TOLL COLLECTION SYSTEMS

A CASE STUDY; DEVELOPMENT OF A COMPUTER PROGRAM FOR THE CALCULATION OF TOLL RATES FOR CLOSED TOLL SYSTEMS

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ABSTRACT

TOLL COLLECTION SYSTEMS

A CASE STUDY; DEVELOPMENT OF A COMPUTER PROGRAM FOR THE CALCULATION OF TOLL RATES FOR CLOSED TOLL SYSTEMS

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There are more than 35,000 Km of tollways throughout the world, in some 16 different countries. The toll systems in use vary considerably, depending on local conditions and requirements, and on the level of toll charges which apply. But, the very well pronounced application is to impose the costs due to the construction, maintenance, financing and operating troubles of motorways to the users of motorway.

The principle purpose of this study concerning the general principles and application details of a toll-tariff systems for toll collection is to describe the toll systems for motorways that exist at present in the world, together with the detail procedures for collecting these tolls for financial justification of motorway investments.

A financial analyses for Gebze-Izmit Motorway which is the first application of tolls in Turkey was performed as a case study and the toll rates that is likely to be applied during future twenty years were calculated, considering that all the motorway networks in Turkey will operate under closed under toll system which was found to be the most reliable toll collecting model with lowest collection costs for Turkey's prevailing conditions. A 701 line - 76499 Byte computer program was developed for sorting the distance classes and applying a general proposed formula implementing the price continuously decreases as the distance increases. The conclusions derived after this study have revealed that the selected Gebze-Izmit Motorway section shall be a self-supporting investment for the next 20 years, applying a toll rate decreasing from 7.25 cent to 1 cent, under the proposed toll-rates applied under closed toll collection model.

Key words : Toll rates, Tollways, Toll collection systems

Science code : 624.04.01

ÖZET

PARALI OTOYOLLARINDA GEÇİŞ ÜCRETİ TOPLAMA SİSTEMLERİ VE KAPALI GEÇİŞ ÜCRETİ TOPLAMA SİSTEMLERİ İÇİN GEÇİŞ ÜCRETİNİ HESAPLAYAN BİR BİLGİSAYAR PROGRAMININ GELİŞTİRİLMESİ

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Bütün dünyada 16 ayrı ülkeye dağılmış 35.000 km'den fazla paralı yol mevcuttur. Kullanılan paralı geçiş sistemleri, yerel şart ve ihtiyaçlar ile, uygulanan ücret seviyesine göre çok değişik olmaktadır. Bu sistemlerin uygulanması genellikle otoyollarında yapım, bakım ve işletmelerindeki finansmanın yoldan yararlananlara yüklenmesi şeklinde olmaktadır.

Bu çalışmanın asıl amacı, dünyada şuanda var olan otoyolların ücret toplama sistemlerini tanıtmak, otoyol yatırımlarını finanse edecek geçiş ücreti tarife sistemini genel ilke ve uygulama ayrıntılarıyla açıklamaktır.

Türkiye'de paralı otoyol uygulamasının ilk örneği olan Gebze-İzmit Otoyolu için bir finansman analizi yapılarak, Türkiye'nin tüm otoyol şebekesinin, Türkiye şartlarında en düşük ücret toplama maliyeti olan ve en güvenilir ücret toplama modeli olarak kabul edilen, kapalı ücret toplama

sistemi olacağı gözönüne alınarak gelecek 20 yıl boyunca uygulanabilecek geçiş ücreti oranları hesaplandı. Geçiş ücreti oranları için mesafe sınırları tespit edip, bu sınırlar arttıkça geçiş ücreti oranını azaltan genel bir formül uygulayarak, 701 line -76499 byte'lık bir bilgisayar programı geliştirildi. Bu çalışmadan çıkarılan sonuç göstermiştir ki gelecek 20 yıllık dönem içerisinde önerilen 7.25 centten 1 cent'e kadar azalan bir geçiş ücretinin uygulanmasıyla hesaplanan gelir, Gebze-İzmit Otoyolununun kapalı ücret toplama sistemi altında kendi kendini amortize edebilecektir.

Anahtar kelimeler : Geçiş ücretleri, Paralı yollar,
Geçiş ücreti toplama sistemleri.

Bilim kodu : 624.04.01

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Abbreviations

VIACARD	Vehicle Identification Card
OVE	On board Vehicle Equipment
EEC	European Economic Community
PC	Passenger Car
TR	Truck
TEM	Trans-European North-South Motorway
CE	Car Equivalent
AADT	Annual Average Daily Traffic
US	United States
Km	Kilometer

Symbols

h_{gant}	toll gantry height
h_{bad}	on board equipment height
h_{HV}	maximum height of the rear end of the previous vehicle
θ	vertical angle between toll gantry and aperture antenna directed
d_{min}	mininum distance between vehicles
I_{loss}	distance of communication lost
I_{acq}	distance of ground-vehicle communication begins
Q_{PC}	traffic category of passenger car
Q_{TR}	traffic category of truck
e_{PC}	coefficient of elasticity for passenger car

LIST OF SYMBOLS (cont'd)

e_{TR}	coefficient of elasticity for truck
F_{PC}	fixed expenditures of passenger car
F_{TR}	fixed expenditures of truck
M_{PC}	marginal cost of passenger car
M_{TR}	marginal cost of truck
S	the infrastructure expenditures
V	the salaries
é	the nominal coefficient of efficiency of the capital
K	coefficient of differentation of the efficiency of the productivity funds
W	construction cost
Pv	the subjective coefficient of productivity of the work reflecting the qualification of the labor input
Y	toll rate
A	annual fixed rate
C	toll collecting cost
M	maintenance cost
L	motorway length
a,b	constants

CHAPTER 1

INTRODUCTION

It is widely known method in very many countries for a long time, to impose the construction, maintenance, financing and operating troubles of motorways to the user of the motorway.Motorway like any other public utility, can be financed by methods falling somewhere in between two extreme limits: on the one side, charging the full cost only to direct users, through a toll system; or, charging the cost to the community through general taxation. Not only is this problem solved in different ways in different countries, but even in individual countries it may be solved in different ways on different motorways. While in the United States and Japan there are both toll and toll-free Motorways, in Europe it was preferred-at least until recently and with the only exception of Italy-to charge no tolls, since the motorways were financed either by budget appropriations (Austria, Great Britan and Netherland) or by funds made up mostly by motorization tax revenues (Belgium, Switzerland, Germany, France, Sweden and Denmark). In Europe too, however, above all in the line of Italy's experience, the idea has been recently taking hold that tolls should be charged. This approach is being generally justified by two considerations; i.e:

1. the realization that, without toll revenues, motorway network construction schedules are being completed for behind those achievable by charging toll;

2. the fact that the motorway network, usually alternative to the ordinary network, produces additional benefits to its users, for which reasons of equity should be taxed.

There is no doubt that the introduction of tolls, and above all their level, can play a significant role, not in so far as financing is concerned but rather from the standpoint of recovering construction and maintanence costs. The principle of collecting only from the direct users of the motorway (at least when the entire construction and operating cost is charged to them) is claimed to be justified, as we have said, by the fact that the users derive certain advantages from the use of a qualitatively better facility.

CHAPTER 2

HISTORY OF TOLLS

Toll have long been set up on public thoroughfares; nearly two centuries ago, in 1800, toll roads already existed in Western Europe.

More recently they were applied to motorways over 60 years ago, or to be more exact in 1924, for the the "autostrada" from Milan to the Italian lakes.(1)*

2.1. History and Development of Toll Motorways

In Europe among the system for financing and servicing motorways, the toll has been selected by all of the countries of Southern Europe, namely France, Italy, Spain, Portugal and Yugoslavia, with the addition of Austria for a small proportion of it is road system. It should be noted that the United Kingdom has toll sections essentially for the bridges.

The historical development of the motorway networks both

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* Numbers in parantheses indicate references

toll and public-finance, of Italy, France, Spain and Turkey is indicated in Table 2.1.

2.2. Present State of Toll Networks

The cases of Italy, France and Spain illustrate the possibilities a toll system can provide.In these three countries the length of motorways built before implementing the toll-financed programmes was negligeable. The connessionees, operating as private or semi-private bodies, have built and now operate 10346 kilometres of motorways and have provided Goverment funds that can be used for secondary roads or other structures or public programmes.The assignment of construction and management to private firms has been additional encouragement to efficient management and financing of limited-access and toll road systems (1).

Table 2.2. gives the length of toll motorway networks in kilometres in the various aforementioned countries. Growth prospects are also mentioned.

However, other countries outside Europe also apply tolls.For instance in the United States which was among the first to use this management system, nearly 7500 km. of toll motorways are available, and in Japan (2500 km.),Canada, Mexico and Southern Korea each owns a few hundred kilometers of toll motorway sections. Lastly, toll also wide spread in the different countries.

Table 2.1. Motorway network (in kilometres) (1)

NAME OF COUNTRY	YEARS 1950	1960	1965	1970	1980	1986
Italy	490	1126	1723	3927	5171	5663
France	-	127	354	1335	2827	4264
Spain	-	-	-	96	660	948
Turkey	-	-	-	-	-	68

Table 2.2. Tollway network as of 1981 (in kilometres) (1)

NAME OF COUNTRY	IN SERVICE	UNDER CONSTRUCTION	PLANNED
Austria	183.9	41.5	9.0
Spain	1633.3	118.0	431.0
France	3695.6	716.8	848.6
Italy	5017.3	112.6	830.4
Portugal	89.7	54.9	146.6
Yugoslavia	312.2	375.5	1071.0

2.3. The Reasons for Toll Collection

Three main reasons for toll-system implementation are as follows:

2.3.1. Financial Advantages

Thank to the toll, loan funds can be accumulated to participate in the construction of the further motorway systems, thus alleviating the burden on the budget of the state.

2.3.2 Equity Sharing

By means of the toll, only those who use the motorway structure and enjoy its advantages pay, at least partly, for its construction.

2.3.3 Optimization of User Choice

By means of the toll, use of motorway can be charged at its true price, enabling the productive sector to be correctly costed and hence optimize orientation of the users' choice.

2.4. Some Cases That Toll can not be Applied

Despite the reasons mentioned in 2.3, on all or part of some high speed road system, no toll is levied; three reasons may underly this choice as follows;

The interurban road network of the country concerned is not dense enough or is not of sufficient quality to ensure a minimum service level on all links; the service is then provided by the motorway infrastructure, which must consequently apply the same tariffs as the remainder of the national network;

In certain regions, the built-up areas can lie relatively close to one another, with the result that the interurban links carry major short or medium range traffic; now, as will be seen later, this type of traffic is higly sensitive to toll collection which means that such a toll can turn out to be both unjustified and ineffective; as an example, certain links in the Federal Republic of Germany can be mentioned, or the case of the Lille, Dunkirk-Valenciennes or Nancy-Metz links in France.

Lastly and in particular, the distribution of budget credits can set aside, for major road investments, a fairly high share for financing motorway work not necessarily resorting to the financial market; this is the result of a political decision at state or regional level, an example of which can be found in the Federal Republic of Germany; in France also, certain major arterials are completely constructed as dual two-lane carriageways (1).

In addition, the fact that a toll does not have to be collected from the user enables more access roads to the motorway to be built, thus ensuring more continuous service to the regions crossed.

CHAPTER 3

TOLL COLLECTION PROCEDURES

3.1 General

Since the type of rates applicable is conditioned by the very manner in which toll are to be collected, let us consider the possible toll collecting methods, thus going in to third type of questions connected with the levying of tolls. The toll systems in use vary considerably, depending on local conditions and requirements, and on the level of toll charges which apply. In theory, five toll collection techniques have been studied.

- closed system
- open system
- mixed system
- by electronic vehicle counters
- by counters mounted directly to the vehicles

Since method 3, 4 and 5. are now under study chiefly for the collecting of tolls in certain urban areas, only the first two methods shall be discussed with their advantages and disadvantages in the following sections.

3.2 Closed System versus Open System

The toll is the money the user pays for the right to avail himself of a means of communication.

In the case of motorways, toll is generally dependent on two variables; the type of vehicle and the distance travelled. Two types of collection facilities are used: the closed system and open system.

Closed system, was adopted and developed in Italy, with the sole exception of the Florence-Sea and Milan-Lakes motorways.It usually comprises two terminal stations of the barrier type, plus a number of interchanges suitably equipped and including a toll-collecting station. With this system, even though tolls can be collected either on entering or leaving the motorway, they are usually collected upon leaving it, in order to avoid the waste of time involved in working out toll adjustments for those who decide to leave the motorway at a point different from that for which they paid the toll. The user stops twice: when entering the motorway and when leaving it. He must indicate where he has entered the motorway or provide proof of where he will leave it, depending on whether the toll is levied on entering or leaving. In actual fact, the payment is almost invariably made on leaving. In this case, the operations take place as follows:

- on entering the motorway, the user receives a ticket showing the name of the entry station, the time of entry and the category of vehicles;

- on leaving, following possible verification of the category of vehicle, the user pays toll depending on the distance travelled.

In the open system is generally adopted for the case of bridges, tunnels (like the Mont Blanc tunnel) and freeways. In Italy it is used on the Florance-Sea and Milan-Lakes motorways and is regarded as extendable to the whole network, in view of the fact that it is cheaper to operate than the "closed" system. It consists of a succession of barrier station, of the type of the terminal stations in a "closed" system, spaced about 30 to 50 kilometers, where a toll, mostly fixed, is paid when going though. The "journey" variable is eliminated in calculating the toll, only the category of vehicle being allowed for. The user is normally stopped by toll barriers and progressively pays the price of the journey depending on the category of his vehicle.

3.2.1 Closed Toll System

3.2.1.1 Advantages of Closed Toll System

- Better knowledge of the characteristics of the traffic.

- Better control for categories that can not be automatically defined.

- A fairer and more rigorous system of levying the toll, based on the length of the journey.

- Greater flexibility in setting differential tariffs over given distances travelled.

- Possibility of adapting any number of connections that can be added at any time without involving any change other than that of increasing the number of possible itineraries.

- Two stops for each itinerary, and only one where a payment has to be made .

- Possibility of installing automatic ticket distributors at the entry points (2).

3.2.1.2 Disadvantages of Closed System

- Greater complexity of the equipment and recording methods,

- In view of the present state of the art, it is difficult to automate the exit stations in actual practice,

- Disadvantages and cost of handling the tickets (2,3).

3.2.2 Open Toll System

3.2.2.1 Advantages of Open Toll System

- Greater simplicity in the equipment and methods

- System is less liable to fraud, with automatic determination of vehicle categories,

- Possibility of almost full automation: single toll at each station for each of the categories,

- Single stop, or two at the most, on short motorways or motorways with only few connections. System is highly appropriate for motorways with traffic pattern (1).

3.2.2.2 Disadvantages of Open Toll System

- Determination of entry and exit point is uncertain or impossible to detect,

- More difficulty in checking without automatic determination of categories,

- Less flexibility for constructing new toll stations and junctions,

- Frequent need to limit tolls,

- Numerous stops on long motorways,

- It can not be used when the motorway is merged by an ordinary road which can be used to bypass the toll stations. More precisely, costwise, while it costs less to built than the closed system, it may cost more to operate, particularly in terms of personnel cost, since all traffic is intercepted and this means that, to prevent holdups, all stations must be dimensioned for the peak traffic flow.

The two systems therefore could be said that they have different fields of application and are complementary rather than competitive.

The closed toll is appropriate for long itineraries.

The open toll is suitable for urban and suburban itineraries or short interurban motorways comprising few traffic exchangers (1).

3.3 Equipment of Toll Stations

A toll point generally consists of:

- A number of exit lanes and a number of entrance lanes (in general, there are two entrance lanes for three exits).

- There are often lanes available in the centre of the toll point operating for light vehicles. Certain lanes are polyvalent and can be easily switched either to exit or entrance, depending on the traffic approaching from either direction.

- A building comprising:

a surveillance room where certain data from the entrance and exit lanes are collected and an equipment room containing the power sources needed to keep the equipment running permenantly.

3.3.1 Open System

The following are to be provided in the open toll system:

- Either toll points blocking off the entire passage, used in either directions,

- Toll points situated at the entrance or exit, used in one direction only.

These toll points comprise two types of lane:

- automatic lanes reserved for light vehicles,

- manual lanes at the ends, capable of processing all users.

3.3.1.1 Automatic Toll Collection Lane

The user who takes this lane is detected by an electromagnetic loop built in the carriageway which stimulates the circuits so as to accept payment. He throws the toll payment into a basket. After counting the coins, the light changes to green and returns to red when the vehicle passes over a second electromagnetic loop. The passage is recorded. Automatic machines are capable of accepting two to four types of coin. They not only test the diameter and thickness of the coin, but also the composition of the metal by electromagnetic verification system.

An average vehicle flow of 500 vehicles per hour can be taken as the reasonable flow per lane (3).

3.3.1.2 Manual Toll Collection Lane

These lanes are intended for user categories other than those reserved for the automatic toll and users without loose change or who wish to obtain a toll slip.

The lane comprises an elecromagnetic vehicle detector and a booth for the toll collector, who is equipped with a control desk.

The desk essentially consists of:

- a keyboard to key-in the category of vehicle,
- a control button for the green light after payment,
- a subscriber card reader replacing the payment,
- if necessary, a distributor of toll slips.

By its organization, the open system ensures considerable operating autonomy of the lanes. At the surveillance room, there is a tendency to replace the hard-wired metering cabinet by a computer cabinet making it possible:

- to collect the data generated on site: passages, receipts, infringements, etc.

- to printout the log of the toll point by means of a printer hourly traffic, started and end of shift, alarms, etc.

Additionally this cabinet provides a dialogue with the operating concern or maintenance technician who can make checks from a listing.

