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AREA WIDE TRAFFIC DEMAND MANAGEMENT BY ROAD PRICING

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Abstract

Cities and governments spent a tremendous amount of money to ease traffic congestion, but the problems are yet unsolved. The difficulties are well-known; increase of costs and time spent on travelling in cities; noise nuisance, air pollution, vibration; increase of urban accident rates; deforming land use patterns.

Recent research suggests to apply some form of Road Pricing as an important tool among many others to manage demand on motorized traffic. Road Pricing may be effective as it reduces costs of traffic; regulates and reduces car use in peak hours and pricing contributes to maintaining better environmental and living conditions in city centres.

Road Pricing system should be included within a comprehensive Land Use and Transport Policy.

Car ownership in Budapest will double to about 400 cars/1000 inhabitants within 30 years. It seems clear that some regulation and restriction on car use cannot be avoided. Simultaneous, coordinated elements of traffic demand management in Budapest may be the following: land use policy; development of public transport; area wide traffic control and route guidance systems; parking policy; other instruments and Road Pricing as a major tool to manage demand for car traffic.

There are several reasonable solutions how to locate charging stations in Budapest. In the far future it seems necessary to charge drivers entering the city area within the M0 circular motorway.

In the first phase outer cordon may be established in line of 'Hungarian Ringroad' after its southern end with 'Lágymányosi Bridge' across the River Danube will have been completed. On the 'Buda' side cordon can be put on the ring road (that cannot be so complete as on the 'Pest' side), and additional charging stations can be located on the Danube Bridges. This preliminary suggestion must be controlled and changed by results of precise and detailed application of traffic models, and interdisciplinary preparation.

Keywords: Demand management road pricing, congestion pricing, traffic management, urban transportation.

Introduction

The rapid development of urban transportation, the fast growth of level of car ownership greatly contribute to the development of cities and, as a whole, improve the quality of life of people, living in urban areas. The increase of mobility gives a number of advantages to individuals and to families: helps to develop cities thus the whole economy. However, the increase of traffic causes severe difficulties as well. Cities and governments spent a tremendous amount of money to ease traffic congestion, but the problems are yet unsolved. The difficulties are well known:

- increase of costs and time spent on travelling in cities;
- noise nuisance, air pollution, vibration;
- increase of urban accident rates (especially in Eastern Europe);
- deforming land use patterns by occupation of more and more territory for traffic purposes.

Unlimited motorized traffic in cities threatens people's health, quality of life, so it threatens the city and its normal operation as well.

More and more experts agree on this recognition recently. Congestion itself is not a reasonable solution to regulate traffic demand in cities at peak time. As a conclusion we have to accept that some form of traffic demand management or some form of restriction is needed according to location and time.

Specialists of the developed world are seeking the conditions, instruments and methods to reach an acceptable balance between the different requirements. Recent research suggests to apply some form of Road Pricing – as an important tool among many others – to manage demand on motorized traffic. According to theory and according to limited practice Road Pricing may be effective:

1. It reduces costs of traffic for individuals, for groups and for the society.
2. It can regulate and reduce car use in peak hours at formerly congested locations by diverting some traffic to public transport and cycling. Road pricing also encourages pedestrian traffic and influences modal split by reduction of car use.
3. Road Pricing contributes to maintaining better environmental and living conditions in cities and especially in city centres, while it works with price mechanism avoiding bureaucratic restriction with its disadvantages [1, 2, 3].

Road Pricing System should be included within a comprehensive Land Use and Transport Policy. The System should operate in harmony with the other elements of the Policy to play its role in urban traffic demand management [4]. However, misuse of Road Pricing may be become a dangerous tool to raise money for the state budget. This misuse surely causes serious public resistance and discredits transport policy.

This topic is covered by a number of Studies and Research Reports. Some cooperation programmes of the European Community also deal with the problem [5].

Principles of Road Pricing Systems

The idea of Road Pricing was born at the beginning of the sixties. The first comprehensive study was made by the 'Smeed Committee' in London in 1962. Scandinavian, Japanese, Dutch reports came a bit later. Road Pricing has two main objectives:

1. To harmonize traffic demand and supply for any mode of transportation, taking into account mobility needs, environmental conditions, and minimizing total costs of society.
2. To collect extra money, for road and transportation improvements.

Recently urban road networks are becoming extremely overcongested. According to relevant traffic forecasts car ownership and demand for car use increases. As reasonable possibilities to increase capacity usually give smaller capacity in peak hours than demand, it seems impossible to relieve congestion by traditional technical measures. Sometimes these technical measures cannot be used because of the historic structure of cities; so congestion becomes constant, pollution increases over tolerable thresholds [6, 7, 8].

