the Transplan model used by the IRTC Consultants (1987) assigns travel between the various "trip generators" and "trip receptor" as to the fastest and most efficient transportation mode. By following this approach, directly measurable and quantifiable benefits are reflected by travel time savings and reduced resource costs devoted to competing transportation modes.

The environmental effects of the metro alternatives, which might be in the form of air pollution, vibration effect and noise effect, will be discussed in some detail in subsequent sections.

8. Direct economic benefits and estimation problems

Direct economic benefits of the metro alternatives are estimated for the years 1995 and 2005 when the full benefits will be realised. The respective costs of the metro alternatives as compared to the no-build baseline are determined. The lifespan of each of the metro alternatives was assumed to be 40 years and the stream of operation and maintenance cost and benefits are computed to derive their present value amounts.

Table 2

Estimated National Parameters and Resource Correction Factors

1. National Parameters	
Standard Conversion Factor (SCF)	0.83
Conversion factor for producer goods (CF_k)	0.83
Conversion factor for consumer goods (CF_c)	0.88
Marginal propensity to save (MPS)	0.29
Marginal productivity of capital (q)	0.24
Consumption rate of interest (CRI)	3.50
Value of public income (v)	
for q= 10 %	3.24
for q= 12 %	3.03
Accounting rate of interest (ARI)	
for q= 10 %	0.05
for q= 12 %	0.06
for q= 24 %	0.09
Shadow wage rates (SWR)	
. skilled labour	1.0
. unskilled labour	
-traditional efficiency price model	0.50
-extended efficiency price model	0.76
2. Resource Correction Factors for Capital Costs	*RCF
Foreign	
-labour	1.0
-materials	0.83
Local	
. labour	
- skilled	1.0
-unskilled	0.76
. material	0.83
. construction materials	0.83
. energy	0.83
. land	1.0

Source: Economic Evaluation of Third Bridge and the Bosphorus Tube Tunnel, Metu studies in Development, vol.16,No.1-2 (Karataş:1989:177-225)

* RCF= resource correction factors

Each of the proposed metro alternatives is compared with Alternative 1, which represents the existing and committed projects. As a rational procedure, if the alternative tested produces a cost increase, then such cost increases are considered to be ‘costs’ and are then included in the category of operation and maintenance cost increases. For the estimation of economic benefits comprising roadway maintenance costs, vehicle operation and maintenance costs, accident costs and travel time costs, the tested alternative was compared with the base alternative. Here the increase in the above measure is treated as a ‘cost’ and the decrease as a ‘benefit’.

9. Estimation of travel time cost

The value of personal time per hour was estimated in order to calculate the value of time cost savings resulting from increased travel speed and thus a decline in the level of congestion. Time cost savings have been computed for each vehicle type under different alternatives. Based on data available for the İstanbul Province, the average wage rate for the İstanbul Metropolitan area was estimated to be 10, 764 TL/hr at 1990 prices. For a more accurate analysis, a distinction has to be made between journeys carried out in working time and non-working time. As in many case studies, it is rational to take some percentage of the wage rate in the precise determination of the time value per hour[5].

Bearing in mind other case studies, the value of "non-working" time was assumed to be 43 % of the average hourly wage rate of full time adult employees[6] and the working time valued at the wage rate plus some allowance for overhead payments. Similarly, this is assumed to be 10 per cent. It should be remarked that the value of time spent on journeys other than business trips (shopping trips, leisure trips by retired people, school children) are in practice valued at a lower level.[7]

Value of time at 1990 prices

- working time: 10764 x 1.1 = 11840 TL/hr
- non-working time: 10764 x 0.043 = 4628TL/hr

In the following analysis it is made clear that personal time cost savings should not be overrated. Therefore the value of non-working time per hour (4,628 TL/hr) was taken as a reasonable estimation. It is also important to note that this assumption was considered to be realistic since 12 % of trips are made during working hours and 88 % during non-working hours (STFA Household Transport Survey, 1988). Table 3 illustrates vehicle-kilometers per year, average speed, and vehicle kilometer savings for each alternative.

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5 In the case of Caracas Metro Project this ratio was 30% and 27% in the case of Taiwan transport projects. For details see Caracas Metro Project, Economic Feasibility Analysis, October 1971, also see Department of Transport (UK) Values for Journey Time Savings and Accident Prevention, March 1987.

6 For details, see British Mass Transit Consultants (1982).

7 Work-trips are those trips to and from work which are made during non-working time, whereas non-work trips implies trips made in people's own time such as social trips, school, and shopping trips which are commonly valued at a lower rate than commuting time.

Table 3

Average Speed, Annual Veh-km and Veh-km Savings:
Auto-taxi-Dolmuş Minibus Category

Alternative	Year	Average speed Km/hr	Million veh-km Per year	Veh-km savings (million veh-km)
Baseline	1985	32.1	2,791,000	-
	1995	26.2	4,565,000	-
	2005	23.6	6,595,000	-
Alt8 Bosphorus Tube	1995	25.9	3,606,000	959,000
Tunnel	2005	25.1	5,551,000	1,044,000
Alt 9B İstanbul Metro	1995	25.7	3,569,000	996,000
System (via Taksim)	2005	25.1	4,952,000	1,643,000
Alt 10B Bosphorus Tube	1995	26.0	3,592,000	973,000
Tunnel plus Metro System via Taksim	2005	25.2	5,326,000	1,269,000

Annual personal time cost savings under each metro alternative as compared to the baseline alternative have also been calculated and presented in Table 4. Given the veh-km savings under each alternative, personal time cost savings is calculated by using personal time cost per hour which is found to be 4,628 TL/ at 1990 prices. It can be illustrative to note the number of persons per vehicle for each type of vehicle; however there is no sufficient data in the IRTC Report to reflect this.

Table 4

Annual Personal Travel Time Cost Saving by Alternatives
(millions of 1990 TL/year)

	Personal time cost saving (a)	
Alternative	1995	2005
Alt 8 versus 1 (inc transit+ -taxi dolmuş+ minibus) auto	2,006,908.0	3,185,276.0
Alt 9B versus 1 (inc transit+auto-taxi dolmuş+minibus	2,071,350.0	3,631,767.0
Alt 10B versus 1 (inc transit+auto-taxi dolmuş+minibus	2,218,646.0	3,746,842.0

Note: (a) Total time cost savings include both auto-taxi-dolmuş and transit (bus) users categories.

