TOLL POLICY, REVENUE, TRAFFIC AND COST RELATIONSHIPS IN MOTORWAYS
A CASE STUDY: ÇAMLICA-KAYNAŞLI MOTORWAY GEBZE-İZMİT SECTION

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ABSTRACT

TOLL POLICY, REVENUE, TRAFFIC AND COST RELATIONSHIPS IN MOTORWAYS
A CASE STUDY: ÇAMLICA-KAYNAŞLI MOTORWAY
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As a result of the development of motorized vehicle technology, the increase of speed and freight highway transportation, the desires of people to travel faster and comfortable, force continuously the construction of high standard roads. Rapid increase of traffic and together with rapid increase of traffic accidents are more effective factors in the construction of these roads. Because, the finance of construction, maintenance and operation of toll roads is high, to charge the finance to road users is the essential of the system.

The objective of this study is to define toll roads, to explain its history, to discuss urban and inter-urban toll road implementations, to investigate the factors affecting preference of toll roads or state highway, to study on the average constant toll per kilometer application based on the principle of self-financing of a road which is the minimum desired condition.

In this study, the reasons that cause the increase of costs and factors that affect negatively have been pointed out on the example of Gebze-Izmit Motorway.

Keywords: Tolls, Toll Roads, Road Pricing, Toll Collection Systems.

Science Code: 624.04.01

ÖZ

OTOYOLLARDA ÜCRET POLİTİKASI, GELİR, TRAFİK VE MALİYET İLİŞKİLERİ ÇAMLICA-KAYNAŞLI OTOYOLU GEBZE-İZMİT KESİMİ ÜZERİNDE ÇALIŞMA

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Motorlu taşıt teknolojisinin gelişmesi sonucu, hız ve tonajın artmasi, kişilerin daha hızlı ve konforlu ulaşım istekleri, karayolu yapımında hergün biraz daha yüksek standartlı yolların yapımını zorlamaktadır. Hızlı trafik artışı, bununla beraber kazalardaki artışlar, bu yüksek standartlı yolların yapılmasında daha da etkili faktörlerdir. Ancak, bu yollarin yapım, bakım ve işletme maliyeti yüksek olduğundan bu finansmanın yoldan yararlananlara yüklenmesi, otoyol sisteminin esasını oluşturmaktadır.

Bu çalışmanın amacı, paralı yolların tanımını yapmak, tarihçesini, kent içi ve kent dışı paralı yol uygulamalarını tanıtmak, otoyol kullanımının tercih edilip edilmemesinin faktörlerinin araştırmak, maliyetlerin finansmanı minimum istenen durum olan bir yolun finansmanının kendisinin karşılaması prensibine dayanarak ortalama kilometre başına sabit ücret uygulamasını ortaya koymaktır.

Bu çalışmada Türkiye'de otoyol kullanımını olumsuz etkileyen faktörler, maliyetleri artıran nedenler de Gebze-İzmit Otoyolu örneği üzerinde incelenmistir.

Anahtar Kelimeler: Geçiş Ücretleri, paralı yollar, yol ücretlendirilmesi, Ücret toplama sistemleri.

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Nomenclature

ETC	Electronic Toll Collection
AVI	Automatic Vehicle Identification
RF	Radio Frequency
ENP	Electronic Number Plate
HOV	High Occupancy Vehicles
Km	Kilometers

Symbols

p^m	probability of using the toll road for demand group "m"
d^{Cm}	difference in generalized cost between the toll road and the alternative road
d^t	travel time difference between the toll road and the existing road (minutes)
$vtts_m$	perceived value of travel time saving (cents/minutes) for market segment "m"
dd	distance difference between the toll road and the existing road (Km)
voc_m	perceived vehicle operating cost (cents/km) for demand group "m"
$toll_m$	toll charge (cents) for demand group "m"
b^m	constant
LAMBDA	the slope of the curve

LAMBDA	the slope of the curve
CAPT	the level of captivity to the toll route
DELTA	the horizontal shift in the demand curve
MVTOLL	computer program name

CHAPTER I

INTRODUCTION

The toll roads are the investments which provide revenue. In many countries, toll roads are being constructed. These countries have defined some goals for the construction of these roads according to their economic conditions. These may be self-financing of the road, either to get surplus revenue to finance the construction of the other roads or to finance only maintenance, operation and administration costs.

The goals can be reached by the revenue obtained by collecting tolls from vehicles. Revenue is a function of traffic and tolls collected. Tolls consist of entry fees to specific sections of road and change according to types of vehicles and distance.

In this study, it has been stated that a goal for the construction of a toll road should be defined and by taking as an example of Gebze-Izmit Motorway which is the first motorway has been opened to traffic in Turkey. Benefit-Cost analysis has been made according to the self-financing principle. Then, to supply self-financing of this road, constant toll application has been studied for the period of 1992-2005 and the economic life of the road which is between the dates of 1985 and 2005. To research the factors affecting usage of motorways in Turkey, roadside survey on the state highway which is alternative of Gebze-Izmit Motorway has been made and the factors that affect drivers' preference of using motorway have been brought out. Moreover, it has been given information about history of toll roads, urban, interurban toll roads and their successful implementations in the world, toll collection systems, their advantages and disadvantages.

CHAPTER II

HISTORY OF TOLL ROADS

The history of the development of road financing systems in the world is identified with the development of various systems of transportation, passenger and freight movements and the creation of industrialized civilizations.

At the time of the fall of the Roman Empire, the roads had suffered from abandonment and lack of maintenance because of the invasions. With the coming of the Renaissance there had been a steady movement in the construction of roads and bridges. During this historical period, when the first banks and banking operations had begun in Italy, highway construction had been financed by the feudal states or by the Kingdoms, and users had been charged "transit" tolls.

In 1716 and 1747, the first true organization of road engineers which is called "Corps des Ponts et Chaussées" and the "Ecole des Ponts et Chaussées" was founded in France. This event was marked as the beginning of the Third Generation of the roads. The studies and experience of French school influenced road building throughout Europe and the United States. During the Napoleonic era, and by the mid 1800's all nations had been adopted similar road legislation especially with respect to road classification and the problems of financing and maintenance.

In Ireland, toll roads were constructed under a series of "Turnpike Road Acts" at the beginning of 1729. All major roads leading west and north of Dublin had been tolled together with the north and south circular roads.

In the United States, following Revolutionary War, in the United States, financing road construction was a difficult undertaking. Local authorities who were responsible for road maintenance appealed to the State Governments to provide financial support for roads. State Governments were burdened with debt accumulated during the Revolutionary War and unable to accommodate the requests. Instead, private companies were chartered to build roads and charge tolls for their use. The first of these companies chartered by Virginia in 1785. It built a turnpike road from Alexandria on the Potomac River. However, the first to be completed for any considerable distance and the most successful financially was in Pennsylvania, between Philadelphia and Lancester. This road which had 100 km. length was completed under 3 years.

The company had collected tolls at rates changing from 1.6 cents per km. for stages and coaches drawn by two horses to 3 cents per km. for 4 horse freight wagons with 10 cm. tires.

Many of the highway toll facilities operating during the 1800's served local needs, while long distance freight and passengers suffered from modal competition. Increasingly, the railroad and canal movement had reduced the profitability of highway toll facilities. The companies underestimated the maintenance and administrative costs or built in areas where demand was low had gone to the bankruptcy.

With the advent of the mass produced automobile, state and federal agencies began to take an active interest in road construction and maintenance. Highway financing methods began to change as states sought ways to impose direct user fees.

Automobiles affected the national economy in many ways in U.S.A. They expanded the steel, glass, rubber and fuel market.

Similar developments occurred in Europe. By 1921 motor vehicles number reached to 60000 in Italy. Half of these vehicles were automobiles. Mr. Piero Puricelli drafted a paper entitled "Road Network for Motor Vehicles". This illustrated his project to connect the city of Milan and Como, Varese, and Lago Maggiore. He had a type of road in mind and called it "Motorway". Work on the motorway began in June 1923, right after finalizing the expropriation of the right of way for the road.

After the first Italian motorways had been built, Germany started to build its own motorway in 1925. With the national-socialist regime, construction of 14000 km motorway was started due to the economic and strategic purposes. By 1941, 3870 km. of motorway had been constructed. The roads were dual carriage-way road and free of tolls.

During this period, Italy had increased the length of her motorways to 483 km. before the Second World War. These motorways were all single carriage-way and made use of tolling.

After the Second World War, countries gave priority to restoring their economy and their communications network which included road systems.

At the beginning of the early fifties, the use of private car spread in the industrialized world and this increased severe problems for road infrastructures.

In 1950's, the U.S had 1100 km. highways. In 1956, it was decided to accelerate financing of the "National System of Interstate and Defense Highway". This network was to link 90 percent of towns of more than 50000 inhabitants and was to serve 80 percent of the population. In accordance with this plan, approximately 66000 km. highway were to complete on the Eastern seaboard and in California. It was financed by federal aid and from taxes, only 5 percent of the network has been financed from toll revenues.

In Europe, Italy and Germany has restored their road infrastructure. Germany has considerably developed its road and motorway network which is now the longest in Europe (8080 km. in 1983) and completely free of tolls: and financed from conventional vehicle user taxes.

In Italy, it was decided to convert the existing motorway with single carriage-way into dual carriage-way motorway and to start a program of new motorway construction. Italian motorway reached 5941 km. in 1984. The use of tolls was virtually completed for all infrastructure.

Other European countries were slower to start the motorway program. In many countries (France, United Kingdom, Belgium), the construction of motorways were realized in the sixties. The use of tolling made them to speed up the construction of a road network. In 1985, in France, 4400 km. motorway are tolled and in Spain 2000 km. toll motorway were operated.

For financing of new infrastructure, countries have chosen different solutions. France and Spain are examples of that choosing toll systems. Some countries like the United Kingdom and the Netherlands are using conventional methods of finance from the national budget, helped by specific taxes or borrowing. Austria and Norway are also examples of that using hybrid system in which tolling is used for local structures. There are also special cases in the world as follows;

- Belgium has used a system of royalties.

- Switzerland, requires the payment of a special tax for using the motorways.

- Development of motorways took place later in some countries like Mexico, Brazil and Australia.

- In Japan, the road network is recent and the toll technique is wide spread for both urban and rural roads and motorways.

CHAPTER III

INTER-URBAN TOLL ROADS

3.1. General

Application of higher standards to the construction of highways is increasing gradually due to the growing demand of people to travel in a more comfortable and safer way, because of the increasing speed and tonnage as a result of the improvements of vehicle technology. Also increasing traffic volume, vehicle operation cost and to minimize the accidents are the other important factors forcing the construction of higher standard highways.

Motorways, which are the most developed type of highways were started to be constructed in 1968 in our country due to the forcing of the above mentioned factors.

Tolling is applied only to the inter-urban motorways in our country including the peripheral roads.

Properties of the motorways are;

- the motorways are closed to the usage of pedestrians, non-motorized vehicles, tractors, etc.
- at-grade intersection does not exist along the motorway

- the entrances to the motorway are under control, that is the entrances are constrained and can be entered from definite places only.

- both directions of the traffic are separated from each other.

- geometrical and physical standards are higher. The radii of horizontal and vertical curves are greater, longitudinal grades are lower, sight distances are longer and the pavements have higher standards.

- shoulder exists near the platform for the broken-down vehicles.

- communication facilities exist along the motorway.

Moreover, the motorways have some advantages mentioned below;

- safety against the traffic accidents.
- reduction of the travel time.
- higher traffic volume.
- economy in vehicle operation costs.

Although the motorways have useful properties and advantages, the construction cost of the motorways are considerably high.

The subject of country-wide spreading of the motorway network depends on the result of transportation policy considering a benefit-cost analysis which is obtained from the below mentioned factors;

- increase of traffic volume in country,
- social and economic development rate,
- technological possibilities and labor power necessary for the construction of infrastructures of highways and other transportation modes,
- type of energy source,

- activities of railroads and maritime lines in terms of operation and infrastructure,

- the balance among the above mentioned factors.

Motorways may be served to the people as;

- toll motorway
- non-toll motorways

In Germany non-toll motorways are in service whereas toll motorways are in service in the South Europe Countries. Also in our country, the toll motorways are in operation. While determining the tolls, the aim must be to maximize the benefits for both the state and the motorway users.

3.2 Objectives of Tolling

Tolls are generally imposed for the purpose of raising additional net revenue. As a revenue raising device, they appear to have equity in their favor; the user pays. In addition, tolling allows revenue streams from roads. Therefore, tolls appear to be suitable instruments if the objective is revenue earmarking or private financing and management of roads. It is, however, as an instrument of efficient pricing of road in use tolls appear to possess unique advantages that are of importance in relation to rational resource allocation. Any particular tolling scheme may have a variety of objectives.

3.3 Conditions under which Tolling may be Appropriate

Theoretically, tolling the entire network as an alternative to other road user charges might represent the most accurate cost recovery means when collection costs are substantially lower than at present and collection can be achieved without stopping vehicles.

For some cases, such as the acceleration of road construction, tolling is more appropriate for general revenue purposes.

