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CURBING OPERATIONAL COSTS OF ROAD USER CHARGING SCHEMES: THE NORWEGIAN EXPERIENCE

1 INTRODUCTION

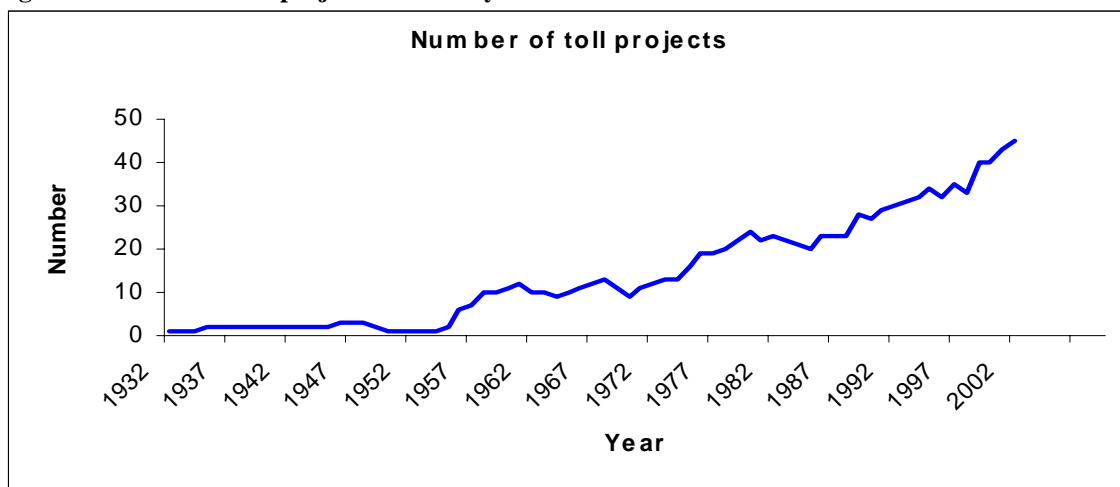
Toll financing in Norway has been used to finance new roads as a supplement to public funds for more than 70 years. While bridges often were subjected to tolls hundreds of years ago, toll financing as we know it today started in the early 1930s when the Vrengen bridge situated near the town of Tønsberg were financed using tolls. Since then over 100 projects have been financed by tolls and only one has ever been declared bankrupt¹.

Traditionally, tolls were used to finance bridges and tunnels to replace ferry connections, but the 1980s saw an increase in both the number of and the type of projects financed by tolls. A reduction in road investment budgets coincided with a liberalisation in the credit market, making tolls a natural alternative. Traffic was growing rapidly and congestion was starting to have a severe impact on traffic flows in the largest cities. This led to the implementation of cordon tolls in the cities of Bergen, Oslo and Trondheim in the years 1986 to 1991. The revenues from the toll cordons (now numbering seven) still make up the bulk of the total toll revenues.

Today there are some 48 toll projects in operation and the numbers are increasing. The net revenues from toll financing make up 25 to 30 percent of the annual budgets for road construction. Norwegian motorists spend averagely 165 euros per vehicle per year on tolls².

The figure below illustrates the development in the number of Norwegian toll projects:

Figure 1: Number of toll projects in Norway

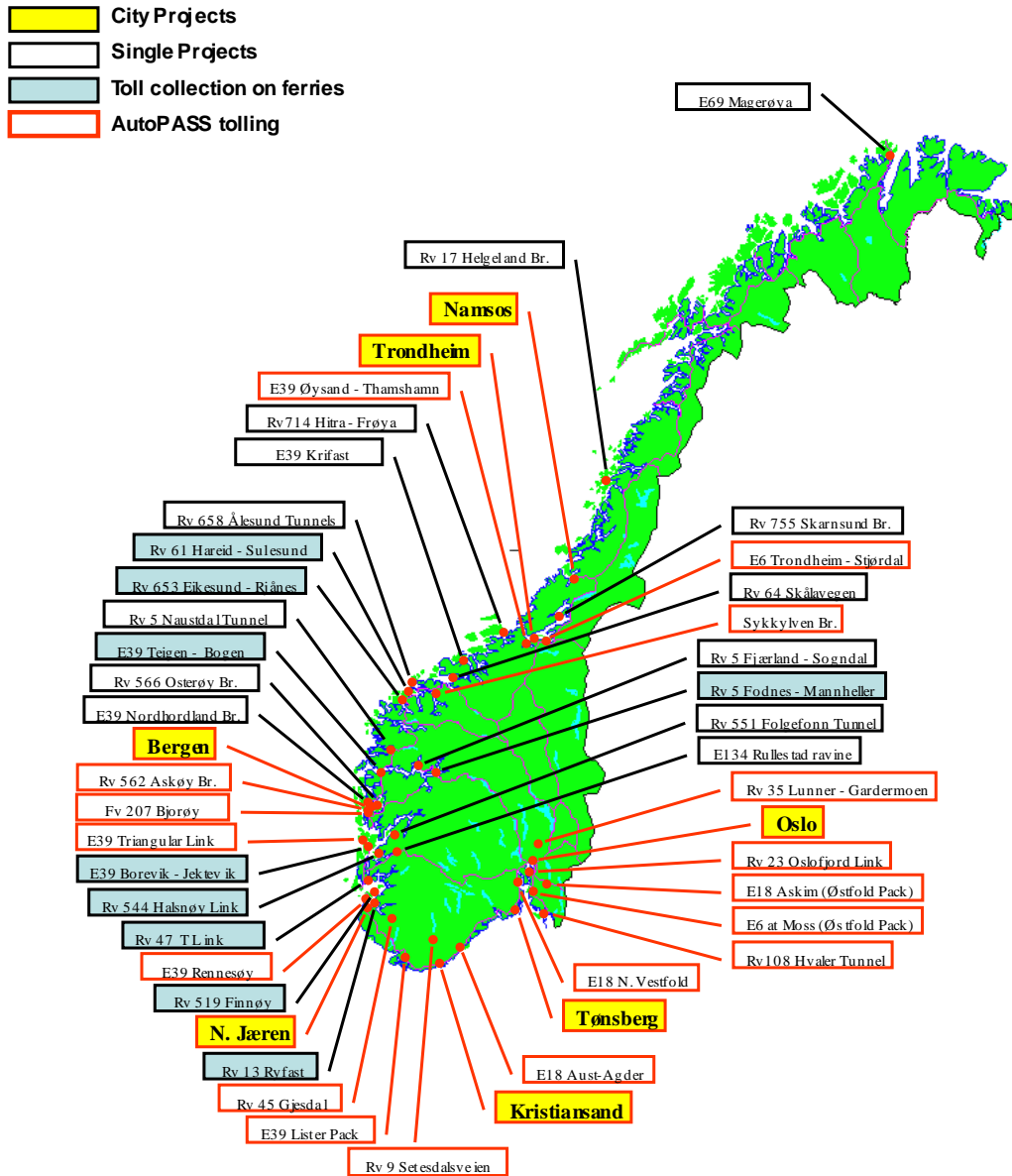


¹ The Ålesund tunnel in the western part of Norway was declared bankrupt in 1994.

² The currency in Norway is kroner. 1 euro equals some 8 kroner,

Figure 2: Tolling projects in Norway.

Tolling Projects in Norway, spring 2004



The figure shows all the tolling projects in Norway. Among the 24 toll projects with AutoPASS payment system seven of them are toll rings. Toll projects without AutoPASS are typically tunnels and bridges which started tolling before AutoPASS were introduced in 1999.

2 THE MODEL

A model with variables covering all characteristics of toll projects can ease the planning of new toll projects by providing more precise estimates of the net revenues and reducing the risk of financial default. Estimating the operational costs can be done by estimating a cost function that shows how costs vary with the factors that influence them. Such a function can also be used for assessing the relative efficiency of the toll companies.

Econometric estimation of a cost function requires the use of an appropriate functional form. There are a number of functional forms available and the choice of functional form is vital for the specification of the model. Using a wrong functional form is a specification error that violates the classical assumptions which must be met for the OLS estimators to be the best available. The choice of functional form should always be based on the underlying theory.

The most commonly applied functional form for estimating cost functions are different logarithmic functions.

In the following we adopt a log-linear function combining variables by the equation:

$$\log Y = \beta_0 + \beta_1(\log Traffic) + \beta_2(\log Traffic)^2 + \beta_3(\log Lanes) + \beta_4(\log Size) + \beta_5(Age) + \beta_6(Age)^2 + \beta_7 OBU + \delta_1(TR) + \delta_2(PC) + \delta_3(EFC) \quad (1)$$

In equation (1), logY will measure the average operating costs per paying vehicle. The equation entails flexibility regarding the scale economies. In the case of $\beta_1 < 0$ and $\beta_2 > 0$, the operating cost per vehicle as a function of traffic will be U-shaped.