10. Vehicle operation and maintenance costs

It is conceived that as a result of the diversion of autos and buses and other vehicles from congested streets, vehicles using these streets will somewhat enjoy the benefits of reduced congestion. In transport economics, it is widely recognised that there is a direct relationship between speed and operation costs as between speed and traffic flow. In the following analysis, variable costs are defined to include, (i) fuel and oil consumption, (ii) tyre wear, (iii) maintenance and repair, and (iv) depreciation.

The proposed metro alternatives, which all aim to improve urban transport in the İstanbul Province, are expected to generate operating and maintenance cost reductions, thus economic benefits resulting from the decline in the degree of congestion on urban streets and much faster average vehicle speed. This will result in savings in energy and non-energy operating and maintenance costs. Operating and maintenance cost savings derived from vehicle types, including the auto-taxi-minibus, are presented in Table 5. The number of vehicles using the roads by vehicle type are not given in the IRTC Report (1987), but it is presumed that the number of vehicles, especially İETT buses will increase at initial stages, while it will show a downward trend after year 2005. Similarly, the impact of metro system on the number of vehicles on the surface traffic is expected to show a discernible decline over the years, especially when the metro system can be extended and implemented more effectively.

Table 5

Operating and Maintenance Cost Savings: by auto-taxi+dolmuş+minibus (million TL at 1990 prices)

		Operating and Maintenance Cost Savings		
Alternative	Year	Energy	Non-energy	Total
Alt 8 Tube Tunnel versus 1	1995	211,294.2	357,795.2	569,089.4
	2005	315.867.5	570,158.9	886,026.4
Alt 9B Metro via Taksimvs 1	1995	213,341,7	358,454.4	571,796.1
	2005	457,535.1	814.589.7	1,272,124.8
Alt 10B Combined Tube+	1995	216,623.3	367,852.4	584,475.7
Taksim Metrovs 1	2005	373,326.7	671.163.8	1,044.490.5

11. Roadway maintenance costs

It is often acknowledged that there is a close relationship between the increased distance travelled and vehicle kilometers and axle loads of vehicles, particularly of heavy vehicles. It is generally accepted that the degree of damage caused to roads is proportional approximately to a fourth power of the axle load, perhaps with a higher power for a thinner asphalt surface (Altan, 1986: 2-6, De Weille, 1966) At the outset, it might be argued that reductions in roadway maintenance are expected to result from lower traffic volumes along the urban roads within the İstanbul Metropolitan area, especially of buses and trucks. For the estimation of road maintenance costs; first the annual roadway maintenance and repair cost per veh-km by vehicle type was calculated to reflect the damage caused to the road surface by the type of vehicles included in each metro alternative. Secondly, the following assumptions are used for the calculation of the annual maintenance costs of roadways:

(a) It was estimated that annual road maintenance cost per km would be 119 500 000 TL at 1990 prices (this includes, materials, energy, labour, machines and other inputs)

(b) based on vehicle type, roadway maintenance cost per veh km was estimated as follows[8]:

- buses (excl. minibuses) = 281.5 TL
- buses (include minibuses) = 147.4 TL
- auto-taxi-dolmuş = 0.070 TL
- trucks = 2,104 TL

The estimated results shown in Table 9 reveal that the roadway maintenance cost savings of the three metro alternatives are negative; it becomes much greater in the cases of the Bosphorus Tube Tunnel and İstanbul Metro System via Taksim. This finding reflects that roadway maintenance cost savings of the three alternatives are not positive as compared to the baseline considered in the analysis. This paradox of disbenefits in all metro alternatives is perhaps due to a significant rise expected in the degree of vehicle-km which might be recorded particularly by İETT buses, service buses and trucks as an integral components of the metro systems both in 1995 and 2005.

8 For details of this estimation see IRTC report (1987: 4-21) and Karataş (1989).

12. Accident costs by alternatives: A resource cost method

Obviously debate continues on what constitutes a realistic determination of accident costs when life and injuries are saved or damage to vehicles is reduced under different transport alternatives. Analysis of accident costs has generally concentrated on (i) loss of income that will occur as a result of absence from work following injury or death in case of accident; (ii) damage to vehicles, property and street equipment; (iii) medical treatment costs of those who are injured, (iv) loss of investment due to those who were killed before the age of 15 (children); (v) police and administrative costs (i.e., police time, court) and finally, (vi) costs in terms of pain and grief of those involved in accidents and their relatives. In the ensuing sections, the ‘resource costs’ approach will be pursued where the accident costs of proposed alternatives are intimately related to vehicle-kilometers driven under each alternative. Based on data given by the Turkish Highway Directorate (TCK: 1983, 1985) it was found that the number of accidents per million veh-km in the İstanbul Metropolitan area is almost 3. Second, the average accident costs including loss of income due to death and injuries, medical treatment costs, damage to various types of vehicles and administrative costs were estimated to be 12 742 000 TL at 1990 constant prices.

The methodology adopted in the estimation of accident costs under each competing alternative can be summarised as follows: First, the number of persons killed or injured according to age categories (working age or children) was determined for the İstanbul Metropolitan area. Second, the number of vehicles involved in accidents for the years 1985, 1995 and 2005 was estimated by taking into account the national average rate of vehicle involvement in accidents[9]. Third it was assumed that the average value of vehicles involved in accidents would depreciate and would be only 60 % of the new vehicle price. Correspondingly, the cost of repairing the damage inflicted to vehicles involved in accidents was determined on the basis of the above assumptions and data, and the original and depreciated value of each category of vehicles was taken into consideration. Fourth, the loss of output due to death in accidents was calculated by working out the average age of those dead resulting

9 In year 1985 and 1990, percentage of involvement by vehicle type was 60% for automobiles and minibuses, 15% for the buses (including service buses), 20% for trucks and 5% for other vehicles. For details see TCK Turkish Highway Directorate, Traffic Bulletins (1985, 1990).