To handle that situation two measures can be used:

a) Increasing costs should be paid mainly by those who use the congested transportation network of the city in peak hours;
b) Traffic demand and modal split should be influenced in order to ensure acceptable environmental conditions for people.

Public transport, pedestrian traffic and cycling should be developed and encouraged while car use should be regulated and even restricted according to time and place with the help of price mechanism. Appropriate use of Road Pricing (Congestion Pricing) seems to be a suitable instrument to improve the present situation and to avoid the possible future consequences of 'do-nothing' options. Certainly the use of Road Pricing must be coordinated with the comprehensive land use and transport policy of the city and the region. The applied technology of Road Pricing should be technically simple, easy to understand for drivers and people. Its operation must not disturb traffic and life of the city.

The principle of Road Pricing is: The road user pays for costs caused to other people. Efficiency increases by this, as trips generated have more benefits than costs. The benefit consists of the revenue collected, the time and cost saved and the more efficient road use by less congestion. The majority of travellers gains by the system; the losers are those who pay more and receive only slightly better traffic conditions, and those who make less trips than earlier, without Road Pricing they would have done.

The system is theoretically not new. Specialists support it as the revenue collected can finance further developments for the benefit of the whole community. System performance undoubtedly improves.

However, difficulties and public resistance occur, when Road Pricing is to be implemented. The benefits should be used by the 'Rule of Three' (*Fig. 1*). One third of road space saved can be given back for environmental purposes to increase green area; one third can improve public transport with bus lanes or by other means of route separation: one third can improve traffic conditions for remaining motorized traffic thus reducing pollution as well. (GOODWIN 1991 [9]). Revenue collected can be spent for the same fields, for environment; for public transport (for better vehicles, better passenger information, for subsidy); and for improving traffic conditions by constructing new roads, implementing route guidance system, or by other means.

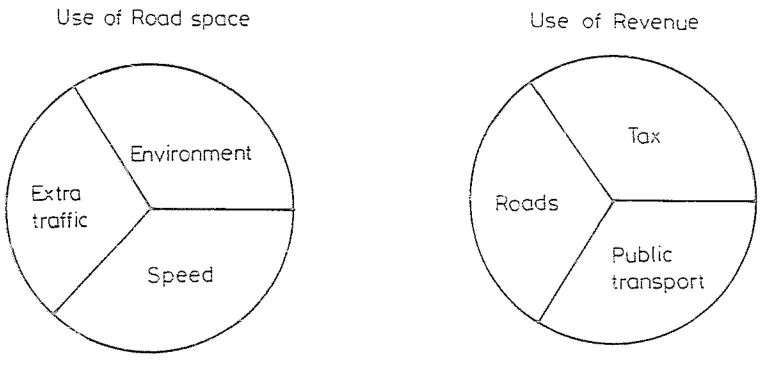

Fig. 1. The 'Rule of Three' allocation of benefits of road pricing, showing (left) released road space and (right) operating revenue [9]

By this approach more groups may feel that they gain and less that they lose. 'The Rule of Three' is not a rigid standard, but symbolizes a balanced rate, that is easy to understand, and gets public support. Social and political support, coherence with land use and transport policy of city are very important to introduce a Road Pricing System.

An ideal Road Pricing System is a flexible complex system. Drivers, car users can pay all their costs as tolls, parking fees and petrol costs in the same way. A special credit card may be suitable to meet these requirements [10].

Road Pricing has two basic forms in international experience:

1. The driver pays when he crosses a certain cordon line; enters and/or leaves the cordon.

2. The driver pays according to the distance travelled on the tolled (inner) side of the cordon line. Earlier suggestions were dropped to pay according to time spent in the tolled area by car as the safety consequences were estimated to be severe.

Some International Examples, Experiments and Plans about Introduction of Road Pricing.

Hong Kong. The First Experiment to Introduce an Electronic Road Pricing System (ERPS)

Electronic Road Pricing Systems could be introduced as the technology of Automatic Vehicle Identification (AVI) had been worked out by the major contribution of Transport and Road Research Laboratory (TRRL) of the United Kingdom. On the basis of TRRL research results achieved at about 1970 Plessey Control Ltd. developed the technology further. However, at this level AVI was not completely reliable. Difficulties occurred with certain vehicle movements (weaving for example), with identification of different types of vehicles, etc.

The progress in the development of microelectronics made it possible to analyse the subject again.

When the feasibility study of Hong Kong Electronic Road Pricing System was carried out in the early eighties, it became clear that the required reliability may already be achieved at reasonable costs. During the experimental operation of Hong Kong ERPS in 1983–85 Automatic Vehicle Identification and the whole system proved to work well and reliably [11, 12, 13]. That meant that ERPS is technically feasible anywhere in the world, though the social and political doubts remained alive. Due to htese doubts and to local specialities the operation of the System was suspended.

