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The Socio-economic benefits of moving from cordon toll to congestion pricing: The Case of Oslo

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Abstract

The substantive issues of this paper is to investigate the magnitude of socio-economic benefits that may be gained by converting the current road financing oriented cordon toll in Oslo to a road congestion-pricing scheme. It is hypothesized that such a move will generate considerable socio-economic benefits as compared to *status quo*. A transport model with four alternative congestion-pricing regimes is developed to assess the hypothesis. The results reveal that transforming the current cordon toll system into a congestion pricing where peak traffic is charged a higher toll than off-peak traffic holds great potential for easing traffic congestion and improving the environment. Further, it will improve the efficiency of both public and private transport while at the same time raising revenues substantially when compared to the current situation. Thus, such a move will not be in conflict with the current road financing oriented toll. These result have direct policy implications in that they should appeal to decision –makers and hence are relevant for the marketing of congestion pricing.

KEY WORDS: Cordon tolls; congestion pricing; socio-economic benefits, and environment.

INTRODUCTION

Congestion is a well- known problem in many modern cities and a major issue for the public, and consequently an important item on the political agenda. Congestion imposes not only a social cost but also a major social cost. All else equal, congested traffic produces more air pollution, increases travel time and consumes more energy than smooth traffic flow. Oslo is no exception in this respect and air pollution from road traffic is a problem in parts of the city. The severity of the problem varies both by location and over time. The problem is amplified under certain weather conditions and maximum concentration of pollutants may grossly exceed international recommendations. Much of the attention of transportation policy makers and planners has in the recent years been focused on means to alleviate congestion in the city.

There are two reasons why the Oslo problem is special with respect to using pricing mechanisms to combat the externalities mentioned above. First, the level of excise taxes on fuel and vehicles is high in Norway as compared to many other countries. Any attempt to increase these taxes in order to reduce the congestion problems will probably be met with skepticism and resistance. The underlying argument will be that the average motorist already pays for the externalities that he causes. Second, there is already a well-established cordon toll ring system around the city, the main purpose of which is to generate funds for road investment within the larger Oslo region. In response to the first problem above, several studies e.g. Larsen [1] and Larsen [2] have shown that an average motorist in Oslo city does not fully pay for the externalities that he/she cause to his surroundings. The cost elements not covered are mainly congestion costs – representing delay to others who use or interact with the network, but also some elements of air pollution and accidents.

The second aspect is the subject matter of this paper. The primary objective is to investigate whether a move from the present cordon toll system to a more road pricing oriented scheme would generate socio-economic benefits in excess of the current system. Specifically we investigate the following issues: (1) the environmental improvements that could be achieved and their magnitudes, (2) The magnitude of revenue that could be collected using the different systems, (3) The impact on public transport and (4) the overall socio-economic impact of a move from toward congestion pricing.

The rest of the paper is organized as follows. Section 2 presents the state of the problem, section 3 presents the methodology, section 4 presents the results and finally section 5 presents some concluding remarks.

2. STATE OF THE PROBLEM

The Oslo toll system was implemented in 1990 to generate funds for road investments in the region; about 50% of the planned projects had been completed by 1998. The Oslo toll system includes 19 toll stations located on all the inbound roads to the central areas of Oslo. The average fee for a round trip is NOK 9 (US$ 1.3)[1]. In 1997 the system collected tolls from 85 million passenger vehicles, and the net operating revenue was NOK 737 million. The accumulated revenue is more than NOK 4000 million at the end of 1998 (US$ 666 million). The toll system is scheduled to be removed 2007. A study conducted since the implementation of the toll ring showed that the mode choice elasticity with respect to toll cost were relatively low at –0.04 and –0.014 for business and other travel purposes respectively (Ramjerdi 1995). Thus

[1] This is the average of single tickets and monthly passes. 1 US dollar is equal to 7.5 NOK

the implementation of the cordon toll system did not help reduce the level of traffic entering the city center; neither was this the intention with the cordon toll system as it was designed to generate funds for the needed road infrastructure investments in the region.

Despite the substantial increase in road capacity due the implementation of road improvement projects financed by tolls and government spending, traffic congestion in the Oslo has increased steadily in the recent years. The negative effects of this increase is widely acknowledged and include a decrease in the air quality and productivity – in terms of increased travel time, and an increase in energy consumption. The air quality problem is amplified under certain weather conditions and maximum concentration of pollutants may grossly exceed international recommendations, especially in peak periods.