3.3.2 Closed Toll System

Closed type toll points comprise two types of lane:

1) entrance lanes where the transit cards are distributed manually or automatically,

2) exit lanes where the user pays the toll.

Two systems are practiced: one uses punched cards, the other magnetic tickets.

Changing public attitudes, high salaries and technical evaluation have brought about generalization of the automatic ticket distributor on entry.

These distributors possess:

a) either a single outlet with distribution at two levels for passenger cards and trucks,

b) or two independent outlets for passenger cars and trucks.

Although the distribution time is less than 3 seconds, a passage of no more than 500 vehicles per hour could only be attained. This is essentially a problem of information and ergonomics, i.e. presentation of the tickets or punched cards.

A rapid examination of what has been accomplished so far in the field of automatic toll collection confirms the tendency to render all repetitive operations automatically as much as possible together with the need to ensure ever greater reliability of the data measured and recorded. These functions rely on the two major keypoints of the system; namely the system for recording the vehicles and the system for recording the data. Particular care has been paid to designing and testing the recording systems and to each component, making for simple, highly reliable equipment built into highly sophisticated systems capable of analyzing the traffic and providing highly interesting statistics.

As regards to recording of the data, which originally printed on tape, the systems have been progressed to the punched tape, minicasettes and finally the disc, and to remote-transmission to a data processing centre. Obviously, the choice was often dictated by technical and economic factors of the resultant cost and profit.

3.4. An Intelligent Toll for Tomorrow's Motorways (Telepass)

Springtime 1990: the first system ever realized for motorway system of "closed type" - for toll-payment without stopping is set on work for about ten thousand habitual users, on the motorway Milan-Naples. It is basically constituted by an on board equipment which communicates with the ground based instruments and automatically stores all the entrance data, transferring them later when the vehicle gets to the exit. The ticket does not exist any more and the a foresaid equipment records all the transits, replacing the ordinary receipt, and allows the periodical payment by direct debit on current account, procedures in use with the VIACARD system (Vehicle Identification Card).

The equipment carried out through advanced technology, is composed by a two way radio, an on board computer, and smart card, which guarantees the univocal identification of its user and his privacy, activating and administrating the service in question. The transceiving system works on 5.72 giga-hertz, a frequency assigned by the Ministry of Telecommunications, and it assures the transfer of all the data from ground to board and vice versa concerning the identification of the vehicle and the perfectioning of the transaction during the transit through the station. The actual skill for data transfer is established in 1 M/bit per second, considering that each message is composed by 40 characters, each lane of 20 metres length and a theoritical speed of 100 km/h allowed by the structure (4).

The toll payment constitutes, in fact, a vital source for all the concessionaires who can subsequently realize new projects. The reduction of time for payment is the main objective on which environmental ergonomics and automation focus their attention, as well as for all the automation plants become more and more sopfisticated as time went on. Nowadays automation and the spreading of informatics have developed a system of "self-service" doors, supported by electronic money for toll payment; something that has improved the general level of services offered, as well as the general run of the company. The constant search for a better quality and safer conditions of travel, made Autostrade look for something definitely new and advanced. Safety and reability on motorway both reduce the state of tension of the driver, and lead to a better organization of transports, thus constituting the very basis for industrial competition, and also leading to a more intelligent and essential use of the energetic resources on the earth. The project of toll payment without stopping is the result of all this accurate planning and subsequent informatic system, that is real need of transforming the toll payment into a simple operation between the user and the service itself. Leaving a-side the stale conceptions based on the ideal of the single product and the right of transit, the role of the concessionaire (like any management of public activities) is surely destined to change thanks to the development of contracting skills, which will lead to a specialization of all services. This way the customers will see the motorway as a nowaday system, like all those systems and structures offered by the city life. In modern times the car is one of the main instruments of man, considering all the time usually spent on it and it constitutes the repeatative motive among all the different moments of a same process: journey, access to town, parking. The TELEPASS project, designed and realized by the Autostrade, plays an important role in the outline concerning both the motorway as a system, and the stations itself; it is the connection link among different ways of transportation. The main innovation, as a concept, is the equipment, which is a terminal, placed on board of the vehicle, interacting with the ground based equipment, along the motorway. This idea is not a new one at all: airlines and shipping lines have always exploited navigation tools but in such cases the companies themselves dispose of trained pilots and organize their convoys.

On the motorway we have to deal with a user who has to be educated on how to use both services and the whole system.

In this quite limited phase of the project, where functions are only conceived for toll payment, the terminal interacts with the driver through a pilot light (red,yellow or green), a double tone bell, signalling the result of controls and admission to service.

3.4.1. Hardware of Telepass

A tiny two way radio, a transcoder, linked with a logic unit which elaborates and stores data, an on-board computer, must be installed on the windshield or on the dashboard of the vehicle, in order to recive the electromagnetic waves emitted by the two way radios on the ground. The operating frequency of the equipments for radio-connection has been chosen among a wide range, in order to insure a good selectivity,with radioelectric coverage areas whose dimension is like those of the vehicles, and good protection from any disturbance or interference. The value (5.72 Gigahertz) has been suggested by the national component organ, being in arrear with the European standards. To obtain this terminal it is necessary to subscribe a contract, for the deferred payment through direct debit on current deposit account. A personal card and an identification code are given to every single subscriber. It is possible to activate on-board terminal only through this personal "smart card" .

At the entrance of the motorway, the first radio-control posting interrogates the vehicle, informing on the availability of the system and activating the on-board equipment, usually in "idle" listening, and proceeding to the execution of all the possible controls for the internal functioning. The positive result of this autodiagnosis informs the driver, through the lighting of the green pilot light and through a short warning sound, about the presence of a door reserved to Telepass, suggesting him to follow the signals on ground. Following the special lane of chanelling, the vehicle can leave the station without stopping to get the ticket. The second radio control posting identifies the driver, interrogates the equipment, consults the block list and covalidates the admission to service classifies the vehicle and concludes the transaction by sending a message to the electronic center. This message is subsequently stored on the on-board computer too, in a cyclic memory, for a first control lead by the user himself. The operations are the same at the exit, following the same order; but besides the personnel identification code the on-board terminal transmits both the station and the class code, previously registered at the entrance. This way it is possible to calculate the pay toll and verify the correspondence of the vehicle. Toll payment without stopping, at a limited speed of 30 km/h for reasons of safety and traffic, which will be sufficient to dispose of the traffic capacity of inflow, allowed by forks. This limit does not depend on technology, and the tests done can ensure results even for higher speeds. Open doors both at the entrance and at exit of the motorway get a quicker transit, but always under control. A system of telecameras constantly observe the flowing of vehicle, registering any infraction. If an unidentified vehicle crossed the gates, the system immediately takes a photo, identifying the number of plate and the time of the passage; the photo is then sent to the Electronic Centre which, being connected to the Public Motoring Register, is able to proceed to a further identification of the vehicle. The expired credit is recovered, together with the collecting charges. Usually the single transactions, collected and ordered according to every code account, are periodically transmitted to the several credit institutions, where the users have their address, for collection (4,5).

3.4.2. Toll Zone Organization for Telepass

The system is designed for use with various toll point configurations:

- exiting toll plazas,
- new toll plazas,
- isolated structures,
- "full lane" toll plazas in standart traffic sections.

and takes into account:

- user safety and comfort,
- traffic safety and free-flow conditions,
- the data and signalling means to be installed,
- the processing and checks to be performed,
- collection means in the event of irregular cases and fraud.

The proposed organization is suitable for both single and multiple lane configurations.

Toll zone entry at the route entry or exit is broken down into four logical phases:

- approach,
- presentation,

- presentation,
- transaction,
- validation.

In the approach phase, users are given the data required for travel weather conditions, traffic conditions, e.t.c. and are informed of their right to use electronic toll lanes: open lanes, efficient on board equipment users right. This phase in which information is supplied, is not required for system operation, but contributes to security of use and reduces processing involving irregular cases.

During the presentation phase, the following information is transferred from the on-board vehicle equipment (OVE) to the payment of control stations:

- user profile,
- user rights (e.g. balance),
- method of payment,
- trip data (entry, network used).

Between the presentation and transaction phases, the system checks data validity, service access conditions and vehicle classification.

The transaction phase enables access authorisation to be confirmed upon entering the network, and toll transactions to be performed and checked when leaving the network. This phase consists of checking the passage of vehicles though the "express" lane. During this phase, the system checks that these vehicles are indeed those correctly identified in the

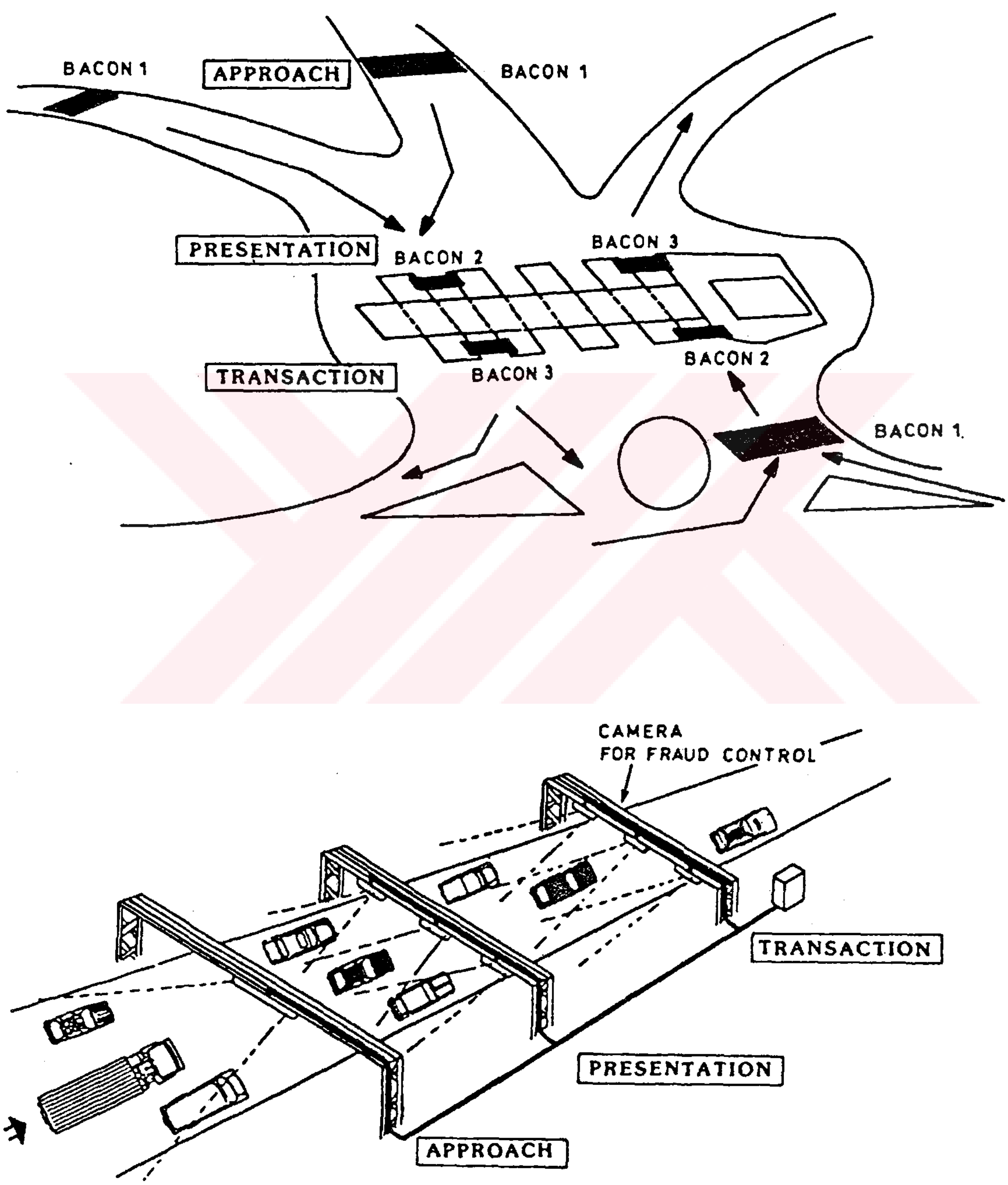


Figure 3.1. Toll Lane Organization (4)

presentation phase and are authorised to use the lane. In the event unidentified vehicles or correctly identified but unauthorised vehicles use the lane, the system actuates auxiliary alarm and vehicle identification devices, e.g. licence plate photos, visual and audible alarms. If the toll plaza geometry is suitable, the vehicle can be directed to specially equipped lanes. The financial data, e.g. new balance, is confirmed in the validation phase on the smart card. This optional phase makes transaction involving plastic money even more secure. The presentation and transaction phases should take place as for upstream from the plaza as possible to enable operators to safety redirect users in irregular situations. This is where the importance of the validation phase becomes apparent.

3.4.3. Exchange Security

The electronic toll system must be protected against fraud and errors in the use of plastic money. Checks must be performed at all levels of the system to ensure that no "financial misappropriation" occurs. The fund circulation diagram is given in Figure 3.2.

The operator then has the issuing company invoice or pay for the rights used on its network (post- or prepayment). It is therefore important to eliminate the various possibilities of falsification in this chain:

- rights issued by unauthorised issuers,
- data modification during exchangers,

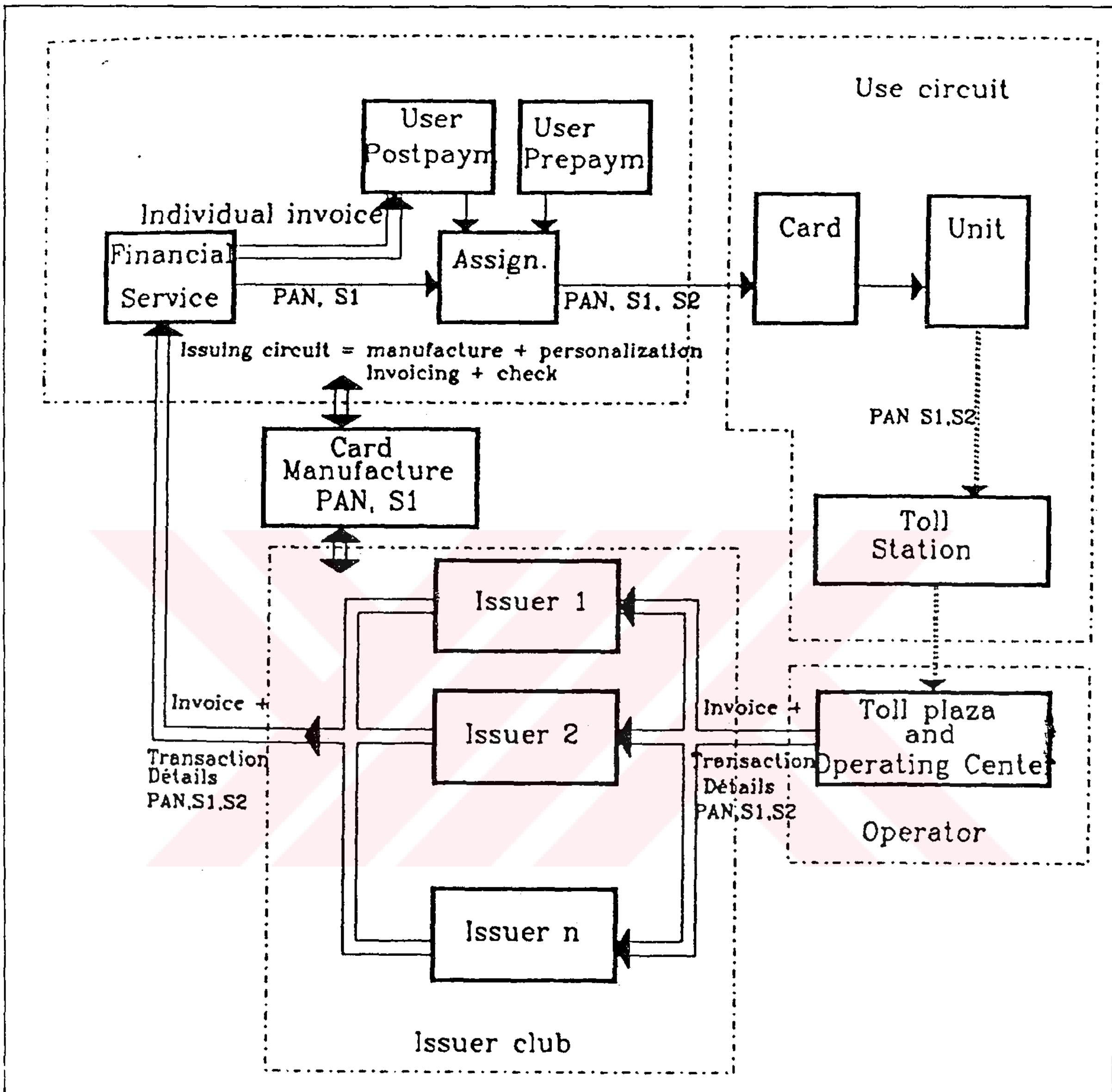


Figure 3.2. The Fund Circulation Diagram (4)

- unjustified claims for payment by network operators.

Authentication procedures must be perfected for recognition of equipment and networks authorised to carry out transactions. These procedures can be based on dual signature techniques. The issuing organization has one signature, which will be used throughout the chain to authenticate the transaction and guarantee payment with collection and earnings distribution organizations. A second signature will be assigned to the method of payment to authanticate the on-board equipment and the payment point.

3.4.4 Geometric Conditions

Clearance laws have to be respected to ensure that transmission beams are not masked when vehicles travel under the ground equipment gantry.

Vehicle Classification:

All road vehicles, including industrial and mass transit vehicles, must be able to access the electronic toll system. According to a simplified road vehicle classification system, Table 3.1. shows the dimensions to be taken into account.