from vehicle accidents. More specifically, in this instance the average age was found to be 36. Thus loss of income receipts resulting from actively employed persons who are killed in road accidents over 29 years was estimated and it was discounted by 6 % to compute its 1990 present value. Fifth, still another assumption was introduced in order to make a distinction between loss of income owing to lightly and seriously injured people involved in road accidents. As in the IRTC Report (1987) it was assumed that 25 % are serious injuries and the remaining 75 % are light injuries. Based on these assumptions, numerical estimates of the loss of income for each type of injury for those who are actively employed were made, given the annual wage rate at 1990 prices. Sixth, another required step was to calculate the loss of investment due to children killed before the age of 15. It was also determined that the average age of these children who were killed in accidents was 7; hence the loss of investment over 7 years was estimated and expressed in terms of present values at 1990 prices by using the 6 % discount rate. Finally, an attempt was made to estimate costs of medical treatment per day which was roughly 16440 TL at 1990 constant prices. In this instance, the duration of medical treatment for each injury type was determined by considering the hospitals data in the İstanbul Province. Total cost of accidents which occurred within the İstanbul Metropolitan area in 1990 was calculated to be as the sum of the various components estimated and mentioned above. The average accident cost was found to be 12 742 000 TL, based on recorded accident number of 17 206 in the İstanbul Metropolitan Area (Table 6).

Table 6

Derivation of Average Accident Cost

	Cost	Million TL, 1990 prices
1	Repair cost of vehicles in accidents	64033
2	Loss of future output due to death and incapacitation	132239
3	Loss of investment due to children killed	10587
4	Loss of income due to injuries at employment age	8376
5	Medical treatment costs of persons injured	1842
6*	Allowance for administrative costs (eg police time, court, etc)	2171
	Total costs	219248
	Average accident costs= 219,248/17,206= 12,742.000 TL	

* Administrative costs were assumed to be 1 % of total accident costs.

Considering the vehicle-kilometers forecast for each vehicle type (under each alternative) the rate of accident was estimated for each alternative. Table 7 presents “saved number of accidents” and thus total accident cost savings for each alternative for the years 1995 and 2005.

Table 7

Number of Accidents Saved and Accident Costs Savings of Bosphorus Tube Tunnel and İstanbul Metro Alternatives

(million TL, 1990 prices)

Alternatives	Year	Number of Accidents Saved	Accident Costs Savings
Alt 8 Bosphorus Tube Tunnel vs 1	1995	1317	16454800
	2005	72	899268
Alt 9B İstanbul Metro System (Taksim) vs 1	1995	1107	13830972
	2005	534	6672174
Alt 10B Bosphorus Tube Tunnel+İstanbul Metro System (Taksim) vs 1	1995	1503	18779412
	2005	1020	12744288

13. Freight time costs analysis

This section is devoted to estimation of the value of time to be saved in freight movements that would be an economic benefit related to operation of the Bosphorus Tube Tunnel. The freight time costs analysis is specifically related to the Bosphorus Tube Tunnel (Alt 8) and the combined alternative (10 B) which includes the Bosphorus Tube Tunnel and the Metro System via Taksim.

In the estimation of freight time cost savings the steps taken are summarised below.

(a) The per ton value of shipping time savings was calculated both for international and domestic goods based on the plausible principle that transport time represents deferred earnings (for inventory costs) which are based on the market value of commodities shipped across the Bosphorus and the opportunity costs of funds for shippers.

(b) Given the relevant data, the average value of international freight by allowing for the annual interest cost on inventory was estimated to be 17 456 820 TL at 1990 prices. Hence, the time value of transit cargo per ton-hr (at constant prices) was found to be 6819 TL. Here the yearly production time was considered to be 2560 hours (320 days x 8 hours)[10].

(c) Similarly, the value per ton of domestic freight adjusted by the relevant interest rates (opportunity cost) was estimated to be 5 433 946

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10 For details of this model, see De Leuw, Cather Swerdrup and Parcel Botek (1983).

TL at 1990 prices. In this instance, for the estimation of the time value of money devoted to working and investment capital, the interest rates on time deposits in 1990 was considered appropriate.

(d) Another step is to break down the Bosphorus freight tonnage carried across the Bosphorus by railway into ‘transit’ and ‘domestic’ freight for an accurate estimation of freight time costs. (Table 8). Total tonnage of freight shipped across Bosphorus is based on high rail projection which has assumed that there will be considerable improvement in the rail transport system between 1983 and 2005 due to the contemplated modernisation of all rail network in İstanbul region.

(e) A comparison has to be made between the existing ‘rail ferry system’ and the proposed ‘Bosphorus Rail Tunnel System’ in order to estimate freight time cost savings. Accordingly, it was assumed that the trans-Bosphorus crossing of freight by rail ferry (loading, shipping, unloading) was 6 hours and 18 minutes; while crossing by the Rail Tube Tunnel would be 30 minutes due to more efficient relocation of some of the rail stations on both sides of the Bosphorus.

Table 8

Bosphorus Freight Tonnage Matrix: Railway Transport Mode

Year	Transit (tons)	Domestic (tons)	Total tons High rail case
1983	359000	43000	402000
1996	1460000	751000	2211000
2005	2425000	1320000	3745000

Source: IRTC: Regional Study, Task No:109 (Callaghan, 1986: 6-21).

In terms of 1990 prices, freight time costs per ton per crossing for the existing rail ferry and the Bosphorus Tube Tunnel are calculated. In the case of transit freight time value per ton/minute was found to be 1136 TL; while it was 35.1 TL for the domestic freight. Similarly, time cost per crossing for rail ferry was 42 959.0 TL in the case of transit freight and 13 279.0 TL in the case of domestic freight. Whereas time cost per crossing under the Tube Tunnel would only be 3 408.00 TL for transit freight and 1 053.00 TL for domestic freight.[11] Based on the data and parameters given above, the freight time cost savings accruing to shippers and also to the local economy by the Bosphorus Tube Tunnel as compared to existing rail ferry transport are presented in Table 9.

[11] For the detailed estimation of time value of transit and domestic cargoes, see Karataş (1989: 73); and Karataş and Payaslıoğlu (1996: 198).