A recent estimation of the marginal congestion cost for an average passenger vehicle commuting round trip in the peak periods has been calculated to be NOK 42 (US$7) (Larsen et al. [2]). Thus there is a considerable gap between private and social costs of rush hour trips in the area.

Unfortunately, an adequate response to control the growth of congestion has not been identified. The municipal authorities are aware of these congestion problems and are constantly looking for ways to alleviate them. However, the use of congestion pricing as a way of solving the problems is more and more being recognized as a possible policy option, not only by economists and planners, but also politicians.

There are however, some problems which could hinder the implementation of congestion pricing in the Oslo area. The most crucial among them is how to combine the existing cordon toll regime meant for financing road investment with a congestion pricing regime, without conflicts of interest.

In this paper we contend that although the Oslo toll scheme was implemented as a means to increase investments in the road system, it can be easily adapted to the principle of road pricing or more precisely – congestion pricing and without any significant conflict of interest. We aim to show that this adaptation will generate sufficient funds for road investments and contribute significant socio-economic benefits in terms of environmental improvement and public transport. The general approach to this study was the development of a transport model for Oslo. Four different alternative charging systems were then assumed and compared to *the status quo*.

3.THE METHODOLOGY

In order to elaborate the rationale behind congestion pricing described in this paper, a simple well-known representation is shown in Figure 1, which illustrates why urban traffic congestion occurs and why congestion pricing will optimize this level. Given the demand D, road users do not take account of the congestion that they impose on others and thus base their trip making decision on their own marginal private cost travel including travel time, tolls, fuel used etc. (MPC). They do not take into account the full marginal cost imposed on the urban road system including congestion and other environmental costs (MSC). Without congestion pricing, the road users will equate MPC with his demand and the number of trips made will be V_0. However, if the road users were made to pay for the full cost of their journey (C1), the number of trips would drop from V_0 to V_1. This effect could be achieved by imposing a "congestion charge" of (C1–C3) on the road user using the link. Of course some congestion may still remain, but the level of congestion is optimized in the sense that the marginal road user is made to base his behavior on knowledge of the full cost of his action.

To analyze the impact of alternative pricing strategies for passenger vehicles traffic in the Oslo region, an aggregate and zonal based transport model system was developed. The model is built around the well-known gravity approach to trip generation, attraction and distribution (see Willumsen et al. [5]), and logit models for mode and departure time choice (Ben-Akiva et al. [7]). The model was developed further to allow departure time choice in the peak periods. The model included four sub models each representing different typical traffic periods in the Oslo region. In all sub-models only one way trips (not round trips that are the most common for this types of models) were accounted for. No connections between the sub models are assumed.

2.1 Matrix estimation

The matrix estimation used data from a comprehensive travel survey conducted in 1992 for the Oslo region, and traffic counts for all inbound and outbound traffic passing the city boundary conducted in 1997. These data sets were combined using entropy-maximizing techniques to obtain four Origin-Destination (O-D) matrices for typical traffic periods as follows:

(i). *Morning rush hours* (from 6 a.m. to 9 am), consisting mainly of commuter traffic.

(ii). *Mid day traffic* (one hour representing an average of the period from 9 a.m. to 3 p.m.). This group is a mix of all traffic categories, but is dominated by business travel.

(iii). *Afternoon rush hou*rs (from 3 p.m. to 6 p.m.). This is a mix of traffic dominated by business, commuting and shopping travel.

(iv). *Low traffic periods* (one hour representing the average traffic situation in evenings, weekends and holidays), consisting of mostly private travel for leisure and visits.

The four matrices represent all the modeled travel activities by passenger vehicles, public transport and cycle/walk).

2.2 Logit models for mode split (and departure choice)

Based on the generalized costs of travel by different modes, a logit model was calibrated splitting the matrices into travel by passenger vehicle, public transport and cycle/walk. There is however a proportion of passenger vehicle and public transport riders who can be assumed to be inelastic to changes in level of transport service. This traffic was entered in inelastic demand matrices. The two models representing the rush traffic periods split the traffic into departure hours (one matrix for each mode and for each of the three hours of the rush periods). The mode specific generalized costs for an OD-pair is formulated as follows:

$$GC_{ct} = \beta_{ct} + \beta_i t_t + \beta_c (oc_t + pc_t + tc_t) \quad (1)$$

$$GC_{pt} = \beta_{pt} + \beta_t (t_t + \alpha_a at_t + \alpha_w wt_t + \alpha_i \# i_t) + \beta_c fc_t \quad (2)$$