Singapore

An AREA Licensing System (ALS) was introduced in Singapore in 1975. The main aim was to reduce car traffic in peak hours in the city centre. The system contains 29 stations for toll collection. Originally drivers entering the cordon between 7.30–11 a.m. were to pay tolls, but later the toll period was extended for the afternoon peak, 4.30– 7.00 p.m. The entering fee was 1.7 Singapore $ per day or 35 Singapore $ per month (approximately 3 US$ and 55 US$). Drivers of buses, lorries emergency, vehicles, and 'high occupancy vehicles' (cars with 4 or more people) do not have to pay the toll. 'Stickers' are sold at post offices and they are to be stuck on the windscreen inside the vehicle. Technically the system is quite simple. Control is made at toll gates. Those travelling without sticker are registered and fined by the police.

As a result of Area Licensing System car use in peak hours sharply decreased, while in off-peak it increased. As a total traffic decreased by 20 %. The number of High Occupancy Vehicles (HOVs) doubled. Business in the center was not badly effected. Authorities in Singapore are considering to develop their Area Licensing System to an Electronic Road Pricing System. [1, 2].

Bergen (Norway)

Since January 1986, toll is collected in the city of Bergen for the use of cars entering the central area. The city of Bergen has 200 000 inhabitants. Toll collecting plazas have been built on six major radial routes (*Fig. 2*). Tolls are paid for about 50000 vehicles daily from 06 o'clock to 22 o'clock Monday to Friday. The basic aim of implementing the system was to collect money for construction of new roads and for better maintenance of the road network. That also means that congestion relief, environmental improvement were secondary considerations [14].

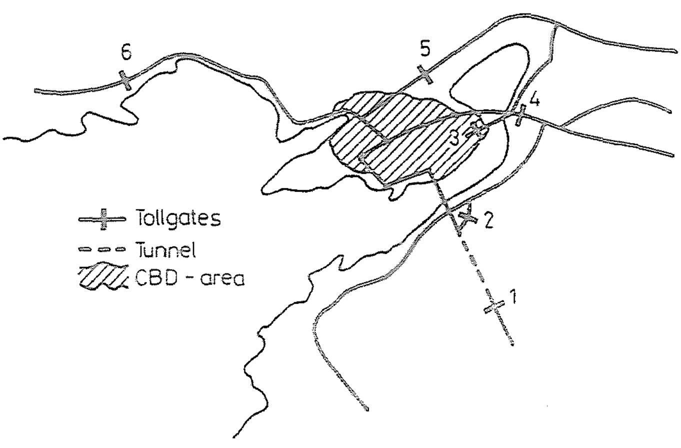

Fig. 2. Major roads leading to Bergen's Central District, showing the location of the toll gates [14]

Toll for a passanger car is 5 NOK (5 Norwegian Krones = 55 Hungarian Forints = 0.70 US $). Lorries pay double rate, buses are free of charge *(Table 1)*.

Table 1
Tolls in Bergen, 1986 [14] (1 NOK = 11 HUF = 0.15 US $)

	Light vehicles		Heavy vehicles	
	NOK	HUF	NOK	HUF
Pass, annual	1,100	12,100	2,200	24,200
Pass, 6 months	575	6.300	1,150	12,600
Pass, monthly	100	1,100	200	2,200
20 pieces of prepaid tickets price/piece	4.50	50	9	100
ticket for one occasion	5	55	10	110
Fine	200	2,200	200	2,200
Gross Revenue 1986	55 million NOK		605 million HUF	
Cost 1986	8.6 million NOK		95 million HUF	
Net Revenue	46.4 million NOK		510 million HUF	

Since 1986 the system works well. Traffic did not increase inside the cordon line while traffic increased with 7–8 % generally in Norway. Financial results have also proved to be good (*Table 2*). Toll plazas do not have bad effects on congestion.

Table 2
Financial results in Bergen 1986

	planned	fact		
	mill. NOK	mill. NOK	mill. HUF	%
Gross Revenue	35	55	605	10
Cost	7	8.6	95	19
Included constr. of toll plazas				
Net Revenue	28	46.4	510	81

Oslo, Trondheim

The capital of Norway, Oslo, introduced Road Pricing in February 1990. 20 toll plazas were built at a distance of 4–6 km from the city center. 200 000 vehicles enter the Central Business District (CBD) area daily including through traffic, as there is no by-pass. The system is similar to the one in Bergen. The most important difference is that the system in Oslo can be developed to an Electronic Road Pricing System.

Trondheim introduced Road Pricing in autumn 1991.