Table 3.1. Vehicle Classification (6)

Vehicle type	Maximum overall dimensions (m)		
	Length	Width	Height
- Passenger cars	4.50	1.50	1.50
- light commercial vehicles	5.00	2.00	2.00
- Industrial and mass transit vehicles			
* tractors	6.00	2.50	4.00
* compact vehicles	12.00	2.50	4.00
* tractor + trailers	18.00	2.50	4.00
* trailers	12.00	2.50	4.00

This classification was used in numerical applications when considering a minimum on-board equipment installation height of 1 meter (on a light vehicle dashboard) and a maximum installation height of 4 meters (behind the rearview mirror in a bus) (6).

3.4.5. Service Area

The drawings on the following Figure 3.3. and 3.4. show a toll gantry (height, h_{gant}) equipped with an aperture antenna directed at angle θ in relation to the vertical. The on-board equipment height is h_{bad}. The on-board equipment radiation pattern is assumed to be much wider (less directional) than that of the fixed equipment, and can therefore be discounted.

The distance from which ground-vehicle communication begins is L_{acq}. The distance at which communication is lost is L_{loss}(6).

The resulting equations are:

$$L_{acq} = (h_{gant} - h_{bad}) \times tg\ (\theta + \alpha) \quad \ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

$$L_{loss} = (h_{gant} - h_{bad}) \times tg\ (\theta - \alpha) \quad \ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

The length of the communications zone is:

$$L_{acq} - L_{loss} = (h_{gant} - h_{bad}) \times (tg\ (\theta + \alpha) - tg\ (\theta - \alpha)$$

where ,

h_{gant} = 7 meters

h_{bad} = 1, 1.5, 3.5 and 4 meters

θ = 0, 7, 15, 30, 45, 60 degrees

α = + 5 degrees

The following results are given Table 3.2.

The Table shows that the working range of the link increases very slowly for angles of inclination θ varying

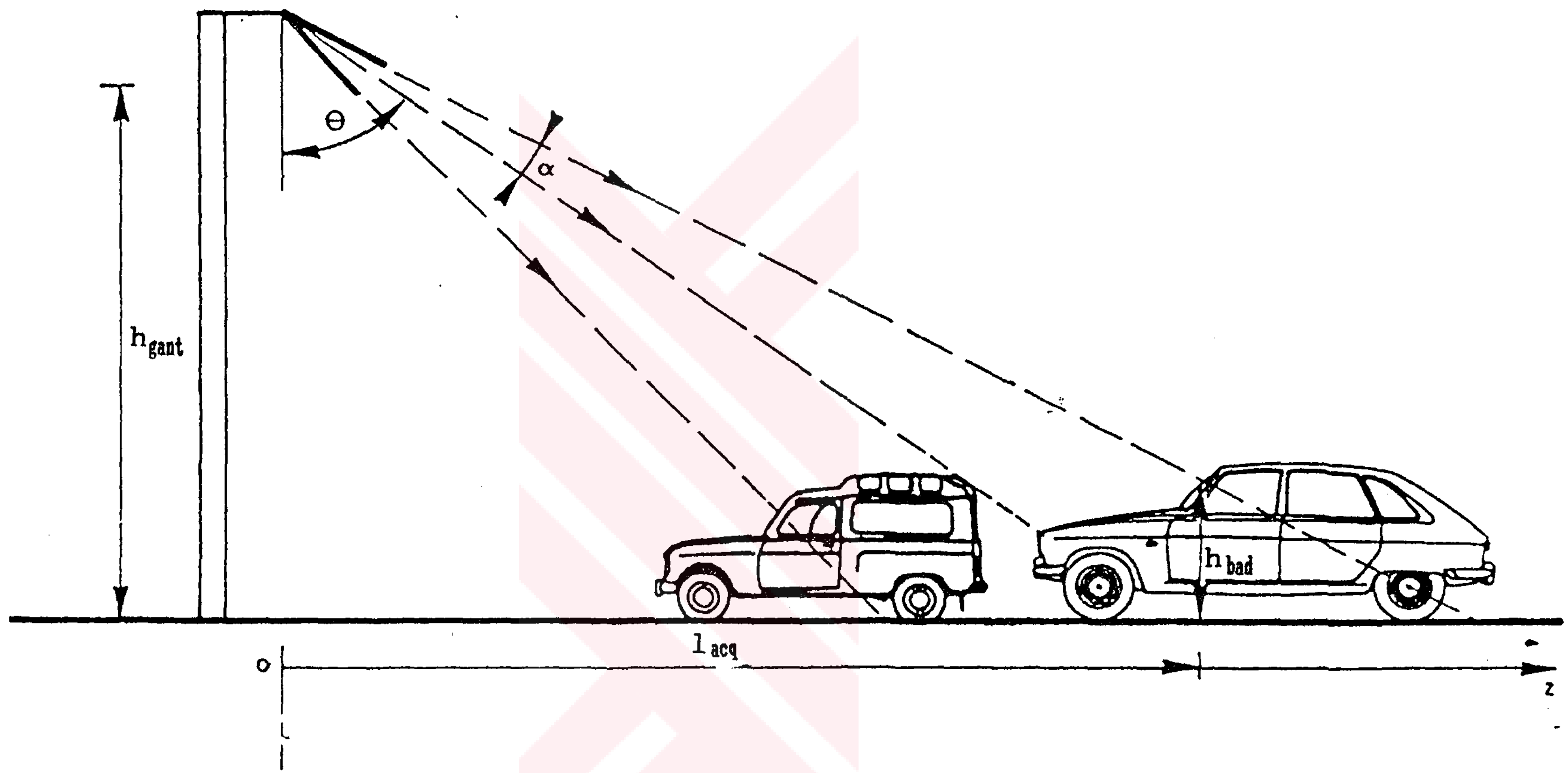


Figure 3.2. A Toll Gantry (height h_{gant}) Equipped with an Aperture Antenna Directed at θ in Relation to the Vertical (6)

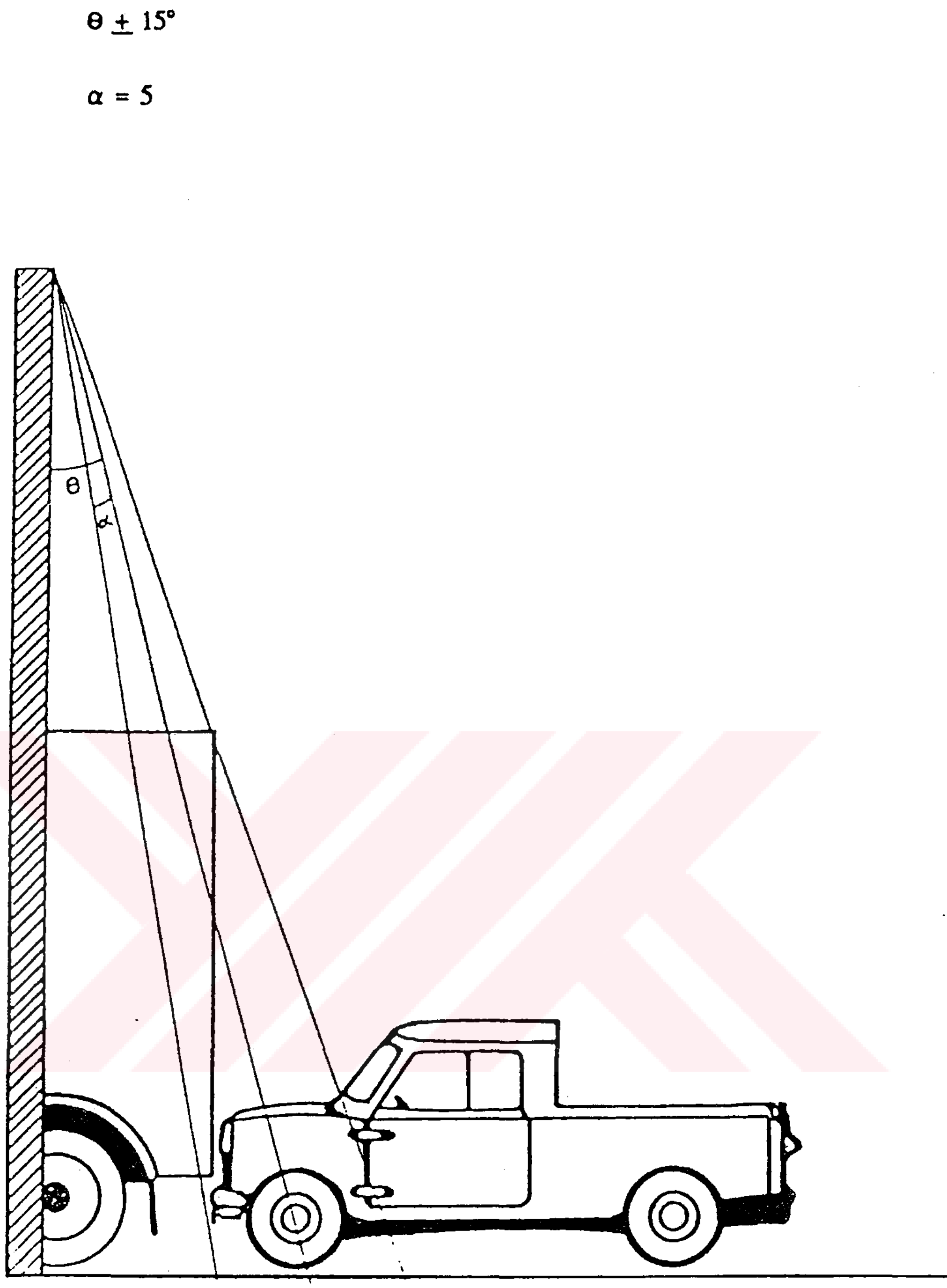


Figure 3.3. A Toll Gantry (height h_{gant}) Equipped with an Aperture Antenna Directed at θ in Relation to the Vertical (6)

from 0 to 30. The working range varies by a much greater ratio when the badge height is varied within the limits set by vehicle classification. The higher the vehicle, the shorter the communications zone and communication duration.

3.4.5.1 Distance Between Vehicles

The beam will be partially masked when the on-board equipment is located in the fixed transmitter service area (1) and the rear and of the previous vehicle is at a distance Oz such that, depending on its height, the radio beam is partially masked (2).

$$L_{acq} = (h_{gant} - h_{bad}) \times tg\ (\theta + \alpha) \quad \text{.................(3.1)}$$

$$L_{loss} = (h_{gant} - h_{HV}) \times tg\ (\theta - \alpha) \quad \text{.................(3.3)}$$

Where h_{HV} is the maximum height of the rear end of the previous vehicle.

The minimum distance (d_{min}) between vehicles is:

$$d_{min} = (h_{gant} - h_{bad}) \times tg(\theta + \alpha) - (h_{gant} - h_{HV}) \times tg(\theta - \alpha) \quad \text{..(3.4)}$$

Numerical applications were performed in order to confirm this second approach, where:

h_{HV} = 4 meters

h_{gant} = 7 meters

h_{bad} = 1, 1.5, 3.5 and 4 meters

θ = 0, 7, 15, 30, 45, 60 degrees

α = ± 5

The following results are given Table 3.3.

Table 3.2. The length of the communication zone

θ° \ h_{bad} (Meter)	1	1.5	3.5	4
0	1.04	0.96	0.61	0.52
7	1.06	0.98	0.62	0.53
15	1.12	1.03	0.65	0.56
30	1.40	1.29	0.82	0.70
45	2.11	1.94	1.23	1.05
60	4.23	3.94	2.51	2.15

Table 3.3. The minimum distance (d_{min}) between vehicles

θ° \ h_{bad} (Meter)	1	1.5	3.5	4
7	0.81	0.71	0.28	0.18
15	1.27	1.09	0.37	0.19
30	2.33	1.98	0.58	0.23
45	3.93	3.33	0.95	0.35
60	7.15	6.08	1.79	0.71

The conclusion drawn from results is that the risk of message collision from succeeding vehicles is slight for low angles of incidence θ. The risk of masking is higher when a light vehicle follows a heavy vehicle. Thus, angles of incidence exceeding 30 seem impracticable since past experiments have shown that it is difficult to set a mandatory minimum distance between vehicles. Since the service area changes only slightly for a fixed directional antenna and 0 angles of up to 30, the most logical solution is to work with quasivertical fixed beams (0 / 30) (6).

3.5. Cost of Equipment and Toll Collection

3.5.1. Cost of The Equipment

The installation of a toll system on a motorway increases the cost of building the motorway, since installation and management of toll station calls for building special equipment either at the level of the infrastructure. For points covering the complete carriageway, the platform width of the motorway has to be widened, calling for the purchase of additional land. It has been estimated that an additional 20000 m^2 of land are needed to set up a toll crossing the full carriageway on a double four-lane motorway . The toll station's annexes and equipment, a surveillance room and if necessary access road reserved for the service personnel connecting it to the outside also have to be built. For a toll combined entrance/ exit, a traffic exchanger is also needed, since the incoming and outgoing traffic has to be brought to a single toll station . Hence this calls for a motorway overpass exclusive to the toll. The toll station and surveillance room have also to be fitted out and the lane built connecting the toll to the nearest road. A toll station can handle a maximum of 500 vehicles per hour for the simplest payment procedures. In the case of a full carriageway barrier, one should provide at least three toll stations per traffic lane on the motorway, enabling the maximum throughput at the toll to be reached, namely about 1500 vehicles per hour, which is appreciably equivalent to the optimum capacity of a motorway lane (1600 to 1650 vehicles per hour). In the case of an urban motorway, with peaks approaching 2000 vehicles per hour, four toll stations per lane need to be erected.

For exit stations, the followings should be planned:

a) one exit up to 1500/1700 outgoing vehicles per day,

b) two exits up to 3000/3500 outgoing vehicles per day,

c) more than two exits beyond this figure.(1)

This extra cost results from the need to build the toll stations and the greater complication of the traffic exchangers.

3.5.2. Cost of Collection

Collecting tolls involves certain annual costs as shown below;

a) depreciation of the toll equipment,

b) direct personnel cost,

c) supplies, and

d) maintenance.

3.5.2.1. Collection Cost Levels

Various studies performed on the maintenance cost of European toll companies show that cost of toll collection per vehicle/kilometer is about 0.3 to 1 US cents (1). The unit costs fall off rapidly as the traffic increases, and then level off. These costs in fact comprise a considerable fixed amount corresponding to salaries of the personnel and the cost of depreciating the equipment; when traffic is low, the collection costs predominate; on the other hand, when traffic is high, the maximum use is the made of the possibilities of the installations, reducing the unit cost of collection. The number of toll booths depends on the traffic. This explains the asymtotic law of collection costs. One can also evaluate the cost of the toll per transaction. With a closed system, a transaction consists of taking the card (mostly from an automatic dispenser) and paying the itinerary , which is also generally made manually. Such a transaction costs from 30 to 50 US cents, for average toll income of about 3 US dollars.With the open system, the transaction consists of paying a fixed sum corresponding to the category of user. This payment may be either automatically or manually. For a toll that is about 50% automated, the cost of a transaction varies from 10 to 20 US cents, for an average income of 1 US dollar (1).

3.5.2.2. Productivity of Toll Operations

Cost analyses show that the personnel cost represents a considerable proportion of the cost of collecting tolls. For a closed toll system, they constitute the 90 to 95% of the cost. This is why costs are distincly lower with the open system and a high degree of automation.

It is hence interesting to obtain good productivity of toll operations by making best possible use of the personnel and to reduce operating costs as much as possible, rating costs as much as possible. The average duration of a toll operation is 26.5 seconds per passenger car and 34 seconds for a truck. On these bases, the communication between user and collector (corresponding to the time vehicle is halted) takes up 2/3 of the time to process a vehicle (where there is a queue). By reducing the user/collector factor, the level of activity should be improvable. One should however not forget that the behaviour of the user is also a dominating factor. A saving of 10% in the collector/user relation (payment) also results in a saving of 3% in the level of activity, through to the detriment of the quality of the "human" interface (1).

On such an assumption, which is ambitious, only 0.6% could be saved in the personnel cost of the system. The human factor is hence decisive. A major asset is good adaptation of the traffic service, which must take place in the context of the satisfactory reciprocal of the interest of the employer and the employee.

CHAPTER 4

METHODS FOR DETERMINATION OF TOLL RATES

4.1 General

This chapter covers the principles in determining the toll rates in particular from the standpoint of methods of estimating.

One may repeat that the three main principles are:

- Maximization of receipts,
- Tariffication for a balanced budget,
- Tariffication in accordance to the law of value.

4.2. Principle of Maximization of Receipts

The toll rate resulting in maximum receipts is easy to evaluate; it corresponds to the maximum receipts curve that can be constructed for a given section or for the motorway as a whole. Theoretical examples of curves are given in Figures 4.1 and 4.2, respectively.