The model is based on total operating costs being the dependent variable, 6 explanatory independent variables and 3 dummy variables. The complete set of variables used in the study is shown in the table 1.

Table 1: List of variables

<i>No</i>	<i>Variable</i>	<i>Measure</i>	<i>Explanation</i>
1	Operating Costs (Y)	Scale	Average operating costs per paying vehicle
2	Traffic	Scale	Total number of paying vehicles (in thousands) per year
3	Size	Scale	Total debts by the end of each year (in millions)
4	Lanes	Scale	Number of lanes in the toll station (-s)
5	Age	Scale	Number of years since the opening of the project
6	OBU	Scale	Percentage of vehicles using on board units (OBUs)
7	Toll Ring (TR)	Categorical	Toll ring or other type of project
8	Passenger Charging (PC)	Categorical	Passenger charging or not
9	EFC	Categorical	Whether the project is using EFC or not

2.1 Hypothesis Concerning the Parameter Values

It is the average cost curve that will have the most profound implications in determining cost structure and efficiency. In the following, we will therefore focus on the average cost curve.

There are no previous studies of the costs of Norwegian toll financing. Which shape the average cost curve holds is therefore to be demonstrated.

It is reasonable to believe that as traffic increases, cost per vehicle will decrease ($\beta_1 < 0$). Our initial presumption is also that $\beta_2 > 0$, that average costs will start to increase after a certain level.

The number of lanes in a toll station will influence the need for staff. As staff goes up, average costs will go up and our presumption is therefore that $\beta_3 > 0$.

The size variable does not necessarily measure the size of the project in road kilometres or traffic levels, as the total debts will decrease over the tolling project. A large project in terms traffic levels will thus have lower debts as the year since opening increases. Financial management is an important part of the responsibility of the toll companies and it is reasonable to expect average costs to increase as debt increases, that is, $\beta_4 > 0$. Our hypothesis is therefore that the toll companies puts more effort/uses more manpower, in handling financing costs, in a situation of larger debts.

The operating costs are adjusted to 2003-levels by using the consumer price index calculated by Statistics Norway, and any increase in cost over time must thus be real increases. As the toll companies gather experience and introduce more efficient technology and organisational solutions, we would expect costs to decrease. Our a priori assumption is therefore that $\beta_5 < 0$. The time trend variable is squared to test whether there is an ideal length of the toll collection period.

As the number of cars equipped with OBUs increase, the need for employees to man toll stations will decrease. As the labour costs are the dominating costs, projects with a high OBU share will have lower average costs than those with a low OBU share or those not using EFC at all. Therefore, our assumption is that $\beta_7 < 0$.

Concerning the parameter values of the dummy coefficients, the toll rings have huge traffic levels. Although a large number of toll stations will increase costs, there is reason to believe that economies of scale are present for toll rings and that $\delta_1 < 0$.

Charging for passengers is only done in fixed link projects that have replaced ferry crossings where passengers traditionally have been charged. It is impossible to combine EFC and passenger charging and these projects might therefore be more labour intensive. Our assumption is thus that $\delta_2 > 0$.

Electronic fee collection requires more expensive tolling equipment but enables huge savings in labour costs. We therefore expect projects with EFC to have lower average costs, that is, $\delta_3 < 0$.

3 DATA

The data for this study was obtained from the NPRAs database containing data from the annual financial statements compiled by the toll companies. In the cases where information was incomplete or missing, the toll companies were asked directly. The data set consists of data from 24 toll companies over the years 1998-2003 and includes 5 toll rings, 5 highway projects and 14 fixed link projects. Only observations from years where there were no significant changes in the operations were included. This means that for some toll companies there are observations for all 6 years while for others we only have observations for one or two years. Some toll companies are not included in the sample because of their non-representability. The sample has a total of 113 observations.

Since the data collected refer to different years, we need to establish a common time reference. This was done by adjusting the data to 2003 price levels using the consumer price index calculator provided by Statistics Norway (available at: <http://www.ssb.no/kpi/>).

A data set like this, where multiple entities are observed over two or more time periods are usually referred to as panel data. Estimation with panel data is useful when a cross sectional data sample would provide us with too few observations. Likewise, repeated observations on the same entities allow us to specify and estimate more complicated and realistic models than a single cross-section or time series model would do. Therefore, estimators based on panel data will often be more efficient than a series of independent cross-sections (Verbeek, 2000).