The conditions under which tolling may be appropriate;

a. It is considered that a transfer from private to public funds increase overall returns in the economy, but if there is no alternative revenue raising measure available or politically acceptable,

b. Tolling is applied to facilities with captive traffic such as tunnels, bridges, roads with poor substitutes. It can be said that tolling is appropriate where demand is inelastic or less elastic than other taxable bases and traffic levels are enough to compensate for toll collection costs.

c. Tolling is applied to existing congested facilities where traffic reduction is desired. Tolls can be appropriate where road supply is not fully elastic.

d. It is applied with discriminatory pricing, it is charged until the market will bear short of diverting traffic on uncongested roads; capturing externalities on congested roads.

e. If a road is to be built and tolled, the following should apply;

- standard design, safety, regulation standards,
- standard economic and least cost evaluation criteria,

3.4 Economic Losses due to Tolling

Operating an uncongested road as a toll road requires more resources than operating it as an untolled road. For toll road investment, its feasibility study should be subjected to tests of sensitivity and risks as regards the estimated impact of the toll rate on the diversion of traffic from the toll road to alternative routes. These tests should include alternative toll collection designs (open or closed or a mix). The impact of diversion on these alternatives should be tested.

The major economic losses associated with the imposition of tolls on inter-urban (or uncongested urban) roads consist of the following;

a. The incremental investment cost for the right of way, for toll plazas, toll booths and collection equipment and interchange costs.

b. The extra cost of toll collection and administration especially when compared to the extra cost of raising revenue through the on-going user charge tax structure.

c. The extra cost imposed on users as a result of stops to pay the tolls and time delays in paying the toll and/or in queuing at toll stations.

d. The costs imposed on potential users of a toll- free facility who are diverted to alternative routes because of the toll and encounter higher economic costs of vehicle operation and time delays.

e. The costs imposed on users of the non-toll facility who would not have been diverted to the toll road in any event but who now experience an increase in congestion costs due to the diversions of potential toll road users on to non-toll facilities.

The extent of these impacts depends on the toll system itself, its operating conditions and prices. These impacts are not independent. Pricing and diversion issues related to toll rates can not be easily separated from design, anticipated traffic, operating conditions, management of the toll system.

Interactions among system elements, affected costs and design and management strategy can be illustrated in Table 3.1.

3.5 Example Study: An Analysis of the Logan Motorway

3.5.1 General

The Logan Motorway is a major bypass route to the south of the main metropolitan area of Brisbane city in Australia. It links the Pacific Highway at Loganholme with the Cunningham Arterial Road at Gailes in the Ipswich City area. It has 32 km. length. This route has been assisting for the development of the Logan City area which has been located immediately to the south metropolitan Brisbane.

Because funds for construction had not been available, Main Roads (Governmental agency responsible from highways in Queensland State) had undertaken some preliminary design of the eastern end of the route. Careful planning and co-ordination with Logan City Council, developers and land owners had resulted in much of the area's growth being compatible with the final location of the road.

Table 3.1 Interactions among System Elements, Affected Costs and Design Management Strategy

System Elements	Affected Costs	Design and Management Strategy
1. Toll System and Design	a)Investment b)Toll collection c)User operating Cost	a)Minimize investment b)Minimize collection Costs c)Control use of Staffing and lower operating costs
2. Operating Procedures	b)Toll Collection c)User Operating Cost	
3. Toll Rate	d)Diversion e)Non-toll Road Users	d)Set rates on Elasticity bases e)Monitor performance

Source: Joseph Revis, Earmarking, Road Funds and Toll Roads. A World Bank Symposium Edited by F. Johansen, June 1989.

Due to the shortage of available funds, it had been decided that full construction could not been undertaken in a reasonable time frame and investigated the viability of the project as a toll road. After establishing feasibility, this project had been accepted as a toll road.

Toll roads have been considering as a means of extending Main Roads' financial sources to improve and expand Queensland's arterial road system. For assessing of toll roads, the important consideration is the amount of revenue that will generate.

For that reason, Main Roads had conducted a study for Logan Motorway. The primary objective was to prove a technique for estimation of toll road usage and revenue which could be applied to other toll road proposals.

In addition for this objective, the answers of the questions which are as follows had been investigated.

- how drivers may share the toll among other passengers,
- the extent to which toll roads may encourage greater car-pooling,
- how motorists perceive vehicle operating costs,

In order to achieve the objective, the study had been designed to collect data before the opening of motorway, to estimate usage and revenue and then to re-collect similar data after the motorway had been opened for three months. Comparisons had been performed between estimated and actual behaviour and appropriate adjustments made to the procedure.

Study components;

1. Before motorway opening

1.1 Field Survey

1.2 Stated Preference Survey

1.3 Analysis

1.4 Software Development

1.5 Forecasting Toll usage

2. After motorway opening

2.1 Field Surveys

2.2 Revealed Preference Interviews

2.3 Analysis

3.5.2 Traffic Surveys Before Motorway Opened

3.5.2.1 Roadside Traffic Survey

The objectives of the roadside interview survey were;

a. to stop a sample of vehicle movements which could divert to the road which would be a link of Logan Motorway after it had opened, so that a trip table could be built and used to estimate motorway vehicle volumes on this link.

b. to record trip details and contact addresses for a sample of potential motorway users so that they could be contacted again later during the stated preference survey and after the motorway was opened for the revealed preference survey. For the interview sample size, minimum 8 to 9 % of traffic counts had been maintained.

3.5.2.2 Travel Time Surveys

In order to evaluate the effects of the Logan Motorway on travel times on the highway network, it had been decided to measure peak and off-peak travel times on the more important links of the road system in that region before and after the motorway had been opened. Measurements had been made by driving an observation car along the routes at major cross roads. Drivers had been instructed to travel at average speed of traffic using the route at the time. At least two measurements had been made in each direction during peak hours and at least one measurement had been made in each direction during peak hours and at least one measurement had been performed in each direction during off-peak hours.

Trip tables had been built from the roadside interview data for each major trip purpose as well as for an all vehicle trip table.

The resulting trip tables had been used as the basis for estimating potential motorway users and as input to the motorway route choice model.

3.5.3 Stated Preference Survey

3.5.3.1 Field Work Survey

The objective of the survey had been to interview with drivers who had been interviewed during the roadside interview survey. These drivers were potential motorway users. With interview, more detailed information had been collected from the drivers about their trips and asked them to change their routes when the motorway had been opened.

Trips had been grouped into five categories based on vehicle type, trip purpose and residency.

The five categories are;

a. Home-based work (Appendix)
b. Employer's business (Appendix)
c. Other (Appendix)

d. Commercial vehicles (Appendix)

e. Day trips (Appendix)

In this survey, an introductory letter had been sent by Main Roads to each candidates' address before the interviewers made contact. It had been essential that interviewing be completed before the motorway opened. Because after opening, they could have used motorway and this would affect the responses.

During the interview, more detailed information about the trip including information about the people in the vehicle, time of travel and duration of the trip, vehicle operating costs, had been collected. A map of the motorway had been displayed and the drivers had been asked whether he/she would use the motorway for the surveyed trip, what the estimated time saving would be, if any, and whether this decision would be the same at each of several toll levels. Also, respondent's household structure and income group had been recorded.

3.5.3.2 Survey Analysis

The survey questionnaire had been focused to get information a wide range of travel characteristics, including:

a. value of travel time savings (VTTS),

b. driver appreciation of vehicle operating costs,

c. the influence of other passengers and travel choices,

d. the extent of cost sharing arrangements between driver and passenger,

e. driver appreciation of travel time variability and its causes,

f. the influence of the ownership status of the car on travel behaviour.

Value of travel time savings and how it varies had been the prime focus of the analysis.

In this stated preference survey, the approach had been to ask respondents to estimate of current trip travel time and travel time savings on the motorway.

3.5.3.3 Value of Travel Time Savings

A simple method had been used for establishing value of travel time savings. This method measures each drivers' stated preferences for motorway use at a range of toll levels. When the point was reached in the interview where the drivers choose not to use the motorway at the price asked, the price between this level and the previous level had been assumed the maximum price the driver was prepared to pay for the estimated time savings. This value had been then assumed as the maximum value of time for each driver.

3.5.3.4 Sensitivity to Tolls

One of the primary objectives of the stated preference survey had been to take the responses of potential motorway users to tolls. This had been undertaken in the household interview by the following sequence;

1. identify the origin and destination of the target trip on a map,

2. with the drivers' help, identify the route for the trip via the motorway and the number of toll plazas to be passed,

3. using a list of toll values, ask if the motorway would be used at each toll levels.

Toll levels and demand curves are shown in Table 3.2 and Figure 3.1 respectively. [20]

3.5.4 Revealed Preference Survey

The objective of the survey had been defined as to contact as many as possible of the people interviewed during the original stated preference survey and to ask them about the original trip. Questions asked them were

- whether the motorway had been used or not, and why,
- toll costs,
- time savings and attitudes.

This data had been then used to compare with the data collected from the stated preference survey. This comparison had shown how closely the stated preferences expressed before the Motorway had been opened agreed with the actual behaviour of drivers who had experience of the time savings and convenience the motorway offered and what it cost.

Table 3.2. Toll Levels Tested in Stated Preference Survey

TOLL LEVEL	PRIVATE CAR			COMMERCIAL VEHICLES														
				2 AXLES			3 AXLES			4 AXLES			5 AXLES			6 AXLES		
	NO OF PLAZAS			NO OF PLAZAS			NO OF PLAZAS			NO OF PLAZAS			NO OF PLAZAS			NO OF PLAZAS		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	0.10	0.20	0.30	0.60	1.20	1.80	0.75	1.50	2.25	0.90	1.80	2.25	1.10	2.20	3.30	1.25	2.50	3.75
2	0.30	0.50	0.75	0.90	1.80	2.70	1.10	2.20	3.30	1.35	2.70	4.05	1.65	3.30	4.95	1.90	3.80	5.70
3	0.50	0.70	1.05	1.20	2.40	3.60	1.50	3.00	4.50	1.80	3.60	5.40	2.20	4.40	6.60	2.50	5.00	7.50
4	0.70	0.90	1.35	1.50	3.00	4.50	1.90	3.80	5.70	2.25	4.50	6.75	2.75	5.50	8.25	3.10	6.20	9.30
5	0.90	1.10	1.65	1.80	3.60	5.40	2.25	4.50	6.75	2.70	5.40	8.10	3.30	6.60	9.90	3.75	7.50	11.25
6	1.10	1.30	1.95															
7	1.30	1.50	2.25															

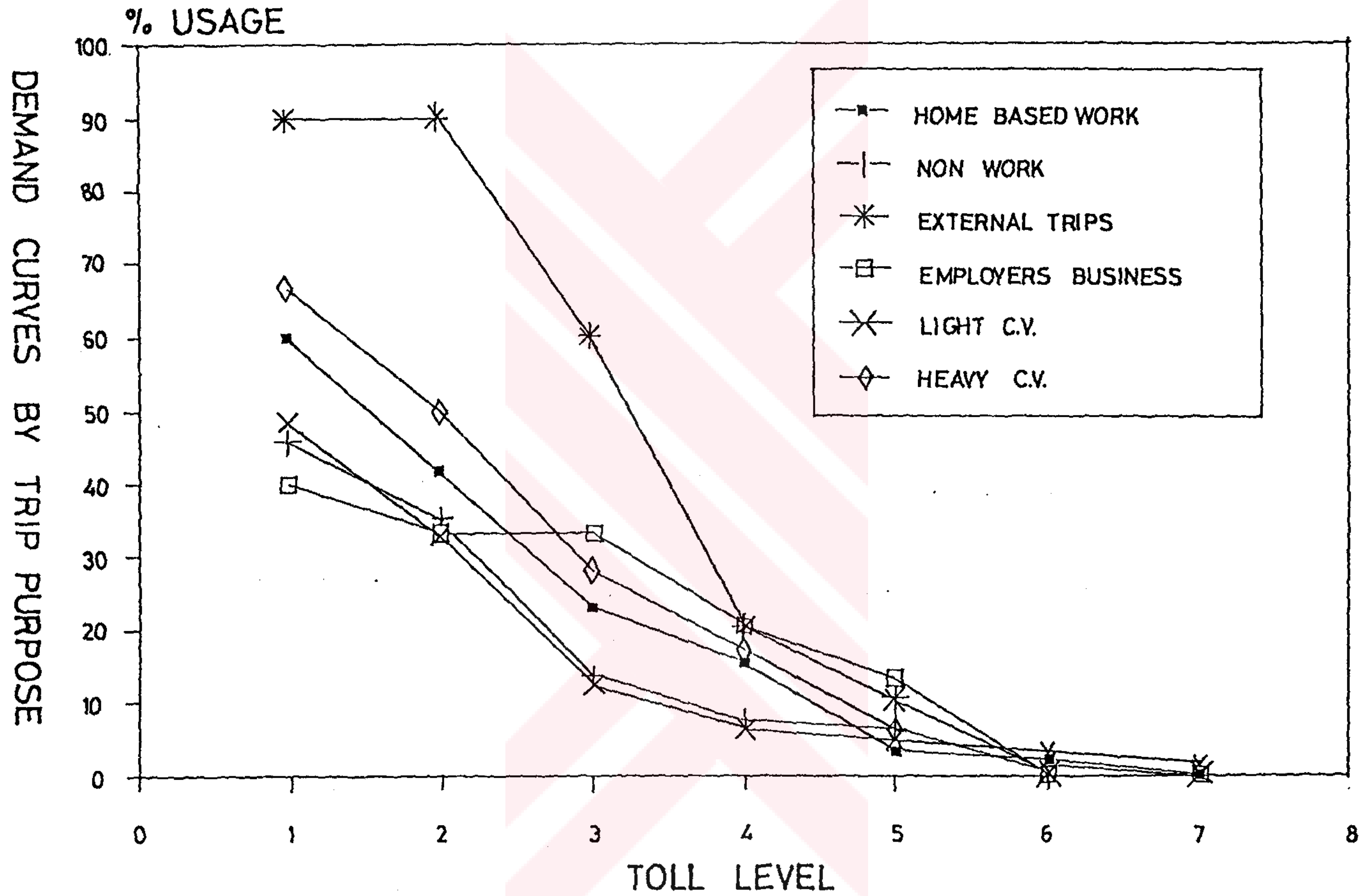

Figure 3.1. Toll Road Demand Curves

3.5.5 Traffic Surveys After Logan Motorway Opened

For this survey, postcard survey had been selected as a method. The postcard had been reply paid and asked drivers to supply the information included vehicle occupancy, whether the vehicle had been privately owned, origin and destination addresses, trip purpose, motorway entry and exit points and comments on the toll road.

