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Road investments and the trade-off between private and public funding

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ABSTRACT

This paper assesses the impacts tolls have on economic profitability. We show that Norway has a long and diversified tradition for financing road construction by means of tolls. 20–30 per cent of the total funds available for road funding consist of toll revenues. Despite this extensive use of tolls, there is a weak tradition for detailed studies of the economic effects from tolls. This implies that the net benefit of the projects may have been overestimated. In order to explore this in more detail, we have studied four tolled road projects. The paper provides an empirical assessment, by means of a transport model, of how to determine optimal funding in order to maximise net present value, given a set of financial and/or political constraints. The main finding of the paper is that tolling can have a significant impact on economic profitability and that these effects should be examined carefully as part of the basis for the investment decision.

1. Introduction – the use of tolls

Road tolls have been in use throughout the world for decades as a means of financing new or upgraded transport infrastructure. A substantial body of research on the effects of tolls on traffic exists (Odeck & Welde, 2017). Mostly all developed countries use tolls, mainly in order to stimulate road construction, but occasionally also to manage demand. Despite this, research on optimal tolls and the combination of public and private funding is scarce. From an economic perspective, the appropriate toll level is a trade-off between the need to maximise revenues on the one hand and to minimise the dead weight loss due to tolls on the other. Thus, toll projects should balance both financial and economic objectives.

European countries have employed different finance regimes. Countries such as Spain, Portugal, France and Italy have made use of concession procurement where a public authority grants specific long-term rights to a private or semi-public organisation (concessionaire), to build, overhaul, maintain and operate an infrastructure. Asset ownership remains with the authority and the assets revert to the authority at the end of the concession period. Profits motivate the concessionaires, who are strongly regulated because of their position as monopolists in many cases. Other countries, such as Austria, Denmark and Slovenia have set up limited companies owned by the government that are responsible for collecting and enforcing tolls on all roads or on parts of the road network (PwC, 2014; Ragazzi & Rothengatter, 2005). The traditional purpose of tolls has been to finance new infrastructure, often for fixed links such as the Humber bridge in the UK or the Confederation bridge in Canada, or as relief roads such as the New Jersey Turnpike in the US or the Birmingham North Relief Road on the M6 in the UK. Today, tolls are increasingly used to reduce congestion and other negative environmental effects in and around major cities, but the purpose of a majority of today's toll schemes remain financial.

The tolls may cover all of or part of the cost of building and operating the new infrastructure. Private capital may contribute to the needed investment through lump-sum payment; nevertheless the tolls from cars and trucks provide the majority of capital. This allows the concessionaire or the government to use borrowed capital to fast-forward projects that would otherwise be postponed or never implemented.

This means that even if toll financing includes an element of private funding, it relies on the use of taxpayers' or motorists' money – often on a combination of both. Furthermore, although private investors and operators may be motivated by profits and receive returns on their investment, the main justification for the investment lies in the prospect of reduced travel time, improved road safety and economic development

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through improved access to national and international markets. In other words, the same potential benefits motivate both toll roads and roads entirely funded by public money. This means that identical decision criteria should be valid for the ex-ante appraisal of roads, including the cost of finance, except in the case when the government only considers as costs those accrued by the public sector, and considers the costs borne by private investors as negative benefits. For example, in the UK, the Benefit Cost Ratio (BCR) of transport projects has a denominator that only includes costs to Public Accounts that directly affect the budget available for transport (Department for Transport, 2018). The same applies to Norwegian BCR calculations. We do not discuss ranking criteria like various variants of BCR in this paper because we focus on how toll funding affects economic profitability, measured by means of net present value (NPV).

There is a wide range of studies that have dealt with the evaluation of toll projects, especially from private investors' perspective (Brown, 2005), the total cost to the government (Shaoul, Stafford, & Stapleton, 2006) and especially optimal tolls in the presence of congestion (Yan & Lam, 1997). Most empirical studies have investigated the traffic impacts of tolls. While there is extensive evidence of underestimation of traffic on non-tolled roads (Nicolaisen & Driscoll, 2013), most studies of toll roads suggest that overestimation is the norm (Baeza & Vassallo, 2012; Bain, 2009; Li & Hensher, 2010). In Norway, Odeck and Welde (2017) studied 68 toll projects and did not find evidence of general over- or underestimation – here the mean deviation from forecasts was only 2 per cent in the first year of operation. Accurate traffic forecasts are particularly important when planning new infrastructure, but the majority of the literature on tolls and the economic effects of tolls are on congestion charging even if tolls on non-congested networks are much more common. Comprehensive evaluation of the impact of tolls on NPV is almost non-existent. Larsen (1995) and Amdal, Bårdsen, Johansen, and Welde (2007) suggested that comparisons of the cost of public funds and the costs of toll financing should be crucial when making investment decisions. These studies did no attempts to quantify the total costs of toll financing. The first and only study that investigated this issue specifically is that by Odeck (2017) who studied the impact of tolls on NPV in 25 projects. He found that tolls were welfare reducing in most cases, but that tolls may have been the appropriate way of financing road projects in other cases.

This paper studies the effect of road tolls on value for money on mainly non-congested roads. We build on the work by Odeck (2017), but use a different methodology. While Odeck used an elasticity-based approach assuming that all user effects are concentrated on the tolled roads, we apply a transport network model that captures network effects in relevant parts of the transport network. . The paper addresses funding of transport infrastructure in a first and second-best perspective. As a part of this, we discuss whether and how constrained public funds and economically profitable transport infrastructure projects may give a good case for private funding by means of road tolls as a second-best option. We also provide an empirical assessment of how to determine optimal funding given a set of financial and political constraints. We use Norway as a case example because of its long and diversified experience in using tolls. The findings of the paper should nevertheless be relevant to all countries that use tolls to fund new transport infrastructure and especially to countries where a positive NPV is an important investment criterion.