However, it is necessary to indicate precisely on exactly which receipt the search for the maximum is to be made;

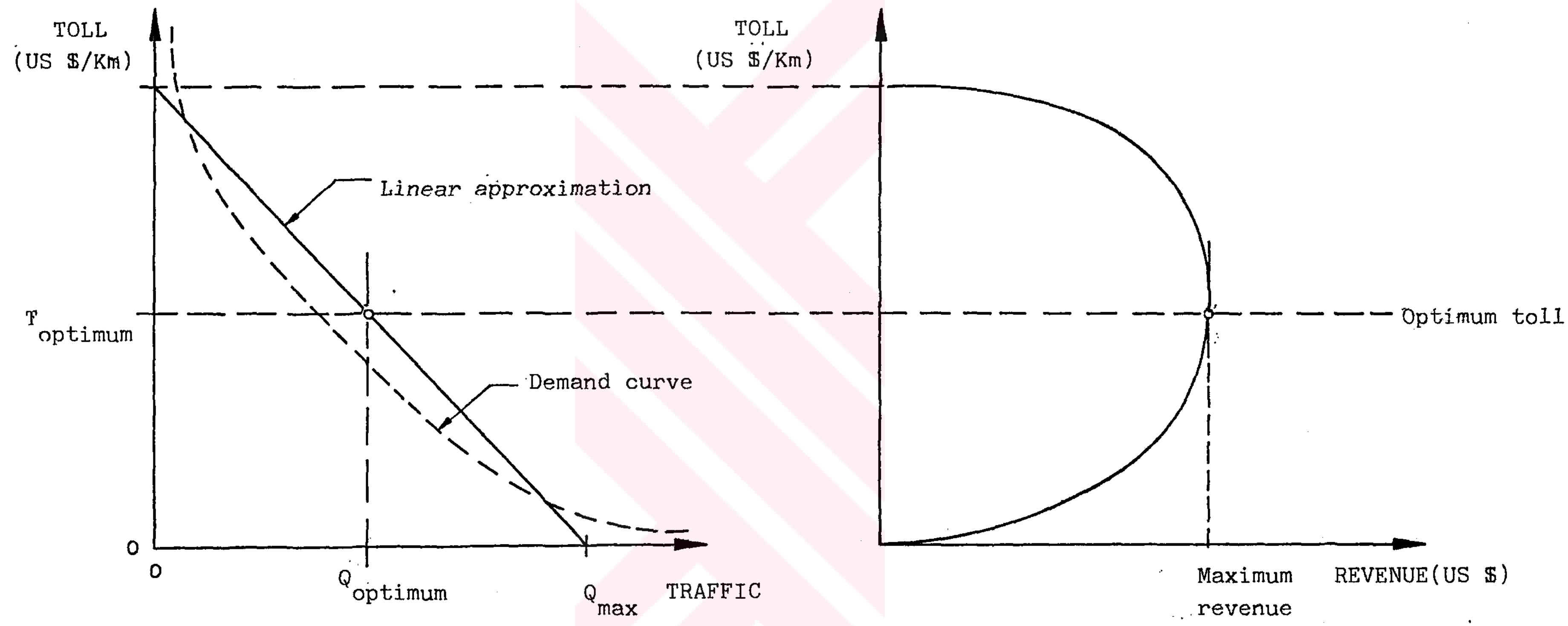


Figure 4.1. Relationship between Traffic Flow, Toll and Revenue (3)

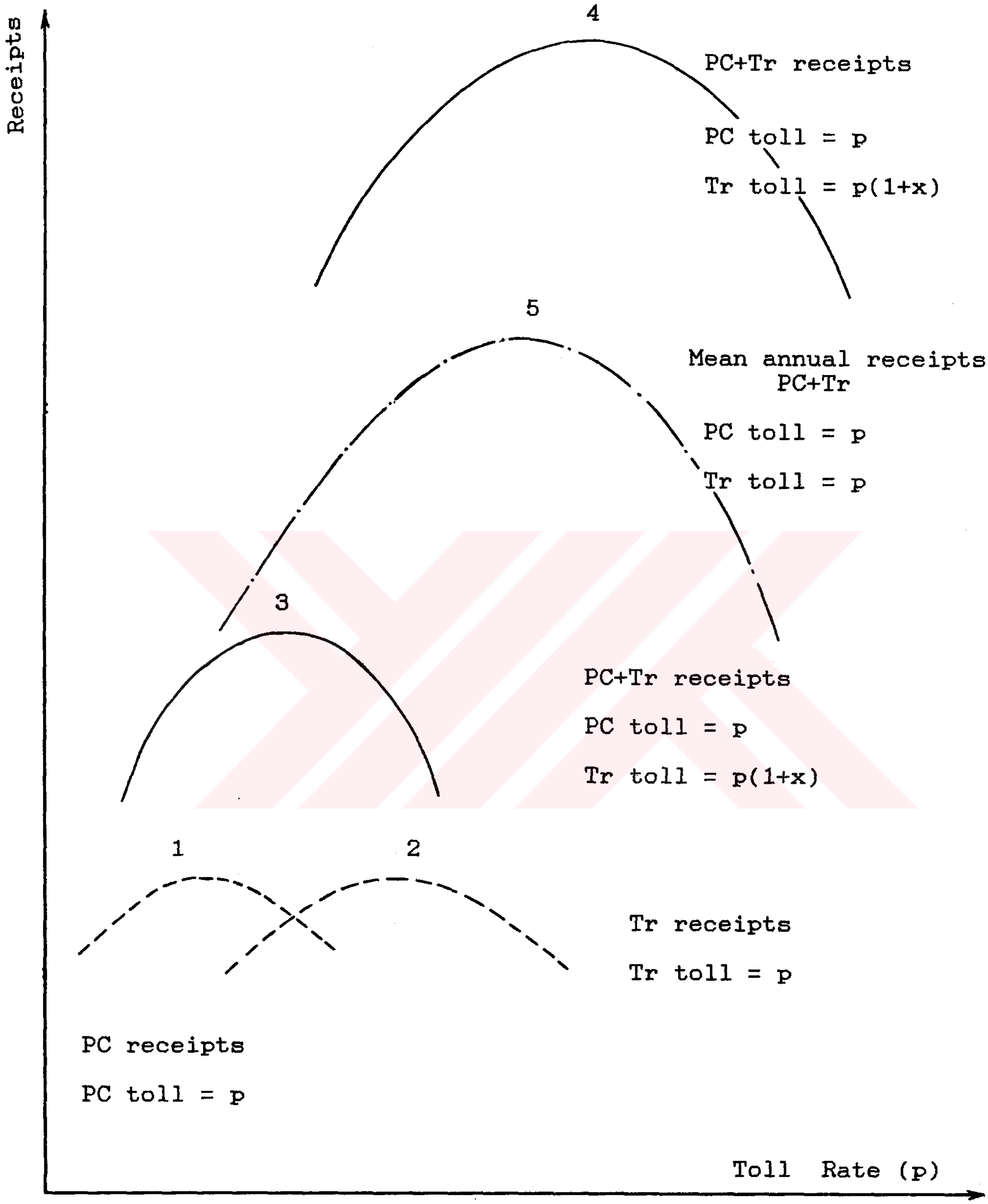


Figure 4.2. Receipts Curves (7)

several approaches are in fact possible, depending on the objectives and constraints set on the tariffication system. First of all, one must recall that the type of receipts to be considered depends on the economy of the country crossed: Maximization must concern the total receipts (collected from both the international and domestic traffic) in the case of countries with a market economy, and only the receipts in convertible currency in countries with a state-run economy.

Next, for the same type of receipt, an initial search for a maximum can be made separately for passenger cars and for trucks (curves 1 and 2): one will then obtain unit toll rates that differ considerably from one vehicle to another, the rate applied to trucks generally being distinctly higher than that applied to passenger cars. Another method is the improvement to seek for an optimum, assuming that the rates applied respectively to passenger cars and to trucks are linked by a constant factor (p (Tr) = (1+x) x p (PC)); one may in fact wish to apply tariffs that are not particularly different types of vehicles, even if the level of receipts attained is not the highest; it will then suffice to construct a total receipts curve (PC+TR) obtained by the sum and for each value of the toll p, from the PC receipts corresponding to toll and the Tr receipts correspondig to toll p x (1+x) (curve 3 and 4) This methods is commonly applied in France with a value of x of 0.5 (7).

Lastly, there is the possibility of either maximizing the receipts year by year or seeking out an optimum over a complete given period, assuming a toll rate that is invariable with time in constant currency; under the first assumption, the optimum rates could "drift" with time, either upwards and downwards, depending on the evolution of the potential traffic structure: this solution is the most appropriate to a strict financing plan, which calls for annual repayment of loans and specific operating charges. The second solution may be preferred should one wish not to apply increases to the annual tariffs that the users would not understand and in the case where the financial balance does not have to be ensured year by year but for the entire period; determination of the toll rate whould then be made on a curve resulting from cumulation of the annual receipts over the period considered (curve 5, deduced to an annual mean).

4.3. Tariffication for a Balanced Budget

The principle of tariffication for a balanced budget does not consist, as before, in establishing a price which depends on the state of the infrastructure supply and demand, but inscribing all the infrastructure costs (capital, operating, maintenance and management of the motorway)to the users. In market economy, once the motorway structure is built, the collective economic optimum will be reached if its uses are charged at marginal cost. However, also, the infrastructures sector has raising mean return (this means that for a given service quality, if a capital investment of X must be made to pass a given vehicle flow, less than 2X will be needed to double this flow), marginal cost tariffication would lead an operating deficit, since the marginal cost is in this case below the mean cost. If this solution is satisfactory from the standpoint of the economic theory, it is not so from an institutional standpoint. The user invariably tend to call for construction of infrastructure, all the more readily, when the price they pay does not cover the expenses of the managing concern. Consequently, it can be understood that a manager interested only in problems of the profitability of his investment requires that the commercial receipts cover the total expenditures. Two tariffication principles for a balanced budget are studied as follows:

The first consists in elaborating the total amount expended and linking the truck toll to that of the passenger car toll (for example, a ratio of toll rates of 1.5). Knowing the curve of variation of commerical receipts with the toll rates when these are linked, it suffices to plot on the y-axis the total expenditures to determine the toll rate by projection on the x-axis. In reality, owing to the shape of the curves are shown in the Figure 4.2., there are two possible projections yielding the same commercial receipts. In this case, the lowest rate is always chosen, so as to benefit the greatest possible number of motorway users. This is the solution most favourable to economic development.

The second balanced budget tariffication principle is more complex, since it does not assume a predetermined ratio between the toll for passenger cars and for trucks. In an initial stage, it consists in making each user pay the price for using the infrastructure as would result from optimum allocation of resources without the constraint of a balanced budget, i.e. in the final analysis its marginal cost. In the second stage, it is a matter of finding an economic criterion for the attribution of the remaining charges which are fixed, amongst the various categories (7).

First, one must take stock of the expenses linked with using the motorway. In addition to the cost of building it, there are maintenance costs of the network, including car parks and motorway centres, operating expenses, police, safety and circulation expenses, personnel and running of service. One must point out that the construction expenses can be taken into account in two different ways: either in the form of annual budgetary expenditures, or in the form of depreciation of the capital and any resultant financial charges. It is the second form that will now be adopted, since it enables annual fluctuations in the levels of expenditure for building the motorway to be avoided.

In order to facilitate the attribution of the above expenditures between passenger cars and truck, European Economic Community (EEC) has adopted a classification into 5 headings of maintenance, operating and management expenditures. These 5 headings are as follows:

1) D0 Fixed expenditures: Independent of the traffic.

For instance, expenditures for lighting, maintenance of engineering structures, moving or pruning of side vegetation, maintenance of fencing, vertical signals and kerbs, together with general overheads.

2) D1 Expenditure to be broken down pro-rate the vehicle-kilometre. For example, the expenses involved in maintaining the motorway operable in winter, and maintenance of horizontal signs and safety barriers.

3) D2 Expenses to be broken down pro-rate the vehicle kilometre, weight of vehicle. For instance, expenses for road surfacings.

4) D3 Expenses to be broken down pro-rate axle-kilometre equivalent to a 13tons-axle. In this expense category D3, for example, lie the asphalt surfacing expenses laid on a reinforced supporting coarse, or, even renewal of the entire carriageway.

5) D4 Police expenses, broken down pro-rate the vehicle kilometre weighted by the following coefficients:

- Light vehicles,
- Utility vehicles with a total authorized payload of below 12 tons,
- Utility vehicles with a total authorized payload of over 12 tons.

This classification into five headings having been defined, an initial methodological difficulty consists in attributing the maintenance, operating and management expenditures amongst the various headings, from an analytical accounting system. Assuming that this breakdown has proved possible, all the expenditures of the manager of the infrastructure are hence classified into six categories D0,D1,D2,D3,D4 and capital cost. The marginal share or coefficient of marginality (ratio of marginal expenditures to total expenditures) varies very widely from one category to the next. In addition, the marginal cost per vehicle differs considerably from one category of expenditures to the next.

For the fixed expenditures, D0, the coefficient of marginality is clearly zero. For categories D1,D2,D3 and D4,it is respectively 50%, 60%, 75% and 60%. As for capital expenditures, again, the coefficient of marginality is naturally zero.

By multiplying the expenditure by the coefficient of marginality, the marginizable share for each expenditure category is obtained. To obtain the marginal cost, the marginal share of each category of expenditure is broken down between the vehicle categories in terms of their responsibility for this expenditure (i.e. the vehicle-kilometres for category D1, the vehicle-kilometres weighted by the weight of the vehicle for category D2 and equivalent axle-kilometres for D3).

It now remains to distribute the fixed share of total expenditures of the motorway, i.e. in maintenance expenses (D0+0.5D1+0.4D2+0.25D3+0.4D4) and construction costs (expenses for depreciating the capital and their related financial charges).

In its specifics, and for the case where a distinction is drawn between only two categories of vehicles: passenger cars and trucks, we arrive at the following attribution of the costs:

Let M_{PC} and M_{TR} be the marginal costs ascribed to passenger cars and trucks and F_{PC} and F_{TR} the fixed costs ascribed to the same respectively, Q_{PC} and Q_{TR} the traffic levels in the vehicle kilometers for the two categories and F the fixed expenditures to be attributed.

The quantities to be determined are F_{PC} and F_{TR} (7).

The elasticities considered are defined by the following formula :

for passenger cars: $$e_{PC} = \frac{\text{Log } Q_{PC}}{\text{Log } (M_{PC} + F_{PC})} \quad \text{....(4.1)}$$

for trucks : $$e_{TR} = \frac{\text{Log } Q_{TR}}{\text{Log } (M_{TR} + F_{TR})} \quad \text{.....(4.2)}$$

$$F_{PC} + F_{TR} = F$$

$$\frac{F_{PC}}{F_{TR}} = \frac{(M_{PC} + F_{PC})}{(M_{TR} + F_{TR})} \times \frac{e_{TR}}{e_{PC}} \quad \text{..........(4.3)}$$

The coefficients of elasticity e_{PC} and e_{TR} that can be assimilated to passenger traffic and goods traffic elasticities have to be estimated for each year, since they depend on the level of the price of the competitions (price of road competing against motorway and rail tariffs). This is why the toll is inversely proportional to the elasticity of the traffic category. Clearly, if a traffic was completely indifferent to the tariff, one could make it pay all the fixed expenditures without modifying the traffic levels (7).

4.4. Tariffication in Accordance with the Law of Value

In a socialist economy, the prices do not reflect the trade value of the products, i.e. are not determined by the interplay of supply and demand, but reflect the conditions of productions, i.e. the quantity of work socially necessary at a given time to produce the good desired. This price must therefore cover the expenditures for the work, past (intermediate consumption) and present (salaries), so as to ensure the reproduction of the working force, whilst also providing a certain profit so as to ensure the development of production. The price reform that the socialist countries underwent in the years following 1965 imparted a content to this profit. The theoretical formula valid for tariffication of use of the infrastructure in the Soviet Union. This formula is of the following form (7) :

$$P = S + V + Pv \times V + é \times K \times W \quad \text{...........(4.4)}$$

Where,

S : the infrastructure expenditures.

V : the salaries.

é : the nominal coefficient of efficiency of the capital (é = 8.4 %).

K : a coefficient of differentation of the efficiency of the productivity funds (K = 0.36 for road construction).

W : the productivite funds used in the production process of the good considered (construction cost).

Pv: the subjective coefficient of productivity of the work reflecting the qualification of the the labor input (0.25).

CHAPTER 5

TOLL FACILITIES

Total area for average toll plaza is about 3000 - 5000 m^2. Figure 5.1 shows the general lay-out (9). The area shall have space for future extension of toll booths. In case services culvert box is planned. It shall be directly connected with the entrance hall of the toll office. Once the toll collection method is chosen, the toll stations will have to be designed according to:

a) the number and dimensions of the toll station lanes;

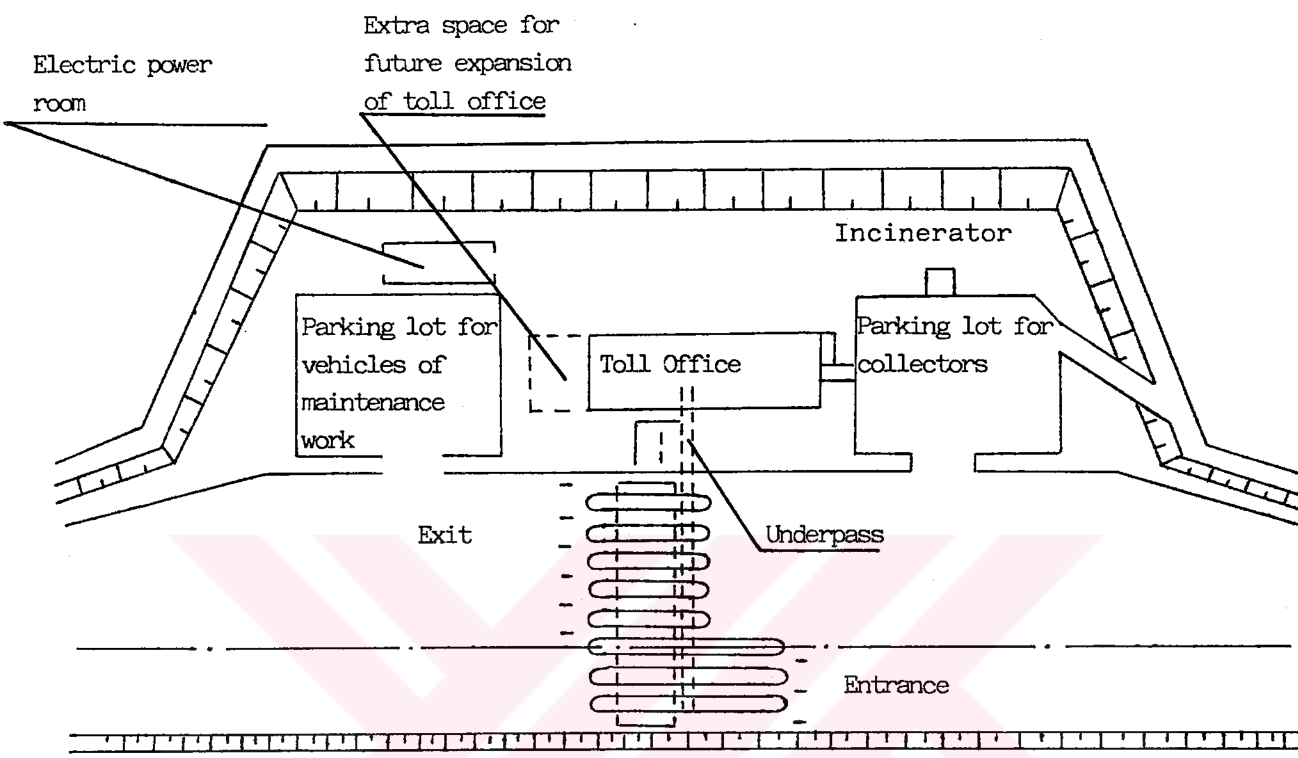
b) the dimensions of the toll station plaza;

c) the dimensions of the buildings and auxiliary structures;

d) the toll collection system.