$$\mathrm{GC}_{\mathrm{wct}} = \beta_{wct} + \beta_d d \quad (3)$$

Where t = in-vehicle travel time; *oc* = operation cost; *pc* = parking cost; *tc* = toll cost; *at* = auxiliary transit time; *wt* = total waiting time; *#i* = number of interchanges; *fc* = public transport fare; and *d* = distance between origin and destination. The subscript *t* denotes the time period for departure. The subscript *c, p,* and *wc,* denotes passenger vehicle, public transport and walk/cycle respectively. The beta and alpha parameters are calibrated. The calibrated parameters imply an implicitly defined (generic) *value of travel time* in the model system of NOK 36 (US$ 6) pr hour. The logit model expresses the market share for the modeled modes of travel (combinations of mode and travel departure time in rush hours models) at each OD-pair as shown in the following expression (market share of mode *i* at departure time *t*):

$$P_{it} = \frac{\exp(GC_{it})}{\sum_{mt} \exp(GC_{mt})} \qquad (4)$$

This model system is based on the idea of equilibrium between demand and supply. This works through the interaction between the passenger vehicle demand and the supply, in terms of capacity on the networks and in turn generalized cost for driving a passenger vehicle. In the rush hour models the demand and generalized cost for passenger vehicle in a certain departure hour is first calculated. The equilibrium here influences the driving conditions in the other departure hours. Thus sub equilibrium for the demand for passenger vehicle transport in each of the three departure hours is calculated several times until a grand equilibrium occurs, usually after 6-7 iterations.

2.3 The networks

The networks and models were implemented in the EMME/2 software package for transport modeling. The networks included 438 zones representing origins and destinations connected by 15000 links with different characteristics, and a varying amount of public transport lines (train, subway, tram and bus) dependent on the level of service in the period. Different volume delay functions represented the driving conditions on the road network and expressed the travel time on each link as a function of free flow speeds, number of lanes, capacity, and the traffic volumes on the links.

2.4 Fuel consumption model

The environmental impacts of congestion pricing in this study are limited to the consumption and combustion of fuel on different parts of the road networks. A very simple model was used to illustrate how less congestion could give rise to considerable environmental improvements in terms of reduced fuel consumption in the most populated and environmental sensitive areas. The model can be expressed in the following way:

$$D_i = \varepsilon x_i \left[1.25 \left({}^{v_i}\!/_{60} + {}^{60}\!/_{v_i} \right) - 1.5 \right] \qquad (5)$$

Where D_i = fuel consumption at link i; ε = minimum fuel consumption in liter pr kilometer for an average vehicle (0.08 l/km); x_i = traffic volumes on link i, and; v_i = speed on link i. The parameters 1.25 and 1.5 are turbulence factors that adjust consumption of fuel for the presence of acceleration and retardation, stop and start, which is the characteristic for trips in urban areas. The parameter 60 is the speed in km/h for which fuel consumption is at minimum. The parameters represents driving conditions in urban areas and the composition of the passenger vehicle park in Norway.

2.5 Designing alternative future congestion pricing schemes

The present system (PS) was simulated as the base case with an average toll cost of NOK 9 pr inbound trip. Since only inbound traffic is charged in the present system, we assumed that this toll cost distributed equally between the inbound and outbound trip. Public transport in the simulation was assumed to offer the same level of service as today. The following four alternatives were simulated and compared with the present system:

Alternative 1 (A1): The toll charges are differentiated over the three hours in the morning and afternoon rush with NOK 20, 40 and 30 respectively. The toll in the mid day periods (incl. Saturdays) is assumed to have the same level as today i.e. NOK 9). Between 6 p.m. and 6 a.m. on working days and in low traffic periods in weekends, the passing is free.
Alternative 2 (A2): The toll charges are differentiated over the three hours in the morning and afternoon rush but with lower fees with NOK 15, 35 and 25 respectively. Otherwise the fees are the same as A1.
Alternative 3 (A3): The toll charges are increased to the same amount in each of the three hours in the morning and afternoon rush (NOK 25). Otherwise the fees are the same as A1.
Alternative 4 (A4): Same as A3 but with free passing on Saturdays as well.