Panel data can be both balanced and unbalanced. In a balanced panel all the variables are observed for each entity and for each time period. An unbalanced panel has some missing observations for at least one time period for at least one entity. Our data set for the Norwegian toll companies is an unbalanced panel. This makes the estimation more computationally demanding. However, as opposed to other studies using panel data, our study covers only a very short time period. It can therefore be argued that the data can be pooled, that is, the data set can be treated as a cross sectional set of independent observations. In the following, the estimation will be based on a cross sectional approach. This is more simplistic than a panel data approach but we assume that the results will be similar regardless of how the data is treated. The data set includes some 55 percent of the projects in operation over the period.

4 EMPIRICAL RESULTS

In the following chapter the results of our findings are presented.

4.1 Summary statistic

The average operating costs vary considerably among the toll companies. Table 2 gives the summary statistic for the average costs (all figures are in Euro):

Table 4: Summary statistics - average costs

	Statistics
No. of cases	113
Mean	€0.83
Standard deviation	€0.86
Median	€0.70
Minimum	€0.09
Maximum	€4.79

The large discrepancy between the observations might be an indication that the performance of the toll companies, their efficiency, vary as well. That is, however, not the focus of this paper.

On the other hand, large cost differences might have consequences for the viability of the projects. If we assume that the total costs of toll financing consists of the operating costs and the social costs of diverted traffic³, the viability of the projects will depend heavily on the costs of collecting the tolls. The cost-/revenue ratio in Norwegian toll projects vary between 5 and 35 percent – a clear indication that some projects should rather have been financed using public funds (or indeed; not been realized at all). Thus, if we can reduce the operating costs of toll projects, this can be a major contribution to increasing the viability of Norwegian road projects.

Table 3 illustrates the distribution of average operating costs. The majority of the toll companies in the sample have average operating costs below 0,9 Euro but there are a significant number of companies whose operating costs exceed 0,9 Euro per vehicle. There are even 12 projects, or 11 percent of the sample, that have operating costs above 1,6 Euro. This indicates that there might be efficiency differences between the toll companies. These differences can be illustrated by the use of a cost function and how the residuals relate to the estimated function.

Table 2: Distribution of companies by average operating costs

Average Operating Costs	Number of Companies	Percent of Companies
€0 – 0,30	36	32%
€0,31 – 0,89	41	36%
€0,9 – 1,59	24	21%
€1,60 -	12	11%
Total	113	100%

³ In this study, we ignore the cost difference between private and public finance.

Table 4 gives the statistical characteristics of the independent variables. As was the case with the average costs, the data set of the independent variables covers a wide range. This will increase the risk of heteroskedasticity (that the distribution of the error term has a non-constant variance), but logging the variables will normally reduce this problem. Nevertheless, it is important to bear this in mind when considering the estimated equation.

Table 3: Summary statistics of the independent variables

Variable	Mean	Std. Dev.	Median	Minimum	Maximum
Traffic	8.760.110	20.148.810	995.665	93.338	89.497.561
Size	375.040	424.160	210.000	0.00	1.735.650
Lanes	11.19	33.59	2	1.00	65
Age	7.46	3.84	8	0.00	17
OBU	19.63	17.68	0	0.00	93.62

4.2 Regression Results

The regression model is run using equation (1)⁴. The results of the estimations are presented in table 5 and suggest some interesting findings. We notice that the adjusted-R-squared is 0.94 implying that the estimated equation explains about 94 percent of the variation in average operating costs. This is a very good overall fit and suggests that the estimated model is close to the true model. Except for β_5 , the t-values of the coefficients are all very high, with a statistical significance at the 1 percent level.

A plot of the residuals shows no systematic derivations from normality. However, in cross sectional data sets there is always a risk that the assumption of homoskedastic error terms is violated. Faced with potential heteroskedasticity the estimation is therefore based on heteroskedasticity robust standard errors. The size of the heteroskedasticity robust standard errors can be larger or smaller than the normal standard errors (Woolridge, 2003).

The Durbin-Watson d-statistic of the estimation is 2.3 implying that serial correlation causes no problems in the estimation.