Other Cities Preparing Road Pricing

The so-called Randstad – the more and more unifying conurbation of Amsterdam, The Hague, Rotterdam and Utrecht in the Netherlands, Stockholm, Copenhagen, London and Cambridge are also planning to introduce Road Pricing. Application of forecasts and various traffic models made it clear that only a package of measures included Road Pricing can manage traffic demand to a level that is environmentally and socially tolerable in these cities [15,16,17,18,1].

Summary of International Experience and Comprehensive Studies Concerning Road Pricing

Since the 'Smeed Report', 1964 it has been widely recognized among experts that:

Capacity, supply for transport demands at a certain time and location cannot be sufficient. The traditional reaction to the challenge – as to construct roads with a capacity enough for demand at peak hours, peak 15 minutes – failed. This solution has proved to be insufficient according to

- environmental
- land use
- economical considerations.

Other solutions (better and/or cheaper public transport; pedestrianization, traffic calming; decentralization; tax measures; parking fees and restrictions) have given some preliminary results, but generally could not have solved the problem. Every solution has had bad side effects, participants of traffic invented some tricks to overcome restrictions.

It should be emphasized that motorization is a pleasant source of state budget revenue all over the world. However, after general tax levels were decided by the parliament, real costs should be analyzed in details carefully. The widely spread view – that environmental and other damages, losses should be covered by tax revenue – is false. In certain cases costs – caused by users of congested roads – are much higher than the price paid including tax. Any form of cross-subsidy, cross financing may cause economical and social inefficiency.

The Smeed Report and some other studies proved that car drivers entering an already congested slow speed (5–15 km/h) traffic flow, cause considerable extra (marginal, differential) costs to other road users [13]. (*Fig. 3, 4, 5)*. These marginal costs include:

1. Time loss of other drivers and passengers,
2. Other extra cost of other drivers, vehicles (higher fuel consumption, higher vehicle operating costs, longer diverted routes, etc.)
3. Extra costs of lower speed public transport. Time loss of public transport passengers.
4. Direct costs of environmental damages (costs of protection, of fines, etc.) and indirect costs (worse living environment; value loss of houses, flats, pieces of land; illnesses, diseases; etc.)

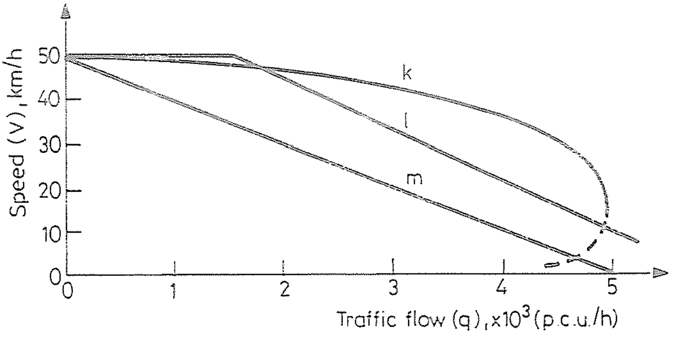

Fig. 3. Traffic flow q: p.c.u./h) – speed (v :km/h) diagrams
k – the well-known HCM diagram
l – a simplified form of HCM diagram
m – $v = a - bq$ linear function; in next example we use
$a = 50$ km/h
$b = 0.01$ km/p.c.u.
According to these values when:
$q = 0$ p.c.u./h $v = 50$ km/h
$q = 5000$ p.c.u./h $v = 0$ km/h
(2500 p.c.u./h/lane)
The example illustrates linear speed-flow relations on a two lane one-way urban arterial. (Modified example of SALTER [19])

Fig. 7 and *Table 4* illustrate the magnitude of differential costs mentioned above. At the current level of technology it is already theoretically possible to make those participants of traffic pay that cause these extra costs.
Using a simplified example:

- Real costs are very high, when somebody uses his car et 4 p.m., Friday on 'High Street' of a metropolis.
- Costs are lower if somebody uses his car at 4 p.m. Friday in the suburbs or in the country.
- Costs are also lower, when somebody uses his car at 5 a.m. Sunday on 'High Street' of a metropolis.

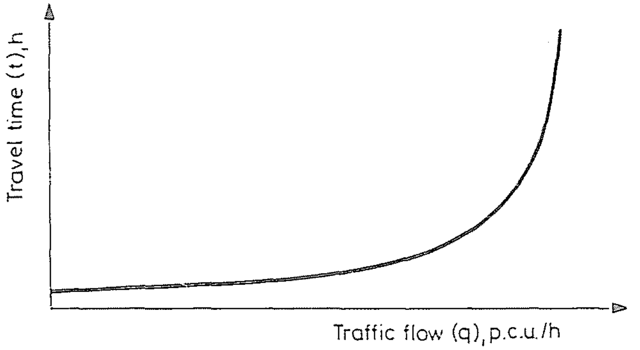

Fig. 4. Traffic flow (q: p.c.u./h) – Travel time (t: h/km) diagram. Linear function m of *Fig. 3* is used. In developed countries traffic flow - travel time traffic flow – travel costs diagrams are practically similar, as travel time is the most important factor of travel cost.

