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

Erik Amdal
Norwegian Public Roads Administration
Centre for Road and Traffic Technology, Trondheim
Morten Welde
James Odeck
Robert Fjelltun Boe
Norwegian Public Roads Administration

## 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 where 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 bankrupt[1].

Traditionally tolls were used to finance bridges and tunnels to supersede ferry connections, but the 1980s saw an increase in both the number of and the type of projects financed by tolls. A reduction in public funds 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 lead 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 46 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 tolls[2].

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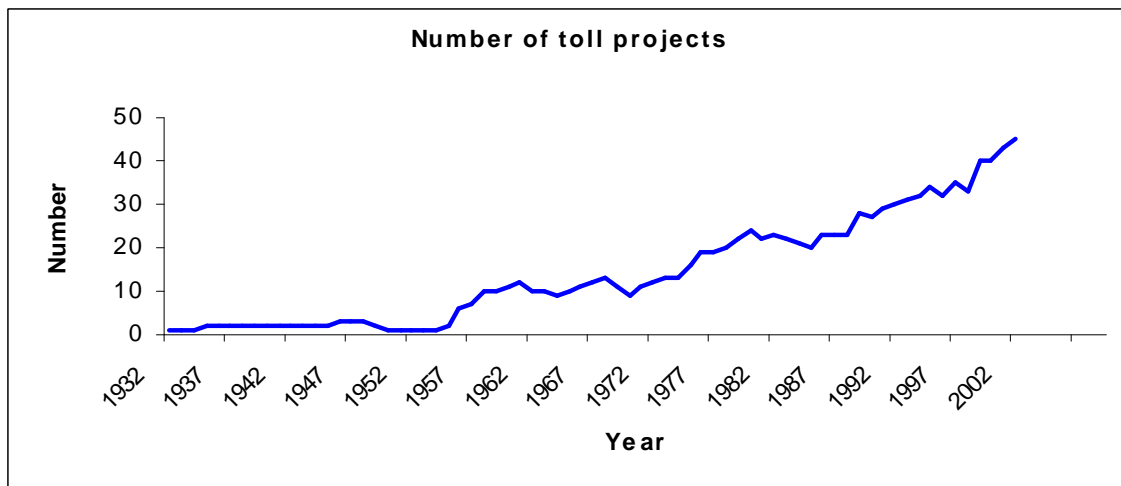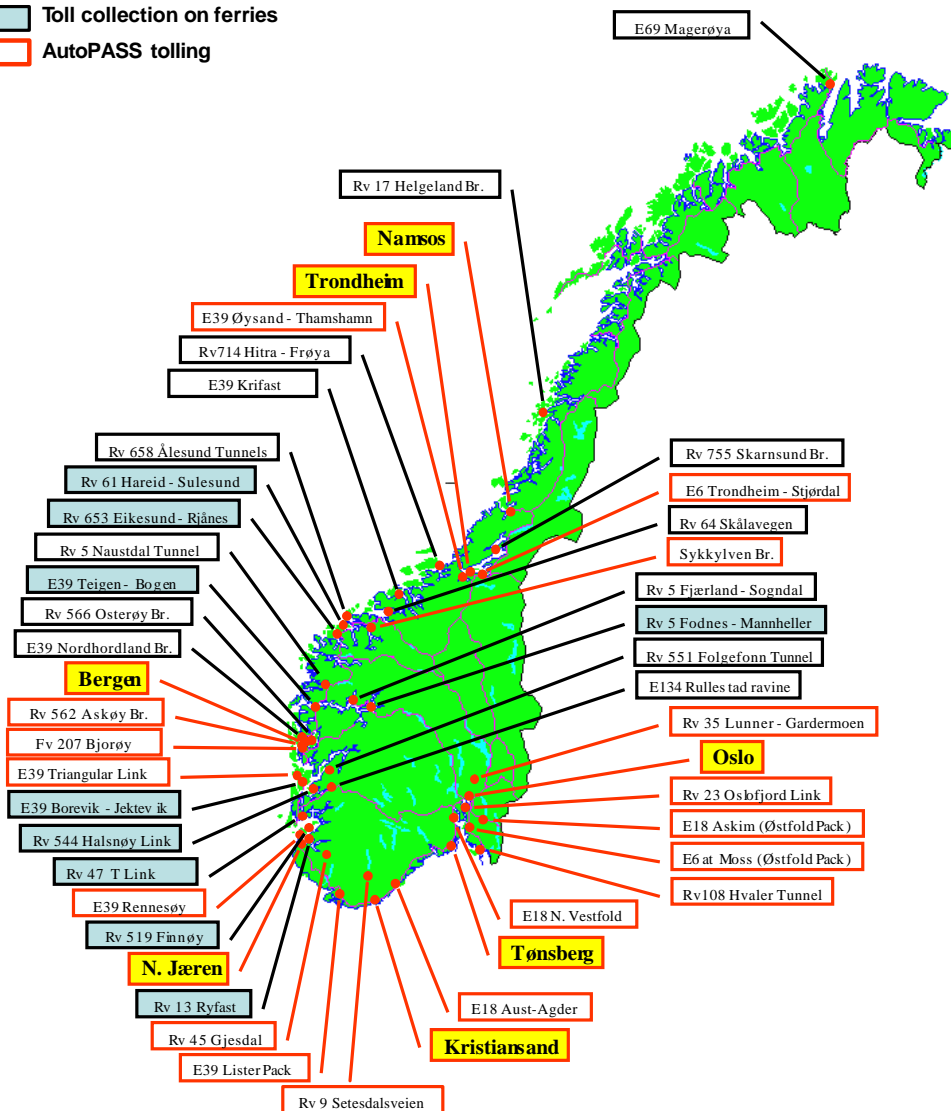
FIGURE: Tolling projects in Norway.
The figure shows all the tolling projects in Norway.  Among the 24 toll projects with AutoPASS payment system seven of them are toll rings. Toll projects without AutoPASS are typically tunnels and bridges which started tolling before AutoPASS were introduced in 1999.