5.1 Toll Station Lanes

The number of toll lanes per station shall be determined depending on the maximum numbers of queueing vehicles calculated on the basis of traffic forecasted. Specifically, the traffic figures to be used as the basis for the calculation should be the volumes at the 50th peak hour of a year between the 5th and 10th year of operation. The number



Location of a Toll Office

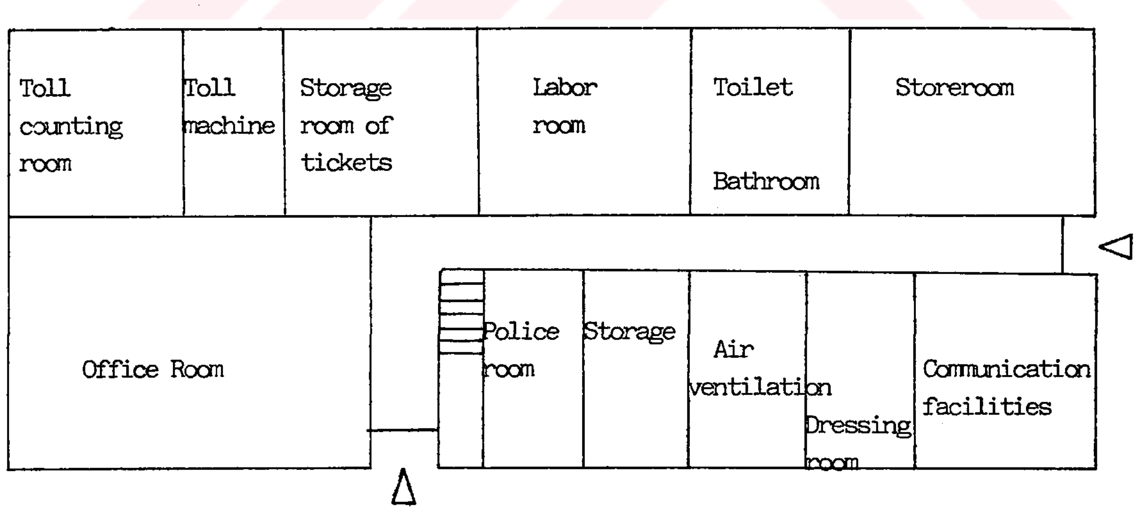


Figure 5.1. Layout of Toll Office (9)

of toll lanes should be sufficient to handle the above traffic volume within parallel queuening lanes not exceeding 500m in length, taking into account the average times needed for toll collection (exit traffic)and vehicle classification (entry traffic). In the case of stations with more than three toll lanes, it is advisable to provide a special lane for freight traffic. At stations handling large volumes of traffic it is desirable to provide the possibility of using a certain number of the central toll lanes in either direction, so as to cope with cyclical traffic fluctuations and reduce construction costs. All stations should be provided with at least one lane of larger size, reserved for exceptional size vehicles and snow removal equipment. The toll lanes should be about 3.00 to 3.50 m. in width. Where such lanes are planned, automatic vehicle counting devices (tripboards, magnetic loops, etc.) should be installed in the lanes. The lanes should further be separated from one another by islands about 2.00 m in width and about 30.00 m long (10).

These islands shall contain:

- booths for the toll collection staff;

- safety fences for the protection of the booths and the staff;

- lifting barriers to close the lanes;

- equipment connected with the toll collection system (automatic ticket dispenser, toll display panel, devices for automatic vehicle classification, etc.)

The toll station shall be protected by an overhang roof with a height clearance of at least 5.00 m. Traffic lights shall be installed on the roof over each toll lane to indicate whether the lane is in operation. The toll booths shall be designed so as to provide the toll collection staff with suitable working conditions. In particular, these booths should be air-conditioned, pressurized, soundproof and equipped with a radiotelephone connected to the Coordination Center. It is advisable to locate the toll stations in well-ventilated places so as to avoide concentration of smoke and exhaust fumes. A passage of at least 2.00 x 2.00 m shall be provided beneath the toll station for the laying of supply cables, heating pipes, etc. At large size stations it is advisable to construct the passage of sufficient size to allow the toll collectors to walk to and from their booths in safety. Figures 5.2 and 5.3 show a schematic drawing of the toll lanes.

5.2. Toll Plaza

The toll plaza of the toll station consists of a widening of the motorway carriageway (open system) or of the interchange slip roads (closed system) necessary to contain the waiting traffic. The width of the toll plaza shall be at least sufficient to contain all the rows of queued vehicles. The length of the toll plaza shall be at least equal to that of the queues forecast. Furthermore, an approach section shall be provided of variable width and of length sufficient

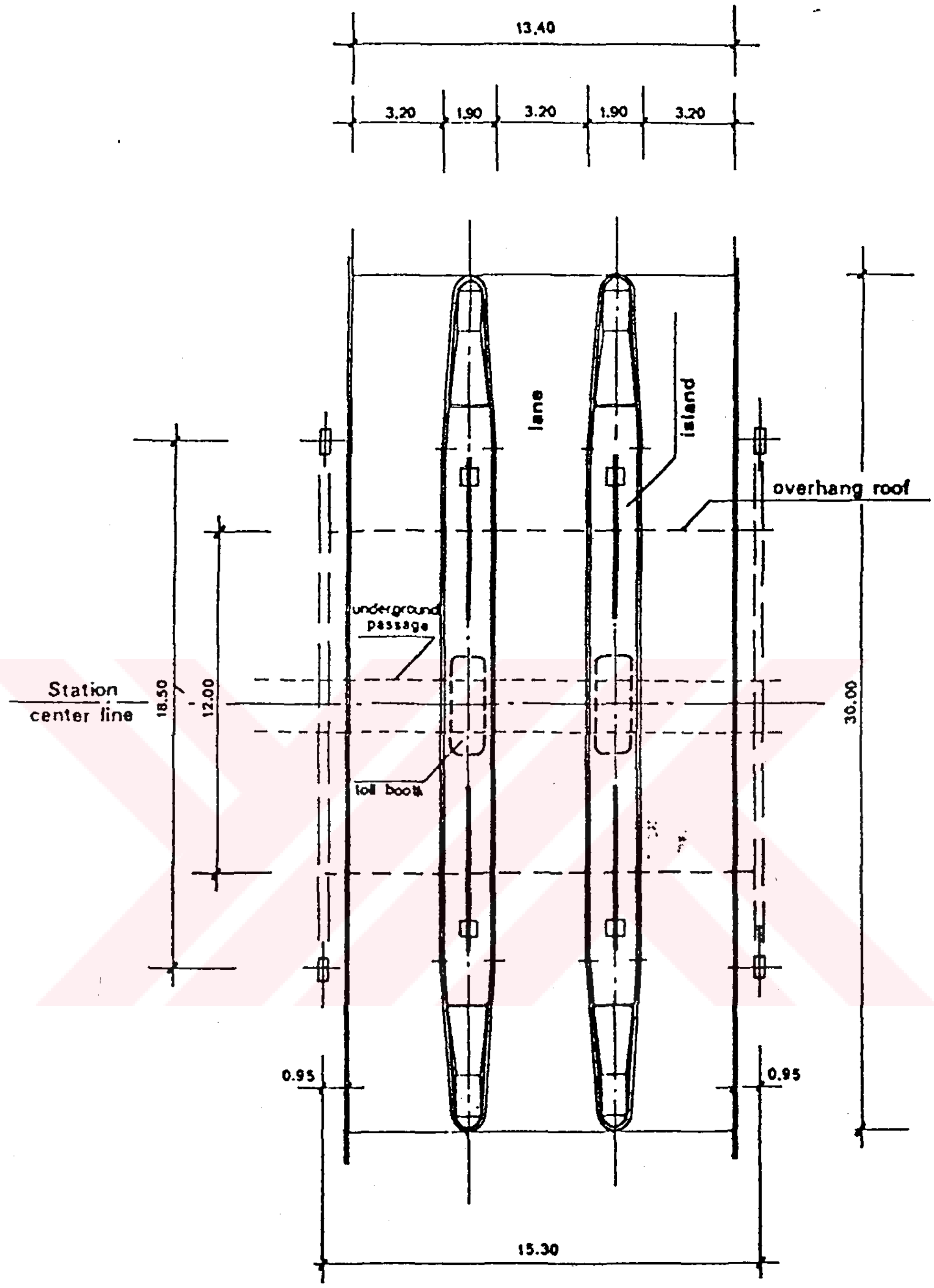


Figure 5.2. Cross Section and Elevation of Toll Lane (11)

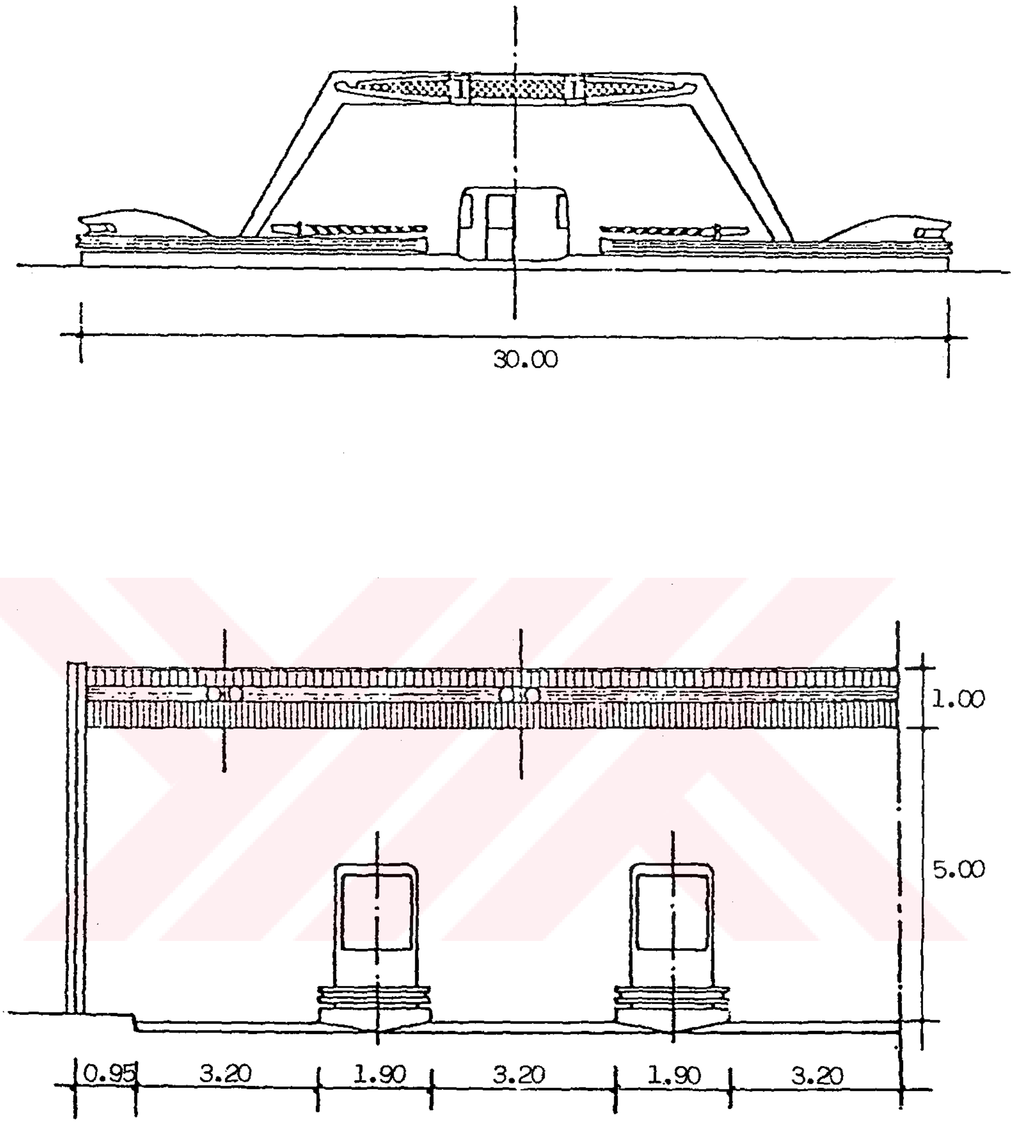


Figure 5.3. Layout of Toll Lane on TEM (11)

to permit safe channeling of the traffic and full use of all the toll lanes. For reasons of safety it is inadvisable to locate the toll station at the end of a long downhill section. Particular care will have to be taken in designing the crossfalls and the rainwater disposal system, so as to avoid dangerous accumulations of water on the pavement.

Toll station buildings;

a) dressing room for toll station personnel, complete with showers and restrooms;

b) office of station chief, which should contain a radiotelephone connected with the offices of the competent authorities of the particular country and a telephone connected with the public telephone network;

c) storeroom for supplies of toll forms (tickets, other printed materials, etc.);

d) strong room containing the safe for toll receipts storage; in station with high traffic volumes this room should be constructed with especially thick reinforced concrete walls;

e) room containing equipment to receive and record the classification and toll collection data obtained from the personnel and the automatic machines.

f) room to house the heating and air conditioning plat;

g) room to house the electric lighting distribution board and generator.(11)

CHAPTER 6

CASE STUDY; DETERMINATION OF TOLL RATE FOR GEBZE-IZMIT MOTORWAY

In this part of the study it is calculated that Gebze-Izmit Motorway toll rate which is necessary for self supporting in 20 years financial term.

The first application of tollroad system in Turkey is Gebze-İzmit Motorway and it has been formed in two steps. The first part of the motorway, which is 20 km, between Izmit-Kirazlıyayla was opened to service in Apr.8,1984; and the whole section of motorway which is 40 km in length was opened to traffic in Dec.28,1984 (14). It has been showed in the map which is Figure 6.1 (13).

6.1. Availability and Use of Cost and Data

6.1.1. Traffic

For these application the vehicle has been seperated into 5 groups as they are shown in Table 6.1 and different tolls have been taken for each group. Table 6.2, Figures 6.2 and 6.3 show the traffic distribution of Gebze-İzmit Motorway and existing E-5 according to the vehicle categories between Apr.8,1984 and 1989.