Table 5: Estimated regression results

Variables	Coefficient	Std. error	t-value
β_0 constant	7.435	0.473	15.693
β_1 log Traffic	-1.278	0.115	-11.086
β_2 log Traffic ²	0.039	0.009	4.626
β_3 log Lanes	0.731	0.080	9.131
β_4 log Size	0.049	0.011	4.686
β_5 Age	-0.032	0.019	-1.692
β_6 Age ²	0.005	0.001	3.440
β_7 OBU	-0.009	0.001	-7.840
δ_1 Toll Ring	-0.859	0.171	-5.019

⁴ The regression package used was LIMDEP 7.0

δ_2 Pass. Charging	0.301	0.062	4.890
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$N = 113$

$\bar{R}^2 = 0.94$

$F = 185.62$

As expected, the values of β_1 is negative and β_2 is positive. The value of β_2 is very small and using equation (2) we find that as traffic moves towards infinity, the slope of $\log Y$ goes towards zero. That is, average operating costs increases on a decreasing rate. Our findings suggest that there are strong scale economies present in the relationship between average costs and traffic, at least over the traffic levels experienced in Norwegian toll projects. The larger the project, the lower the operating costs. Even though we can conclude that the traffic level at which average costs reach their minimum are outside the reach of all of today's toll companies in Norway. The shape of the cost curve indicates that all the present levels of traffic are smaller than the level that would minimise costs.

We find that the number of lanes is the most important cost driver in toll projects. This is not surprising. Tolling equipment such as toll booths, coin machines and other road side equipment is expensive both to purchase and to maintain, and by increasing the number of lanes in a toll station, the operating costs will increase. The value of β_3 is positive and shows that when the number of lanes increase by 1 percent, average operating costs increase by 0.73 percent. Hence, if a project in which tolls are collected in 10 lanes adds one extra lane to its toll station (-s), the operating costs per vehicle are likely to increase with 7.3 percent, assuming all other variables remain unchanged.

Furthermore, the size of the projects β_4 , measured in total debts in the end of each year will influence costs positively, that is, a 1 percent increase in debts (in millions) will increase costs by 0.049 percent.

The results show β_5 to be negative but it is not statistically significant at the 5 percent level (but at the 10 percent level). We can draw the conclusion that the toll companies' operating costs decrease by 3.2 percent ($\beta_5 * 100$ percent) per year in real terms but further studies are necessary to determine whether time has cost reducing effect or not. The value of β_6 indicates that the age curve takes on a U-shaped form although the insignificant value of β_5 makes any final conclusions about the shape difficult to make.

The most important technological innovation in Norwegian toll collection is the introduction of electronic fee collection and especially the development of the AutoPASS-standards for tags and central system. This has reduced the need for cash handling and staff and therefore, as expected, β_7 is negative. That is, as the percentage of vehicles using OBUs increase with one percentage point, the average operating costs will decrease by 0.9 percent. Thus, if a project manages to increase its OBU-share from 60 to 80 percent, operating costs should decrease 18 percent.

The dummy variable for toll cordons, δ_1 , is negative. This means that we can conclude that toll cordons have substantial lower average costs than other toll projects. One explanation for

this remarkably high estimate is benefits from scale economics and extensive use of modern technology, a characteristic of all Norwegian toll cordons.

Projects with passenger charging, on the other hand, are often characterised by a simplistic or no technology and low traffic levels. And as expected, δ_2 is positive, indicating a cost disadvantage for projects who charge passengers as well as vehicles.

After the introduction of the AutoPASS-technology few, if any, new projects will be based on passenger charging. Given the huge cost disadvantage of the toll companies that are charging passengers as well as vehicles – the practice of passenger charging should be abolished as soon as possible. Considering the usually very low traffic levels in these projects, one must also consider whether other types of financing such as shadow tolls or public funds are more suitable in these, usually fixed link projects.

This is similar to the conclusions in other studies which have found the welfare effects from introducing tolls to be lower on urban motorways than on rural roads (Odeck m.fl, 2003). The cost of toll financing is lower than public finance when the traffic level is high and the toll is low. From a social perspective it is also worth noticing that it is usually easier to provide alternative modes of transportation in urban than in rural areas and that the elasticity of high tolls is higher than the elasticity of low tolls. This may have implications for public acceptance as well.

5 RECOMMENDATIONS FOR THE FUTURE

Norwegian toll financing has not been subjected to any cost studies in the past and the design of the projects have thus not focused on how operating costs can be minimised. The results in table 5 offer some interesting implications for the design and organisation of future toll projects.