There are some practical problems connected to the model simulations of the different schemes assumed here. The current toll stations are located at inbound roads only, and there are no plans to charge tolls on outbound roads. Our simulations are most appropriate for situations where the traffic is charged on outbound trips as well. This is due to the strong assumption made earlier that the motorists divide the toll cost equally on inbound and outbound trips. Thus in our simulations for the rush periods we may obtain a distribution over time of passenger vehicle traffic on outbound trips that is not likely to occur. However, one can argue that the choice of departure time for inbound commuting trips in the morning more or less sets the departure time for the outbound (home) trip. The differentiated toll in the afternoon peak for outbound trips could capture the timing of departure time in this period.

A second problem that arises when a system based on differentiated tolls is to be introduced is the timing of the changes in tolls. Alternative 1 for instance implies a sudden increasing of charges from NOK 20 to NOK 40. The question is what the behavioral effects of a doubling of charges would be. To circumvent this problem, the exact timing of the change of prices could be drawn randomly each day from a short time interval around a certain point of time when the change should take place.

In the simulations of all alternatives the level of public transport service is adjusted to satisfy the increased demand due to more expensive passenger vehicle travel.

The alternatives analyzed in this project are all based on the present cordon. In previous projects more sophisticated tolling systems have been analyzed. All these systems are however far more difficult and costly to implement in practice. Perfect marginal cost pricing means that motorists instead of the average cost of driving are faced with the marginal congestion cost which varies with the volume capacity ratio in time and space. In such a system the exact toll of a trip is not determined until after the trip is finished, or at least until all the choices (of mode and route) are already made. In practice this type of pricing is difficult to implement.

Our test analyses of marginal cost pricing on links showed that such systems are easy to implement in a model and a considerable proportion of the benefits seemed to be connected to the route choice. We have also analyzed systems based on zone tolls. The area was divided into several zones and the motorists were charged when passing each boundary. Such a system was considerably more expensive to operate than the present system, and the benefits did not exceed the benefits of a differentiated toll on the present system to any extent.

4. EMPIRICAL RESULTS

The four pre-defined alternatives were assessed and then compared to the current situation as the base case. The results of the analysis are preferably split into three streams: (i) impact on revenue collected, (ii) impact on public transport, (iii) socio-economic benefits and (iv) environmental performance.

4.1 Impact on revenue collected

Table 1 shows the performance of the defined alternatives by revenues collected in different time periods. It is seen that under the current system the off-peak traffic contributes more than one third of the total revenue collected while the peak traffic contributes with only one third of the revenue collected. One of the aims with a change of regime to a system based on congestion pricing is to obtain a more appropriate distribution of taxation of the motorists. Thus, the current pricing regime in Oslo is such that the motorist driving in periods more or less characterized by free flow of traffic and low utilization of road capacity subsidize to a great degree investments in more capacity on the road network i.e. capacity needed by the peak traffic.

As can be seen, from Table 1, implementation of road pricing strategies proposed will increase the revenue in peak periods for all alternatives. These systems are only operated between 6 a.m. and 6 p.m. in weekdays and between 9.a.m. and 3 p.m. on Saturdays. Collected in off-peak periods. In A4 collection on Saturdays is also eliminated. This alternative is also the one with total revenue closest to the present level. The slight reduction of revenue in mid day hours is due to improved public transport. This effect is explained in the next section.

Thus it may be concluded that a congestion pricing system can be formulated such that more funds are attainable than with the current system. Thus a congestion pricing will not necessarily be in conflict with the current pricing regime where the aim is to obtain funds for road financing. This latter fact may make congestion pricing acceptable both to the public and policy makers in the road sector who's main interest is to see funds being generated for road improvement. We however, acknowledge that there are no economic reasons for earmarking of funds collected from road pricing scheme for road improvements

[INSERT TABLE 1]

4.2 Impact on public transport

The traffic situation in the morning peak periods in large measure determines the capacity of public transport services. Public transport capacity will most likely need to be increased with congestion pricing, as some motorists not willing to pay the increased toll will look for other means of transport. A procedure was thus developed in the model system to increase the frequencies on transit lines to cater to increased demand for public transport in the peak periods.

This procedure differentiated between transit lines that are part of the base service (lines that are operated non-stop) and transit lines that are just operated in peak periods. If the frequency of a base line is increased to satisfy the increased demand in the peak hours this yield also in low traffic periods. This is a great advantage in terms of cost effectiveness for production of the public transport service. It is much less expensive to operate new public transport vehicles all day than it is to operate them only during a few peak hours (Larsen [4],). Another impact is that the improved level of service also attracts new riders to public transport and that it represents benefits for the initial public transport users as a result of increased frequency. Thus, the impacts of congestion pricing on public transport are readily quantified into two categories; a) changes in demand for public transport and b) impact on income and operation costs for public transport as follows.