Extra cost is a function of time and location. Earlier forms of price and tax mechanism do not handle that problem. Higher petrol tax may restrict economically and socially useful traffic in the country, or holiday traffic; Higher parking fees do not affect cars using private parking places, and do not affect through traffic.

Only Electronic Road Pricing System (ERPS) may give a theoretically true answer for the problem. Extra price must be paid at location and time where and when extra cost occurs. Efforts to make that system work are applicable thanks to current level of microelectronics and technology:

- Toll collection does not affect, does not disturb traffic;
- Cost of ERPS is fairly low;
- Administration can be solved;
- Drivers avoiding to pay, may be fined efficiently, etc.

'Road Pricing is an attempt to change the principle that highways should be treated as welfare services that is financed out of taxes to the principle that they should be treated as public utility services for which charges are made. It has been argued that road pricing is democratic because it is the tripmaker who makes the decision as to whether or not the trip should be made at the given price rather than a government body making a decision that his trip was in the interests of the community' [14] (Salter, 1989). Application of market mechanism in this field helps to make better use of resources for individuals, for groups and for the society as well; efficiency improves, social costs decrease [20].

Advantages and disadvantages (both real and imagined) of ERPS have been widely analysed by specialists. Most arguments against the system

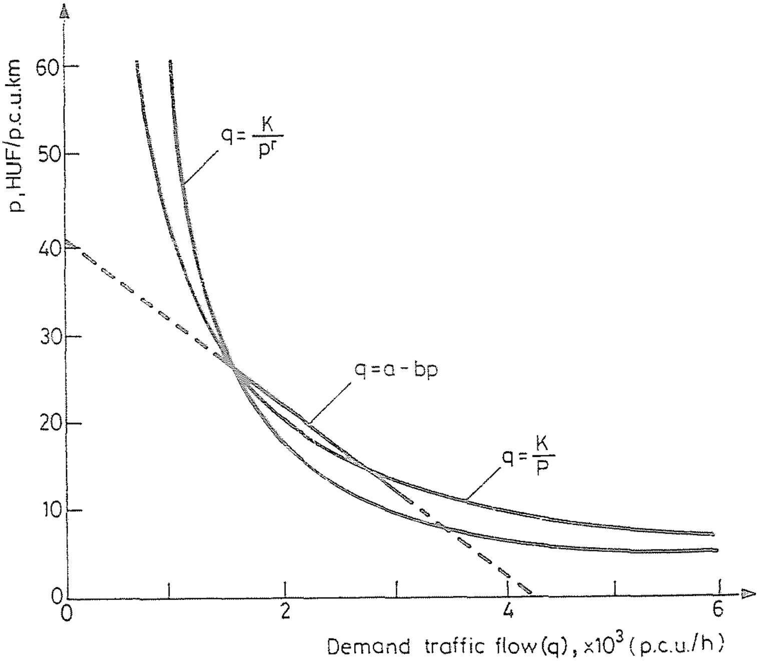

Fig. 5. Typical demand curves
q – Traffic demand – traffic flow [p.c.u./hour]
p – Travel cost or price [HUF/p.c.u.km = Hungarian Forints/p.c.u.km] typical demand curves
$q = f(p) \quad p = f_{-1}(q) = f_{-1}(D)$
q = traffic flow; D = demand
$q = a - bp$; linear
$q = \frac{K}{p}$: hyperbolic
$q = \frac{K}{p^r}$; $K.p_{-r}$

were taken into consideration, but it seems that 'old' market mechanism is a much better tool for traffic demand management than congestion itself. However, public acceptance of ERPS needs careful preparation. The most important advices and experiences are the following [21]:

1. ERPS should be an element of an attractive, promising transport policy package.
2. Before introduction detailed analysis is needed about possible reactions, consequences. Application of comprehensive transport models is needed to forecast future trends.