3.5.6 Comparison of Before and After Results

The data collected before and after the motorway had been opened in home interviews had been compared. Some results had been drawn as follows;

- there had no substantial difference between the surveys in relation to car ownership,

- there had been a substantial variation in the perceived levels of fuel consumption in both the before and after surveys,

- from the responses, for route selection purposes, most drivers had been understood that they could not consider distance related costs, because they had no clear idea of their magnitude. So, this had been important conclusion for traffic assignment route choice modelling .

-In the before survey, drivers had been asked to estimate the possible travel time savings for the their future travel after opening of the motorway.

In the after survey, same drivers had been asked to estimate their actual travel time savings. According to results, the actual (perceived) time savings were on average three quarters of the anticipated savings.

3.5.7 Model Development and Application

For the model development, the basis for the motorway usage had been established on binary route choice. (Probability of an alternative route to be chosen from the other one)To improve demand forecasting precision, the demand population had been divided as many as possible in to groups which behave significantly different from each other.

3.5.7.1. Model Specification

The probability of choosing toll road rather than the existing road has been assumed as a binary choice. The general form is;

$$p^m = \frac{1}{1+\exp(-b^m d^{Cm})}$$

p^m = probability of using the toll road for a demand group m

d^{Cm} = difference in generalized cost between the toll road and the alternative road.

$$d^{Cm} = dt * vtts_m + dd * voc_m + toll_m$$

where;

dt = travel time difference between the toll road and the existing road, (minutes)

$vtts_m$ = perceived value of travel time saving (cents/minutes) for a demand group m.

dd = distance difference between the toll road and the existing road. (km)

voc_m = perceived vehicle operating cost (cents per km.) for a demand group m.

$toll_m$ = toll charge (cents) for a demand group m.

bm = constant.

Australian authorities had used a computer network simulation method to develop estimates of d^{Cm} for each origin-destination combination.

From studies of travel demand behavior, studies of route choice and mode choice, they had found that consumer perception of travel prices are more important than actual values.

For calibration of a general model which allows for deviations from a perfect choice environment, they had re-specified the model for incorporation into an application module as follows:

$$p = CAPT + \left[(1-CAPT) * \frac{1.0}{1.0 + EXP(LAMBDA(dC + DELTA))}\right]$$

LAMBDA, CAPT and DELTA define the shape of the diversion curve.

LAMBDA=defines the slope of the curve.

CAPT = defines the level of captivity to the toll route (generally zero except business travel)

DELTA = defines the horizontal "shift" in the demand curve and a non-zero value implies that the generalized cost specification does not adequately describe all the perceived costs of using the toll road.

To develop this model of travel demand on a toll road, it is necessary to find estimates of the following parameters;

vtts : the perceived value of travel time saving.

voc: the perceived value of vehicle operating cost.

It is also necessary to estimate the total travel demand (or potential toll road users). This estimation can be made from the roadside interviews in the traffic corridor.

The generalised cost definition includes time and distance related costs. In this research , it had been indicated that distance related costs had been perceived poorly and not a factor affecting route choice. So, they had assumed that vehicle operating cost value was zero.

The value of travel time savings for each trip purpose had been derived from the stated preference survey and the revealed preference surveys.

The values of LAMBDA, CAPT and DELTA had been estimated from the data captured during the stated preference surveys.

The demand curves had been constructed using toll levels rather than actual tolls because the actual toll depends on how many toll plazas are passed. The toll levels tested in the stated preference survey and demand curves in this research are shown in Table 3.2 and Figure 3.1 respectively.

At the end of this research, a computer program which is a toll route choice program, MVTOLL, had been written to apply the models as specified to split input trip matrices into toll road users and non- users according to the generalised cost of travel on each route. According to this study , multiple toll levels can be specified for each trip purpose to allow the optimum toll to be estimated. The ability to examine the response of different demand group and identify the maximum revenue toll strategy had been incorporated.

The estimate of potential motorway uses had been derived from the original roadside interview surveys. A trp matrix of movements for each trip purpose had been developed from the roadside interviews. These potential trip matrices had been used as input for the route choice model. This study had identified important characteristics of drivers responses to tolls and been succesfull in achieving its stated objectives and identified a number of areas for further analysis.

A diversion curve is employed in calculating the choice of route. This curve may be specified as a mathematical function or supplied by the user as a curve defined by a series of points. General characteristics of choice probability function is shown in Figure 3.2.

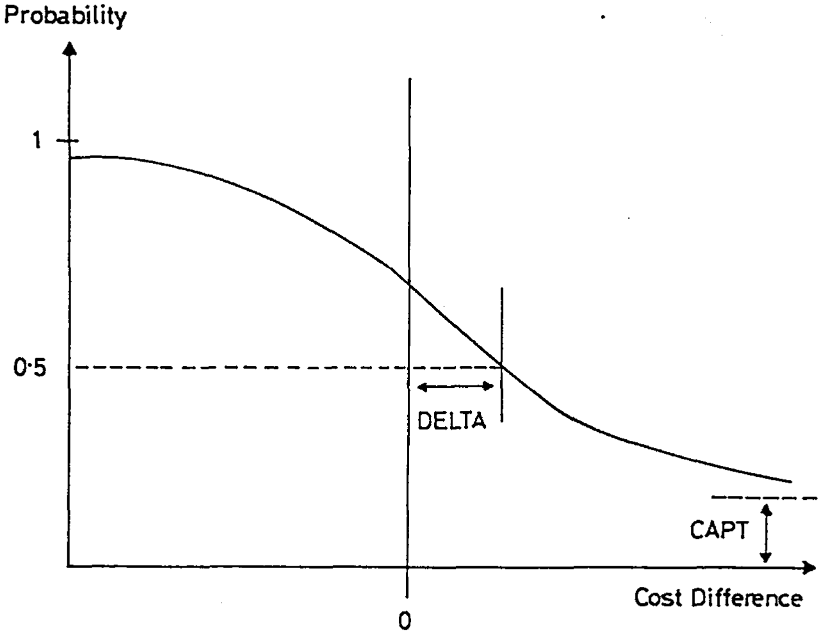

Figure 3.2. General Characteristics of Choice Probability Function

CHAPTER IV

URBAN TOLL ROADS

4.1 Introduction

Urban transport problems represent essential issues in many European countries and our country. There are two types of issues which have motivated public and political debate:

a. Transport problems which directly affect on vehicles and their users and are related to the competition for scarce road space. These include;

- traffic congestion
- shortage of space for on-street parking and loading
- an increase in vehicle accidents.

b. Adverse effects on non-vehicle road users and on people living and working in properties adjacent to the highway. These include:

- traffic accidents/road safety
- traffic noise
- severance of social networks
- the general unpleasantness of using street spaces
- vehicle pollution

At European Communities as a whole, it has been estimated that the total loss through congestion and detours amounts to 500 billion ECU per year. Around 55000 people died on community roads and 1.7 million are injured and the contribution of vehicle emissions to environmental pollution is estimated being to cost the community between 5 and 10 billion ECU per year.(Peter Jones, 1989)

These "congestion" and "environmental" problems are getting worse in many European cities and our big cities, as a result of the continued increases in traffic flows.

Although many countries counter growing interurban traffic problems through new road construction such as United Kingdom and Turkey, this action is not a solution for cities. In some cases, new road construction may be appropriate, but other policies to alleviate congestion, noise, pollution,.. etc. should be investigated for cities: These can include improvements in public transport, safer facilities for cycling and walking measures to encourage peak spreading and various forms of restraint on car use.

Present transport policies show significant variations from one country to another in Europe. For example, in Germany "traffic calming" measures in many of cities has been applied. Italy has imposed access controls on entry to the centers of many historic cities, and Norway and Sweden has introduced road charges in urban areas.

The operating and policy issues for urban toll roads are different than for interurban facilities. The pricing design and operating criteria that apply to uncongested interurban systems has to be modified for urban systems. On uncongested systems, the primary objective is to maximize their use in order to generate the potential economic benefits. When congestion occurs, the use of the road may have to be restricted in order to preserve an efficient level of service.

In designing urban facilities, it is essential to take network repercussions into account lest alleviation of congestion at one point only generates it to another. The design of the facility is also important. Because its operation does not in itself create problems.

Urban expressways are designed to provide a considerable degree of access to urban activity centers, central areas, commercial activity and entertainment and convention centers. This require an extensive ramp (off or on) system designed to provide reasonably smooth flow.

In urban contexts, the use of closed toll collection methods generates high costs of collection and contributes significantly to the congestion the expressway purposes to alleviate. Very few cities in the world have used a closed toll collection system in some part of expressways in urban areas. The most extensive examples of such closed system are Tokyo and other large Japanese cities.

4.2 Urban Road Congestion

4.2.1 General

Urban road congestion is a major problem in developing countries. Traffic conditions in these countries are characterized by poor road layouts (particularly at junctions), insufficient road maintenance, mixed traffic (pedestrians, hand-carts, head-loading, cycles, three-wheelers, etc.), weak traffic management, badly parked vehicles, encroaching road side activities, lack of driver discipline and lax enforcement of laws and regulations. Much of the congestion is therefore attributable to the poor management and unsuitable configuration of the road network.

Congestion is a major restraint on a car Use it discourages journeys where time is important.

4.2.2 Controls on Moving Traffic

There are two types of control mechanism of demand management measures;

- Non-pricing controls on moving traffic.
- Pricing controls on moving traffic.

Classification of traffic restraint measures;

1. Restrictions on road capacity and traffic speeds;

a. Speed-limiting (traffic 'calming') measures.(Appendix A)

b. Creation of "Traffic collars", by reducing vehicular capacity at key points, either:(Appendix)

- through reductions in space, by providing bus/HOV (high occupancy vehicles) or cycle lanes, or

- by using traffic signals to impose time penalties

c. creation of "Traffic Mazes or "Traffic Cells", using a series of link and junction closures and one-way streets.(Appendix)

2. Regulating traffic access to a link or area

a. Banning or limiting entry to certain classes of road user (e.g. ban heavy goods vehicles, only permit use by pedestrians)

b. Type of owner (e.g resident),driver or vehicle occupant (e.g disabled person), or by journey purpose, often relying on a permit system.

3. Charging for the use of road space:

a. Toll charges for using a section of road (or for crossing a cordon line)

b. An area licensing fee, giving the right to use a vehicle in an otherwise prohibited area.

c. A road pricing charge-either a sophisticated version of (a) or (b),or a system based on mileage or time spent in an area.

4.2.3 Road Pricing

Road pricing has a well established history in the transport economy. It has been developed and refined in various ways. It investigates the relationship between marginal social cost and road maintenance costs. Among traffic engineers and transport planners there are arguments on the basis of the meaning of "road pricing". While it means to refer to the imposition of direct charges on road use with a variety of objectives, this is in contrast to economics, where "road pricing" is usually taken more specifically to mean the setting of price equal to the social marginal cost of a trip (covering track and congestion costs).

Many countries have a tradition for using tolls on selected sections of road to pay for new road construction, but for the use of a pre-existing urban road network, there are legal impediments to charging. Payment might be based on some principles, such as link or junction charges, cordon pricing, supplementary licensing, or continuous pricing. There are strong arguments in favor of road pricing as a method of directly combating urban congestion, or for making drivers face the various social and environmental costs of vehicle use when they plan their journeys. (Goodwin and Jones,1989)

4.2.3.1 Objectives of Road Pricing

At the present time, a number of European Countries are implementing or are actively considering some form of urban road charging scheme. There are three alternative objectives for road pricing.

1. To raise money for new road construction (and to finance public transport improvements). This is the primary objective in Norway.
2. To regulate demand through the price mechanism and to eliminate traffic congestion. (it is actively considered in United Kingdom.)
3. To reduce traffic levels in order to achieve environmental improvements (reduce pollution, traffic noise, energy use, accidents.). This is important factor for Swedish debate.

In the Netherlands, for road pricing, the three objectives explained above are being considered.

There are important relationships between the objective of the charges, the type of charging system used, the spatial pattern of charging and the time distribution of the pattern of charges (time of day, day of week).

These are;

a. If the objective is to raise money for road construction then the maximum number of people should pay the minimum charge,

- a cordon around an area is preferable, with little opportunity to detour and avoid the charge,
- the cordon should be located to intercept the maximum number of trips
- the charge should be a uniform one, throughout the week or for as long as is politically acceptable

b. If the objective is to reduce congestion, then,

- a cordon, area license, or travel-related charge may be appropriate depending on the circumstances
- it will usually be desirable to locate the restricted area boundary at a point where traffic can detour to avoid payment, but that incorporates the main congested area.
- charges are normally varied by time of day being greatest at peak periods, and zero when traffic is light.

c. If the objective is an environmental one, related to traffic pollution in an area, then;

- charges may be lower for "green" vehicles.
- an area-wide scheme (multiple cordons or an area license would be most appropriate.
- the area covered would probably be larger than for a traffic congestion objective.
- there would probably be less time of day variation in price than with a congestion objective (Peter Jones,1989).