4.2.1 Changes in demand for public transport

The logit models for the four periods were used to calculate the changes in demand for public transport. The changes are influenced by several mechanisms with different implications for the modeled periods. In the peak models the main impact is caused by increased cost of passenger vehicle use. This reduces the volume of passenger vehicle traffic and reduces the costs for the remaining passenger vehicle traffic. The model iterates between demand and supply until the generalized travel costs clears the market, i.e. an equilibrium is obtained between demand and supply in departure hours and on modes. Increased market share on public transport requires higher capacity in public transport. This demand is met by higher frequencies on transit lines that get congested when the tolls are increased. If the lines are part of the base services the higher frequency is maintained also in between the peak periods. As a result the demand for public transport between peaks increases even though the toll is assumed fixed at the present level. In low traffic periods the toll is completely removed but public transport remains improved.

Table 2 shows the results of changes in demand for public transport that may be achieved by alternative strategies for congestion pricing as compared to *status quo*. Public transport is estimated to increase by 4.5% to 6.5% on an annual basis compared with the present situation. Strategy A1 has the greatest impact on demand for public transport. This is not surprising as strategy A1 is the alternative with the highest charges and hence will toll-off the largest number of motorists. Thus the planners and decision-makers wish for increasing the share of public transport within the city can be achieved by a move toward congestion pricing. This increase in demand for public transport will also have an impact on income and costs for public transport as discussed in the next section.

[INSERT TABLE 2]

4.2.2. Income and operation costs

The income generated from improved public transport is relatively easy to estimate once we have estimated the effects on demand. In relation to Table 2 it is easily postulated that income from public transport is likely to increase the most in peak hours and is most likely to drop as compared to the current system.

The estimation of operation costs is far much difficult. The following formula was suggested and used for calculation of time and distance dependent cost:

$$C_t = \sum_L \left(v^L \tau^L + d^l v^L \delta^L \frac{60}{h^L} \right) \qquad (6)$$

Where C_t = total operating costs in an hour t; v^L = number of vehicles needed to operate the transit line L; τ^L = cost pr hour for line L; d^L = total distance of line L; δ^L = cost pr km for line L; h^L = time of a roundtrip with line L. The first component of (6) expresses the time dependent cost of operating a transit line, and the second component expresses the distance dependent cost.

The first component of (6) is dominated by the labor costs for the operator of the vehicle, and the second component contains costs of fuel, oil, etc. The cost of positioning of the vehicle is excluded. The unit costs vary by type of vehicle. The summation over all transit lines gives the total operating costs in hour, t.

The fixed cost of public transport is assumed constant except of capital costs that are calculated on the basis of the need for investments in extra vehicles. In the different analyzed alternatives there is a need for between 122 and 142 new vehicles or train/tram/subway sets. The capital costs however are difficult to trace back to a certain operating period and are therefore not considered here, although we realize that this is a weakness.

Figure 2 shows the impact of alternative congestion pricing strategies on income and operation costs for public transport. We note that the increased cost of operating the public transport exceeds the increased income

[INSERT FIGURE 2]

4.2.3 Environmental performance

In Norway the tax on fuel and vehicles is among the highest in Europe, perhaps even in the world. Previous studies have shown that an average motorist in Norway more than covers, through taxes, the average negative external impacts he causes (Larsen [2]). These studies have shown, however, that during peak periods the taxes do not fully cover external costs. Thus there is a reason to believe that the implementation of congestion pricing of the type described in the previous sections will contribute toward reducing externalities in the peak periods. The Oslo region is the densest populated area in Norway, with a large proportion of the population exposed to the local pollution from the traffic. Environmental quality is of great importance and interest to the public.
The fuel consumption equation in (5) was used to investigate the impacts of the congestion pricing regimes. The results are presented in Table 5.

[INSERT TABLE 3]

The figures in Table 3 coincide satisfactorily with fuel sales in the Oslo region. As can be seen the consumption on the road network inside the present cordon, which is the most sensitive area, is reduced by 14 % to 18 % in rush hours. The reduction of fuel consumption for the whole area is between 10 % and 14 % in the rush hours, while the annual reduction for the whole area is about 4 %. This is a considerable energy saving; in addition it is an environmental improvement.