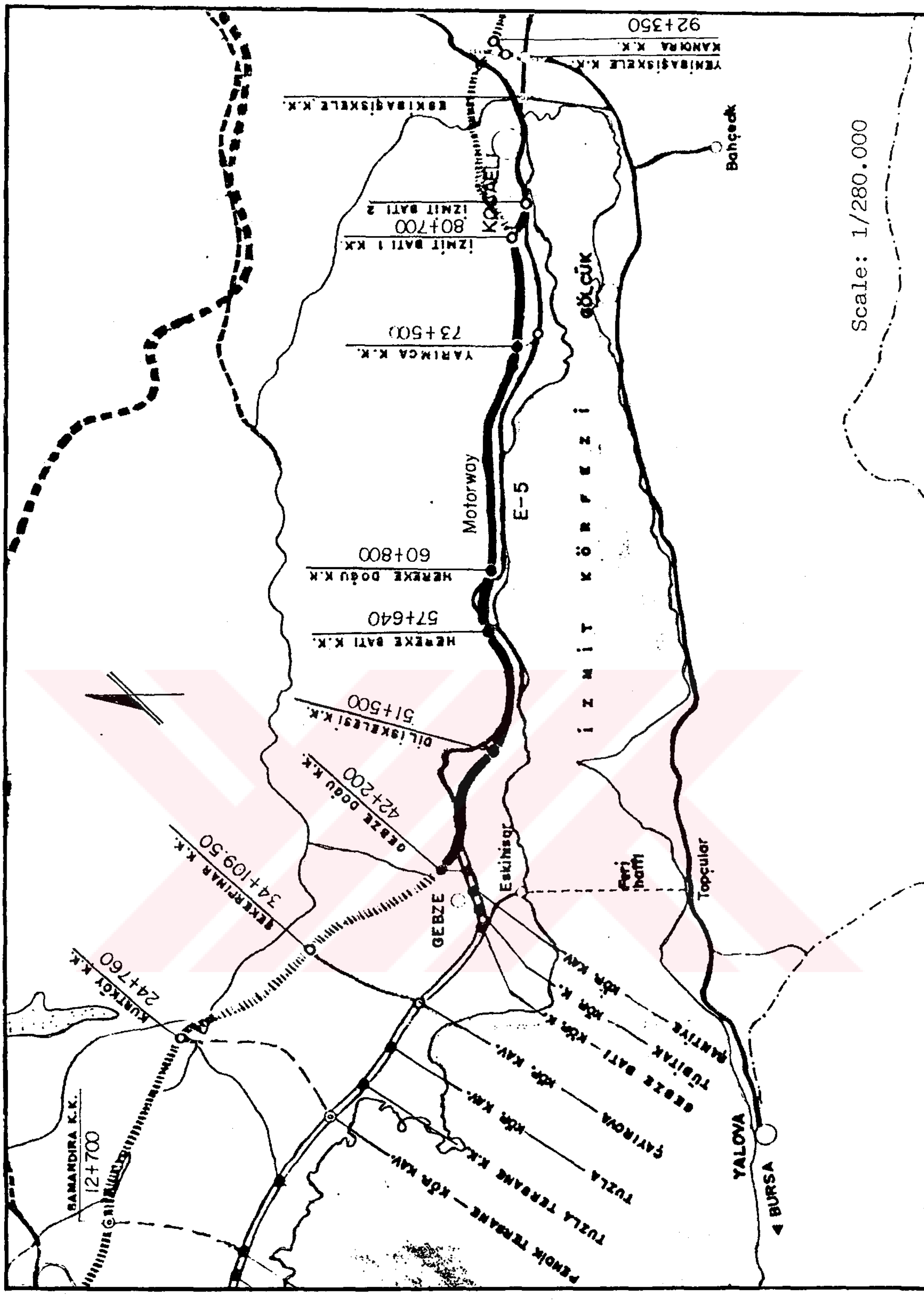


Figure 6.1. The Map of Gebze-İzmit Motorway (13)

Table 6.1. Vehicle Classifications for Gebze-Izmit Motorway (14)

Class	Vehicle Type	Axle
1	a- Motorcycle b- Pick-up, Light good vehicle c- Minibus	2
2	a- Truck b- Bus c- Tow Truck	2
3	a- Truck b- Semi trailer	3
4	a- 2 Axle trailer to carry 2 or more than 2 semi trailer b- Trains c- 3 Axle tow truck to carry vehicle	4 - 5
5	Trailer	6 - 8

Table 6.2. The Traffic Distribution between Gebze-Izmit Motorway and E-5 according to the Vehicle Categories between 1984 and 1989 (13,14)

Year	Vehicle type	Motorway		E-5	
		A.A.D.T	Usage Rate %	A.A.D.T	Usage Rate %
1984*	Passenger car	3698	44	4683	56
	Bus	715	19	3122	81
	Truck	913	7	11708	93
		5236	27	19513	73
1985	Passenger car	5543	93	423	7
	Bus	1797	49	1898	51
	Truck	1821	15	10230	85
		9161	42	12551	58
1986	Passenger car	6661	92	579	8
	Bus	2256	78	638	22
	Truck	1284	10	11269	90
		10201	45	12486	55
1987	Passenger car	8247	73	3046	27
	Bus	2491	80	605	20
	Truck	1614	15	9508	85
		12352	57	9470	43
1988	Passenger car	9270	76	2950	24
	Bus	2774	83	582	17
	Truck	2255	18	9315	82
		14299	54	11967	46
1989	Passenger car	9165	-	-	-
	Bus	2779	-	-	-
	Truck	2192	-	-	-
		14136	-	-	-

* Motorway opened in Apr. 8, 1984.

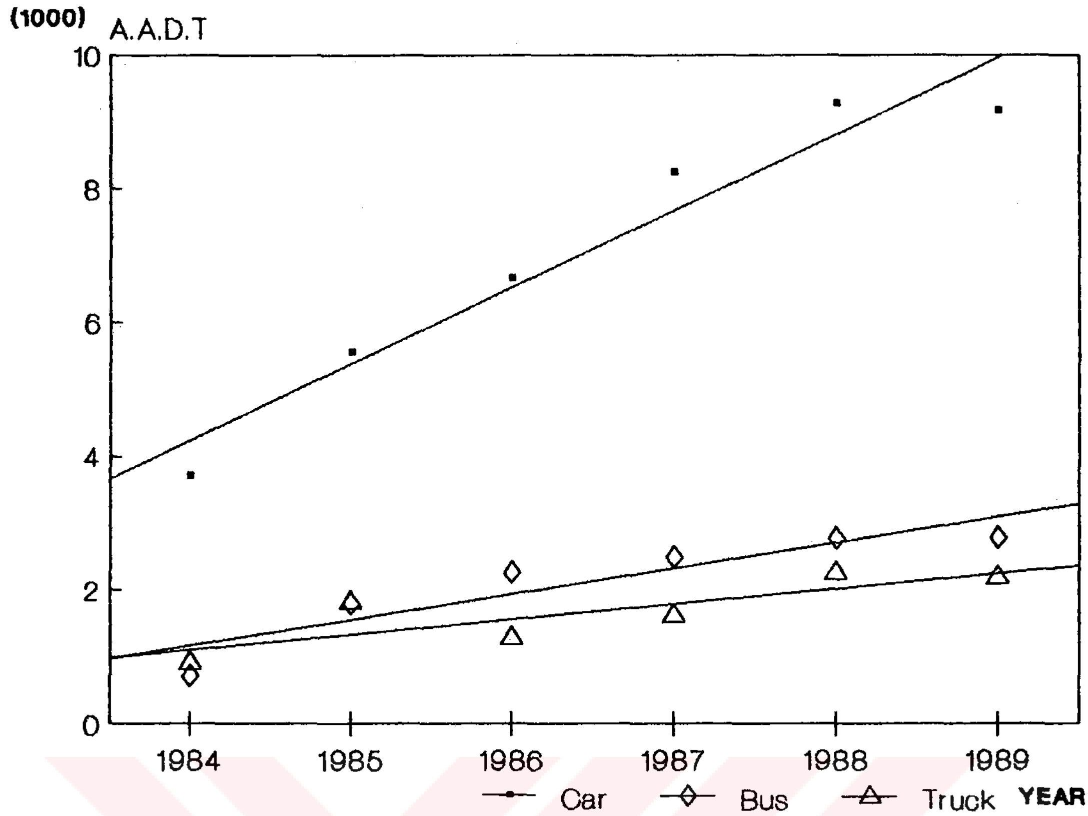


Figure 6.2. The Traffic of Gebze-Izmit Motorway according to the Vehicle Categories between Apr.8, 1984 and 1989 (13)

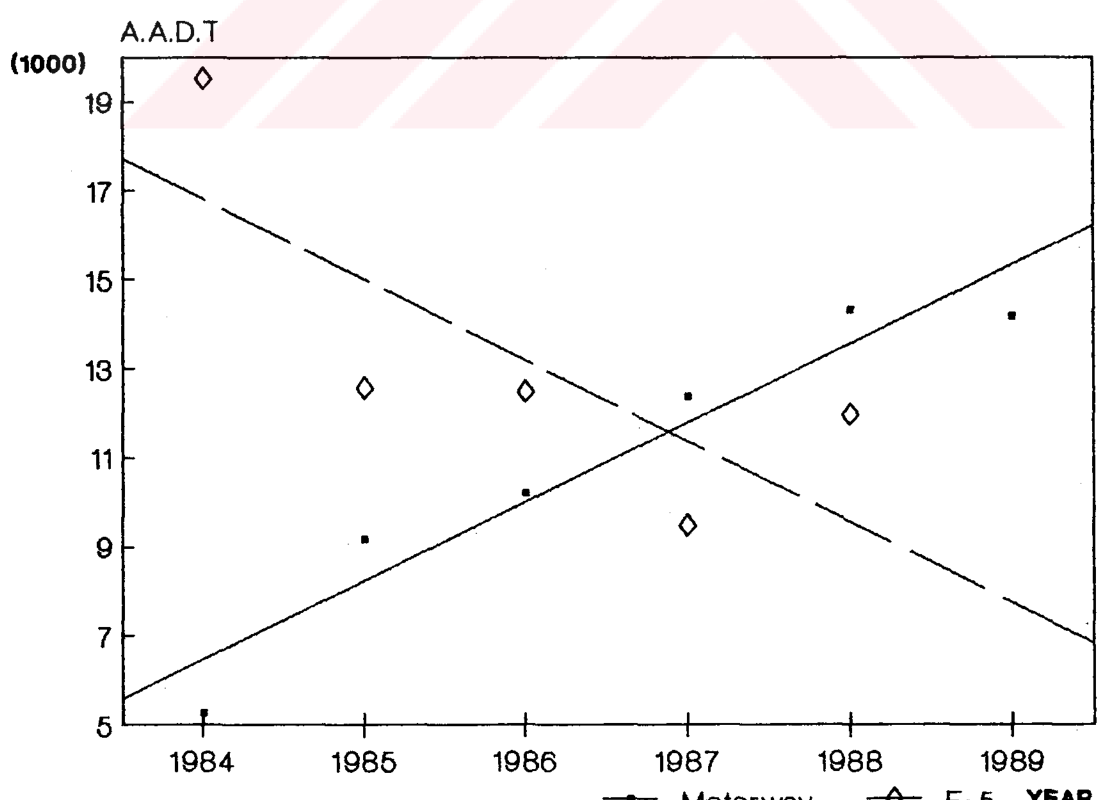


Figure 6.3. The Traffic Distribution between Gebze-Izmit Motorway and E-5 (12,13)

According to the registration, maximum traffic volume is between July and August (18621 vehicle/day). In the same Table 6.2 . It is shown that the 65 percent of the total traffic is passenger cars and 35 percent is heavy truck traffic. When it is taken into consideration, the vehicles like trailers have to use the motorway and it shows that the 35 percentage is a rather low traffic.

Standard CE (Car Equivalent) equivalents adopted were car=1; bus=2; truck=3 (level tangent conditions). The assigned AADT volume along the Gebze-Izmit 2-lane highway segment was 14600 CE in 1985 (3). At this point the AADT for the years between 1985 and 2004 should be estimated. To this end it was assumed that traffic will grow at a linear rate as in the intermediate years shown in Table 6.3 and Figure 6.4 .

6.1.2. Construction Cost

It was not possible to obtain actual construction cost using the documents of Gebze-Izmit Motorway contracts. The total estimated cost is US $ 96 408 318 or an average of US $ 2 410 208 per km.(May 1984 prices).

6.1.3. Maintenance and Operating Costs

Maintenance and operating costs form a part of the economic evaluation of highway cost and benefits. Adequate maintenance is essential if a highway facility is to be maintained to provide the level of service for which it was designed. The maintenance effort on asphalt surfaced roads

Table 6.3. Growth in Annual Average Daily Traffic at Gebze-Izmit Motorway

Year	Car Equivalent (CE)
1985	14600
1986	15025
1987	18071
1988	21583
1989	21299
1990	27161
1991	30692
1992	34682
1993	39190
1994	44285
1995	50042
1996	56547
1997	63899
1998	72206
1999	81593
2000	92200
2001	104186
2002	117730
2003	133035
2004	150329

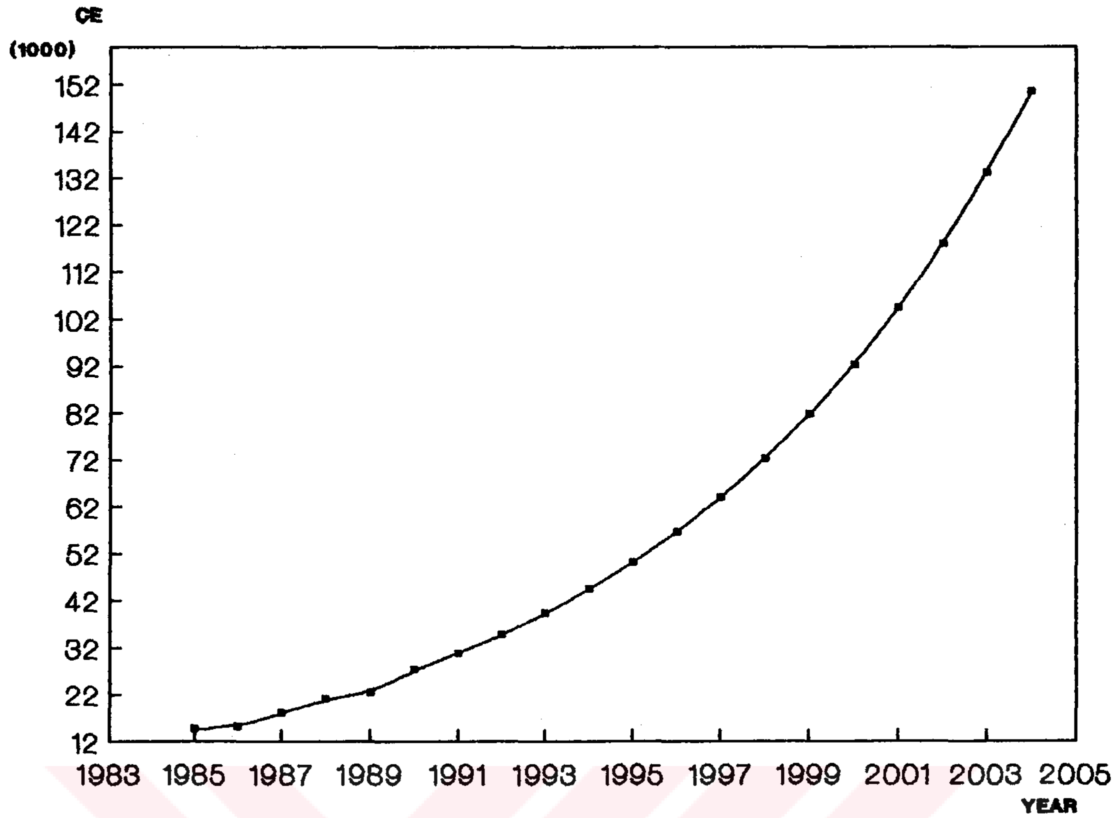


Figure 6.4. Growth in Annual Average Daily Traffic (CE)

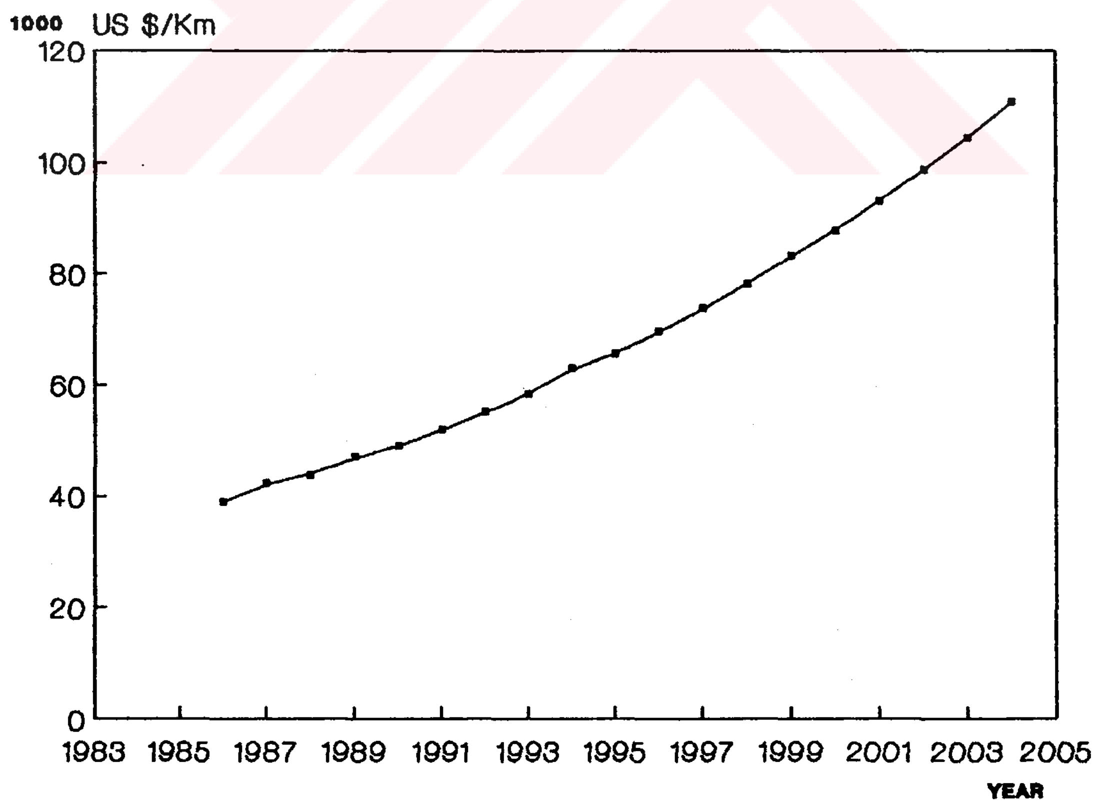


Figure 6.5 Graph of Maintenance and Operating Average Cost in accordance with year (US $/Km)

should normally increase as traffic increases. Appropriate maintenance cost streams over a 20-year period for motorway is shown in Table 6.4 and Figure 6.5. These costs presume execution of routine and periodic maintenance activities on a regular basis, by full-time maintenance teams. Maintenance cost streams, tabulated in Table 6.4, are intended to reflect the average impact of future traffic over a 20 year life of the facility. Regular annual routine maintenance is assumed with appreciable patching, resurfacing and repair works, etc in the 5th, 10th and 15th years.

6.2. Financial Plan

We must at this point set up the financial plan in order to evaluate the cost flow to be borne annually. As regards the construction cost they are shown below. They have to be amortized in 20 years at the rate of 15% according to fixed quotas of recovery rate, the annual cost flow will amount to 15 402 335 US $ as shows in detail in Table 6.5.

As regards the operating cost of the facility, we must consider the annual financial cost of maintenance and the toll-collecting cost. Adding the sum of these two components to the annual quota previously calculated, one may obtain the total financial cost given in Table 6.6.