4.2.4 Charging Schemes

Car-use related charging schemes can generally be divided into zone, cordon and route charging systems.

a. In a ZONE scheme the charge is made for being or driving within a zone. Zone-based parking management schemes are common. A typical road pricing for zone scheme is the Singapore Area License Scheme. A general problem with zone systems is enforcement: Control of permits within the zone can be complex and expensive.

b. In a CORDON scheme, vehicles are charged for entering or leaving a defined area. A typical cordon scheme is the toll-ring around the city of Bergen in Norway. At toll sites installed on the major roads to the city, drivers pay directly or show their prepaid vignette to gain access to the city center.

A cordon scheme does not affect trips that are made within the cordon. This can be solved by designing multiple cordons or grid-like schemes of the kind employed in Hong Kong road pricing scheme.

c. In a ROUTE scheme, the charge is made for using a particular road or road section. The toll roads of Southern European countries are examples of this scheme. Table 4.1 shows the schemes, the cities which have applied those schemes and characteristics.

4.2.4.1 An Example of Charging Schemes: Area Licensing

Area Licensing is a form of road pricing scheme in which charges are applied to low-occupancy vehicles entering the congested area during rush periods. The desired effect is to reduce congestion and to achieve more efficient use of limited road space. This system encourages greater use of public transport and shared private cars and discourages unnecessary journeys during rush periods.

For the system success, public transport has to be adequate and suitable for motorists and passengers diverted from private cars.

To date, Singapore is the successful city applied area licensing in order to combat traffic problems.

In Singapore, different prices has been applied for the different vehicle classes. Busses, commercial vehicles, emergency vehicles, motorcycles and scooters, cars and taxis with four or more occupants have been exempt.

Table 4.1 Road Pricing Schemes in the World

City	Actual Start Date proposed*	Pricing Scheme
Manual Charging Systems		
Singapore	June 1975	Area Licensing Scheme
Bergen	January 1986	Cordon
Stockholm	June 1989	Area Licensing Scheme
Mixed Charging Systems		
Oslo	February 1990	Automatic vehicle id.
Trondheim	May 1991	Automatic vehicle id.
Electronic Charging Systems		
Hong Kong	1983/1985	Mult. zones W/AVI
Stockholm	April 1989	Mult. zones W/AVI
Singapore	Mid 1991	AVI or Smart card
Cambridge	1990/1992	Cong.-based smart card
Randstand	1992/1995*	Mult.zones W/smartcard

The following factors which were present in Singapore are assumed for the successful implementation of any area pricing scheme by the authorities;

1. Competent management with an organizational structure that supports comprehensive policy-making and planning for all aspects of transport in the metropolitan area including traffic management, traffic policy, bus services and motor vehicle registration.

2. Carefully worked-out, detailed provisions for issuance of licenses, erecting signs on the approaches to the restricted zone, enforcing the rules and handling all administrative details.

3. Good design of the scheme, including upgrading of the circumferential route, expending public transport facilities, laying out of the boundary.

4. Advance education of the public for explaining the reasons of road pricing, its expected benefits for long-run and short-run periods.

5. Pragmatism as exemplified in Singapore by an effective program of monitoring results and quickly making traffic management changes, or modifying the rules of the scheme to overcome observed problems.

In Singapore, the target had been defined as reducing commuter traffic entering the central area. It has been achieved Area License Scheme has forced motorists to modify their behavior at least in the short-run. It had reduced congestion by inducing people to public transport and car pools.

4.2.5. Example for Urban Toll Roads: Toll Ring in Bergen, Norway

Bergen is the second largest city with a population of 200,000 in Norway. The toll ring was implemented on January 1986. It has six toll gates located on the accesses to the Central Business District (CBD) area. The period of operation is from 06:00 to 22:00, Monday to Friday.

Only scheduled busses are exempted from toll payments. To reduce delays and decrease the cost of toll collection, seasonal passes had been chosen as a means of toll payment. The passes are placed on the windscreen. The control of vehicles in reserved lanes is based on video- tape recordings of the license plates. The lanes used by motorists who pay for single trips are manually operated.

In Bergen, the major roads are classified as national roads and Central Government is responsible for financing of improvements and maintenance. However, the funds allocated for the main roads in Bergen has not been enough to cover expenses of the growing traffic. Then, the toll ring had been proposed by the County Road Administration in a new master plan for the main roads. This plan had included the problems of congestion, traffic safety and noise and air pollution. The plan had presented a cost estimate for the road projects needed to implement this system. When the cost estimates had been compared with the funds from Central Government, it had been understood that the problems would not be able to be solved with the traditional Government funds. This issue had led to the proposal of a toll ring to raise money for supplementary financing.

Some kind of toll or road pricing scheme can be seen as a measure of restraining traffic and relieve congestion. In Singapore, this idea had been taken as an objective. But in Bergen, restraining traffic is not an objective. If the use of road tolls to restrain traffic and relieve congestion, had been an objective, to operate toll ring in the peak hours at higher toll rates would be more effective.

According to the authorities who studied on the toll ring in Norway, there are some advantages compared with the traditional toll financing;

- there are no attractive alternative routes for motorists who want to avoid the toll
- motorists are not diverted by tolls from new high capacity roads that they preferably should use.
- extensive use of seasonal passes reduces delays.

As mentioned, restraining traffic is not an objective in Bergen. However, some impacts on traffic had been expected and 3 percent decrease in traffic had been used in the assessment of impacts and revenue. The impacts of the toll ring is increased by seasonal variations in traffic volumes and technical problems due to the malfunctioning of vehicle detectors at the toll gates.

A properly-designed scheme may provide an extremely cheap source of financing in real cost terms. An additional advantage is that more appropriate pricing of urban road use makes a correct assessment of the benefits provided by capacity expansions in the road system much easier.

In Norway because of both for legal and political reasons, it has been explained by authorities that it was impossible to introduce road tolls as a measure of traffic restraint, but road tolls have been accepted as a source of financing for road projects.

CHAPTER V

TOLL COLLECTION SYSTEMS

5.1 General

The application of toll collection systems differ according to the status of the roads whether they are interurban or urban. The system design involves choices about the type of toll system, the number of collection points, the location of collection points, and the degree of automation in the system. The choices made about each of these items will have important effects on capital and operating costs of toll collection. However, toll collection design decisions can not be rest on cost criteria alone. For the design decisions, user access, traffic route choice, toll revenue, and safety must be considered.

The complexity of the design decisions changes with the type of highway facility. The design choices for bridges are relatively simple according to the ones for highways. The choices are primarily concerned with two questions: whether to collect tolls in one or both directions and at which end or ends of the bridge to locate toll barriers. The most favorable circumstances for collecting tolls in only one direction are situations in which a high percentage of the trips use the same route in both directions, such as work trips. In these situations tolls can be doubled and collected in only one direction without arousing strong political objections. If tolls are to be collected in both directions an additional choice must be made between using one or two barriers.

Determining the physical configuration of the toll collection system is more complex for highways than for bridges. Two major decisions must be made. One of them concerns the traffic that is to pay tolls. The decision about the traffic is the prevailing factor on the choice of the type of toll collection system and this decision is made with consideration of the accessibility and cost characteristics of alternative collection systems. The second is a choice about the number of interchanges. Both decisions should be made interactively for the same issues of facility access, traffic impacts and community reactions.

The key objectives in regard to the design of a toll collection system are :

- to reduce collection costs to a minimum by decreasing staff costs and purchasing equipment that can be easily and cheap maintained.
- to maximize toll booth capacity by simplifying the transaction and minimizing the time required for it giving necessary information to the users to check their payments.
- to offer the user the widest choice of payment types (coins, banknotes, credit cards, and automated lanes...etc.)
- monitor receipts
- to reduce the use of money at toll booths which will facilitate handling of cash of toll attendants.

5.2 Toll Collection Systems

There are three types of toll collection systems;

5.2.1 Closed Toll Collection System

In this system, tolls are paid on the basis of trip length and a card or ticket is obtained at the entrance gate and a toll is paid at the exit gate. The accesses usually have grade separated intersections which are highly cost. The closed system diverts almost all short distance trips (under 15 or 20 kilometers) to local roads, as well as large numbers of medium distance trips (20 to 30 kilometers), because the limited number of access points are not always convenient to the origins and destinations of trips. The number and distance between access points (interchanges) determine the users who will use the road section. The longer the distances between access points, the fewer short trips. This will result in less local use.

5.2.2 Open Barrier System

It allows local, short-distance traffic to use the facility without paying tolls. Barriers are located at intervals along the road. Toll booths are not placed on the interchange ramps. All traffic must stop at the barriers to pay the toll. However, local traffic may avoid paying tolls if there is no barrier between entry and exit points. The percentage of trips allowed to pay no toll depends on the location and number of the main-line barriers. Toll barriers can be located on the section of road near the central area of each major city or urbanized area through which the road passes. No exits and entrances are provided at the barriers. This design approach tends to protect service levels for a longer period against traffic encroachment from urban areas. Alternatively, an open road toll collection system can be designed with toll collection barriers located between city boundaries. This system encourages local traffic use between barriers.

In a properly planned open toll system, the toll collection stations are located at the points where the largest proportion of vehicles are travelling long distances. Since they receive the greatest benefits from the toll expressway, there is the least amount of diversion to other roads.

5.2.3 Barrier-ramp System

It is a mix of the other two systems. It can be designed either as a closed or an open system and is found on the urban or rural toll roads. If designed as a closed system, toll barriers are located at intervals along the main line. In addition, most interchange ramps also contain toll booths so no segment of the road can not be used without payment of a toll.

Open barrier-ramp systems allow the flow of some toll-free traffic. They can be designed with main-line toll barriers and toll booths placed on the high-revenue interchange ramps.

5.2.4 Differences Between the Open and Closed Toll Systems

a. Cost

For the closed system costs, the number of interchanges are important. The choice of number of interchanges involves a relation between total costs and user accessibility. Both of them vary directly with the number of interchanges. Existing non-toll limited access have higher density of interchanges and are more accessible than typical closed system toll roads. Because of that the interchanges require collection facilities at each entry and exit points, the high density of interchanges makes the cost of converting existing non-toll limited access highways to closed system toll roads very expensive, in terms of the capital cost and maintaining and operating costs of the toll collection points.

Costs can be decreased by closing some interchanges, but this action may reduce toll revenue and accessibility. Closing an interchange can impose significant changes in travel patterns and social interactions. Objections may arise from the motorists who are frequent users of the interchange near business and commercial establishments.

Barrier systems have the potential of maintaining the accessibility while minimizing the cost of toll collection by concentrating the toll collection function in a few locations. By not collecting tolls on low-volume interchanges, barrier systems avoid points where toll collection expenses are high. This cost advantage of barrier systems is balanced to a degree by the need for more toll collection lanes per collection point due to the higher volumes found on the main-line. Furthermore, construction costs for each main-line barrier lane are higher than for closed-system collection lanes because of the need for longer and wider approaches to each collection point.

Because of the balancing costs, barrier systems are not inherently less costly than closed toll collection systems, even though, in practice toll collection is less expensive on main-line barrier toll roads. By limiting the number of toll collection points to a few locations, some cost of toll collection facilities can be saved. The flexibility of reducing toll collection points is the principal advantage of barrier systems.

b. Toll Collection System Safety

Although barrier toll collection systems have potential cost advantages, there are some disadvantages relative to closed systems. Barriers along the main-line raise the potential for accidents. Because the motorist travelling highly speed must completely stop at the barrier and at the same time, he jockeys for the shortest queue for the payment of toll. At the closed systems, vehicle decelerates primarily on the exit ramps before the toll collection area, so, closed toll system is safer than barrier systems.

c. User Reaction to Alternative Toll Booth and Barrier Configurations

When choosing a toll collection arrangement, user reaction to the arrangement and the resulting impact on the distribution of traffic between toll and alternative toll-free routes and on toll revenue. User reaction is likely to vary between toll collection systems primarily as a function of trip lengths. Motorists who use short segments of a free road would not change their travel pattern if those segments remain open or free under a barrier or open barrier-ramp toll system. At the closed toll collection system, some marginal trips would not be made or some traffic would be diverted to alternative free routes. These marginal trips are those made by people with low incomes or which travel time is not highly valued.

The impact of the toll collection configuration on longer trips is mainly a function of total toll charge and barrier density. Given equal total toll charges, barrier and open hybrid systems, may divert a high number of long trips than closed systems. Because the higher number of barriers increase the travel time. Although travel delay at toll barriers may be short relative to trip times, but such irritating delays are perceived more longer than they actually are. This perception may cause more diversion from barrier and open hybrid configurations to alternative free routes than from the closed systems.

d. Variations in the Equity of the Toll Collection System

The basic theme in highway finance is that the highway user should pay for the highway system. Two principles for charging users are most popular:

- The "benefit principle" is that users should pay for roads in proportion to the benefits received.
- The "incremental cost principle" is that users should pay according to the highway construction costs required for their type of vehicle.

On the basis of the benefit principle, the closed system is potentially more equitable toll collection design, because each user must pay a toll for using the facility. On open toll systems, some users are allowed to move toll free. Hence, they can never be charged for the benefits of making the trip.

On the basis of the incremental cost principle, closed systems are inherently more equitable because their charges are based on each increment of road service consumed. Open system charges are much more lumpy, some users pay high costs per unit of service while other users pay no toll.

5.3 Electronic Toll Collection

5.3.1 General

Electronic toll collection (ETC) is a state-of-art technology which is ready for implementation in the urban toll ways. It has recently been implemented in real toll road applications in Norway and the U.S.A.