## Tolling Projects in Norway, spring 2004

**City Projects**
**Single Projects**
**Toll collection on ferries**
**AutoPASS tolling**

E69 Magerøya

Rv 17 Helgeland Br.

**Namsos**

**Trondheim**

E39 Øysand - Thamshamn

Rv714 Hitra - Frøya

E39 Krifast

Rv 658 Ålesund Tunnels

Rv 61 Hareid - Sulesund

Rv 653 Eikesund - Rjånes

Rv 5 Naustdal Tunnel

E39 Teigen - Bogen

Rv 566 Osterøy Br.

E39 Nordhordland Br.

**Bergen**

Rv 562 Askøy Br.

Fv 207 Bjorøy

E39 Triangular Link

E39 Borevik - Jektevik

Rv 544 Halsnøy Link

Rv 47 T Link

E39 Rennesøy

Rv 519 Finnøy

**N. Jæren**

Rv 13 Ryfast

Rv 45 Gjesdal

E39 Lister Pack

Rv 9 Setesdalsveien

Rv 755 Skarnsund Br.

E6 Trondheim - Stjørdal

Rv 64 Skålavegen

Sykkylven Br.

Rv 5 Fjærland - Sogndal

Rv 5 Fodnes - Mannheller

Rv 551 Folgefonn Tunnel

E134 Rullestad ravine

Rv 35 Lunner - Gardermoen

**Oslo**

Rv 23 Oslofjord Link

E18 Askim (Østfold Pack)

E6 at Moss (Østfold Pack)

Rv108 Hvaler Tunnel

E18 N. Vestfold

**Tønsberg**

E18 Aust-Agder

**Kristiansand**

**Statens vegvesen**

Traffic on Norwegian roads is increasing at a higher rate than forecasted and large parts of the trunk road network cannot handle traffic efficiently. Along with a high number of casualties on many parts of the road network, this implies a need for new road investments in the years ahead. The Norwegian economy is, however, close to its capacity level and a large increase in public funding for road investment is unlikely due to a risk of overheating the economy. The Norwegian Public Roads Administration (NPRA) is therefore expecting tolls to remain an important and decisive part of the total road investments.

The use of technology plays an important part in the collection of tolls. Since the early 1990s an increasing proportion of tolls have been collected using electronic fee collection (EFC), which in Norway means that motorists pay their tolls using a tag attached to the windscreen of their car. The AutoPASS tag is based on an open standard owned by the NPRA and used in all new toll projects. It allows an antenna on a gantry above the road to read the tag after which the toll is deducted from each motorist's pre paid account.