14. Breakdown of total economic benefits

The total benefits of metro alternatives, based on the assumptions described in the above sections, have been estimated for the block years of 1995 and 2005 and illustrated in Table 9.

15. Comparison of alternatives by ranking criteria

In this section, an attempt is made to discuss the admissibility of the three metro alternatives by comparing them on the basis of internal rates of return (IRR), the benefit-cost ratio (b/c) and the discounted net present value (NPV) criteria. If the economic objective is maximizing total returns to the limited public sector capital funds available, then it is conceived that the most appropriate measure for economic ranking would be the net present value, calculated at ‘accounting prices’. The NPV analysis discounts cost and benefit streams over 40 years from the time of project inception. Based on a set of basic assumptions (regarding individual benefits and other key parameters), the NPV is computed first by using market prices; and then analysis is performed by using ‘resource-corrected prices’. However, in order to conduct sensitivity analysis, the benefit-cost ratios and the NPV computations are carried out on the basis of 9% , 12% and 15% discount rates[12].

16. Internal rate of return

The Bosphorus Tube Tunnel and metro alternatives are analysed both at market and social prices. For instance, at social prices, the highest IRR is exhibited by the İstanbul metro system (via Taksim) with 42.2 %, being followed by the Bosphorus Tube Tunnel with 39.42 % and the combined alternative with 33.18 %. Apparently, on this measure, the least attractive alternative turns out to be the combined alternative. (Table 12).

17. Benefit-cost ratios

The analysis was first performed by using market prices, then repeated using resource-adjusted prices. In terms of benefit-cost ratio and social prices the most attractive project turns out to be the İstanbul metro system (via Taksim) with 7.61, folllowed by the Bosphorus Tube

12 For detailed models used for the estimation of economic discount rates, see Shukla (1997).

Tunnel with 6.81 (at 9 % social discount rate). Clearly, based on benefit-cost ratio, the least admissible projet becomes the combined alternative, 10 B (6.12) because it has the highest initial capital costs. If the benefits and cost streams were discounted at 12% rate of discount, the corresponding benefit-cost ratios become notably much lower; however, the ranking of alternatives does not vary at all (Table 10).

Table 10
Benefit-Cost Ratios of Metro Alternatives

	Market prices			Social prices		
Alternatives	I=9%	i=12%	i=15%	i=9%	i=12%	i=15%
1.Bosphorus Tube Tunnel (8)	6.14	4.83	3.81	6.81	5.45	4.36
2. İstanbul Metro System (via Taksim) (9B)	6.94	5.40	4.25	7.61	6.05	4.82
3. Combined Alt (10B) (Bosph. Tube Tunnel plus Metro via Taksim)	5.41	3.98	3.01	6.12	4.50	3.47

18. Net present value analysis

The NPV analysis is first performed on the basis of market prices. As an integral part of the Little-Mirrlees method, a social discount rate (or ARI) was estimated by considering sub-parameters which include the marginal productivity of capital, marginal propensity to save, value of public income and conversion factor for consumer goods[13]. Based on the Little-Mirrlees appraisal method, as a key parameter the social discount rate for Turkey was estimated to vary between 6% and 9% in real terms. However, in order to conduct sensitivity analysis, the benefit-cost ratios and the NPV computations are also carried out on the basis of 12% and 15% discount rates. The results demonstrate that under the NPV method and social prices, contrary to earlier findings, the most admissible metro alternative appears to be the "combined alternative" (10B) which comprises the Bosphorus Tube Tunnel plus the İstanbul Metro System

13 The accounting rate of interest can be derived from the formula of; $ARI = sq + \frac{(1-s)q}{v.CFc}$,

wheres is marginal propensity to save, q is marginal productivity of capital, v is value of public income and CFc is conversion factor of consumer goods.

If the parameters which are taken into account are q=24%, s=0.29, CFc=0.88 and v=7.99 then the value of ARI becomes 9 percent. But for lower values of q (12%) and (2.52) the social discount rate turns out to be only 6 percent. For various methods of deriving an appropriate social discount rates, see, Little-Mirlees (1974), Curry and Weiss (1993) and Shukla (March, 1997).

(via Taksim). Evidently at 9% discount rate the NPV of the combined alternative would be 23.3 trillion TL, while that of the Metro System (via Taksim) 22.3 trillion TL. (Table,11) Contrary to its popularity, the least acceptable alternative by NPV rule would be the Bosphorus Tube Tunnel with 19.9 trillion TL. It is interesting to note that the combined alternative (10 B) which is the largest and most costly project would still rank first, even if the social discount rate were raised to 12%. But the combined alternative (10B) would rank second once the discount rate were raised from 12% to 15%. At 15% rate of social discount rate the first priority would be given to the metro system via Taksim and then the combined alternative (10B).

Table 11

Net Present Value of Bosphorus Tube Tunnel and Metro Alternatives (billion TL. 1990 prices)

	Market prices			Social prices		
Alternatives	i=9%	i=12%	i=15%	i=9%	i=12%	i=15%
1 Bosphorus Tube Tunnel (Alt 8)	19608.9	11904.5	7553.1	19981.2	12259.9	7891.5
2 İstanbul Metro System (via Taksim) (9B)	22067.7	13269.3	8394.8	22319.3	13556.3	8691.9
Combined Alt (10B) (Bosph. Tube Tunnel plus Metro via Taksim)	22721.9	13337.0	8091.8	23310.1	13894.1	8618.2

Again in terms of NPV, at social prices discounted NPV of the Bosphorus Tube Tunnel is strongly positive even though it exhibits slightly lower NPV as compared to the other two alternatives at test discount rates. This result holds true for both market and resource-adjusted prices. Table 12 summarises the sensitivity of results to varied discount rates and choice of criterion, based on resource-adjustment prices.