The traditional toll plazas involving mechanical collection of tolls in the form of cash, tokens, other transferable material or a document that requires physical inspection, requires a complete transaction at the toll booths for each vehicle. This system is inefficient for many reasons that;

1. The traffic has to slow and stop for the transaction of payment. Delays are incurred until the exit light changes for passing vehicles at automatic coin booths and finding right coinage. At manual toll booths, there is delay where change is required and where the collector checks the payment.

2. The number of toll booths is typical well in excess of the number of lanes of traffic on the road. This increases the infrastructure costs, including land requirements.

3. There is a substantial amount of labor involved in the payment and equipment maintenance cycle. This also increases the cost and it is less reliable than fully-automated systems.

4. The frustration related with spot physical payment between driver and collector causes delays and this adds a non quantitative cost to the effectiveness of tolled facilities.

Recent interest in electronic toll collection systems from the recognition of the inefficiencies of the current systems of manual collection and many attractive features of ETC.

ETC is a programmable remote automatic vehicle identification (AVI) system which uses microwave technology to identify the presence of a vehicle in the traffic stream, and automatically calculate and charge the vehicle owner for the use of the tolled road. There are a number of ways of establishing a charging procedure. The most efficient and almost private way is a computerized identification code in the AVI tag which is placed on the front windscreen of the vehicle.

5.3.2 Setting the Level of Toll

ETC opens up the possibility of setting any toll pricing regime. If desired, the tolls can be distinguished by time of day, type of vehicle, laden weight, speed of travel, distance travelled, and traveller types entitled to a discount. The discrimination requires an appropriate mixture of software code for instructions accompanied by in-ground pezas for weight measurement on each axle and light curtains for vehicle separation. The light curtains provide to identify each vehicle.

The cost of implementing ETC way increases the amount of differentiation increases.

At the charging points, there should be non-electronic toll booths for irregular road users. In Norway, the toll set for ETC is heavily discounted relative to the toll paid by vehicles choosing non-ETC lanes so as to encourage adaptation of ETC.

The toll collection can be two types. The first and simplest one is that a driver is charged when he passes a charging point. This was applied in Hong Kong, and it can be used for toll collection at bridges and tunnels. The second method is that a driver is charged for distance travelled or time spent in the charge area. For this type of system, it is necessary to record, centrally or in the IVU, (In Vehicle Unit) the time and location when the vehicle enters the charged area. On leaving the charged area, the time and location of exit are recorded and the charge is based upon time spent or distance travelled or both. Most of the European toll roads charge on distance travelled.

5.3.3 The General Requirements of a System

The general requirements of a system can be listed as follows:

a. The system should allow both pre-and post- payment.

b. Driver and vehicle anonymity should be provided for those who require it, providing that a valid charge transaction is made.

c. If post-payment is considered, the system should provide transaction data storage for checking the billing by users.

d. If pre-payment is considered, credit balance should be informed whether it is available for use to the driver.

e. Different charging rates at different times of day, and for different classes of vehicles should be allowed for.

f. As a driver approaches to charging point, he should be given information about the charge levied.

g. The system must be applicable to all types of vehicle.

h. The system must be secure. Offending vehicles should be detected and individual accounts must be very secure from unauthorized access.

i. The system must be simple and convenient for the driver to use.

5.3.4 System Outline

A general outline of a system is shown in Figure 5.1. It is shown in five sections;

1. Vehicle-to roadside communications
2. Security system
3. Communications system
4. Central computers
5. Payment system

Items 4 and 5 are standard in banking and similar systems, item 3 can be little different to a traffic control system.

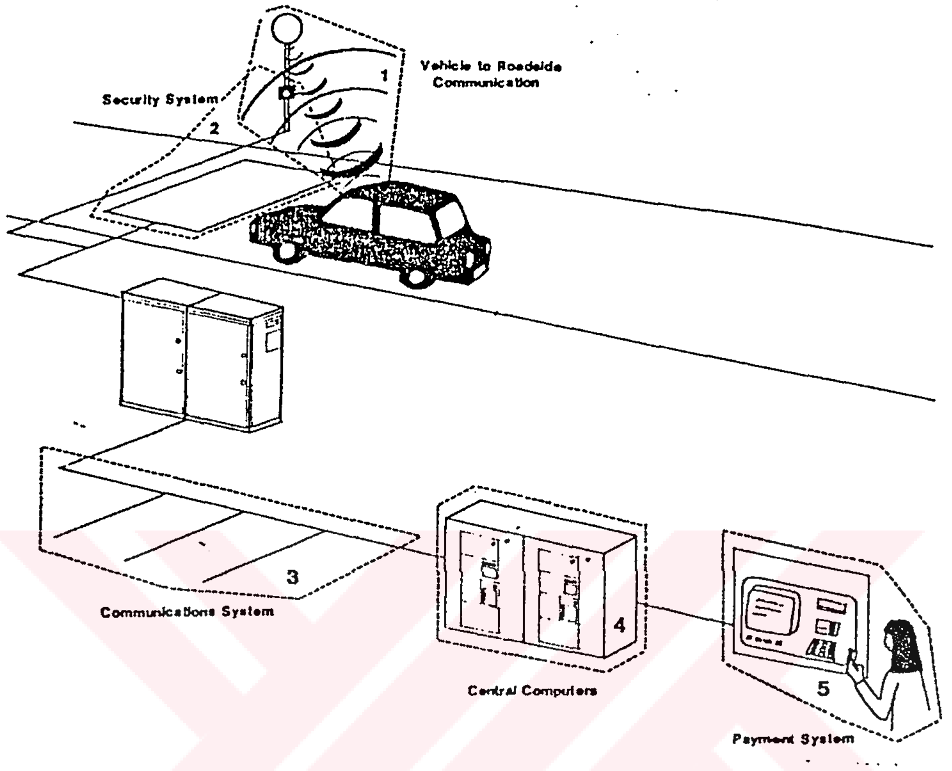

Figure 5.1 General Outline of an Electronic Toll Collection System

5.3.4.1 Vehicle to Road-side Communications

Road use charging and toll collection systems fall into two main categories;

- Tag systems
- Smart card system

a. Tag-Based System

All the tags are small and light (similar to a thick credit card) and it would be fitted to the windscreen. The fixing allow the tag to be moved easily by the driver if he wishes to change the tag for anytime purposes.

For a tag-based system, nothing is stored on the tag except its identification number, and hence all records must be kept centrally. Anonymity of use can be ensured by designing the system that the tags are not associated with particular vehicles or with named users. This is feasible only for a pre-paid account. At this payment system, the user can purchase use of a tag on payment of any deposit required and a suitable sum into the account. There would be no need for him to identify himself or the vehicles in which the tag would be used. He would only need to say the class of vehicle so that appropriate tag account can be provided.

On passing a charging point, the tag on the vehicle is read and the associated account is debited. Providing that the account is in credit, and the tag in appropriate for vehicle class, the vehicle would not be identified.

In tag-based system, there are some potential problems. One of them is theft of a tag. If it is associated pre-paid account, it can be potentially quite valuable. As a theft is discovered, the user would report the tag's number which could be entered in the database. If the stolen tag was detected while the vehicle passing a charge point, the vehicle would be photographed and action taken against the driver using it. The system is very well able to struggle with theft. Another potential problem is caused because the system does not inherently give an indication of transactions and balance details. This can be partly overcome by payment indications at charging points. But it can be desired to have individual information that account has been debited. At toll sites, this can be provided by red, amber and green lights, or equivalent means. Green means "account debited-significant balance remaining", amber means "account debited-balance low", red means "no account". When red lights, a photograph of vehicles offending is taken. This arrangement is impossible in a multi lane situation unless the road was separated into lanes with a small island to accommodate the lamps.

The main tag-based systems in operation at present are supplied by Amtech from the U.S., Micro Design from Norway, and Phillips from Netherlands.

b. Smart Card Systems

The basic aim of a smart card system is to ensure anonymity by having account details and a record of previous transactions stored only in a smart card in the vehicle. There is no central record and individual's movement can not be traced by the system. From the view of anonymity, this system may seem to have potential advantages, but there are some disadvantages. From the view of operation of the road, the problem of theft of smart card and tracing infringements in the use of system are difficult to be dealt with.

Unlike a tag, a smart card system has no identification number. This provides anonymity. But if a card is stolen, until its stored balance expires, vehicle can not be stopped.

The basis of operation of the system is a two-way communication between roadside equipment and the IVU. The IVU consists of a holder for the smart card with suitable means of two-way communication to the roadside using infrared or high frequency radio frequency. Power would be needed and this would preferably be provided by internal long-life battery. The unit consists of a contactless smart card which fits into a reader and high frequency radio frequency transceiver.

On approaching to the charging point, a communication from the roadside prime the IVU and initiate a check of smart card. Then, the vehicle class and account balance is identified. The roadside equipment signal the charge to be deducted and taken confirmation from the vehicle. System should provide for motorway speed and multi-lane working. For multi-lane operation, the communication zone must be restricted to around five meters.

The advantages of smart card system are;

- Anonymity
- More complex communications between vehicle and roadside equipment is available for some uses such as route guidance and provision of traffic information.

5.3.4.2 Security System

Security system is a very important part of the system, whether tag or smart card-based. A practical road use charging system must operate on normal multi-lane roads.

Each vehicle as it passes the charging point must be able to communicate individually with the road side equipment for charging purposes. In parallel with this, each vehicle must be separately detected to ensure that all vehicles are charged. If the classification of vehicles does not match, if a vehicle is detected without an IVU or if an account related with an IVU (In Vehicle Unit) is not valid for some reasons, a photograph must be taken which accurately identifies the vehicle in default.

5.3.5 Successful Implementation: Hong Kong Study

Electronic Road Pricing (ERP) has been introduced for Hong Kong by the Government as a pilot study in 1987. Hong Kong has unique topographical, economic, geographical and political features to make it an ideal place to be the first in the world to introduce this measure to combat highway congestion.

The objective of the transport planning study had been to access the possible effects on patterns and levels of travel demand of alternative electronic road pricing strategies, together with the associated levels of revenue and the economic and social costs and benefits attributable to each strategy.

In the Hong Kong's Electronic System, every vehicle has Electronic Number Plate which is a passive unit containing custom-built integrated circuits and transmits a unique identification code. Hong Kong urban area comprises up 200 charge zones. At each site, an array of loops is buried in the road surface, a power loop energizes the ENP and one of a series of receiver loops pick up the vehicle's transmitted coded identity.

Road-side cabinets handle data transmitted from the receiver loops. Data are transferred to Control Center. At this center, vehicle data are checked and validated before being passed to the accounting system which generates regular bills for vehicle owners.

CHAPTER VI

TOLL POLICY: THE GOAL OF SELF-FINANCING

CASE STUDY: Çamlıca-Kaynaşlı Motorway Gebze-İzmit Section

6.1 General

Gebze-İzmit Motorway is the first motorway which opened to traffic in Turkey. It has 40 km. length. Its construction was began in 1975. Its Kirazlıyalı-İzmit section (approximately 20 km. length) and the rest have been opened to traffic on 8.4.1984 and 28.12.1984 respectively. Because of the increase of traffic, two intersections which are in Dilderesi and Hereke had been needed and their constructions had been completed in 1989. This section has been shown in Figure 6.1.

On this section there are;

- 4 intersections which are in Gebze, Western Hereke, Yarımca (Körfez) and Western İzmit
- 14 viaducts. Total length is 2*2680 m.
- 3 tunnels. Total length is 2*830 m.
- 30 under passes and over passes.

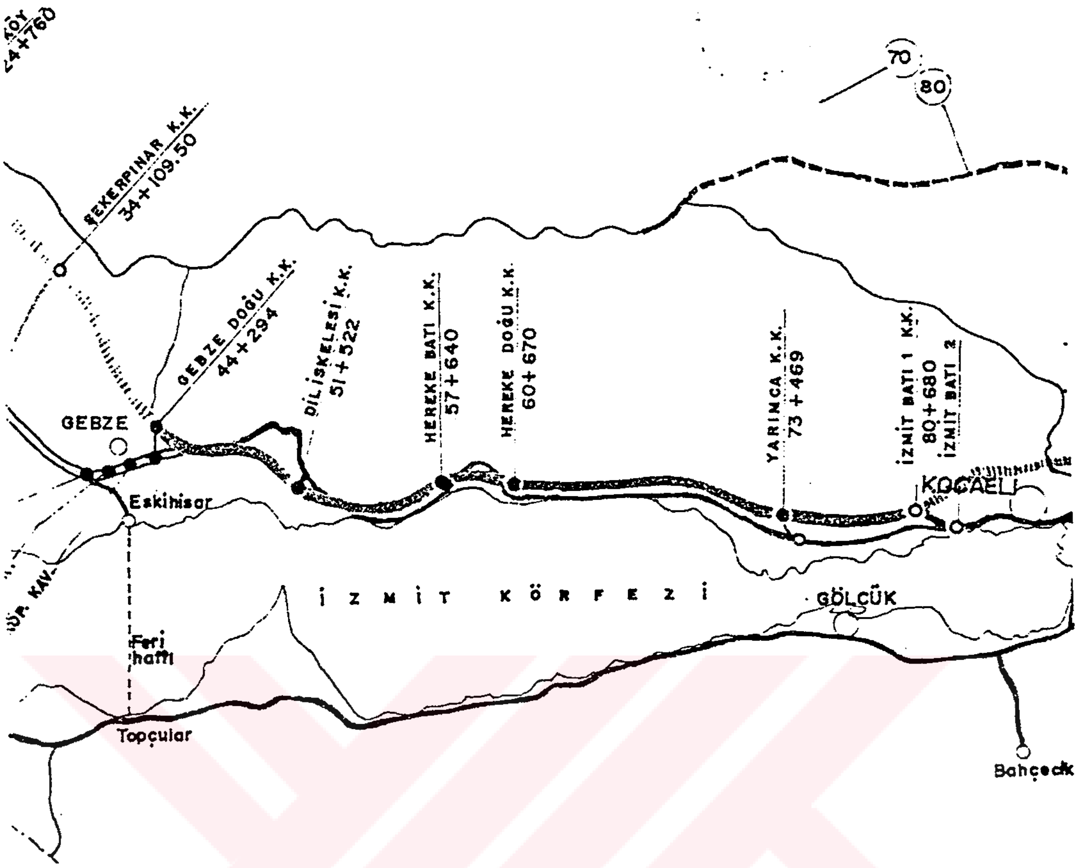

Figure 6.1 The Map of Gebze-İzmit Motorway

6.2 Physical and Geometric Properties

The physical and geometric standarts of Gebze-İzmit Motorway are as follows;

- platform width : 2*11.90 m.
- maximum grade line level :170.00 m.
- minimum grade line level :10.00 m.
- the largest radius of curvature :4000 m.