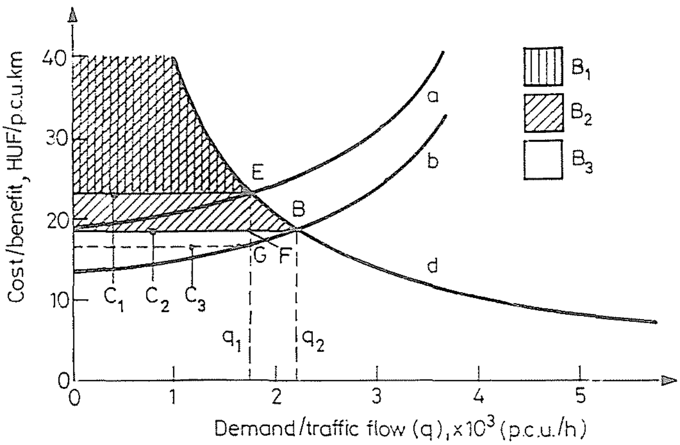

Fig. 6. The change of road user benefit (consumer surplus) as a result of road improvement.

q - demand or traffic flow [p.c.u./h = p.c.u./h]

p - cost or benefit of road use [HUF/p.c.u.km = Hungarian Forints/p.c.u.km]

a - original average cost curve

b - new average cost curve

c_1 - original cost; intersecting point of curves 'a' and 'd'

q_1 - original traffic flow

c_2 - new cost after improvement; intersecting point of curves 'b' and 'd'. $c_2 < c_1$

q_2 - traffic flow after road improvement. $q_2 < c_1$

$q_2 - q_1$ generated traffic

B_1 = consumer surplus in original state

B_2 = consumer surplus after road improvement

B_3 = consumer surplus if a toll $t = c_1 - c_3$ is introduced

in most cases $B_3 > B_2$ as usually area c_3, G, F, c_1 >area E, F, B

$B_1 = \int_0^{q_1} f^{-1}(q)dq - c_1 q_1$

$B_2 = \int^{q_2} f^{-1}(q)dq - c_2 q_2$

$B_3 = \int^{q_1} f^{-1}(q)dq - c_3 q_1$

3. Even a good and reasonable package of measures can only slow down increase of total traffic flows. Reduction of traffic in real terms is rarely possible.

Some informations of present and future ERP Systems are summarized in *Table 3.* Economical background is shown in *Figs 3-7* and in *Table 4* with an example.

Table 4
Average cost and system short run marginal costs of road users as a function of traffic flow [19]. (Look at *Fig. 7* as well)

1 q pc.u/h Traffic flow	2 v km/h 50–q/100 Speed	3 c_v Ft/pc.u/km $6.25+18750/v^2$ Differential cost	4 c_p Ft/pc.u/km 6.25+375/v Private cost average cost	5 c_o Ft/pc.u/km (3)–(4) Costs of other road users	6 q, D pc.u/h 40000 Ft/c_p Demand
0	50	13.75	13.75	0.00	2909
200	48	14.39	14.06	0.33	2844
500	45	15.51	14.59	0.92	2742
1000	40	17.34	15.63	1.71	2561
1500	35	21.56	16.96	4.60	2360
+1700	33	23.46	17.61	5.85	2271+
1700x	-	23.46			1704x
2000	30	27.08	18.75	8.33	2134
+2090	29.1	28.39	19.14	9.25	2090+
2500	25	36.25	21.25	15.00	1882
3000	20	53.12	25.00	28.12	1600
4000	10	193.75	43.75	150.00	914
4500	5	756.25	81.25	675.00	492
4900	1	18756.25	381.25	18375.00	105

The Possibility and Necessity to Apply Road Pricing in Budapest

Possibility for Traffic Demand Management in Budapest

Modest estimations expect that car ownership in Budapest will double to about 400 cars/1000 inhabitants within 30 years. It is difficult to handle that problem both for car use and for parking as the present situation is considered to be unbearable by the public. It seems clear that some regulation and restriction on car use cannot be avoided. Simultaneous, coordinated elements of traffic demand management in Budapest may be the following:

1. A land use policy that influences and if possible reduces traffic demand. (Separation of housing and labour areas in the past increased traffic demand above reasonable level).
2. The development of public transport and its level of service especially in the central area.
3. Introduction of sophisticated area wide traffic control and route guidance systems with priority for public transport.