4.2.4 The overall socio-economic benefits

Estimating social benefit from transport policies has been a subject of discussion in the literature. Larsen [4] suggests the following expression as a measure of social benefits

$$\left\{\begin{array}{l}\text{Consumer surplus}\\ +\text{ Revenues form congestion pricing}\\ +\ \text{ Income from public transport}\\ \ \text{- Operating cost for public transport}\end{array}\right\} \qquad (7)$$

All the components of this expression are already accounted for in the previous sections except for the term “consumer surplus”. In cost-benefit analysis of transport projects consumer surplus often is the most important component on the benefits side. To estimate the user benefits "*the rule of the half*" is often applied. A change in consumer's surplus in this method is estimated as changes in generalized cost times the average demand before and after the introduction of the project as shown in (8).

$$CS = \frac{1}{2}(GC_1 - GC_0)(X_1 - X_0) \qquad (8)$$

Where GC_0 = generalized costs before implementation; GC_1 = generalized costs after implementation; X_0 = demand before implementation; X_1 =demand after implementation. In our analyses however there are changes in generalized costs both for motorists and for public transport users. In the rush hours models the changes also vary with departure time. Thus we have applied an alternative method of estimating the consumer surplus, based on the well-known property of the logit model. Changes in the logsum of the logit model are conceptually equivalent to the traditional consumer surplus indicator shown in (8)(see De la Barra [7] for instance). The logsum can be expressed as

$$LS = \frac{\ln(\sum_{it} \exp(GC_{it})}{\beta_c} \qquad (9)$$

Where GC_{it} = is the generalized costs expression in the model for mode i at departure time t shown in (1), (2) and (3); β_c = the model parameter for monetary costs.

Figure 3 summarizes the calculation of consumer surplus made for the alternatives analyzed in this project. The commuters in the peak periods become worse off in all the alternatives. This is due to the increased tolls. The traffic in midday periods become better off due to better public transport and slightly improved accessibility on the road network. Since tolls are assumed in the low traffic periods, the traffic in low traffic periods becomes much better off.
The negative impacts in peak periods are one the main reasons why this type of policy for a long time has not been accepted among decision-makers and the general public. However, in recent years the problems created by congestion i.e. demand for road capacity, environmental deterioration, has been in focus and congestion pricing is being actively considered as a solution.

The overall socio-economic impact of the analyzed alternatives, calculated by (7) is shown also shown in Figure 3. In the figure we have also included the capital cost due to investments in new transit vehicles to meet the new demand. We have however not included the effect of environmental performance as we lack prices for these effects. The fact that the impact on environmental performance is positive implies that the socio-economic benefits will be even larger than the table shows.

[INSERT FIGURE 3]

Figure 3 suggest that all the analyzed alternatives are profitable from an socio-economic point of view. Ideally one should choose the most profitable among them.

5. CONCLUDING REMARKS

The Oslo Cordon toll system, in its original form was designed to collect funds from road users for road investment purposes. Increasing environmental problems caused by road traffic within the inner city raises the question as to whether motorists should be made to pay the full social cost of their trips. Both the local and central authorities are looking for ways to deal with the Oslo problem. Specifically, the question that is being raised now is whether a move toward optimal congestion pricing would generate any benefits worth consideration.

In this paper, we have demonstrated that such a move will generate significant social benefits worth consideration. Specifically, we have shown that a move from cordon tolls towards congestion pricing will:

(i) Raise the revenue substantially as compared to the current situation. This is because in a congestion-pricing regime, the peak traffic is taxed more in line with marginal cost pricing as compared to the current situation where peak traffic contributes only one-third of the total revenue collected.

Optimal congestion pricing increases the costs of passenger vehicle use and therefore reduces the traffic volume. This in turn increases demand for public transport as well as reduces travel time for the remaining traffic. Increased demand for public transport implies increased income for public transport. Arguably, congestion pricing leads to an improvement in environmental conditions as it reduces passenger vehicle traffic. (iii) Even though the cost for public transport will increase, the sum of consumer surplus and income to public transport will be large enough to offset it. Thus the total social benefit for moving from cordon toll to congestion pricing will be greatly positive.

There is however, one area that this research has left untouched. In involves optimal pricing in general. Optimal pricing in transport is an attempt to set the prices right not only in the road but also across sectors. Ideally, optimal pricing in public transport should also have been also considered. This however, is left for future research.