6.2.1. Determination of Toll Rate

We may reach the conclusion that the Gebze-Izmit Motorway operated as a Toll Road can be self supporting by

Table 6.4. Tabulation of Maintenance and Operating Cost in accordance with year

Year	Maintenance and Operating Cost US $
1985	58432
1986	1554442
1987	1648451
1988	1747358
1989	2477112*
1990	1956590
1991	2073985
1992	2198424
1993	2330330
1994	3314935*
1995	2618358
1996	2775460
1997	2941988
1998	3118507
1999	4436131*
2000	3503954
2001	3714192
2002	3937043
2003	4173266
2004	4423662

* Periodic Maintenance (Patching and Selective resurfacing + Asphalt concrete overlay + Allowance for maintenance of interchanges)

Table 6.5. Financial Plan of The Gebze - Izmit Motorway (in US $)

Year	Interest Quota	Capital Quota	Fixed Rate	Residual Debt	Paid Debt
1985	14461248	941087	15402335	95467231	941087
1986	14320085	1082250	"	94384981	2023337
1987	14157747	1244588	"	93140393	3267925
1988	13971059	1431276	"	91709118	4699201
1989	13756368	1645967	"	90063151	6345168
1990	13509474	1892862	"	88170289	8238030
1991	13225544	2176791	"	85993498	10414820
1992	12899025	2503310	"	83490188	12918131
1993	12523528	2878807	"	80611381	15796938
1994	12091707	3310628	"	77300753	19107566
1995	11595113	3807222	"	73493531	22914788
1996	11024030	4378305	"	69115226	27293093
1997	10367284	5035051	"	64080175	32328144
1998	9612027	5790308	"	58289867	38118452
1999	8743480	6658855	"	51631012	44777307
2000	7744652	7657683	"	43973329	52434990
2001	6596000	8806335	"	35166994	61241325
2002	5275049	10127286	"	25039714	71368611
2003	3755956	11646379	"	13393335	83014983
2004	2009000	13393335	15402335	0	96408318
Total	211638382	96408318	308046700	-	-

Table 6.6. Total Financial Cost of the Gebze-Izmit Motorway (in US $)

Year	Maintenance and Operating Cost	Annual Fixed Rate	Total
1985	58432	15402335	15460767
1986	1555142	"	16957477
1987	1648451	"	17050786
1988	1747358	"	17149693
1989	2477112*	"	17879447
1990	1956590	"	17358925
1991	2073985	"	17476320
1992	2198424	"	17600759
1993	2330330	"	17732665
1994	3314935*	"	18717270
1995	2618358	"	18020693
1996	2775460	"	18177795
1997	2941988	"	18344323
1998	3118507	"	18520842
1999	4436131*	"	19838466
2000	3503954	"	18906289
2001	3714192	"	19116527
2002	3937043	"	19339378
2003	4173266	"	19575601
2004	4423662	15402335	19825997
Total	55003320	308046700	363050020

* Periodic Maintenance (Patching and Selective resurfacing + Asphalt concrete overlay + Allowance for maintenance of interchanges)

applying the toll rates proposed below over a period of 20 years.

Toll rate is defined by the following formula :

$$Y = \frac{A + C + M}{365 \times L \times CE} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6.1)$$

Where,

CE = Car Equivalent (AADT)

Y = Toll Rate (US $/Km)

A = Annual Fixed Rate (US $)

C = Toll Collecting Cost (US $)

M = Maintenance Cost (US $)

L = Motorway Length (Km)

Calculated toll rates are shown in Table 6.7.

6.3. Toll Collection

Having regard to the proposed location of the motorway, an inexpensive, closed system of toll collection would be the most appropriate.

Closed system; vehicles entering the motorway would be issued with a magnetically encoded ticket by simply pushing a button a booths provided with a manually operated barrier. This barrier would be interlocked with the lane microprocesser and the overhead lane sign such that the lane can not be opened without the barrier being fully opened. This "ticketing" machine would distinguish the cars and trucks individually.

Table 6.7. Tabulation of Toll Rate in accordance with Year

Year	Maintenance and Operating Cost US $	Annual Fixed Rate US $	Toll Rate US $/Km
1985	58432	15402335	0.0725
1986	1555142	"	0.0773
1987	1648451	"	0.0646
1988	1747358	"	0.0544
1989	2477112	"	0.0574
1990	1956590	"	0.0438
1991	2073985	"	0.0390
1992	2198424	"	0.0348
1993	2330330	"	0.0310
1994	3314935	"	0.0289
1995	2618358	"	0.0247
1996	2775460	"	0.0220
1997	2941988	"	0.0197
1998	3118507	"	0.0176
1999	4436131	"	0.0167
2000	3503954	"	0.0140
2001	3714192	"	0.0126
2002	3937043	"	0.0113
2003	4173266	"	0.0101
2004	4423662	15402335	0.0090

On exiting from the motorway, the driver's ticket would be classified by vehicle type and a microprocessor terminal would calculate the appropriate toll to be collected.

At each entrance/exit ramp a data 'concentrator' would transmit traffic and toll collection statistics to a central computer system, or a computer center located at a central point located along the motorway.

6.4. The Computer Program for Closed System Motorway

Considering that all motorway networks in Turkey will be closed system, a computer program, written in Turbo Basic Programming Language, is developed for tolls. This computer program, fixing the distance classes, decreasing the vehicle/Km rate as the distance class increases and applying a general formula;

$$Y = \frac{a}{\mathrm{Log}(L)} + b \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6.2.)$$

Where,

Y : Toll rate (US $/Km)

L : Motorway length (Km)

a,b : Constants

Whereby the price continuously decreases with the increment of distance.

The program according to their relative weight and reduce rate, the saving rate of the vehicle operation cost because of the vehicles' using motorway instead of ordinary road, and according to the distance groups selected, the above formula calculates tolls for every single vehicle group, as it is given in the Appendix A. Toll graph of all vehicle groups for Gebze-Izmit Motorway during the year of 1991 is illustrated in Figure 6.6 .

In addition, it calculates tolls for any given distance as "round off". Finally, it calculates toll for a closed Motorway system. A reference point is taken and number of toll gates, gate names and gate Km. are given and according to entrance gates it calculates toll rates, total tolls and rounded off according to every exit point for every vehicle group. i.e. This computer output (for 1991) for Gebze-Izmit motorway is given in the Appendix A.

6.4.1. Instructions to Use the Computer Program

In order to enter the program, write "TOLL" . When the name of the program is seen on the screen, press "enter" button. Then, enter "description of vehicle groups", "relative weight", "fixed", "initial rate", "reduce rate and apply rate" data. Press "page down" button to see the second page. Enter the number of distance group (12). Using "down arrow" button, write the fixed distances. After this is completed, press "page down"to see the third page. Then press "F1" to see the "toll rates for in each distance group". And then press first, "G" and then, "1" to see the toll graph for 1st group of vehicles. Repeat the same steps for the other groups. In order to see all vehicles press "G"

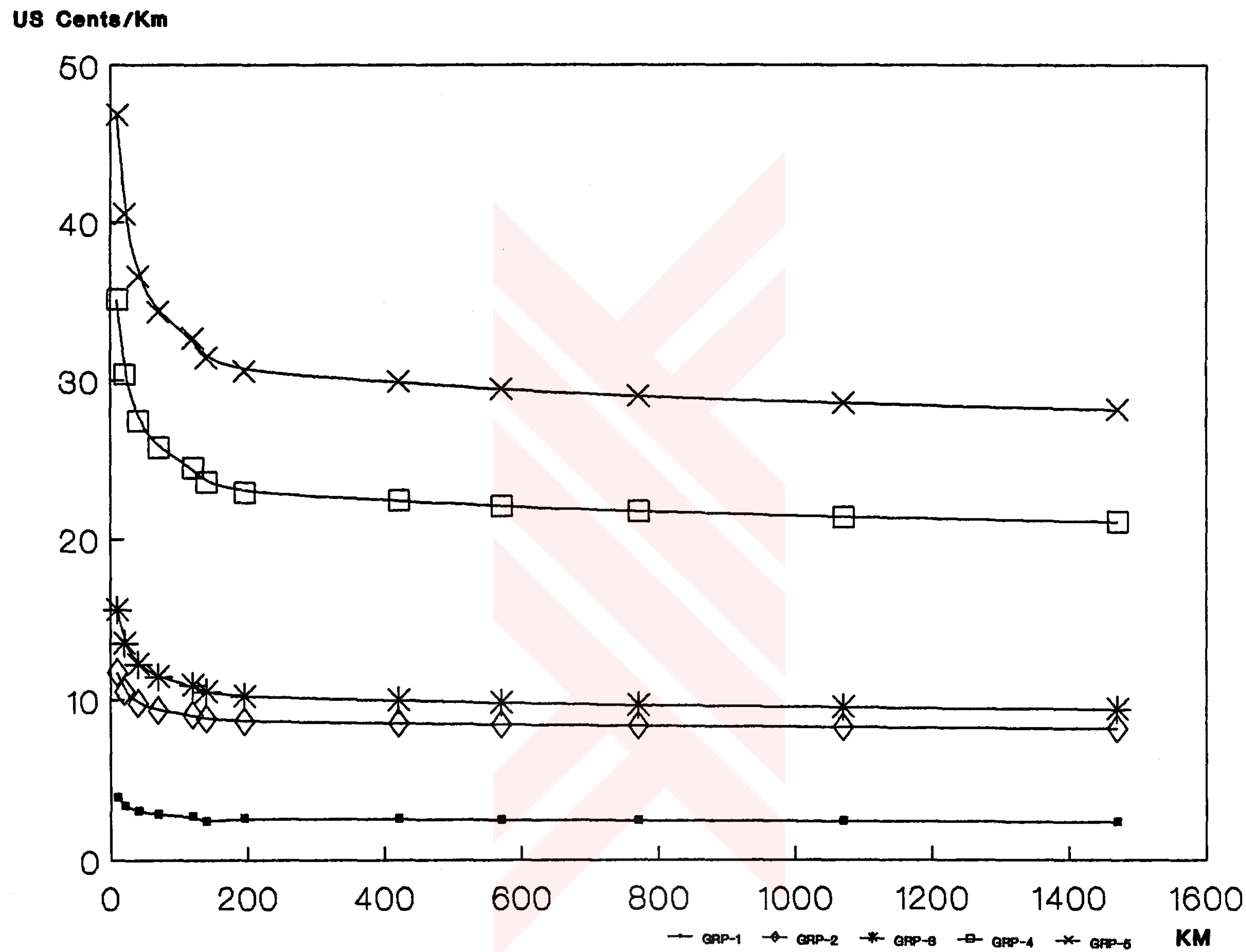


Figure 6.6. Toll Graph of all Vehicle Group for Gebze-Izmit Motorway during the Year of 1991

and then "O". Exit from this page pressing the "page up" button.

Press "F2" to see the tolls for any given distance and enter toll distance as Km. and toll will be given in US $. To exit from this page, press "page up".

Press "F3" to see the toll for closed motorway system. And enter number of toll gates, the reference point and reference Km. in the closed system. The toll gates names and Km. are written to the section given. Then save the data file pressing the "F10" button. Finally press "page down" and according to the question of "input gate number for toll gates?" write the gate number or put "*" to calculate the toll.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

The following conclusions can be drawn from this study.

1) In situ toll on the infrastructure is applied according to two procedures, the open system and closed system. The open system is suitable for short sections, whilst the closed system is suitable for long distance links. However, in both cases, technical improvements ensure low collection costs and 100% reliability.

2) This study shows that the 65 percent of the total traffic is passenger cars, and 35 percent is heavy truck traffic for the section studied when it is taken into consideration, the vehicles like trailer are likely to use the motorway since their share in traffic composition is rather low.

3) The conclusions derived after this study have revealed that the selected Gebze-Izmit Motorway section is an investment which recovers all the expenses in 20 years of operation provided that the proposed toll-rates are to be collected under closed-toll collection system.

4) A 701 line - 76499 Byte computer program, written in Turbo Basic Programming Language, is developed for closed toll systems.

5) This study reveals that tolls calculated according to the toll rates defined in the study is lower than the tariff rates currently applied for Gebze-Izmit Motorway.

7.2. Recommendations

1) In order to define toll rate more soundly, the data related to construction cost, maintenance cost and toll operating cost should be stored a central data bank and should be available for future use.

2) Since the determination of toll-rates to be collected is mainly dependent on the type of toll collection system proposed, all collection systems should be throughly examined with all respects to be able to end up with a rational result.

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APPENDIX

TOLL

DECEMBER, 1990 - ANKARA/TURKEY

TUTAŞ, MEHMET

TOLL RATES OF MOTORWAYS   Assumptions   Page-1

NUMBER OF VEHICLE GROUP : 5

DESCRIPTION OF VEHICLE GROUPS	RELATI. WEIGH.	FIXED (Cents)	INITIAL (Cents)	REDUCE. RATE(%)	APLLY RATE(%)
CAR	1		3.9	60	100
BUS	3		11.7	70	100
TRUCK	4		15.6	60	100
HEAVY TRUCK	9		35.1	60	100
TRAILER	12		46.8	60	100

TOLL RATES OF MOTORWAYS   Assumptions   Page-2

NUMBER OF DISTANCE GROUP : 12

GROUP NO	DISTANCE (KM)	GROUP NO	DISTANCE (KM)
1	10	11	300
2	10	12	400
3	20		
4	30		
5	50		
6	75		
7	100		
8	125		
9	150		
10	200		

TOLL RATES OF MOTORWAYS   Output Design Page-3

F1 : Toll Rates for in each Distance Group

F2 : Tolls for any given Specific Distance

F3 : Tolls for a Closed Motorway System

TOLL RATES OF MOTORWAYS   Toll Rates in Distance Groups

			VEHICLE GROUPS.....				
DISTANCES......			GRP- 1	GRP- 2	GRP- 3	GRP- 4	GRP- 5
GR- 1:	10	10	3.900	11.700	15.600	35.100	46.800
GR- 2:	10	20	3.373	10.513	13.490	30.353	40.470
GR- 3:	20	40	3.043	9.772	12.173	27.389	36.519
GR- 4:	30	70	2.856	9.351	11.423	25.702	34.270
GR- 5:	50	120	2.717	9.038	10.867	24.450	32.600
GR- 6:	75	195	2.616	8.810	10.463	23.542	31.389
GR- 7:	100	295	2.543	8.647	10.173	22.889	30.519
GR- 8:	125	420	2.489	8.526	9.957	22.404	29.871
GR- 9:	150	570	2.447	8.432	9.790	22.027	29.370
GR-10:	200	770	2.410	8.348	9.640	21.690	28.920
GR-11:	300	1070	2.373	8.264	9.491	21.355	28.473
GR-12:	400	1470	2.340	8.190	9.360	21.060	28.080

TOLL RATES OF MOTORWAYS Tolls for any given Distance

TOLL DISTANCE : 9.300

VEHICLE GROUPS	TOLLS (Cents)	TOTAL (Cents)	R.OFF (US $)
CAR	36.27	36.27	0.36
BUS	108.81	108.81	1.09
TRUCK	145.08	145.08	1.45
HEAVY TRUCK	326.43	326.43	3.26
TRAILER	435.24	435.24	4.35

TOLL RATES OF MOTORWAYS Tolls for any given Distance

TOLL DISTANCE : 22

VEHICLE GROUPS	TOLLS (Cents)	TOTAL (Cents)	R.OFF (US $)
CAR	78.81	78.81	0.79
BUS	241.68	241.68	2.42
TRUCK	315.25	315.25	3.15
HEAVY TRUCK	709.30	709.30	7.09
TRAILER	945.74	945.74	9.46

TOLL RATES OF MOTORWAYS Tolls for any given Distance

TOLL DISTANCE : 65

VEHICLE GROUPS	TOLLS (Cents)	TOTAL (Cents)	R.OFF (US $)
CAR	204.99	204.99	2.05
BUS	651.34	651.34	6.51
TRUCK	819.94	819.94	8.20
HEAVY TRUCK	1844.87	1844.87	18.45
TRAILER	2459.82	2459.82	24.60

TOLL RATES OF MOTORWAYS   Tolls for closed motorway system

NO OF TOLL GATES : 6   REFERENCE POINT : GEBZE BAT.KAV.   REF. KM : 37.100

NO	GATE NAME	KM.
1	GEBZE DOĞ.K.	42.200
2	DiL iSKELESi	51.500
3	HEREKE BAT.K	57.640
4	HEREKE DOĞ.K	60.800
5	YARIMCA K.K	73.500
6	iZMiT BAT.K	80.700

GEBZE DOĞ.K. : TOLL RATES ACCORDING TO FOLLOWING ENTRANCE GATES

	DİL İSKELESİ	HEREKE BAT.K	HEREKE DOĞ.K	YARIMCA K.K
GATE DISTANCE (Km)	9.300	15.440	18.600	31.300
VEHICLE GROUP - 1				
TOLL RATE (Cents)	36.27	57.35	68.00	107.11
TOTAL TOLL (Cents)	36.27	57.35	68.00	107.11
ROUNDED OFF (US $)	0.36	0.57	0.68	1.07
VEHICLE GROUP - 2				
TOLL RATE (Cents)	108.81	174.19	207.41	332.56
TOTAL TOLL (Cents)	108.81	174.19	207.41	332.56
ROUNDED OFF (US $)	1.09	1.74	2.07	3.33
VEHICLE GROUP - 3				
TOLL RATE (Cents)	145.08	229.39	272.01	428.46
TOTAL TOLL (Cents)	145.08	229.39	272.01	428.46
ROUNDED OFF (US $)	1.45	2.29	2.72	4.28
VEHICLE GROUP - 4				
TOLL RATE (Cents)	326.43	516.12	612.03	964.02
TOTAL TOLL (Cents)	326.43	516.12	612.03	964.02
ROUNDED OFF (US $)	3.26	5.16	6.12	9.64
VEHICLE GROUP - 5				
TOLL RATE (Cents)	435.24	688.16	816.04	1285.37
TOTAL TOLL (Cents)	435.24	688.16	816.04	1285.37
ROUNDED OFF (US $)	4.35	6.88	8.16	12.85