The use of EFC is regarded as an important instrument for improving the cost efficiency of toll collection even if use of tags can give regular users discounts of up to 50 percent and hence lowering the gross revenues. In this paper we give some guidelines on how the operational costs can be minimised.

We divide our guidelines into the following groups:

- technologies employed
- the role of legislature
- organisational framework
- the structure of financing

## 2    OPERATIONAL COST AND NORWEGIAN TOLL FINANCING

### 2.1    Operational costs

The main volume of Norwegian toll financing is based on toll companies financing part of the construction costs through loans. These loans are then paid off during a period of usually 10-15 years. This implies that it is the finance costs that make up the main part of the total costs of toll financing.[3] The diagram below shows how finance and operational costs have developed during the latest 14 years:

**Cost-/Revenue ratio, finance- and operating costs**
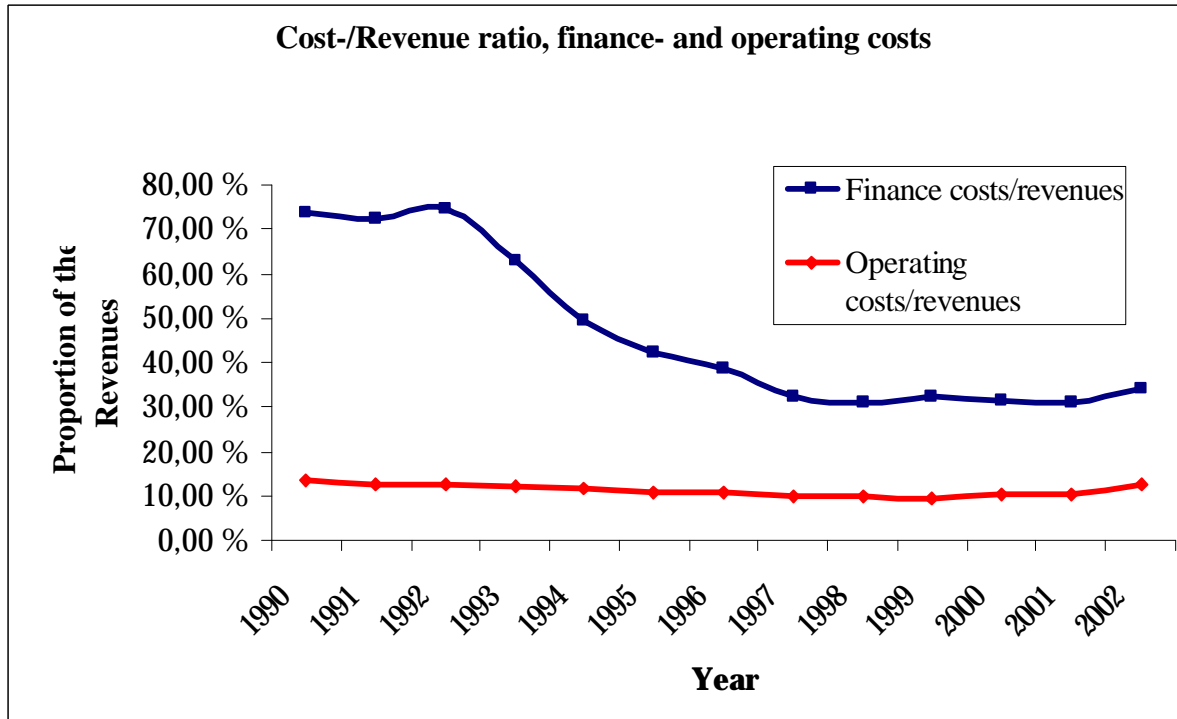


As the figure shows, the finance costs of toll financing are substantial. In periods where the interest rate has been high, the net revenues have hardly been sufficient to pay off the loans. The success of toll financing will therefore depend on the development in the interest rate.

A common critique against toll financing is that financing road investment financed through loans is costly to society as the sum of the total finance costs over the tolling period will be huge. However, if we assume that the average interest rate is equal to or close to the discount rate, the net present value of finance costs paid over the project period will be zero or at least close to zero. The cost which remains is the additional risk premium private finance requires compared to public finance. For non-profit organizations this premium will be low or non-existing but it is generally acknowledged that private finance is more expensive than public. Due to this fact the public sector will often contribute to the financing of a project through equity and soft loans when project finance is carried out through a Public Private Partnership (Merna and Njiru, 2002). The difference in finance costs between the public and private sector is likely to vary between countries and contractual structures. However, given the long tradition and the low risk of Norwegian toll financing it is likely that this difference is comparatively small.