Table 12

Sensitivity of Metro Alternatives to Different Criteria and discount rates (resource adjusted) (billion TL,1990 prices)

		9 % discount rate		% 12 discount rate		15 % discount date	
Alternative	IRR	b/c ratio	NPV	b/c ratio	NPV	b/c ratio	NPV
1 Bosphorus Tube Tunnel (Alt.8)	39.4	6.81	19981.2	5.45	12259.7	4.36	7891.5
2 İstanbul Metro System (via Taksim) 9 B	42.0	7.61	22319.3	6.05	13566.3	4.83	8691.1
3 Combined Alt (10B)	33.1	6.12	23310.1	4.50	13894.1	3.47	8618.2

19. Discussion of the results

Based on the foregoing analysis, it can be seen that in terms of the IRR measure and the b/c measure, the İstanbul Metro System via Taksim appears to be the most admissible project at a 9% social discount rate; representing a 42% rate of return and a benefit-cost ratio of 7.6. The next-best alternative turns out to be the Bosphorus Tube Tunnel with an economic rate of return of 39.4% and benefit-cost ratio of 6.81. Note that, the combined alternative ranks third in terms of IRR (33.1%) and the benefit-cost ratio (6.12) under 9% discount rate. The order of ranking does not seem to alter when the discount rate was even raised to 12% or 15% (Table 12).

However, it should be noted that the b/c ratio like the IRR measure creates a bias against large projects with a relatively large capital outlay. Similarly, the IRR measure might also be misleading in the appraisal of projects particularly when mutually exclusive and competing projects are under consideration (Turvey, 1963; Feldstein and Flemming, 1964; Little and Mirrlees, 1974). Therefore, for the final selection of competing metro alternatives, the NPV measure would be more reliable and produce efficient results. If the objective is maximization of total net benefits (NPV, total PV of benefits minus total PV of costs) to public investment, it becomes obvious that at both 9% and 12% social discount rates the combined alternative (10B) turns out to be more attractive than the other two metro alternatives. More specifically, NPV of the combined alternative (10B) at a 9% discount rate would amount to 23.3 trillion TL, while that of the Metro System via Taksim would be much lower with 22.3 trillion TL. Nevertheless, once the social discount rate was raised to 15%, the combined alternative becomes less preferable and ranks second and under this test discount rate the Metro System via Taksim would be more acceptable (compare 8691.1 billion TL with 8618.2 billion TL).

20. Economic valuation of air pollution

20.1. Theoretical debate and practice

Despite the fact that there would be a significant decline in the veh-kilometers driven by different vehicle types in the Bosphorus Tube Tunnel and proposed Metro Alternatives and thus considerable savings in air pollutants (NO_2, SO_2, HC, CO), there is still some necessity to examine a damage function that relates the level of pollution to the degree of the health effect. In practice ‘cost-of-illness’ approach is often used to value the cost of pollution-related morbidity (Dixon *et al*., 1995).

It is usually emphasised that 'dose-response functions' used in developed countries may produce inaccurate results when they are used in developing countries. In this approach 'costs due to illness' would include loss of earnings resulting from illness, medical costs such as for doctors, hospital visits (or stays) and medication (Dixon *et al*., 1995: 48-50). Yet this approach has its limits because it tends to exclude non-market losses related to sickness, such as the pain and suffering to the individual and to others concerned and restrictions on non-work activities. A number of studies (especially USA studies) has shown that there is a close relationship between mortality and ambient pollution concentrations (Evans *et al*., 1984: 78). They concluded that cross-sectional studies reflected a causal relationship between exposure to air-borne particles and premature mortality. Small and Kazimi (1995: 17) argued that other studies also provided additional support for this evidence, where particulate matter caused increased mortality. It was pointed out that inhalable particles, especially particles of less than 10 microns diameter (PM10) are the most responsible. Apparently, among the components of PM10, the most consistently found effects are from fine particles (FP) which are with a diameter of less than 2.5 microns, and from sulphates (SO_4) which are mainly aerosols of aluminum sulphate (sulphate particles are very small in size and are included in PM10 and FP). Similarly Özkaynak and Thurston (1987) using cross-sectional data for the USA, related mortality in metropolitan areas to ambient pollutant concentrations in the central cities (i.e., Los Angeles) where they used four alternative measures of particulates: total suspended particulates (TSP), PM10, FP and SO_4. The strongest and most consistent relationship was obtained in the case of SO_4 and the next strongest using FP. From these and other studies, it can be inferred that sulphate aerosols caused increased mortality as well as the other components of PM10 (Small and Kazimi, 1995: 17).[14]

It should be noted that motor vehicles, especially those using fuel, emit some particulate and also sulphur oxides (SO_x), primarily sulphur dioxide (SO_2). Sulphur dioxide is an irritant and contributes to particulate formation and acid rain. The same is true of nitrogen dioxide (NO_2) which is formed in the atmosphere from other (NO_x) emissions. (Small and Kazimi, 1995: 8)

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14 A number of studies showed that sulphate aerosols caused increased mortality as well as the other components of PM10. For stimulating discussion and estimation methods, see Small and Kazimi (1995: 16-17) and Özkaynak and Thurston (1987).

Studies on motor vehicle emissions have been extended to include the global effects of certain “greenhouse gases”, primarily carbon dioxide (CO_2) whose accumulation over decades or centuries may cause a gradual warming of the earth’s atmosphere. This eventually might lead to dramatic changes in wind and rainfall patterns. (Small and Kazımi, 1995: 7-10).

21. Analysis of the environmental effects of the metro proposals

In the various metro alternatives proposed for the İstanbul Metropolitan area; buses, trains, passenger ferries, vehicle ferries, sea buses, light rail and metro vehicles will be involved. In general, the environmental effects will include (a) air pollution and dust from excavation activities, (b) vibration effects from the established tunnels and rail tracks and (c) noise effects that will influence residential areas and passengers.

It is noted in Ünsal (1986) that, depending on the congestion of traffic, the concentration of (a) particulate material, (b) hydrocarbon, (c) nitrogen oxides, (d) carbon monoxide, and (e) sulphur dioxide in the air will tend to increase (Ünsal, 1986: 83). In so far as indirect effects are concerned, the pollutants which have direct effect on air quality might cause the formation of photo-chemical oxidizers as a result of reactions that take place in the atmosphere. In addition, during the construction stage, there is the effect of air polluting emissions of the road construction, vehicles and machinery used during the construction.