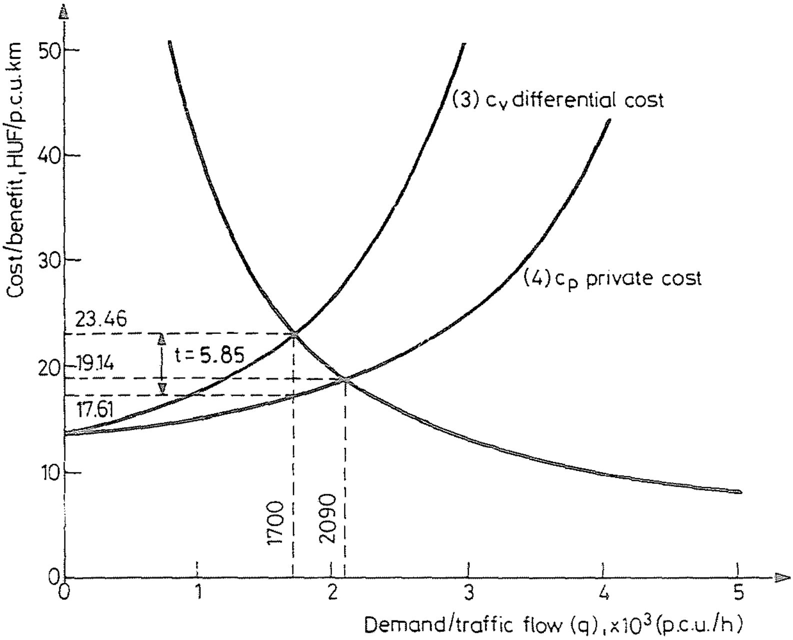

Fig. 7. Average cost and marginal cost curves as a function of traffic flow
Introducing a toll of 5.85 HUF/p.c.u.km
(23.46 HUF - 17.61 HUF=5.85 HUF; differential cost - average cost)
(Look at *Table 4* as well)

4. Parking policy in accordance with Public Transport and Road Pricing System.
5. Other instruments to reduce car traffic speed reduction; Through traffic restriction; Priority for pedestrians and cyclists.
6. Road Pricing as a major tool to manage demand for car traffic.

The Role of Road Pricing in Budapest

Road pricing may have two major functions in Budapest:

1. To manage and restrict demand for individual car use.
2. To form additional revenue for cost of transportation development.

Road Pricing can be the most powerful instrument to influence car use as it

- regulates traffic demand according to time and location;
- ensures the operation of market mechanism, and in this way influences modal split and traffic demand to a socially better state;

- forms a flexible tool that can follow changing needs with the change of location, time limits and toll levels;
- has low operation costs, can be automated and does not disturb traffic. ERPS can give additional traffic informations;
- has a controlling and enforcement method, that fines drivers cheating the system;
- is easy to understand, and gives advantage to every major road user group.

The other important argument for Road Pricing is that it establishes fund to develop and operate the total transportation system. This fund is collected in a socially fair way; those contribute to the costs mainly who use the congested sections, junctions very frequently right in peak hours. Those contribute most, for whom expensive investments to increase capacity are decided, those who enjoy the benefits of these investments. As mentioned in above other forms of taxation do not give that result.

The public may accept the system and considers it fair, if revenue collected will be really used for transport development, and Road Pricing does not become a new form of taxation. The revenue collected should be used to improve public transport, to help pedestrians and cyclists with better facilities, to improve environmental conditions and to develop the road network and its operation. In this case the majority will gain, and losers will be compensated. It is also necessary to make an agreement – with participation of inhabitants, car owners, environmental movements, local authorities and Central Government – about the structure and quantity of taxes levied on motorization, and this agreement should be legislated by Parliament.

According to experience even with Hungarian income levels a Road Pricing System would be profitable. Costs for equipment may return within 2-3 years. Foreign capital would probably be interested in such a project especially in form of concession.

It should be emphasized that Road Pricing is a major tool to ensure tolerable environmental conditions in the city by reducing congestion and pollution. The system is fair as the polluter pays principle is put into practice. Those who cause more pollution by travelling in congestion pay more.

Experience in Hong Kong, studies about Randstad, Stockholm, Cambridge, London convincingly prove that Electronic Road Pricing is the best, most efficient form of any kind of Road Pricing System. ERPS can be the best solution for Budapest as well, especiallyby keeping future demand for car use at reasonably low level, close to present conditions. Foreign experience shows that to slow down the increase of car use is much easier, than to reduce car use that once has already grown from present (about 30 %

car use–70 % public transport) modal split rate to internal (50 %–50 %) modal split.