Public funds, on the other hand, are not free. A deadweight loss arises because consumers and producers are facing different prices

There are different estimates of the size of the deadweight loss of taxation. In Norwegian CBAs the marginal deadweight loss due to taxation is assumed to be 20 % (Kostnadsberegningsutvalget, 1997).

Introducing tolls[4] on a road will generate a deadweight loss. By tolling the road, generalized costs will not be reduced according to the potential time savings by constructing the road and a deadweight loss will occur (Bråthen et al, 1996). The deadweight loss due to traffic deterrence will depend on the slope of the demand curve and the deviation from the marginal cost. Inelastic demand (a steep demand curve) will be largely unaffected by tolls whereas elastic demand will be more sensitive to tolls. According to Fridstrøm and Markussen (2001) the deadweight loss due to tolls will increase in proportion to the square of the toll. The deadweight loss can thus be minimized through low tolls and a long tolling period.

Therefore, if we assume that the net discounted finance costs of toll financing is close to zero, the real costs of toll financing will consist of the social costs due to traffic deterrence and the operational costs. As was shown in the figure above, the operational costs as a percentage of the toll revenues have been 10-15 percent on average in the years 1990-2003. The finance costs make up a larger part of the revenues than the operational costs. The finance costs are, however, determined by the interest rate and the toll companies will thus have fewer opportunities to influence them. The operational costs will largely depend on decisions taken within the toll companies. The cost/revenue ratio says very little about the cost efficiency of different toll companies and of toll financing in general. It does, however, illustrate whether toll financing is a viable alternative to using public funds for road financing. If the shadow price of taxation is 20%, the sum of the net costs from traffic deterrence, and finance and operating costs must be below 20 percent of the toll revenues for toll financing to be socio economically viable compared to public financing.

## 2.2 Norwegian tolling

From a political point of view, the use of tolls to finance new roads has been a success as over 100 projects have successfully been realised this way. Contrary to some European projects, which encountered, financial difficulties during the 1970s and –80s and had to negotiate state aid (Farrell, 1999), Norwegian toll projects have been financially viable on their own.

The use of tolls has lead to a faster implementation of projects than otherwise possible and has probably also lead to realisation of projects that would not have been financed by public funds. In the case of socially profitable projects, tolls have lead to a faster realisation of the benefits associated with the projects. On the other hand, tolls have also enabled a possible and faster realisation of socially unprofitable projects. Because all toll projects are initiated locally, the NPRA can be subjected to local political pressure and may hence recommend the realisation of projects that may not have passed the economic profitability test (Odeck and Bråthen, 2002).

The toll companies are not subject to competition. Each company are enjoying a monopoly within its own area of responsibility and, as the number of toll projects is increasing, so is the number of toll companies. As some of the key figures in the toll companies are employed in several companies, this has led to a concern that toll companies and their administration is developing into an industry of its own exempted from competition and that this might affect the cost-efficiency or lead to an undesired mix of professional roles.

Little research has been done to investigate how efficient toll financing has been compared to public financing in order to examine the socio economic profitability of toll financing compared to other alternatives. There are, however, indications that Norwegian decision makers put more emphasis on the financial and political viability of projects than the results of the Cost Benefit Analysis. Odeck (1996) carried out a study of whether Norwegian decision makers ranking of road projects where explained and/or influenced positively by a positive benefit cost ratio (BCR). Contradictory to expectations he found that the BCR were a significant explanatory variable in only four out of fifteen regions. Projects with a positive BCR were sometimes not put on the priority list at all while projects with a negative BCR where sometimes given a very high ranking.

Each toll company has a responsibility for its toll revenues and to meet its financial obligations. Apart from what is regulated by the tolling agreement, the toll companies enjoy an independence from the NPRA. This has led to regulatory problems. The NPRA is responsible for the road and the charging schemes in operation along the road network. This creates a need to instruct the toll companies from time to time, but this has proven difficult in many cases due to the autonomy of the toll companies. A frequent concern for the NPRA is the disproportion between the opportunities for instruction and management of the toll companies and its responsibility for following up the toll projects.