The most important sources of carbon monoxide are motor vehicles. This becomes significant especially in the context of the urban roads in the İstanbul metropolitan area. The evidence indicates that motor vehicles are responsible for 80% of the carbon-monoxide emissions within cities. Similar research work was conducted by Öztürk (1983) and this ratio was estimated to be 84%.

22. Valuation of air pollution impacts of the Tube Tunnel and metro alternatives

The only data available regarding emitted pollutants of particulate material (PM), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), hydro carbons (HC) and carbon monoxide (CO) are given in the Report on Environmental Impact Assessment prepared by Prof. Ünsal (1986:98).

The projected changes and reduction in pollutant emissions of the Bosphorus Tube Tunnel and metro alternatives as compared with the existing and committed baseline alternative are shown in Table 13. It can be seen that in terms of tons/year, the greatest amount of sulphur oxides (SO_2), particulate material (PM), nitrogen oxides (NO_2) and carbon monoxides (CO) would be saved under the combined alternative (10B), the Light Railway System (LRT) and finally the Bosphorus Tube Tunnel. Relatively, the lowest savings in pollutant emissions will be in the case of North-South Topkapı Metro (via Taksim) system which is already under construction.

Table 13

Estimated Reduction of Pollutant Emissions by the Tube Tunnel and Metro Alternative Projects (tons/year): 1995

Alternative	Particulate Material (PM)	Sulphur dioxide (SO_2)	Nitrogen dioxide (NO_2)	Hydro carbons (HC)	Carbon Monoxide (CO)
North-South Metro System (via Dolapdere) 9 A	-75	-676	-2827	-244	-1554
North-South Metro System (via Taksim) 9 B	-92	-704	-2912	-281	-1770
Bosphorus Tube Tunnel (Alt.8)	-120	-862	-3594	-352	-2177
Combined Alternative (Bosph. Tube Tunnel plus Metro System via Taksim (10B)	-158	-1060	-3943	-411	-2392
Light Rail System (LRT) (Alt.6)	-165	-941	-4908	-482	-2976

Source: Ünsal (1986:98)

Note: Negative signs indicate relative reductions in pollutant emissions under each alternative as compared to the existing alternative.

In this section, valuation of the environmental effects of the proposed metro alternative projects is based on the economic value of monetary outlays which should be invested in "abatement schemes" to obtain the equivalent degree of emissions reduction.The approach to estimate the monetary value of ‘abatement system’ to eliminate air pollution is basically used for the air pollution stemming from industrial establishments. Therefore at first sight this might not be considered as an appropriate method for calculation of air pollution resulting from transport projects; however in the absence of data, this ‘abatement scheme’ described below, has been adopted as a second best to the

Bosphorus Tube Tunnel and metro alternatives. Thus, a conceptual cost to construct a system for reduction of emission parameters (SO_2 , NO_2 and particulate material (PM)) is used as a measure for the valuation of environmental effects. The monetary values of potential investment costs in mitigation process is considered to be equivalent to the environmental benefits stemming from the proposed alternatives. This will represent a proxy for the environmental benefits.

The steps used for the valuation of environmental benefits is summarised below:

(i) In some environmental impacts studies, abatement costs for NO_X is given to range from \$250 to \$1000 per ton of NO_2, depending on the baseline level of emission (Potts and Lomas, 1998: 5). For this purpose, in the context of our case study, it is perhaps more logical to employ the low cost technologies to reduce emission levels in the İstanbul Metropolitan area. Therefore, mitigation costs of \$250 per ton of NO_X were taken as a proxy for mitigation benefits. It should be noted that this level is commonly used as a norm in other developing countries such as Yugoslavia (Dondur and Chetkovic, 1997:123) and Lithuania (Potts and Lomas, 1998:5).

(ii) Similarly, in the case of sulphur dioxide (SO_2), the costs of desulphurisation process for district heating project in Yugoslavia were given as ranging from \$634 to \$1379 per ton of sulphuric dioxide (Dondur and Cvetkovic, 1997:123). We also notice that Potts and Lomas (1998: 6) in their study of the Lithuanian District Heating Sector have also used mitigation costs of \$600 per ton of SO_2 which was based on the values estimated in damage studies in other developing countries. In this study, the mitigation costs of sulphur dioxide (SO_2) which was used both in Yugoslavia and Lithuania was considered fairly plausible to be used for the estimation of mitigation costs and thus as proxy for mitigation benefits.

(iii) A similar approach was adopted for particulate material (PM) costs where cost of mitigation of PM was taken as \$1000 per ton; an assumption used both in Yugoslavia, Poland and Lithuania (Potts and Lomas, 1998: 6).

On the basis of these assumptions together with the data on the reduction of emissions (Table 13), we can estimate the values of environmental benefits during the operation period of the Tube Tunnel and Metro alternative projects. The mitigation costs are first calculated as an annual value in thousands of US dollars. Then these values were converted to Turkish Liras (at the official exchange rate in 1995) to give the environmental costs savings. Undoubtedly, the environmental benefits would be much higher if the figures for hydro carbons (HC), and carbon monoxide (CO) had been included. Table 14 shows the value of environmental benefits associated with air pollution resulting from the three alternatives reflecting 1995 environmental benefits which are not discounted to present values. Nevertheless, these figures show, to some extent, the magnitude of the environmental benefits stemming from the proposed metro alternatives.

Table 14

Value of Environmental Benefits Associated with Air Pollution by Metro Alternative Projects (1995)

Alternative	Benefits associated with particulate material (PM)		Benefits associated with Sulphur dioxide (SO_2)		Benefits associated with Nitrogen dioxide (NO_2)		Total Environmental benefits	
	$	bill.TL	$	bill.TL	$	bill.TL	$mil.	bill.TL
1. İstanbul Metro System via Taksim (9B)	92000	4.2	422400	19.3	728000	33.3	1242.4	56.8
2. Bosphorus Tube Tunnel (Alt.8)	120000	5.5	517200	23.7	898000	41.1	1535.7	70.3
3. Combined Alt (10B)	158000	7.2	636000	29.1	985750	45.1	1779.7	81.4

As can be seen from Table 14, estimated benefits associated with air pollution due to sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and particulate material (PM) appear to be highest in the case of the combined alternative (10B), followed by Bosphorus Tube Tunnel (Alt.8) and lastly by the Metro System via Taksim (9B). In the case of combined alternative (10B), the value of environmental benefits associated with sulphur dioxide is $636000, while it is $985750 for nitrogen oxides and $158000 for particulate material, total environmental benefits reaching $1.77 billion. On the other hand, under the Bosphorus Tube Tunnel, the mitigation benefits are $517200 for sulphur dioxide, $898500 for nitrogen oxides and $120.000 for particulate material, the total benefits reaching $1.53 billion (Table 14). The total mitigation benefits associated with the three pollutant emissions are $1.24 billion in the case of the metro System via Taksim (9B). Clearly, these results demonstrate the substantial environmental benefits that are emanating from all the proposed alternative projects.