- the smallest radius of curvature :600 m.
- maximum slope :4.97 %
- design speed :110 km/hr.
- excavation and fill :16,000,000 m^3
- the superstructure of the road :2,000,000 tons
- asphaltic concrete :550,000 tons
- lighting tunnel and intersection :12 km.
- mechanical base :0.35 m.
- cementeous base :0.20 m.
- asphaltic concrete :0.19 m.

The cross section of this motorway is shown in Figure 6.2

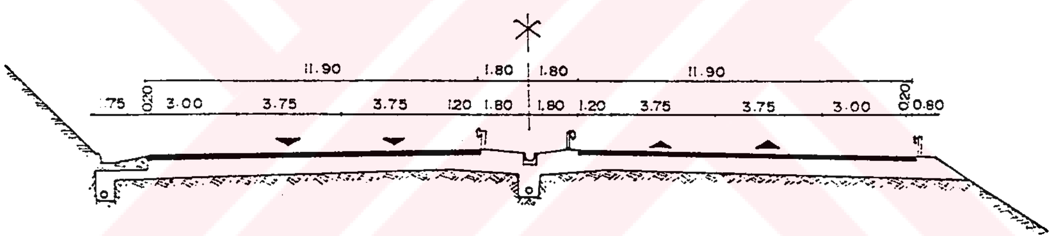

Figure 6.2 The Cross-Section of Gebze-İzmit Motorway

Gebze-İzmit Motorway resembles to the Çamlıca-Gebze Section of Kınalı-Sakarya Motorway with its properties. The comparisons are shown in Table 6.1.

Table 6.1 Properties of Two Motorway Sections

PROPERTIES	CAMLICA-GEBZE	GEBZE-IZMIT
PLATFORM WIDTH (m)	15.65	11.9
LENGTH (km)	39	40
EXCAVATION/FILL (m3)	12,739,500	16,000,000
VIADUCTS (m)	7(1660*2)	14(2*2680)
TUNNELS (m)	_	3(2*830)
OVER.&UNDERPASSES each	35	30
ASPHALTIC CONCRETE(m3)	559000	550000

Çamlıca-Gebze Motorway is a section of Kınalı-Sakarya Motorway. The whole Kınalı-Sakarya Motorway has been awarded in 1985 and this section has been opened to traffic in 1990. Its construction cost per kilometer is approximately 4.72 million US$ according to base year 1985. However, the construction cost of Gebze-İzmit Motorway is 10,642,641 US$ per kilometer as of 1985. The cost of this motorway can be also compared with the example from Australia. Logan Motorway, which has 32 kilometer length, had been opened to traffic in 1988 and its construction had been completed in two years. Its construction cost per kilometer is 2.063 million US$ in 1988.

When the results above mentioned are compared, one of the reason that causes the increase in costs per kilometer is the longer construction period. Gebze-İzmit Motorway had been awarded to many small firms These firms were incapable in motorway technology and not qualified . Thus, motorway tenders should be given to qualified and competent firms which will complete their work in a short time with optimum prices. Delays in construction of a motorways can cause financial and economic loss.

6.3 Data Used in Financial Analysis

A toll road is an investment which provides revenue. This revenue can be utilized for many aims which require financial resources. Among these aims, the primary one is to finance itself. This aim is a minimum required condition for an investment.

In our country, since 1985, tolls have been collected from vehicles according to their classes and distance travelled on Gebze- İzmit Motorway. Tolls have been increasing according to the inflation rate every year.

In analysis, construction, operation and maintenance costs, revenue and interest rate have been used as data and explained how the have been handled below.

6.3.1 Interest Rates

In financial analysis, London Interbank Offer Rates on US Dollar yearly have been used for interest rate. For calculations, the year 1985 has been assumed base year. To compound and to discount all values, related interest rate for every year has been used. The calculations of compound and discount factors are shown in Table 6.2 and Table 6.3.

Table 6.2. Calculations of Compound Rates

YEARS	LIBOR	1+LIBOR	COMPOUND RATE
1974	0.1084	1.1084	3.0348
1975	0.0775	1.0775	2.7380
1976	0.0612	1.0612	2.5411
1977	0.0629	1.0629	2.3945
1978	0.0930	1.0930	2.2528
1979	0.1170	1.1170	2.0611
1980	0.1344	1.1344	1.8452
1981	0.1613	1.1613	1.6266
1982	0.1369	1.1369	1.4007
1983	0.1018	1.1018	1.2320
1984	0.1182	1.1182	1.1182
1985	0.0911	1.0000	1.0000

Table 6.3. Calculations of Discount Rates

YEAR	LIBOR	1/(1+LIBO	DISCOUNT RATE
1985	0.0911	0.9165	1.0000
1986	0.0695	0.9350	0.9165
1987	0.0761	0.9293	0.8569
1988	0.0841	0.9224	0.7963
1989	0.0931	0.9148	0.7346
1990	0.0845	0.9221	0.6720
1991	0.0629	0.9408	0.6196
1992	0.0415	0.9602	0.5830
1993	0.0415	0.9602	0.5597
1994	0.0415	0.9602	0.5374
1995	0.0415	0.9602	0.5160
1996	0.0415	0.9602	0.4955
1997	0.0415	0.9602	0.4757
1998	0.0415	0.9602	0.4568
1999	0.0415	0.9602	0.4386
2000	0.0415	0.9602	0.4211
2001	0.0415	0.9602	0.4043
2002	0.0415	0.9602	0.3882
2003	0.0415	0.9602	0.3727
2004	0.0415	0.9602	0.3579
2005	0.0415	0.9602	0.3436

6.3.2 Costs

6.3.2.1 Construction Cost

Construction costs and right of way costs are shown as of yearly in Table 6.4.

Table 6.4. Yearly Construction and Right of Way Costs

YEARS	CONST.COST	R/W COST($)
1973	0	2,284,734
1974	1,181,458	8,038,217
1975	10,033,529	2,209,216
1976	20,462,686	896,970
1977	34,415,988	709,776
1978	36,934,157	1,885,765
1979	25,329,076	420,168
1980	18,955,953	370,529
1981	13,274,376	546,943
1982	10,527,471	51,633
1983	11,970,634	117,332
1984	14,570,591	698,259
1985	10,443,463	4,577,875
1986	1,476,614	933,993
1987	9,610,555	426,600
1988	3,067,127	369,227
TOTAL	222,253,677	24,537,238

6.3.2.2 Operation and Maintenance Costs

In the financial analysis, real operation and maintenance costs have been considered for the period of 1985-1992. For the period of 1992-2005, these costs are the projected values. While maintenance costs show linear projection,operation costs show exponential trend. Real and projected values and related graphs are shown in Table 6.5., Figure 6.3 and Figure 6.4.

Table 6.5. Yearly Operation, Maintenance Cost and Revenue

YEAR NO.	YEARS	OPE.COST($)	MAIN. COST(	REVENUE $
0	1985	418,385	0	5,695,004
1	1986	519,155	102,763	5,953,079
2	1987	720,605	323,105	6,193,885
3	1988	693,370	230,860	6,612,886
4	1989	942,259	399,579	9,820,562
5	1990	1,335,891	671,545	12,603,204
6	1991	1,527,217	709,782	12,978,463
7	1992	1,895,053	831,186	15,204,497
8	1993	2,351,485	952,589	17,812,336
9	1994	2,917,850	1,073,993	20,867,465
10	1995	3,620,626	1,195,397	24,446,603
11	1996	4,492,669	1,316,801	28,639,625
12	1997	5,574,747	1,438,205	33,551,825
13	1998	6,917,449	1,559,608	39,306,554
14	1999	8,583,545	1,681,012	46,048,319
15	2000	10,650,928	1,802,416	53,946,416
16	2001	13,216,248	1,923,820	63,199,176
17	2002	16,399,437	2,045,224	74,038,947
18	2003	20,349,310	2,166,627	86,737,929
19	2004	25,250,527	2,288,031	101,615,010
20	2005	31,332,222	2,409,435	119,043,772
	TOTAL	159,708,980	25,121,978	784,315,557

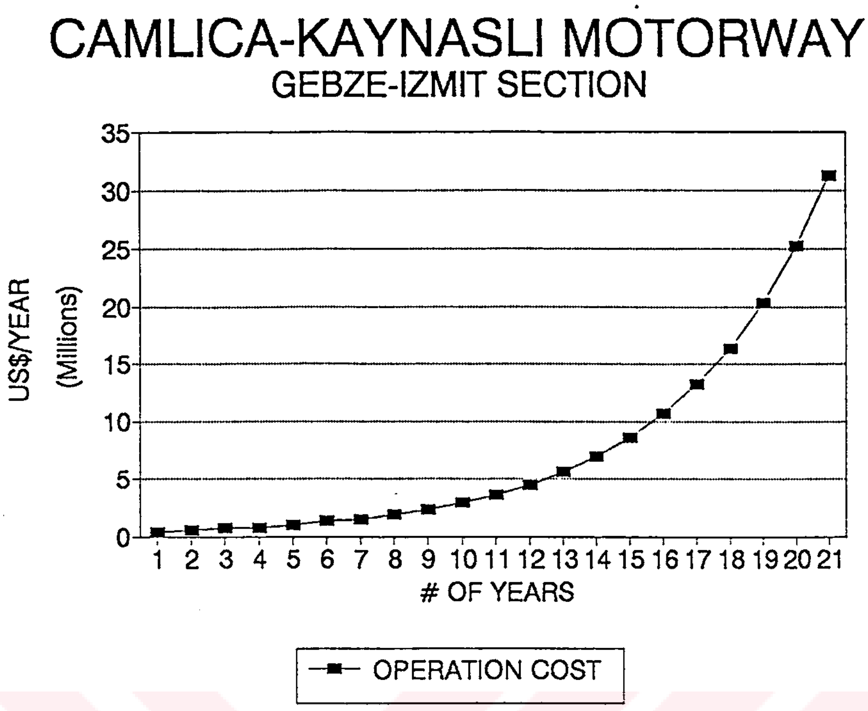

Figure 6.3 Annual Operation Costs for the Economic Life between 1985 and 2005.

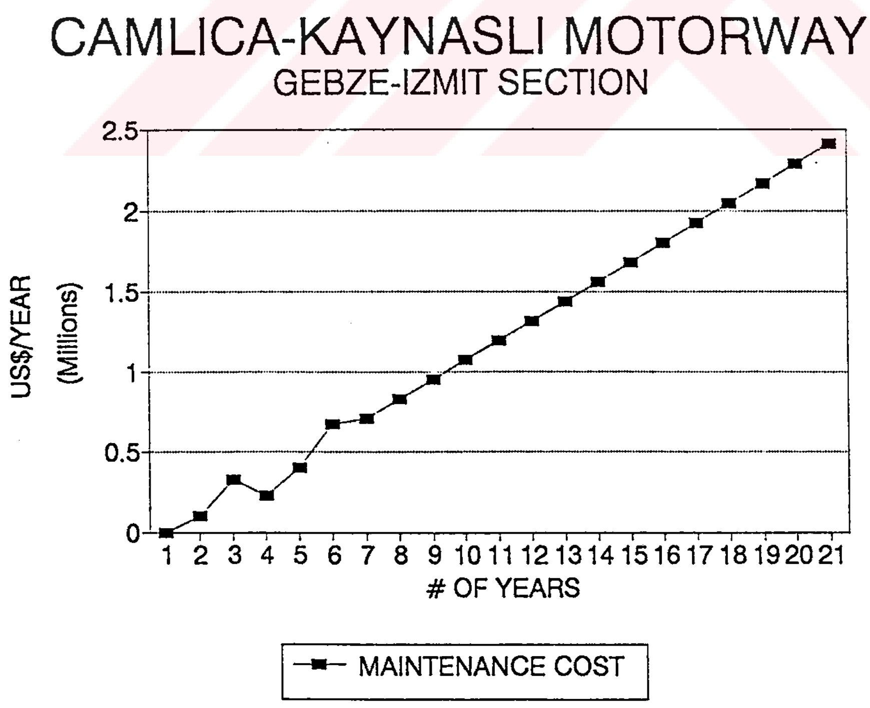

Figure 6.4 Yearly Maintenance Costs for the Economic Life between 1985 and 2005.

6.3.3 Revenue

Revenue is a function of traffic and tolls. Besides, there is an interrelation between toll policy and number of vehicles using the road. To observe this relation on Gebze-İzmit Motorway, roadside survey on the state highway (alternative of Gebze-İzmit Motorway) has been made. In the analysis,the real revenue values and projected values have been used for the periods 1985-1992 and 1992-2005 respectively. Projected values show exponential increases . The yearly revenue values in the economic life 1985-2005 are shown in Table 6.5 in tabular form and in graphical form. in Figure 6.5.