This has also been noted by the Office of the Auditor General of Norway (National Audit Office, 1999), which in a report on five selected toll companies pointed out several weaknesses on how road tolling and the toll companies were being managed. The financial management was unsatisfactory, the organisation of the toll companies should be reviewed and the apportionment of liability between the toll companies and the authorities was unclear. In Innst. S. nr 165 (1998-1999) the Parliamentary Standing Committee on Scrutiny and Constitutional Affairs supported the conclusions of the National Audit Office. In a report to the Ministry of Transport and Communications, the NPRA concluded similarly and proposed changes in the current organisational structure (NPRA, 2003). These proposals are currently being considered by the Ministry.

Norwegian toll projects are based on toll companies covering parts of or (in very few cases) all of the construction costs. Planning new toll projects therefore depend heavily on precise estimates of revenues and costs.

The NPRA has observed that the cost- revenue ratio among the toll companies vary substantially with some companies having a cost/revenue ratio of 5 percent and others up to 35 percent. The implications of this are twofold: There might be needless

differences between the toll companies in terms of economic efficiency and some projects might be better suited for toll financing than others.

## 3 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 cst functions are different logarithmic functions.

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

$$\log Y = b_0 + b_1 (\log Traffic) + b_2 (\log Traffic)^2 + b_3 (\log Lanes) + b_4 (\log Size) + b_5 (Age) + b_6 (Age)^2 + b_7 OBU + d_1 (TR) + d_2 (PC) + d_3 (EFC) \tag{1}$$

In equation (1) [5], logY will measure the average operating costs per paying vehicle. The equation entails flexibility regarding the scale economies. In the case of $b_1 < 0$ and $b_2 > 0$, the operating cost per vehicle as a function of traffic will be U-shaped, where the optimal size of production is given by:

$$X = 10^{-b_1/2b_2} \tag{2}$$

An age component is included to measure whether operating costs change over time. The age and the OBU component are not expressed as logs as there are many zero-observations in these columns.

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**

| No | Variable | Measure | Explanation |
|----|----------|---------|-------------|
| 1 | Operating Costs | Scale | Total/Average operating costs |
| 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 | Categorical | Toll ring or other type of project |
| 8 | Passenger Charging | Categorical | Passenger charging or not |
| 9 | EFC | Categorical | Whether the project is using EFC or not |

Two variables that may influence costs are not included: ownership and outsourcing.

As mentioned in the section above, the organizational framework of Norwegian toll financing has some inherent weaknesses that cause regulatory problems and which also may cause cost differences. However, the ownership of the toll companies and the legal arrangement between the NPRA and the toll companies are based on a standardized model with minimal differences. This implies that the organizational structure is non-measurable in a quantitative context.

The operation of the toll collection is increasingly being subjected to competitive tender. Historically the toll companies have carried out this task themselves but as specialized and commercial toll collection companies have emerged, new toll projects usually contract out the toll collection. However, this trend mainly started in 2003 and so far there is not enough data to empirically measure whether outsourcing the toll collection has lead to reduced operational costs. Some of the companies in the sample outsourced parts of or all of the toll collection during the 1990s. There are, however, doubts whether the legal obligations to advertise and to allow competition between bids have been respected in all of the cases. Determining whether outsourcing the toll collection contributes to reducing the operating costs will therefore be left for future studies.

We will formulate both a total cost and an average cost function. The purpose of the former is to identify the main cost drivers and to plan future toll projects with a greater degree of certainty while the latter will be used for determining the cost structure of the industry and to compare the relative efficiency of the toll companies. The total cost function will be estimated after identifying a set of 'best-practice' companies allowing future projects to be planned based on the performance of the most efficient of today's toll companies.

Average costs are defined as total costs per unit of output. The toll companies do, however, not produce a specific output. Their objective is to produce a revenue stream sufficient to pay off the projects' debts. But, the tolls themselves are set by the NPRA and projects with high tolls will naturally generate higher revenues per vehicle than projects with low tolls. The most appropriate measure of average costs is therefore cost per charged vehicle. Cost per vehicle will tell us something about the suitability of toll financing in each project and, when used as the dependent variable, help us measure the relative efficiency of the toll companies.