23. Vibration impacts of alternative metro projects

The points which are emphasised in this section reflect the Environmental Impact Report prepared by Prof. Ünsal of İstanbul Technical University (1986). First it is argued that the sensitivity of the buildings can be analysed by changing the frequency amplitude of the artificial vibration. The vibration effect of metro construction in the buildings will depend upon the beating action and whether the tunnel is bored in rock or soil layers (sediments, clay, sand, etc.). It is also emphasised that in a rocky environment vibration spreads easily and there is less damping. The effect of a sudden thumping action deep below on the buildings at the surface will be less than the vibration transferred through rock because the damping coefficient of soil is much greater than that of rock (Ünsal, 1986: 101). Secondly, equually important is the vibration impact of the metro alternatives during operation. In the case of tunnels, these would be the vibrations between the road and the rail vehicles. Clearly, the degree of vibration will vary according to the area taking place in each metro alignment. Thirdly, Yenikapı-4.Levent Section of the Metro System (via Taksim) was designed to run in tunnel form. The tunnel will go under Gazi Mustafa Kemal Street, the settlement area, Ordu Caddesi and will reach the proposed Beyazıt station (centre of the historical area), which is to be located 65m deep and runs between the Faculty of Sciences and the İstanbul University Main Enrance Gate.

The area between Beyazıt Station and Süleymaniye happens to be a dense settlement area. There are also underground ‘Byzantine aquaducts’ in this particular area. On the other hand, propagation of vibration depends on the types of rock or soil surrounding the tunnel; location and type of strata interfaces and to a lesser extent ground water levels. Obviously, a more detailed historical and engineering survey will be required during the engineering works and design stage to prevent the loss of these cultural and historical assets[15].

24. Noise impacts of metro alternatives

Environmental noise is an important factor causing discomfort and annoyance in the residential areas; therefore it must be taken into

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15 The contingent valuation technique (CVT) is one way of estimating the values of these assets; however the limitations inherent in these techniques make it difficult to arrive at meaningful estimates. For discussion of this issue see Dixon *et al.* (1995: 114-116).

account during the construction and operational phases of the metro systems and the Bosphorus Tube Tunnel. Railroads are significant noise sources due to their impact noises and mechanical vibrations in addition to high levels of air-borne sounds. Normally, railway noises are generated by (i) trains passing by and (ii) manouvering and maintenance works. Meanwhile, sound levels may depend on several factors such as train types, train composition (locomotive and rail carriages), train speed, railway conditions (gradients, curbs, at grade or aerial structures), rail types and supporting systems.

It is often claimed that there is 6-7 dBA (decibel scale) difference in the noise outputs between the diesel and electrified locomotives. Aerodynamic noise increases with the train speed and exhaust noises are as high as 98 dBA (Ünsal, 1986: 128). Moreover, noise from brake systems and from the interaction between wheels and rails and from the signals, which may be up to 105 dBA at 30 meters are significant levels especially in railway noise control[16].

Noise impacts will be more significant in noise-sensitive areas such as residential, institutional and parkland areas and when there is a direct line of sight between the noise source and the receptor. It is likely that the most severe impacts would be for cut-and-cover construction that occurs in the earlier stages of construction, during ground clearing and excavation. As for the combined alternative (Bosphorus Tube Tunnel plus Taksim Metro), its design and specified alignment would result in a greater number of cut-and-cover stations at grade construction. The estimates show that the ventilation system would generate noise levels of 85 dBA during the emergency conditions (e.g., fires) and 80 dBA during peak daytime periods at a distance of 10 meters (IRTC, 1987: 5-10).

25. Concluding remarks

The economic appraisal of the Bosphorus Tube Tunnel and İstanbul Metro Alternatives shows us that under the NPV rule and social prices the most acceptable alternative appears to be the Combined Alternative 10B, which includes both the Tube Tunnel and the North-South Taksim metro (9B). At 9% and 12% social discount rates the combined alternative exhibits a much higher net present value compared to the other alternatives. The NPV of the Combined Alternative in 1990 prices is 23.3 trillion TL and 13.8 trillion TL at discount rates of 9% and 12%

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16 For stimulating discussion on sound and noise impacts see Morris and Therivel (1995: 51-53).

respectively (see Table 11). At both discount rates the İstanbul Metro via Taksim (9B) would rank second and the Bosphorus Tube Tunnel third. Owing to the lack of data as well as to identification and estimation problems, indirect costs (or benefits) in terms of air pollution, noise and vibration effects have not been integrated into the above analysis. This might make the implemented analysis look slightly incomplete, especially from the viewpoint of environmentalist economists or environment policy makers. In recent years, the CBA has undergone a positive conscious development, in that it has increasingly included environmental and non-market valuation in economic analyses.

Clearly the gaseous emissions of CO, CO_2, SO_2, NO_X and particulate emissions from motor vehicles under the existing baseline alternative are the main causes of air pollution[17]. Therefore, it can safely be argued that the Bosphorus Tube Tunnel and Metro Alternatives proposed would most likely reduce the level of air pollutants and thus reduce the risk on human health, particularly of children and of those who are suffering from respiratory illnesses. There might be savings (or benefits) in the loss of earnings resulting from illness, medical costs such as doctors' fees, hospital visits and medication (Dixon *et al*., 1995:48).