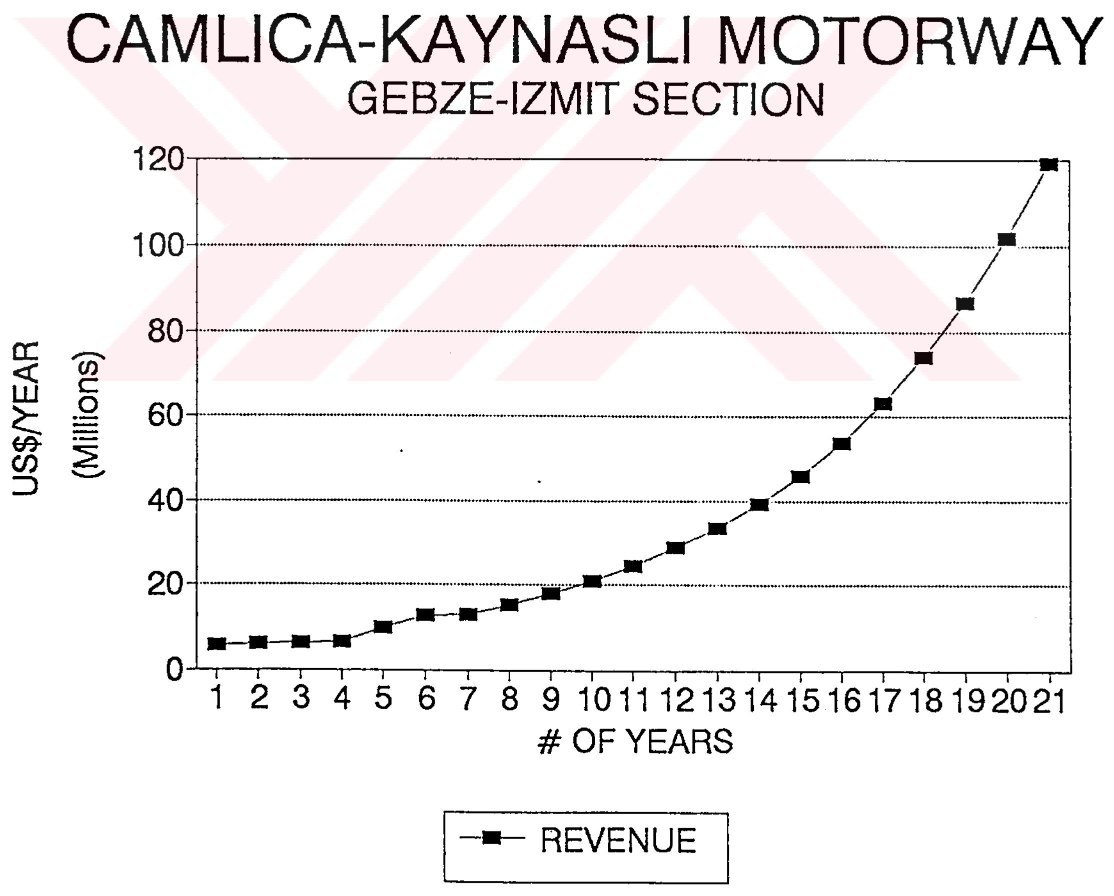

Figure 6.5 Annual Revenue for the Economic Life between 1985 and 2005.

6.3.3.1 Roadside Survey

Roadside survey depends on interviews which have been made with car and truck drivers. In these interviews, the questions have been asked. These questions were;

1. What are the origin and destination of your travel ?
2. What kind of load do you carry ?
3. Why don't you use the motorway ?
4. Which road (motorway or state highway ɔetter for your vehicle ?
5. What do you think about vehicle operating costs ?
6. What do you think about tolls ?
7. If the tolls are decreased at the rate of 0.5 at night, do you prefer the motorway ?

On the state highway, 1.class are local users. These people are the ones who work at the markets, gas stations, factories or workshops along the state highway. Because motorway does not have the accesses to these places, the motorway users are long distance travelers. Bus drivers except local bus firms prefer motorway.

For trucks, the conditions are different. Interviews were made with drivers who have mostly 3 axles trucks. While the load capacity and number of axles increases, the ownership changes from the individuals to firms. Firms prefer their trucks to be driven on motorways because of the safety against accidents and for time saving. Interviews were made with 58 truck drivers. The response percentages of the truck drivers to the questions have been shown in Table 6.6.

Table 6.6. The Response percentages of Truck Drivers

QUESTIONS	RESPONSES		
Why don't you prefer the motorway?	High Toll	Non-existance of service area	Both
	% 5.2	% 16	% 67.2
Do you use the motorway at nights with rate of 0.5 of the current toll?		YES	NO
		% 37.5	% 36.2
Do you know the operation cost of your vehicle?		-	% 100
Do you think that motorway is more economical than the state highway with respect to operation cost?		% 86.2	% 13.8

NOTES: 1. The local truck drivers wre not included to the sample interviews.
2. The ones who say 'Yes' to the second question stipulate that the service areas should be completed.

According to the answers;

- Truck drivers prefer the motorway if their load is time dependent such as fresh fruits and vegetables,
- Some of the truck drivers prefer the motorway if their trucks are laden,
- All the drivers perceive that vehicle operating costs are low for vehicles on motorways. But they are not interested in these costs except fuel.
- The most important factors affecting not using the motorway for them are;

  a. non-existance of service areas

  b. high tolls

- For the seventh question, the answer were mostly negative because of the non-existance of the service areas.

6.3.3.2 Traffic

In financial analysis, all types of vehicles have been converted to equivalent car. For conversion, car=1, bus=2, truck=3 have been assumed. To estimate the number of vehicles using Gebze- İzmit Motorway, depending on the observations of Chief of Planning in Tütünçiftlik, the vehicle numbers exiting the toll plazas which that are located along Çamlıca-Kaynaşlı Motorway, have been taken at some ratios. Because of inadequateness of software of computers in toll collection plazas, the computers record only exiting vehicles and give information only about the destinations of vehicles and can not give information about origins as output.

For this reason, the individual observations which are explained below have been considered for the estimation of vehicle number.

The ratios used are;

- Western İzmit, Körfez, Western Hereke, Eastern Hereke, Diliskelesi, Gebze, Şekerpınar, Eastern İzmit..100 % of vehicles

- Adapazarı, Anadolu	80 % of vehicles
- Sapanca	40 % of vehicles
- Kurtköy	30 % of vehicles

The classes of vehicles;

1. Group: Motorcycles, cars, minibuses, pickups
2. Group: Truck, bus, tow truck
3. Group: 3 axles truck, semi-trailer
4. Group: 2 axles tow truck towing 2 or more axles semi-trailer, 3 axles tow truck.

5. Group: 6 or more axles truck.

Vehicle numbers have been used as real and projected values for the periods of 1985-1992 and 1992-2005 respectively. Real traffic counts are shown for four group of vehicles in Figure 6.6. As shown in Figure 6.6, the prevailing traffic group is 1. class vehicles.

Traffic counts and conversion to equivalent cars used in the analysis are shown in Table 6.7, Table 6.8, Table 6.9.

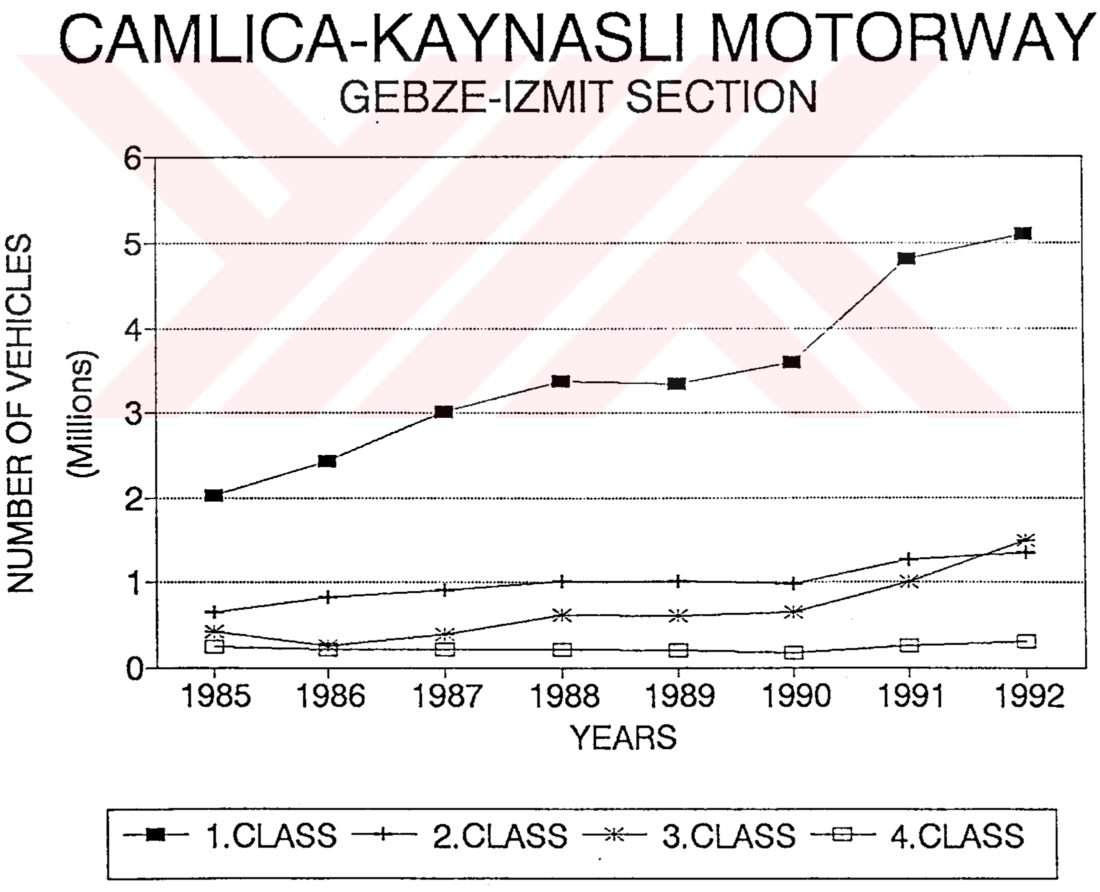

Figure 6.6 Gebze-İzmit Motorway Traffic Flow between 1985 and 1992

Table 6.7. Annual Traffic Counts (Actual).

YEARS	CLASS 1	CLASS 2	CLASS 3	CLASS 4
1985	2,023,362	655,828	417,889	246,721
1986	2,431,376	823,480	253,785	214,895
1987	3,010,086	909,198	379,599	209,462
1988	3,383,890	1,012,408	618,245	204,448
1989	3,345,260	1,014,410	603,737	196,274
1990	3,592,896	980,826	652,364	173,323
1991	4,809,242	1,256,156	997,295	253,588
1992	5,097,940	1,347,948	1,503,356	301,531

Table 6.8. Annual Traffic Estimates Between 1985 to 2005

YEARS	CLASS 1	CLASS 2	CLASS 3	CLASS 4
1985	2,023,362	655,828	417,889	246,721
1986	2,431,376	823,480	253,785	214,895
1987	3,010,086	909,198	379,599	209,462
1988	3,383,890	1,012,408	618,245	204,448
1989	3,345,260	1,014,410	603,737	196,274
1990	3,592,896	980,826	652,364	173,323
1991	4,809,242	1,256,156	997,295	253,588
1992	5,097,940	1,347,948	1,503,356	301,531
1993	4,196,375	1,173,226	874,312	169,224
1994	4,346,584	1,197,886	944,623	165,558
1995	4,487,092	1,220,193	1,014,934	162,242
1996	4,619,328	1,240,558	1,085,245	159,214
1997	4,744,412	1,259,293	1,155,555	156,429
1998	4,863,239	1,276,638	1,225,866	153,851
1999	4,976,539	1,292,786	1,296,177	151,450
2000	5,084,911	1,307,891	1,366,488	149,205
2001	5,188,860	1,322,080	1,436,798	147,095
2002	5,288,811	1,335,458	1,507,109	145,107
2003	5,385,128	1,348,113	1,577,420	143,225
2004	5,478,125	1,360,118	1,647,731	141,441
2005	5,568,073	1,371,538	1,718,041	139,743

Table 6.9. Conversion of Vehicle Types to Equivalent Car.

YEARS	CLASS1	CLASS2	CLASS3	EQUI. CAR
1985	2,023,362	1,311,656	1,993,830	5,328,848
1986	2,431,376	1,646,960	1,406,040	5,484,376
1987	3,010,086	1,818,396	1,767,183	6,595,665
1988	3,383,890	2,024,816	2,468,079	7,876,785
1989	3,345,260	2,028,820	2,400,033	7,774,113
1990	3,592,896	1,961,652	2,477,061	8,031,609
1991	4,809,242	2,512,312	3,752,649	11,074,203
1992	5,097,940	2,695,896	5,414,661	13,208,497
1993	4,196,375	2,346,451	3,130,608	9,673,434
1994	4,346,584	2,395,771	3,330,543	10,072,898
1995	4,487,092	2,440,386	3,531,526	10,459,005
1996	4,619,328	2,481,117	3,733,376	10,833,821
1997	4,744,412	2,518,585	3,935,953	11,198,951
1998	4,863,239	2,553,275	4,139,150	11,555,665
1999	4,976,539	2,585,571	4,342,881	11,904,991
2000	5,084,911	2,615,782	4,547,077	12,247,770
2001	5,188,860	2,644,161	4,751,681	12,584,702
2002	5,288,811	2,670,917	4,956,647	12,916,375
2003	5,385,128	2,696,226	5,161,935	13,243,290
2004	5,478,125	2,720,237	5,367,514	13,565,875
2005	5,568,073	2,743,076	5,573,353	13,884,502

6.4 Analysis

In this financial analysis, Benefit-Cost Analysis has been used by Present Worth Comparison according to base year 1985. With the principle of self-financing of an investment which should be, at least, in Turkey because of her economic conditions,

1. it has been investigated whether this investment finance itself , or not
2. a constant toll, which must be applied for self- financing has been studied;

a. for the period of 1992-2005

b. for the period of economic life, which is between 1985 and 2005.