### 3.1 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 ($b_1 < 0$). Our initial presumption is also that $b_2 > 0$, 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 $b_3 > 0$.

The size variable doesn't 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, $b_4 > 0$.

The operating costs are adjusted to 2003-levels 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 $b_5 < 0$. 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 $b_7 < 0$.

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 $d_1 < 0$.

Charging for passengers is only done in fixed link projects that have superseded 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 $d_2 > 0$.

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, $d_3 < 0$.

## 4  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 were 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. When, for example, tolls are collected on a ferry service to accumulate capital to finance a future fixed link, the operational costs are minimal. Although tolls were collected on ferries on 9 out of 45 projects in 2003, these projects are not representative of Norwegian toll financing because of their low share of the total revenues and because they only have a capital-accumulating role[6]. 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.

## 5  EMPIRICAL RESULTS

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

### 5.1  Summary Statistics

A summary of the average costs are presented in tables 2 - 4. Table 2 describes the average costs in the sample. The mean average cost per vehicle is 6.89 Norwegian

kroner. The range is very large with a minimum of 0.78 and a maximum of 39.79. The standard deviation which gives an indication on how average operating costs in each toll company are spread around the mean is 7.16. This is rather large and illustrates further the huge variation among the toll companies' average operating costs.

**Table 2: Summary statistics of average costs**

|                     | Statistics |
| ------------------- | ---------: |
| No. of cases        | 113        |
| Mean                | 6.89       |
| Standard deviation  | 7.16       |
| Median              | 5.84       |
| Minimum             | 0.78       |
| Maximum             | 39.79      |

Table 3 illustrates the distribution of average operating costs. The majority of the toll companies in the sample have average operating costs below 7.5 kroner but there are a significant number of companies whose operating costs exceed 7.5 kroner per vehicle. There are even 12 projects, or 11 percent of the sample, that have operating costs above 12.5 kroner. 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 3: Distribution of companies by average operating costs**

| Average Operating Costs | Number of Companies | Percent of Companies |
| ----------------------- | ------------------: | -------------------: |
| 0 - 2.49                | 36                  | 32%                  |
| 2.5 - 7.49              | 41                  | 36%                  |
| 7.5 - 12.49             | 24                  | 21%                  |
| 12.5 -                  | 12                  | 11%                  |
| Total                   | 113                 | 100%                 |

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 4: 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      |

In choosing the right variables for an equation, one must be aware of the risk of multicollinearity, that is, that one variable is a linear combination of another variable. Perfect multicollinearity is rare but severe imperfect multicollinearity can also cause

substantial problems. Multicollinearity has the same consequences as serial correlation and heteroskedasticity in that it increases the standard errors of the estimates of the coefficients and generally reduces the reliability of the equation. A feature of multicollinearity is that it increases the likelihood of obtaining an unexpected sign for a coefficient even if the coefficients remain unbiased. Table 4 describes the correlation between the independent variables.

**Table 5: Correlation matrix for the independent variables**

|         | Traffic | Size | Age  | Lanes | OBU   | TR    | PC    | EFC   |
|---------|---------|------|------|-------|-------|-------|-------|-------|
| Traffic | 1.00    | 0.50 | 0.24 | 0.88  | 0.51  | 0.72  | -0.24 | 0.46  |
| Size    | 0.50    | 1.00 | 0.11 | 0.37  | 0.24  | 0.09  | 0.14  | 0.30  |
| Age     | 0.24    | 0.11 | 1.00 | 0.19  | 0.05  | 0.21  | -0.02 | 0.01  |
| Lanes   | 0.88    | 0.37 | 0.19 | 1.00  | 0.75  | 0.83  | -0.31 | 0.66  |
| OBU     | 0.51    | 0.24 | 0.05 | 0.75  | 1.00  | 0.46  | -0.34 | 0.95  |
| TR      | 0.72    | 0.09 | 0.21 | 0.83  | 0.46  | 1.00  | -0.31 | 0.36  |
| PC      | -0.24   | 0.14 | -0.02| -0.34 | -0.31 | -0.31 | 1.00  | -0.36 |
| EFC     | 0.46    | 0.30 | 0.01 | 0.66  | 0.95  | 0.36  | -0.36 | 1.00  |

Two of the relationships may cause some concern. Traffic and lanes have a correlation coefficient of 0.88 and OBU and the EFC-dummy are highly correlated with a correlation coefficient of 0.95. In the following, lanes will be kept in the equation while the EFC-dummy will be dropped.