Because a fewer number of vehicles will be entering the surface traffic and a relatively lower veh-km will be recorded by motor cars, buses and express buses and ferries, it is expected that there would be a significant decline in the gaseous emissions of CO_2, CO, SO_2, NO_2 and particulate materials under the Bosphorus Tube Tunnel and Metro Alternatives (Table 14). For instance, the present value of saved costs of illness (morbidity cost) or saved mortality rates may be considered to be the environmental benefits of the Metro Alternatives and Tube Tunnel compared to the Existing Alternative. Nevertheless, against these environmental benefits with respect to the Existing Alternative (relative avoidance of air pollution) the Tube Tunnel and Metro Systems might also cause environmental costs (disbenefits) in terms of noise annoyance and vibration impacts. Therefore, actual environmental benefits resulting from the proposed Metro Alternatives might be overrated, if adverse noise and vibration effects are not considered.

A number of concepts of value and practical valuation techniques have been developed to trace the welfare effects of environmental changes in production and changes in environmental quality. However, the total economic value of a resource or asset should be used with some

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17 In fact, ambient SO_2 and NO_2 plays a key role in particulate formation, which appears to be more important to human health. For details of effects of various pollutants, see Small and Kazimi (1995: 8-20).

caution because some concepts of value (benefits or costs) cannot simply be aggregated.

The extended benefit-cost rule for appraising an investment project can be derived as:

$$Extended \quad NPV = \sum_{t=0}^{n} \frac{B_t - C_t - E_t}{(1+r)^t}$$

where, B_t, C_t and E_t are economic benefits, economic costs and net environmental costs at time t respectively; n is the duration of the study period, and r is the discount rate. However, Pearce and Warford (1993) draw attention to the fact that the net value of E_t is considered as a cost, but in a number of cases E_t may well be a benefit. Regardless of the difficulty in estimating environmental impacts precisely, an attempt should be made to incorporate them into the economic analysis to carry out the extended benefit-cost analysis. Inclusion of environmental benefits and/or costs will add considerable refinement to the economic analysis carried out; but the ranking of the proposed Tube Tunnel and Metro Alternatives might not be altered because there will be comparable environmental benefits in terms of improved air quality owing to reduced emissions associated with the Metro Alternatives considered.

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Özet

Boğaz tüp tunnel projesi ile İstanbul Metro alternatiflerinin ekonomik değerlendirmesi ve çevresel etkileri

Bu yazıda, Boğaz Tüp Tünel Projesi ile İstanbul Metro Alternatiflerinin ekonomik değerlendirmesi ve çevresel etkileri incelenmiştir. Ekonomik değrlendirmede, Little ve Mirrlees metodu uygulanmış ve bu modelin öngördüğü kaynak çeviri faktörleri (conversion factors) ve ulusal parametreler belirlenmiştir. Alternatif projelerin ekonomik analizinde, önce piyasa fiyatları daha sonra da sosyal fiyatlar kullanılmıştır. Önerilen projelerin değerlendirmesinde iç kârlılık oranı, fayda-maliyet oranı ve net bugünkü değer kriterleri uygulanmıştır. Karşılaştırmada net bugünkü değer kriterine ve sosyal fiyatlara göre, Taksim metro projesi ile Boğaz Tüp Tünel projesini içeren bileşik alternatifin daha üstün olduğu saptanmıştır. Aynı varsayımlara göre, Taksim metro projesi ikinci sırada yer almaktadır. Ancak, iskonto haddi 15% seviyesine yükseltildiği zaman Kasim metro projesi birinci sırayı almaktadır. Araştırmanın ikinci bölümünde ise önerilen projelerin çevresel etkileri ele alınmış ve bu bağlamda hava kirliliği, titreşim etkisi ve gürültü etkisi tartışılmıştır. Önerilen metro ve diğer seçeneklerin, partiküler, sülfür diyoksit ve nitrojen diyoksit gibi sağlığa zararlı gazlar bakımından çevresel etkileri karşılaştırılmıştır. Kapsamlı ve daha rasyonel ekonomik değerlendirme için çevresel fayda ve maliyetlerin de genişletilmiş sosyal fayda-maliyet analizlerine dahil edilmesi gerektiği vurgulanmıştır.

Table 9

Breakdown of Total Benefits of the Bosphorus Tube Tunnel and İstanbul Metro Alternatives

		Travel Time Cost Savings	Auto-taxi-Dolmufl Operat+maintenance Cost saving		Truck Oper+main Cost saving	Transit Oper+main Cost Saving	Roadway Maintenance Cost saving	Accident Cost saving	Freight Time cost saving	Total benefits
Alternative	Year		Energy	Non-Energy						
ALT 8 Bosphorus Tube Tunnel vs. BASE	1995	2,006,908.0	211,294.2	357,795.2	(1,142.1)	30,465.8	(12,908.7)	16,454.8	71,152.3	2,680,019.5
	2005	3,185,276.0	315,867.5	886,026.4	8,680.7	(245,517.5)	(29,862.4)	899.2	119,469.4	4,240,835.5
ALT 9A İstanbul Metro System (Dolapdere), v.s. BASE	1995	2,085,159.0	221,967.9	599,907.8	(462.3)	(40,088.1)	(11,874.6)	16,042.9	…………..	2,870,652.6
	2005	3,668,591.0	445,082.6	1,238,938.2	9,192.9	(245,877.5)	(21,270.8)	17,766.7	…………..	5,112,423.1
ALT 9B İstanbul Metro System (Taksim), vs. BASE	1995	2,071,350.0	213,341.7	571,796.1	(2,179.5)	(48,620.4)	(13,349.3)	13,830.9	…………..	2,806,169.5
	2205	3,631,767.0	457,535.1	1,272,124.8	8,918.4	(225,986.8)	(20,387.3)	6,672.1	…………..	5,130,643.3
ALT 10 B Bosphorus Tube Tunnel+‹stanbul MetroSystem (Taksim)	1995	2,218,646.0	216,633.3	584,475.7	(804.3)	39,470.0	(3,175.4)	18,779.4	71,152.3	3,145,167.0
	2005	3,746,842.0	373,326.7	1,044,490.5	9,507.8	(165,615.0)	(11,265.5)	12,744.2	119,469.4	5,129,500.1

Note: The figures in brackets represent disbenefits, resulting from metro alternatives