6.4.1 Benefit-Cost Analysis

Construction Cost	= 425,705,658.- US $ (Table 6.10)
Operation and Maintenance Cost	= 77,364,252.- US $ (Table 6.11)
Revenue	= 343,024,209.- US $ (Table 6.11)

$$\text{Benefit/Cost} = \frac{\text{Revenue}}{\text{Costs}} = 0.682$$

For a toll road which is an investment that provides revenue, this ratio is an undesired result. For such an investment, ratio desired for this investment must be at least, 1.00.

6.4.2 Constant Toll Application

In this application, self-financing of the road has been defined as an objective. After 1992, to finance itself, 0.17 US$ should be paid per equivalent car. All calculations have been shown in Table 6.12.

Table 6.10. Calculation of Construction Cost According to Base Year 1985

YEARS	CONST.COST ($)	COMP. RATES DISC. RATES	COMP.CONST. COST ($)
1974	1,181,458	3.0348	3,585,488
1975	10,033,529	2.7380	27,471,804
1976	20,462,686	2.5411	51,997,731
1977	34,415,988	2.3945	82,409,083
1978	36,934,157	2.2528	83,205,269
1979	25,329,076	2.0611	52,205,758
1980	18,955,953	1.8452	34,977,525
1981	13,274,376	1.6266	21,592,100
1982	10,527,471	1.4007	14,745,828
1983	11,970,634	1.2320	14,747,821
1984	14,570,591	1.1182	16,292,835
1985	10,443,463	1.0000	10,443,463
1986	1,476,614	0.9165	1,353,317
1987	9,610,555	0.8569	8,235,284
1988	3,067,127	0.7963	2,442,354
		TOTAL	425,705,658

Table 6.12, the calculations have been made as follows;

Compound Construction Costs + Ope.& Main.Costs in 1985= Sum of Discount Factor* Real Revenue of related years between 1985 and 1992 in 1985 + Sum of Discount Factor* Traffic in equivalent car of related years* Unit toll* ($/km.)*40.00

If a constant toll application had been defined before opening to traffic to provide self-financing condition, 0.11 US$ would be paid per equivalent car for economic life of this road. The calculations have been made as follows;

Table 6.11. Calculations of Discounted Operation and Maintenance Costs, and Revenue.

YEAR NO.	YEARS	DISCOUNT RATES	OPE.COST($)	MAIN. COST($)	REVENUE $	DISCOUNTED OPE. & MAIN.COSTS ($)	DISCOUNTED REVENUE($)
1	1985	1.0000	418,385	0	5,695,004	418,385	5,695,004
2	1986	0.9165	519,155	102,763	5,953,079	569,988	5,455,997
3	1987	0.8569	720,605	323,105	6,193,885	894,355	5,307,540
4	1988	0.7963	693,370	230,860	6,612,886	735,964	5,265,841
5	1989	0.7346	942,259	399,579	9,820,562	985,715	7,214,185
6	1990	0.6720	1,335,891	671,545	12,603,204	1,348,997	8,469,353
7	1991	0.6196	1,527,217	709,782	12,978,463	1,386,044	8,041,455
8	1992	0.5830	1,895,053	831,186	15,204,497	1,589,397	8,864,222
9	1993	0.5597	2,351,485	952,589	17,812,336	1,849,290	9,969,565
10	1994	0.5374	2,917,850	1,073,993	20,867,465	2,145,216	11,214,176
11	1995	0.5160	3,620,626	1,195,397	24,446,603	2,485,068	12,614,447
12	1996	0.4955	4,492,669	1,316,801	28,639,625	2,878,592	14,190,934
13	1997	0.4757	5,574,747	1,438,205	33,551,825	3,336,061	15,960,603
14	1998	0.4568	6,917,449	1,559,608	39,306,554	3,872,320	17,955,234
15	1999	0.4386	8,583,545	1,681,012	46,048,319	4,502,035	20,196,793
16	2000	0.4211	10,650,928	1,802,416	53,946,416	5,244,103	22,716,836
17	2001	0.4043	13,216,248	1,923,820	63,199,176	6,121,130	25,551,427
18	2002	0.3882	16,399,437	2,045,224	74,038,947	7,160,217	28,741,919
19	2003	0.3727	20,349,310	2,166,627	86,737,929	8,391,690	32,327,226
20	2004	0.3579	25,250,527	2,288,031	101,615,010	9,856,050	36,368,012
21	2005	0.3436	31,332,222	2,409,435	119,043,772	11,593,633	40,903,440
	TOTAL		159,708,980	25,121,978	784,315,557	77,364,252	343,024,209

Table 6.12. Constant Toll Calculation for the Period of 1992-2005.

YEAR	DISCOUNT RATE	REVENUE ($)	TRAFFIC	DISCOUNTED REVENUE(1985) ($)	DISCOUNTED BENEFIT*40.0
1985	1.0000	5,695,003.52		5,695,003.52	
1986	0.9165	5,953,078.82		5,455,996.74	
1987	0.8569	6,193,885.49		5,307,540.48	
1988	0.7963	6,612,885.70		5,265,840.88	
1989	0.7346	9,820,562.34		7,214,185.09	
1990	0.6720	12,603,203.83		8,469,352.97	
1991	0.6196	12,978,378.40		8,041,403.26	
1992	0.5830	15,204,393.92		8,864,161.66	
1993	0.5597		9,673,434		216,568,842
1994	0.5374		10,072,898		216,527,017
1995	0.5160		10,459,005		215,873,857
1996	0.4955		10,833,821		214,726,332
1997	0.4757		11,198,951		213,093,633
1998	0.4568		11,555,665		211,145,112
1999	0.4386		11,904,991		208,861,159
2000	0.4211		12,247,770		206,301,434
2001	0.4043		12,584,702		203,519,795
2002	0.3882		12,916,375		200,565,471
2003	0.3727		13,243,290		197,430,965
2004	0.3579		13,565,875		194,209,068
2005	0.3436		13,884,502		190,828,595
			TOTAL	54,313,485	2,689,651,280

CONSTRUC.COST	425,705,658	
MAIN.&OPE.COST	77,364,252	UNIT TOLL($)/KM = 0.17
DIS.REAL REVENUE	54,314,121	
DIS.BENEFIT*40.00	2,689,651,280	

Compound Construction Costs + Ope.& Main. Costs in 1985= Sum of Discount Factor* Traffic in equivalent car of related years between 1985 and 2005 * Unit toll($/km.)*40.00.

In these formulas, unit tolls are drawn as unknown.

In Table 6.13, it has been seen that unit toll is 0.11 US$. All calculations are shown in Table 6.13.

When unit tolls have been compared with each other;

After 1992, for self financing, unit toll must be 0.17 US $. This result is a level which can be caused to public and political reactions. However, if self-financing had been considered as a goal, after 1985, unit toll would be as 0.11 US $ which will be in a rational level. The Figure 6.7 shows the unit tolls calculated according to the self-financing condition and real application.

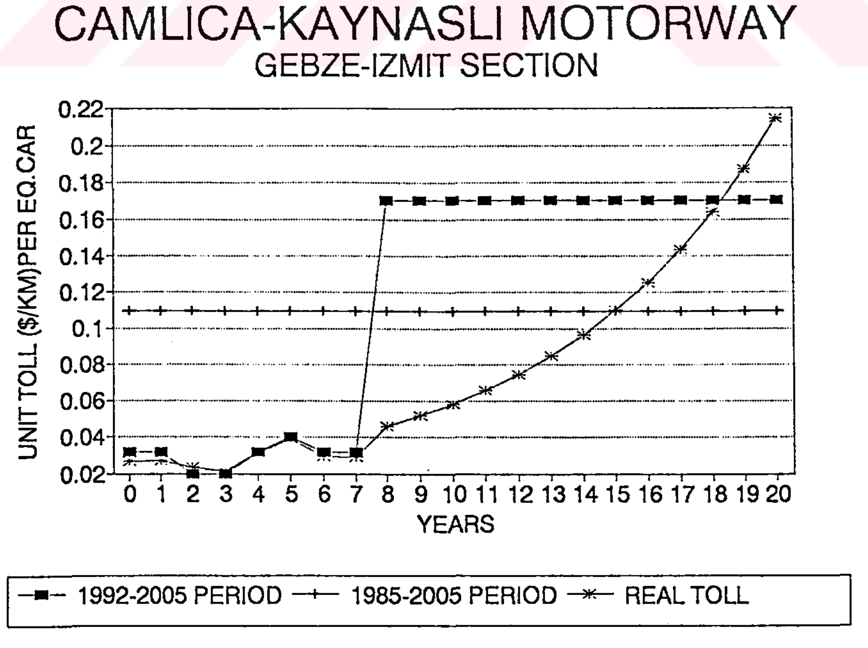

Figure 6.7. Comparison of Unit Tolls for the Economic Life between 1985 - 2005

Table 6.13. Constant Toll Calculation for the period of 1985 - 2005

YEAR	DISCOUNT RATE	TRAFFIC(EQ.CAR)	DISCOUNTED BENEFIT*40.0
1985	1.0000	5,328,848	213,153,920
1986	0.9165	5,484,376	201,057,224
1987	0.8569	6,595,665	226,073,014
1988	0.7963	7,876,785	250,891,356
1989	0.7346	7,774,113	228,434,536
1990	0.6720	8,031,609	215,889,650
1991	0.6196	11,074,203	274,463,047
1992	0.5830	13,208,497	308,022,150
1993	0.5597	9,673,434	216,568,842
1994	0.5374	10,072,898	216,527,017
1995	0.5160	10,459,005	215,873,857
1996	0.4955	10,833,821	214,726,332
1997	0.4757	11,198,951	213,093,633
1998	0.4568	11,555,665	211,145,112
1999	0.4386	11,904,991	208,861,159
2000	0.4211	12,247,770	206,301,434
2001	0.4043	12,584,702	203,519,795
2002	0.3882	12,916,375	200,565,471
2003	0.3727	13,243,290	197,430,965
2004	0.3579	13,565,875	194,209,068
2005	0.3436	13,884,502	190,828,595
		TOTAL	4,607,636,177

CONSTRUC.COST	425,705,658	
MAIN. &OPE. COST	77,364,252	UNIT TOLL($)/KM 0.11
DIS.BENEFIT*40.00	4,607,636,177	

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

In this thesis, when the revenue obtained from the motorways is analysed, a relationship between revenue and the toll policy applied is observed where the revenue is a function of traffic and tolls.

Since the revenue obtained from motorways is also used as a resource for the construction, operation and maintenance of motorways, toll rates must be determined for each class of vehicle according to the predefined objectives.

Roadside interviews indicated that the safety and maintenance facilities (in winter conditions) and the existance of sevice areas along motorways affect the choice of road users (rather than the time served and the operational cost) for the use of motorways. The lack and / or inadequacy of such facilities affect the traffic and in turn the revenue adversely.

For an accurate estimation of revenue, the actual traffic compositions and the motorway section over which this exist, must be determined. Electronic toll collection systems with less human interference must be used to get more reliable and accurate data, which end up in real revenue of motorway usage.

7.2 Recommendations

1. Detailed and reliable traffic counts should be made by the related institutions for use in further research.

2. Road user interviews (before and after the motorway) must be used in determining the optimum toll rates.

3. Regional, social and economic policies and the governmental subsidies must be defined to set up different rates throughout the country.

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APPENDIX

APPENDIX A. DESCRIPTIONS OF TERMS

- Traffic Calming:

This measure enables to tame traffic by reducing speeds. So, vehicle and non-motorized traffic are more compatible and noise levels and environmental pollution are reduced. This system is widely used in many German cities.

- Traffic Collars:

This method enables to aim reducing traffic volumes rather than lowering traffic speeds. By this method, car travel can be less attractive and drivers are encouraged to change their travel mode to public transportation mode.

Capacity can be restricted in two ways; One of them is to limit space, the other is time. With related to time, traffic signals can impose more delays. The authorities suggest that in theory, it offers a very effective measure but in practice it is difficult to implement.

- Traffic Cells and Mazes:

They are a network-wide approach to the problems of traffic. They require careful design. Traffic cells are traffic re-routing rather than restraining require careful design. Traffic cells are traffic re-routing rather than restraining techniques and therefore involve the transfer of traffic problems to other locations.

Traffic maze movement provides indirect routing that makes it an unattractive option.

- Vehicle Categories Used in Analysis of Logan Motorway:

1.Home-based works: Trips by cars or motorcycles between the driver's home address and place of work.

2.Employer's business: Trips by cars or motorcycles from one place of work to another.

3. Other: Trips by cars or motorcycles for other purposes, e.g. home to school, shops to recreation, work to shops.

4. Commercial Vehicle: Trips by light or heavy goods vehicles either privately or company owned.

5. Day Trips: This category include trips by day trippers and visitors.