Our study has thus identified a number of points that are of direct relevance for marketing of congestion pricing in Oslo. Previous studies on user attitudes towards the Oslo toll ring have shown that the public are more likely to accept the pricing regimes if the intentions are positive and are of given direct tangible benefits to them (Odeck and Bråthen [8]). One way of demonstrating the positive impacts of congestion pricing would be by trying it out as a case example. In this respect Oslo is a suitable case in that its results may be used in other cities facing the same problems under similar conditions such as such as Trondheim and Bergen, the second and third largest cities in Norway. The bottom line is that a move from current cordon toll to congestion pricing will improve both the environmental quality and the quality of transport services in these cities.

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Tables

Table 1: The performance of the alternatives pricing systems by revenues collected in different time periods.

Table 2: changes in demand for public transport achieved by alternative congestion pricing strategies as compared to the current system

Table 3: Expected changes in fuel consumption due to alternative pricing strategies

Table 1: The performance of the alternatives pricing systems by revenues collected in different time periods.

Tolling regime	*Morning rush hours*	*Afternoon rush hours*	*Mid day traffic*	*Low traffic periods*
Current system	19.4 %	14.5 %	32.0 %	34.1 %
A1	43.3 %	11.1 %	45.5 %	0.0 %
A2	42.3 %	12.3 %	45.5 %	0.0 %
A3	41.1 %	12.3 %	46.6 %	0.0 %
A4	43.4 %	7.5 %	49.2 %	0.0 %

Table 2: changes in demand for public transport achieved by alternative congestion pricing strategies as compared to the current system

	A1	A2	A3	A4
Morning rush	*13.2 %*	*10.4 %*	*9.7 %*	*9.7 %*
Afternoon rush	13.7 %	10.7 %	10.5 %	10.5 %
Between peaks	3.4 %	3.3 %	3.0 %	2.0 %
Other periods	-2.1 %	-2.2 %	-2.5 %	-2.5 %
Total	6.5 %	5.0 %	4.6 %	4.5 %

Table 3: Expected changes in fuel consumption due to alternative pricing strategies

	Total	In peak periods	Inside cordon system	Inside cordon in peak periods
A1	-4.70 %	-14.00 %	-5.80 %	-18.00 %
A2	-3.70 %	-11.30 %	-4.60 %	-14.50 %
A3	-3.60 %	-10.90 %	-4.40 %	-13.90 %
A4	-3.50 %	-10.90 %	-4.20 %	-13.90 %

Figures:

Figure 1: Theory of congestion pricing

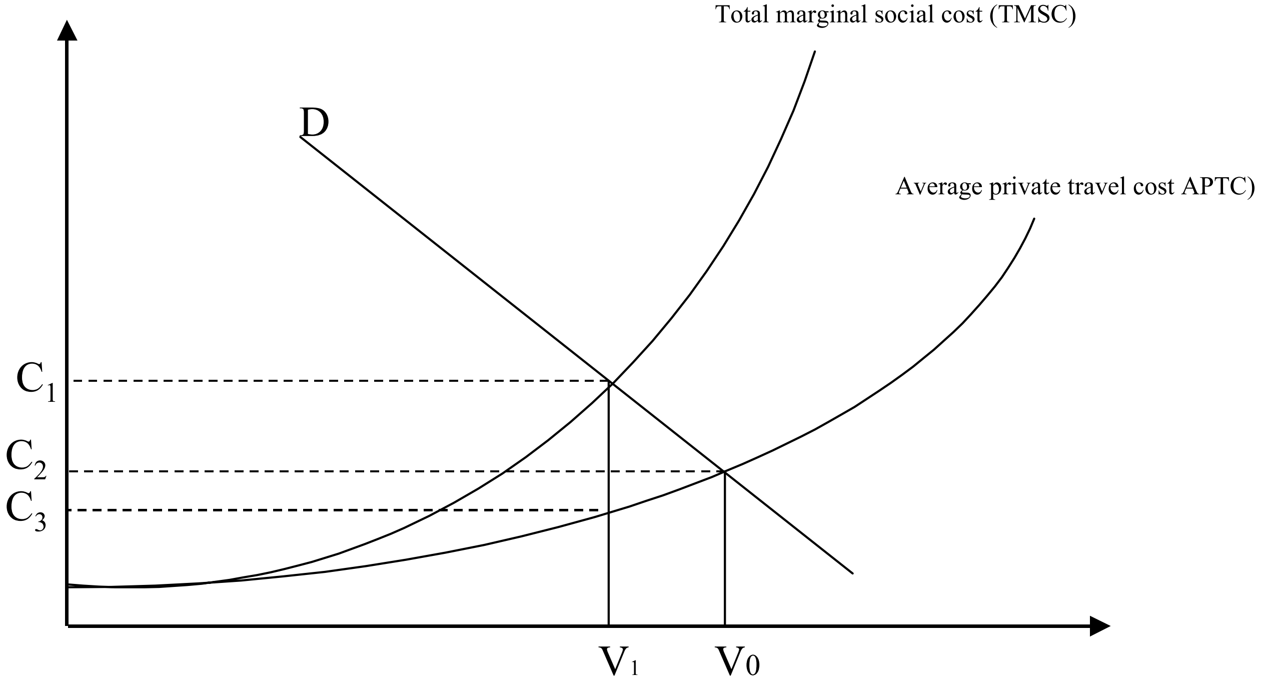
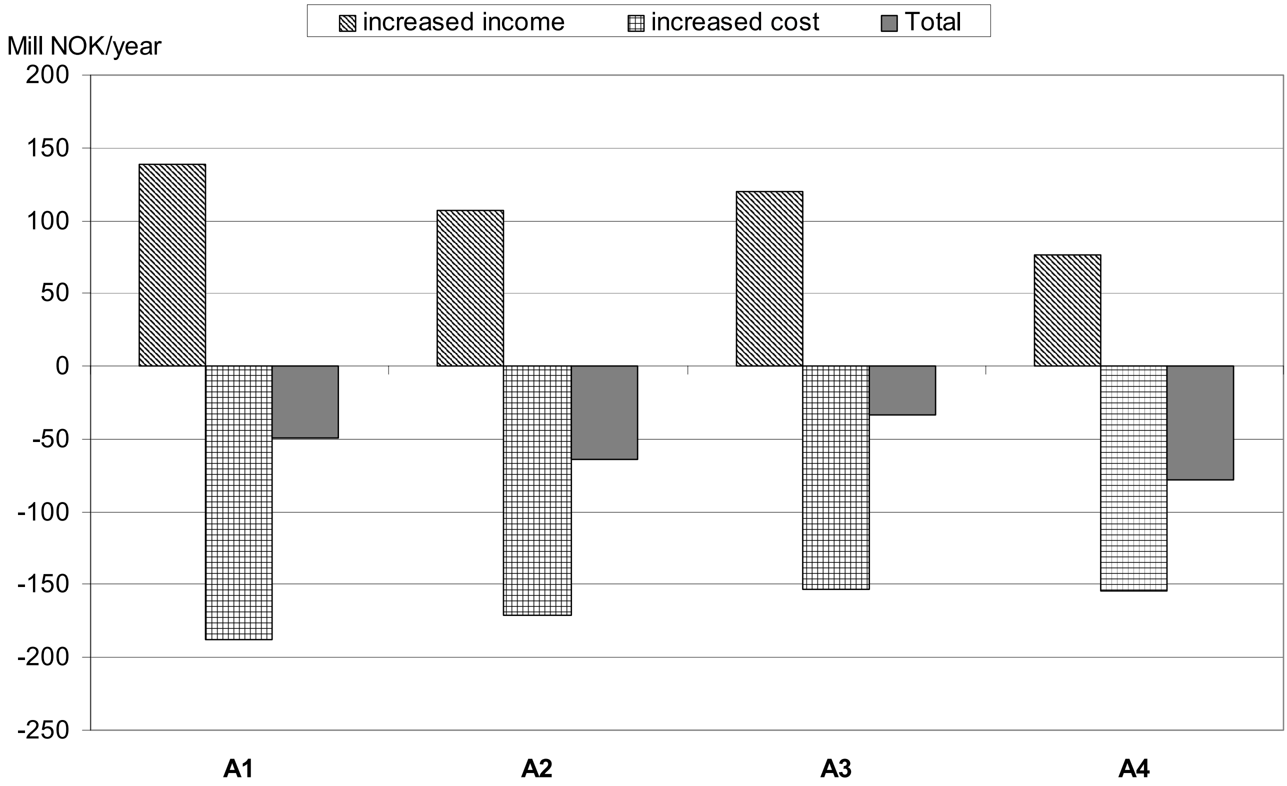


Figure 2: the impact of alternative congestion pricing strategies on income and operation



costs for public transport.

Figure 3: The socio-economic impact of alternative congestion pricing strategies