GEBZE DOĞ.K. : TOLL RATES ACCORDING TO FOLLOWING ENTRANCE GATES

	İZMİT BAT.K	HEREKE BAT.K	HEREKE DOĞ.K	YARIMCA K.K
GATE DISTANCE (Km)	38.500	15.440	18.600	31.300
VEHICLE GROUP - 1				
TOLL RATE (Cents)	129.03	57.35	68.00	107.11
TOTAL TOLL (Cents)	129.03	57.35	68.00	107.11
ROUNDED OFF (US $)	1.29	0.57	0.68	1.07
VEHICLE GROUP - 2				
TOLL RATE (Cents)	402.92	174.19	207.41	332.56
TOTAL TOLL (Cents)	402.92	174.19	207.41	332.56
ROUNDED OFF (US $)	4.03	1.74	2.07	3.33
VEHICLE GROUP - 3				
TOLL RATE (Cents)	516.10	229.39	272.01	428.46
TOTAL TOLL (Cents)	516.10	229.39	272.01	428.46
ROUNDED OFF (US $)	5.16	2.29	2.72	4.28
VEHICLE GROUP - 4				
TOLL RATE (Cents)	1161.23	516.12	612.03	964.02
TOTAL TOLL (Cents)	1161.23	516.12	612.03	964.02
ROUNDED OFF (US $)	11.61	5.16	6.12	9.64
VEHICLE GROUP - 5				
TOLL RATE (Cents)	1548.30	688.16	816.04	1285.37
TOTAL TOLL (Cents)	1548.30	688.16	816.04	1285.37
ROUNDED OFF (US $)	15.48	6.88	8.16	12.85

DiL iSKELESi : TOLL RATES ACCORDING TO FOLLOWING ENTRANCE GATES

	GEBZE DOĞ.K.	HEREKE BAT.K	HEREKE DOĞ.K	YARIMCA K.K
GATE DISTANCE (Km)	9.300	6.140	9.300	22.000
VEHICLE GROUP - 1				
TOLL RATE (Cents)	36.27	23.95	36.27	78.81
TOTAL TOLL (Cents)	36.27	23.95	36.27	78.81
ROUNDED OFF (US $)	0.36	0.24	0.36	0.79
VEHICLE GROUP - 2				
TOLL RATE (Cents)	108.81	71.84	108.81	241.68
TOTAL TOLL (Cents)	108.81	71.84	108.81	241.68
ROUNDED OFF (US $)	1.09	0.72	1.09	2.42
VEHICLE GROUP - 3				
TOLL RATE (Cents)	145.08	95.78	145.08	315.25
TOTAL TOLL (Cents)	145.08	95.78	145.08	315.25
ROUNDED OFF (US $)	1.45	0.96	1.45	3.15
VEHICLE GROUP - 4				
TOLL RATE (Cents)	326.43	215.51	326.43	709.30
TOTAL TOLL (Cents)	326.43	215.51	326.43	709.30
ROUNDED OFF (US $)	3.26	2.16	3.26	7.09
VEHICLE GROUP - 5				
TOLL RATE (Cents)	435.24	287.35	435.24	945.74
TOTAL TOLL (Cents)	435.24	287.35	435.24	945.74
ROUNDED OFF (US $)	4.35	2.87	4.35	9.46

DiL iSKELESi : TOLL RATES ACCORDING TO FOLLOWING ENTRANCE GATES

	iZMiT BAT.K	HEREKE BAT.K	HEREKE DOĞ.K	YARIMCA K.K
GATE DISTANCE (Km)	29.200	6.140	9.300	22.000
VEHICLE GROUP - 1				
TOLL RATE (Cents)	100.72	23.95	36.27	78.81
TOTAL TOLL (Cents)	100.72	23.95	36.27	78.81
ROUNDED OFF (US $)	1.01	0.24	0.36	0.79
VEHICLE GROUP - 2				
TOLL RATE (Cents)	312.04	71.84	108.81	241.68
TOTAL TOLL (Cents)	312.04	71.84	108.81	241.68
ROUNDED OFF (US $)	3.12	0.72	1.09	2.42
VEHICLE GROUP - 3				
TOLL RATE (Cents)	402.89	95.78	145.08	315.25
TOTAL TOLL (Cents)	402.89	95.78	145.08	315.25
ROUNDED OFF (US $)	4.03	0.96	1.45	3.15
VEHICLE GROUP - 4				
TOLL RATE (Cents)	906.51	215.51	326.43	709.30
TOTAL TOLL (Cents)	906.51	215.51	326.43	709.30
ROUNDED OFF (US $)	9.07	2.16	3.26	7.09
VEHICLE GROUP - 5				
TOLL RATE (Cents)	1208.68	287.35	435.24	945.74
TOTAL TOLL (Cents)	1208.68	287.35	435.24	945.74
ROUNDED OFF (US $)	12.09	2.87	4.35	9.46

HEREKE BAT.K : TOLL RATES ACCORDING TO FOLLOWING ENTRANCE GATES

	GEBZE DOĞ.K.	DiL iSKELESi	HEREKE DOĞ.K	YARIMCA K.K
GATE DISTANCE (Km)	15.440	6.140	3.160	15.860
VEHICLE GROUP - 1				
TOLL RATE (Cents)	57.35	23.95	12.32	58.76
TOTAL TOLL (Cents)	57.35	23.95	12.32	58.76
ROUNDED OFF (US $)	0.57	0.24	0.12	0.59
VEHICLE GROUP - 2				
TOLL RATE (Cents)	174.19	71.84	36.97	178.61
TOTAL TOLL (Cents)	174.19	71.84	36.97	178.61
ROUNDED OFF (US $)	1.74	0.72	0.37	1.79
VEHICLE GROUP - 3				
TOLL RATE (Cents)	229.39	95.78	49.30	235.05
TOTAL TOLL (Cents)	229.39	95.78	49.30	235.05
ROUNDED OFF (US $)	2.29	0.96	0.49	2.35
VEHICLE GROUP - 4				
TOLL RATE (Cents)	516.12	215.51	110.92	528.87
TOTAL TOLL (Cents)	516.12	215.51	110.92	528.87
ROUNDED OFF (US $)	5.16	2.16	1.11	5.29
VEHICLE GROUP - 5				
TOLL RATE (Cents)	688.16	287.35	147.89	705.15
TOTAL TOLL (Cents)	688.16	287.35	147.89	705.15
ROUNDED OFF (US $)	6.88	2.87	1.48	7.05

HEREKE BAT.K : TOLL RATES ACCORDING TO FOLLOWING ENTRANCE GATES

	iZMiT BAT.K	DiL iSKELESi	HEREKE DOĞ.K	YARIMCA K.K
GATE DISTANCE (Km)	23.060	6.140	3.160	15.860
VEHICLE GROUP - 1				
TOLL RATE (Cents)	82.04	23.95	12.32	58.76
TOTAL TOLL (Cents)	82.04	23.95	12.32	58.76
ROUNDED OFF (US $)	0.82	0.24	0.12	0.59
VEHICLE GROUP - 2				
TOLL RATE (Cents)	252.03	71.84	36.97	178.61
TOTAL TOLL (Cents)	252.03	71.84	36.97	178.61
ROUNDED OFF (US $)	2.52	0.72	0.37	1.79
VEHICLE GROUP - 3				
TOLL RATE (Cents)	328.15	95.78	49.30	235.05
TOTAL TOLL (Cents)	328.15	95.78	49.30	235.05
ROUNDED OFF (US $)	3.28	0.96	0.49	2.35
VEHICLE GROUP - 4				
TOLL RATE (Cents)	738.34	215.51	110.92	528.87
TOTAL TOLL (Cents)	738.34	215.51	110.92	528.87
ROUNDED OFF (US $)	7.38	2.16	1.11	5.29
VEHICLE GROUP - 5				
TOLL RATE (Cents)	984.45	287.35	147.89	705.15
TOTAL TOLL (Cents)	984.45	287.35	147.89	705.15
ROUNDED OFF (US $)	9.84	2.87	1.48	7.05

HEREKE DOĞ.K : TOLL RATES ACCORDING TO FOLLOWING ENTRANCE GATES

	GEBZE DOĞ.K.	DiL iSKELESi	HEREKE BAT.K	YARIMCA K.K
GATE DISTANCE (Km)	18.600	9.300	3.160	12.700
VEHICLE GROUP - 1				
TOLL RATE (Cents)	68.00	36.27	12.32	48.11
TOTAL TOLL (Cents)	68.00	36.27	12.32	48.11
ROUNDED OFF (US $)	0.68	0.36	0.12	0.48
VEHICLE GROUP - 2				
TOLL RATE (Cents)	207.41	108.81	36.97	145.39
TOTAL TOLL (Cents)	207.41	108.81	36.97	145.39
ROUNDED OFF (US $)	2.07	1.09	0.37	1.45
VEHICLE GROUP - 3				
TOLL RATE (Cents)	272.01	145.08	49.30	192.42
TOTAL TOLL (Cents)	272.01	145.08	49.30	192.42
ROUNDED OFF (US $)	2.72	1.45	0.49	1.92
VEHICLE GROUP - 4				
TOLL RATE (Cents)	612.03	326.43	110.92	432.95
TOTAL TOLL (Cents)	612.03	326.43	110.92	432.95
ROUNDED OFF (US $)	6.12	3.26	1.11	4.33
VEHICLE GROUP - 5				
TOLL RATE (Cents)	816.04	435.24	147.89	577.27
TOTAL TOLL (Cents)	816.04	435.24	147.89	577.27
ROUNDED OFF (US $)	8.16	4.35	1.48	5.77

HEREKE DOĞ.K : TOLL RATES ACCORDING TO FOLLOWING ENTRANCE GATES

	iZMiT BAT.K	DiL iSKELESi	HEREKE BAT.K	YARIMCA K.K
GATE DISTANCE (Km)	19.900	9.300	3.160	12.700
VEHICLE GROUP - 1				
TOLL RATE (Cents)	72.39	36.27	12.32	48.11
TOTAL TOLL (Cents)	72.39	36.27	12.32	48.11
ROUNDED OFF (US $)	0.72	0.36	0.12	0.48
VEHICLE GROUP - 2				
TOLL RATE (Cents)	221.08	108.81	36.97	145.39
TOTAL TOLL (Cents)	221.08	108.81	36.97	145.39
ROUNDED OFF (US $)	2.21	1.09	0.37	1.45
VEHICLE GROUP - 3				
TOLL RATE (Cents)	289.55	145.08	49.30	192.42
TOTAL TOLL (Cents)	289.55	145.08	49.30	192.42
ROUNDED OFF (US $)	2.90	1.45	0.49	1.92
VEHICLE GROUP - 4				
TOLL RATE (Cents)	651.49	326.43	110.92	432.95
TOTAL TOLL (Cents)	651.49	326.43	110.92	432.95
ROUNDED OFF (US $)	6.51	3.26	1.11	4.33
VEHICLE GROUP - 5				
TOLL RATE (Cents)	868.65	435.24	147.89	577.27
TOTAL TOLL (Cents)	868.65	435.24	147.89	577.27
ROUNDED OFF (US $)	8.69	4.35	1.48	5.77

YARIMCA K.K : TOLL RATES ACCORDING TO FOLLOWING ENTRANCE GATES

	GEBZE DOĞ.K.	DiL iSKELESi	HEREKE BAT.K	HEREKE DOĞ.K
GATE DISTANCE (Km)	31.300	22.000	15.860	12.700
VEHICLE GROUP - 1				
TOLL RATE (Cents)	107.11	78.81	58.76	48.11
TOTAL TOLL (Cents)	107.11	78.81	58.76	48.11
ROUNDED OFF (US $)	1.07	0.79	0.59	0.48
VEHICLE GROUP - 2				
TOLL RATE (Cents)	332.56	241.68	178.61	145.39
TOTAL TOLL (Cents)	332.56	241.68	178.61	145.39
ROUNDED OFF (US $)	3.33	2.42	1.79	1.45
VEHICLE GROUP - 3				
TOLL RATE (Cents)	428.46	315.25	235.05	192.42
TOTAL TOLL (Cents)	428.46	315.25	235.05	192.42
ROUNDED OFF (US $)	4.28	3.15	2.35	1.92
VEHICLE GROUP - 4				
TOLL RATE (Cents)	964.02	709.30	528.87	432.95
TOTAL TOLL (Cents)	964.02	709.30	528.87	432.95
ROUNDED OFF (US $)	9.64	7.09	5.29	4.33
VEHICLE GROUP - 5				
TOLL RATE (Cents)	1285.37	945.74	705.15	577.27
TOTAL TOLL (Cents)	1285.37	945.74	705.15	577.27
ROUNDED OFF (US $)	12.85	9.46	7.05	5.77

YARIMCA K.K : TOLL RATES ACCORDING TO FOLLOWING ENTRANCE GATES

	iZMiT BAT.K	DiL iSKELESi	HEREKE BAT.K	HEREKE DOĞ.K
GATE DISTANCE (Km)	7.200	22.000	15.860	12.700
VEHICLE GROUP - 1				
TOLL RATE (Cents)	28.08	78.81	58.76	48.11
TOTAL TOLL (Cents)	28.08	78.81	58.76	48.11
ROUNDED OFF (US $)	0.28	0.79	0.59	0.48
VEHICLE GROUP - 2				
TOLL RATE (Cents)	84.24	241.68	178.61	145.39
TOTAL TOLL (Cents)	84.24	241.68	178.61	145.39
ROUNDED OFF (US $)	0.84	2.42	1.79	1.45
VEHICLE GROUP - 3				
TOLL RATE (Cents)	112.32	315.25	235.05	192.42
TOTAL TOLL (Cents)	112.32	315.25	235.05	192.42
ROUNDED OFF (US $)	1.12	3.15	2.35	1.92
VEHICLE GROUP - 4				
TOLL RATE (Cents)	252.72	709.30	528.87	432.95
TOTAL TOLL (Cents)	252.72	709.30	528.87	432.95
ROUNDED OFF (US $)	2.53	7.09	5.29	4.33
VEHICLE GROUP - 5				
TOLL RATE (Cents)	336.96	945.74	705.15	577.27
TOTAL TOLL (Cents)	336.96	945.74	705.15	577.27
ROUNDED OFF (US $)	3.37	9.46	7.05	5.77

iZMiT BAT.K : TOLL RATES ACCORDING TO FOLLOWING ENTRANCE GATES

	GEBZE DOĞ.K.	DiL iSKELESi	HEREKE BAT.K	HEREKE DOĞ.K
GATE DISTANCE (Km)	38.500	29.200	23.060	19.900
VEHICLE GROUP - 1				
TOLL RATE (Cents)	129.03	100.72	82.04	72.39
TOTAL TOLL (Cents)	129.03	100.72	82.04	72.39
ROUNDED OFF (US $)	1.29	1.01	0.82	0.72
VEHICLE GROUP - 2				
TOLL RATE (Cents)	402.92	312.04	252.03	221.08
TOTAL TOLL (Cents)	402.92	312.04	252.03	221.08
ROUNDED OFF (US $)	4.03	3.12	2.52	2.21
VEHICLE GROUP - 3				
TOLL RATE (Cents)	516.10	402.89	328.15	289.55
TOTAL TOLL (Cents)	516.10	402.89	328.15	289.55
ROUNDED OFF (US $)	5.16	4.03	3.28	2.90
VEHICLE GROUP - 4				
TOLL RATE (Cents)	1161.23	906.51	738.34	651.49
TOTAL TOLL (Cents)	1161.23	906.51	738.34	651.49
ROUNDED OFF (US $)	11.61	9.07	7.38	6.51
VEHICLE GROUP - 5				
TOLL RATE (Cents)	1548.30	1208.68	984.45	868.65
TOTAL TOLL (Cents)	1548.30	1208.68	984.45	868.65
ROUNDED OFF (US $)	15.48	12.09	9.84	8.69

iZMiT BAT.K : TOLL RATES ACCORDING TO FOLLOWING ENTRANCE GATES

	YARIMCA K.K	DiL iSKELESi	HEREKE BAT.K	HEREKE DOĞ.K
GATE DISTANCE (Km)	7.200	29.200	23.060	19.900
VEHICLE GROUP - 1				
TOLL RATE (Cents)	28.08	100.72	82.04	72.39
TOTAL TOLL (Cents)	28.08	100.72	82.04	72.39
ROUNDED OFF (US $)	0.28	1.01	0.82	0.72
VEHICLE GROUP - 2				
TOLL RATE (Cents)	84.24	312.04	252.03	221.08
TOTAL TOLL (Cents)	84.24	312.04	252.03	221.08
ROUNDED OFF (US $)	0.84	3.12	2.52	2.21
VEHICLE GROUP - 3				
TOLL RATE (Cents)	112.32	402.89	328.15	289.55
TOTAL TOLL (Cents)	112.32	402.89	328.15	289.55
ROUNDED OFF (US $)	1.12	4.03	3.28	2.90
VEHICLE GROUP - 4				
TOLL RATE (Cents)	252.72	906.51	738.34	651.49
TOTAL TOLL (Cents)	252.72	906.51	738.34	651.49
ROUNDED OFF (US $)	2.53	9.07	7.38	6.51
VEHICLE GROUP - 5				
TOLL RATE (Cents)	336.96	1208.68	984.45	868.65
TOTAL TOLL (Cents)	336.96	1208.68	984.45	868.65
ROUNDED OFF (US $)	3.37	12.09	9.84	8.69

TOLL GRAPH ALL VEHICLE GROUPS