5.1 Technologies employed

There seems to be strong economies of scale in the relationship between operating costs and traffic over the traffic levels experienced in Norwegian toll projects. As traffic increases the average cost curve is rather flat. The reason for this is probably that once one or more toll stations are in operation, the marginal cost per extra vehicle is very low. The toll companies are not responsible for any maintenance of the road, only the toll station and the toll station area in itself, and the deterioration of the tolling equipment caused by an extra vehicle is probably non-noticeable in the short run. However, it is likely that as traffic increases, stepwise increased costs will occur due to an increased need for lanes and employees.

The number of lanes is the most important cost driver in toll projects. This is not surprising. Tolling equipment such as toll booths, coin machines, antennas and cameras is expensive both to purchase and to maintain and by increasing the number of lanes in a toll station, the operating costs will increase. To minimise the operating costs new projects should therefore focus on technological solutions that not only minimises the need for staff and toll booths but also for coin machines and other equipment that requires the motorists to stop. A combination of few lanes and a high OBU share will therefore be an optimal solution if one wishes to keep the operational costs at a minimum.

As indicated by the remarkably high coefficient of the toll ring dummy variable, it seems that toll rings are the projects that most successfully have managed to combine these factors in

order to keep costs at a minimum. Both the traffic levels and the OBU share are high in toll rings and extremely high cost of land acquisition in urban areas implies that the number of lanes must be kept to a minimum.

5.2 The role of legislature

We believe that there is a strong potential for costs reductions in Norway not just through an optimal design of the projects but also through changes in the current legal arrangement under which the toll collection operates.

Exemptions and discounts play an important role in securing public and political acceptance for different toll projects. However, as the average discount in many projects reaches 40 percent and a large number of vehicles are exempted from paying the toll, arrangements like this will strongly affect the revenues generated by the toll projects.

5.3 Organisational framework

Considering the results in 5.1, rethinking is needed within Norwegian toll financing. Projects must be planned, not only to maximise revenues, but also to minimise the operating costs. The results of this study show that the design of the toll projects is vital to keeping operating costs at a minimum level. There is a potential for cost reductions if the size of the toll projects are increased and hence a case for fewer and larger toll companies. Any equity issues must be addressed outside the realm of toll financing as increased fairness inevitably will increase costs for all motorists.

5.4 The structure of financing

Our analysis indicates that the size of the project, measured in total debts at the end of each year, will increase the costs. In order to achieve this effect the toll companies seek the best interest rate at all times. Even though Norwegian tolling projects are considered relatively safe, lenders do calculate with some risk. Due to the economical status the country of Norway finds itself, it may be wise that the government offered such loans to toll companies. So far no loans or guarantees have been made from the Norwegian government.

5.5 Summing up

To sum up our findings in order to design an optimal toll collection system these conditions are crucial for lowering the operational cost:

- Few lanes with no toll booths and coin machines
- High OBU share
- No passenger charging
- High traffic level
- Tolling in urban rather than rural areas.
- No discount, just one basic fee for each class.
- Bigger tolling projects and fewer toll companies.
- For Norway – governmental guarantees for loaning.

The project categories that most successfully have managed to combine these factors in order to keep costs at a minimum are the toll cordons. Both the traffic levels and the OBU share are high in these projects. The extremely high cost of land acquisition in urban areas have resulted in a greater focus on keeping the number of lanes in toll cordons at a minimum as well. This has encouraged new technological solutions such as the fully automatic toll stations that were implemented in Bergen and Tønsberg in February 2004. These toll stations

eliminate the need for coin machines and uses only as many lanes as the traffic flow requires. Motorists pay through the tag on their windscreen. Those without tags will have their number plate photographed and are later invoiced by mail.

Figure 5: Fully automatic toll stations at Gravdal in the city of Bergen.



Some few steps towards a more efficient operation of road user charging schemes have been done in Norway. By introducing road user charging schemes like those in Bergen and Tønsberg we are moving in the right direction with respect to the technology.

The Norwegian experience suggests that low operating costs are feasible if focus is on minimising these. Although average operating costs per vehicle of €0.08-0.1 and cost-/revenue ratios of 5-8 pst. are internationally highly competitive, the NPRA are planning to increase its focus on operating costs in the years ahead. The current large cost differences between the toll companies are unacceptable. As new and improved technology is introduced, the structure of financing and the legal and organisational framework of toll financing are revised, we can hopefully further improve the cost efficiency of Norwegian toll financing in the future.

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