Possible location of Electronic Road Pricing System in Budapest

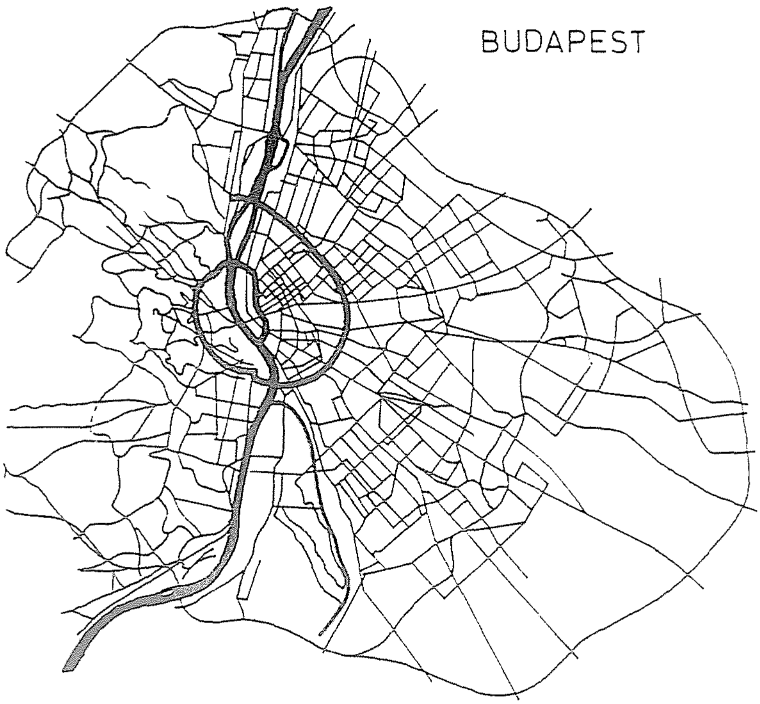

Fig. 8. Possible location of ERPS cordon line with charging stations in phase 1 in Budapest (around year 2000)

There are several reasonable solutions how to locate charging stations in Budapest. In the far future it seems necessary to charge drivers entering the city area within M0 circular motorway. Charge would be smaller close to M0 in the outskirts, and would increase by set of other charging stations closer and closer to the city centre. In peak hours every charging station would be in operation, in off peak charge can also be varied in a flexible way in accordance with traffic demand, policy objectives and local conditions. However, the total charging system should remain simple and understandable for drivers. *Table 5.* shows a preliminary example about possible charge levels and system operation modes.

The system can be put into operation gradually in two – three phases. In the first phase outer cordon may be established in line of 'Hungaria

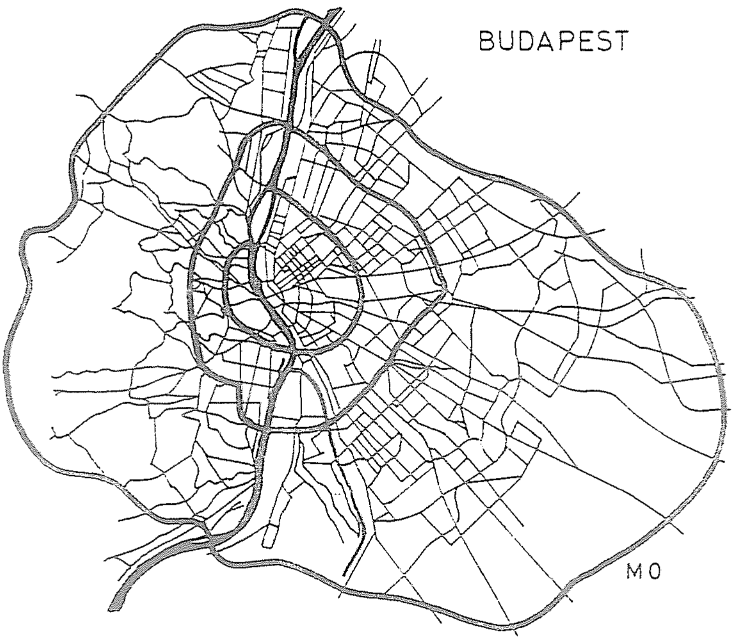

Fig. 9. Possible location of ERPS cordon line with charging stations in phase 2 in Budapest (around year 2020)

Ringroad' after its southern end with 'Lágymányosi Bridge' across the River Danube will have been completed. On the 'Buda' side cordon can be put on the ring road (that cannot be so complete as on the 'Pest' side), and additional charging stations can be located on the Danube Bridges. An additional inner cordon may be established at 'Small Ring' roughly around district V., around the historical City. *Fig. 8* shows Phase 1 with possible cordon lines and location of charging stations. *Fig. 9* shows a possibility for the final phase.

The Electronic Road Pricing System mentioned above has a precondition that the majority of vehicles is equipped with the 'smart card', while for foreign vehicles and for vehicles from the countryside a sticker can be bought that operates as a season ticket for a shorter period. Suggestions of Professor HILLS (1991) how to implement such a system can be useful in Budapest as well [18]. It should be emphasized that careful traffic model experiments, car-use–price elasticity studies must be made before implementing the System.

Table 5
Possible charge levels and operation modes of ERPS in Budapest
(Preliminary example)

Charge level	Time of application	Operation mode of charging stations in City center	Operation mode of charging stations in outskirts close to 'M0'	Average charge collected money unit/ vehicle
1.	Environmental emergency	all in operation	all in operation	10
2.	Peak period Monday–Friday 6–9 a.m. 2–6 p.m.	all in operation	all in operation	5
3.	Weekdays off peak 9 a.m.–2 p.m. 6–9 p.m.	all in operation	majority in operation	3
4.	9 p.m.–6 a.m. weekdays and Saturdays Sundays all day	all in operation	not in operation	1

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