A correlation coefficient of 0.88 is high and may cause disturbances in the estimation. However, there are strong theoretical arguments for keeping lanes in the estimation. Each lane in a toll station requires equipment which requires annual maintenance, some lanes will be operated by toll attendants and each lane is costly to construct. Not including lanes will potentially bias the other coefficients and increase the risk of ignoring one of the main cost drivers when planning a new toll project.

 The EFC-dummy will be dropped as the OBU percentage will express the impact of electronic fee collection on average costs anyway. In cases where the EFC dummy would have been 0, the OBU percentage will always be 0 as well.

## 5.2   Regression Results

The regression model is run using equation (1)[7]. The results of the estimations are presented in table 6 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 $b_5$, 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 terns 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 that 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 6: Estimated regression results**

| Variables | Coefficient | Std. error | t-value |
|---|---|---|---|
| $b_0$ constant | 7.435 | 0.473 | 15.693 |
| $b_1$ log Traffic | -1.278 | 0.115 | -11.086 |
| $b_2$ log Traffic$^2$ | 0.039 | 0.009 | 4.626 |
| $b_3$ log Lanes | 0.731 | 0.080 | 9.131 |
| $b_4$ log Size | 0.049 | 0.011 | 4.686 |
| $b_5$ Age | -0.032 | 0.019 | -1.692 |
| $b_6$ Age$^2$ | 0.005 | 0.001 | 3.440 |
| $b_7$ OBU | -0.009 | 0.001 | -7.840 |
| $d_1$ Toll Ring | -0.859 | 0.171 | -5.019 |
| $d_2$ Pass. Charging | 0.301 | 0.062 | 4.890 |

$N$ = 113
$\overline{R}^2$ = 0.94
$F$ = 185.62

As expected, the values of $b_1$ is negative and $b_2$ is positive. The value of $b_2$ 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.

The value of $b_3$ is positive and shows that when the number of lanes increase by 1 percent, average operating costs increase by 0.73 percent.

Furthermore, the size of the projects $b_4$, 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 $b_5$ 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 ( $b_5$*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 $b_6$ indicates that the age curve takes on a U-shaped for although the insignificant value of $b_5$ 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, $b_7$ 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.

The dummy variable for toll cordons, $d_1$, is negative. This means that we can conclude that toll cordons have 86 percent 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, $d_2$ is positive, indicating a cost disadvantage of 30 percent in projects who charge passengers as well as vehicles.


## 6    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 6 offer some interesting implications for the design and organisation of future toll projects.

### 6.1    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. Large projects will often be responsible for huge debts as well and this might reduce the cost saving potential of projects with huge traffic volumes.

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. This has encouraged new technological solutions such as the fully automatic toll stations that were implemented in Bergen and Tønsberg in February 2004. [8] As an example, if a toll project has 10 toll stations, each with one lane, and one extra toll station is added, the operating costs will increase by 7.3 percent according to our estimates.

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 by Odeck et al (2003), who found the welfare effects from introducing tolls to be lower on urban motorways than on rural roads. 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.

Regarding the minimum efficient scale, we conclude that the traffic level at which average costs reach their minimum are outside the reach of all of today's toll companies. The shape of the cost curve indicates that all the present levels of traffic are smaller than which would minimise costs.

The operating costs will also influence the social viability of toll financing compared to public funds. As mentioned in section 2.1 the costs of toll financing will consist of the social costs due to traffic deterrence and the operating costs. Designing projects to keep operating costs to a minimum will hence increase the social viability of toll financing. As operating costs are lower in toll rings and in projects with high traffic levels and as the demand elasticises are higher in projects with high tolls, toll financing should be implemented in urban rather than rural areas. However, there are, of course, political implications why a change like this might be hard to achieve. Tolls are often implemented when other sources of financing are lacking and large construction projects with low traffic levels will often resort to toll financing even if this may be costly to society.

## 6.2   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.

As an example consider a toll company with a basic tax of 20 NOK and a traffic level of 4.000.000 vehicles pr year. Expected annual income should then be some 80 mill NOK/year. Due to different types of discount and exemption of paying for some

vehicles the real income are only 50 mill NOK/year. Not only are discounts and exemption of paying costly to handle, but it also brings in less money to the toll company. This is a case for the legislatures, but we as "experts" on tolling, must give them the advice to minimize the use of discounts and exemptions.

In order to have a united tax and discount system NPRA is working with new regulations on this.
Suggestions that have been made so far are:
- no discount, just one basic fee for each class,
- fewer taxations classes,
- taxation and invoicing done by financial institutions.

Thus further studies are necessary before we can conclude anything on this.

## 6.3 Organisational framework

Considering the results in 6.1, a rethink 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.

As stated above the NPRA has done a report up on the subject.

## 6.4 The structure of financing

Our analyse indicates that the size of the project, measured in total debts in 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 tough 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.

## 6.5 Recommendations for the future

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.

By taking into account these findings we will expect an operational cost that is below 6 %.

# 7 BIBLIOGRAPHY

Amdal, E., Welde, M. Odeck, J. and Fjelltun Bøe, R. (2004): Curbing operational costs of road user charging schemes: Experiences of Norway. Paper to be presented at the European Transport Conference, Strasbourg (forthcoming).

Bråthen, S., Hervik, A., Nesset, E. (1996): Is it a good deal? : cost benefit analysis for tolled crossings. Møreforsking, Molde.

Farrell, S. (1999): Financing European Transport Infrastructure. Policies and Practice in Western Europe. Macmillan Press Ltd., London.

Fridstrøm, L. and Markussen, T.E. (2001): Evaluating Private-Public Partnerships for Road Construction. TØI report 506, Oslo March 2001.

http://www.ssb.no/kpi/ (Accessed July, 2004).

Innst. S. nr. 165 (1998-99): Innstilling fra kontroll og konstitusjonskomiteen om Riksrevisjonens undersøkelse av vegmyndighetenes styring I fem utvalgte bompengeprosjekter.

Kostnadsberegningsutvalget (1997): Nytte-kostnadsanalyser. Prinsipper for lønnsomhetsvurderinger i offentlig forvaltning. Oslo: FIN, NOU 1997:27.

Merna, T. and Njiru, C. (2002): Financing Infrastructure Projects. Thomas Telford, London.

Norwegian Public Roads Administration (1995): Håndbok 140. Prinsipper og Metodegrunnlag.

Norwegian Public Roads Administration (2001): Håndbok 102. Bompengeprosjekter.

Norwegian Public Roads Administration (2003): Organisering av bompengeforvaltningen. Report to the Ministry of Transport and Communication.

Odeck, J. (1996): Ranking of regional road investments in Norway. Does socio economic analysis matter? Transportation 23, pp. 123-140.

Odeck, J. and Bråthen, S. (2002): Toll financing in Norway: The success the failures and perspectives for the future. Transport Policy 9, pp. 253-260.

Odeck, J., Kjerkreit, A. and Bråthen, S. (2003): Users reaction to toll user charges: Elasticities and attitudes combined. Paper presented at the European Transport Conference, Strasbourg.

The Office of the Auditor General of Norway (1999): Study by the Office of The Auditor General of the Road Authorities' management of five selected toll-road projects. Document no. 3:3. Oslo, January 1999.

Verbeek, M. (2000): A Guide to Modern Econometrics. John Wiley & Sons Ltd., Chichester.

Welde, M., Fjelltun Bøe, R., Odeck, J. and Bråthen, S. (2003): A comparison of non-profit toll companies and Built Operate transfer initiatives – the case of Norway. Paper presented at the European Transport Conference, Strasbourg.

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[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,

[3] In some cases tolls are collected before and during the construction takes place. Fixed links as bridges and tunnels are usually financed by tolls before, during and after the construction is completed while toll cordons finance investments as the tolls are collected.

[4] Shadow tolls have not been used to finance road investment in Norway. All tolls are real tolls.

[5] A similar cost function is used in a study by Jørgensen and Solvoll, G. (1995).

[6] There is also another form of toll collection in operation: In the town of Tromsø tolls are collected by adding an additional tax to the price of petrol. The special geographical conditions in this isolated town make this possible.

[7] The regression package used was LIMDEP 7.0

[8] These toll stations eliminate the need for coin machines and only use one lane in each direction. Motorists pay the through the tag on their windscreen. Those without tags will have their number plate photographed and later receive an invoice in the mail.