The paper proceeds as follows. Section 2 provides a description of Norwegian road tolling, its organisational framework and its role in the appraisal process. Section 3 discusses the economic costs of the two funding mechanisms. Furthermore, Section 4 outlines the data and methodology that we use for calculating these costs, for different toll levels. Section 5 presents the results. Section 6 offers a discussion and some concluding remarks.

2. Road tolling in Norway

Norway has used toll financing in order to fund new roads since the 1930s. The use of tolls accelerated with the introduction of toll cordons around the largest cities from the late 1980s. Today, tolls finance packages of investment projects along transport corridors, urban transport infrastructure and fixed fjord links. More recently, tolls have been applied in order to manage demand at peak times and there are plans to use the current toll systems to enforce a low emission zone in the capital Oslo. Despite the increasing multi-modal use of the revenues and the range of goals supported by toll collection in the cities, the main purpose of tolling remains financial. There are currently some 85 tolled projects in operation throughout the country. Fig. 1 shows the net contribution of tolls to road financing from 2002 to 2019. Even if government investment levels have increased considerably during the same period, tolls still account for some 20–30 per cent of the total funds available for road investment.

The majority of toll revenues are collected in the eastern part of the country around the capital Oslo (48 per cent), followed by the western part of the country (21 per cent). Only five per cent of the revenues are collected in the northern part of the country (Statens vegvesen, 2019).

It may be difficult to understand why Norway, with abundant public funds would need to supplement government funds with tolls. There is however a broad political consensus that excessive government spending would overheat the economy. In addition, since 1996 the government has invested parts of its oil revenues in international capital markets in order to avoid a general increase in costs throughout the national economy. Tolls have thus allowed the government to increase its spending in other parts of the economy and to save for future generations.

Besides this type of fiscal responsibility, the stable and standardised organisational framework for tolling is perhaps the most important explanation for the general public acceptance of toll funding, at least up to now. It can be described as a bottom-up approach, where local stakeholders act as promoters in most cases and where toll road approval requires municipal decisions and parliamentary resolutions (Bråthen & Odeck, 2009; Odeck, 2017). The argument why tolling is mainly implemented is that getting the necessary road infrastructure in place by means of public funds only would take too much time. The Norwegian Parliament (NP) must approve all projects, irrespective of the proportion financed by tolls. The business case for each project includes a cost estimate, the estimated net present value, toll levels and all the assumptions that the financial appraisal is based on. A non-profit company, usually owned by local or regional authorities, is responsible for taking up loans for construction and for running the toll collection systems in the project's operational phase. If NP approves the project, they set the toll rates in the parliamentary bill.

Fig. 2 provides a simplified illustration of the main phases in a Norwegian road project. After the idea/conceptual phase, the Ministry of Transport and Communications can instruct the Norwegian Public Roads Administration (NPRA) to carry out a conceptual appraisal (CA) in order to assess different concepts. A first and indicative cost–benefit analysis is a part of the CA. The recommended choice of concept then undergoes the scrutiny of external consultants by means of a quality assurance 1 (QA1). The consultants may support the recommendation of the road authorities or suggest an alternative. They may even suggest ceasing further planning. Subsequently, the government makes the decision of whether to allow the project to be further developed or not. If the government makes the decision to allow the project to be further developed, the project may be included in the National transport plan. Then another round of quality assurance (QA2) assesses the cost estimates and other crucial assumptions of the project. The final parliamentary approval is normally uncontroversial (Volden & Samset, 2017; Welde & Odeck, 2017).

In addition to these main phases, all road projects require planning permission according to the Planning and Building Act of 2008, which

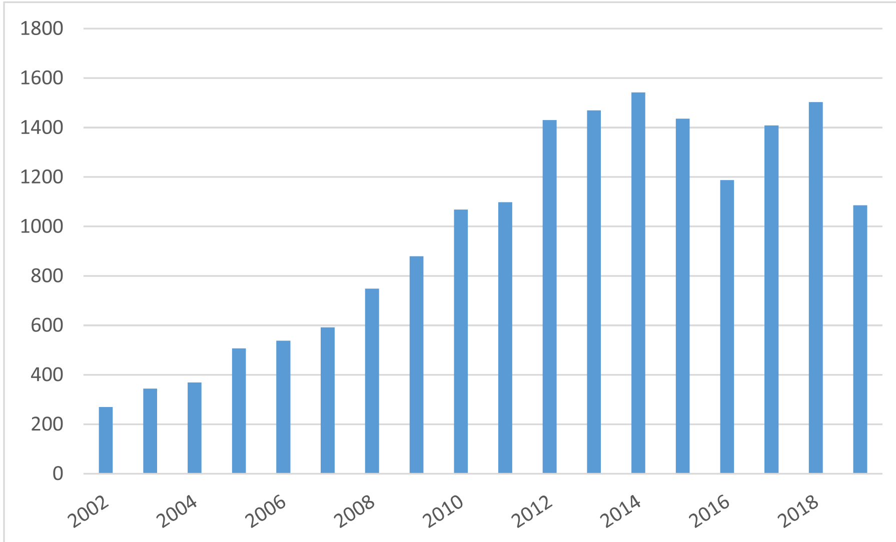

Fig. 1. Net toll revenues used for transport investment (million euros in 2019-prices).

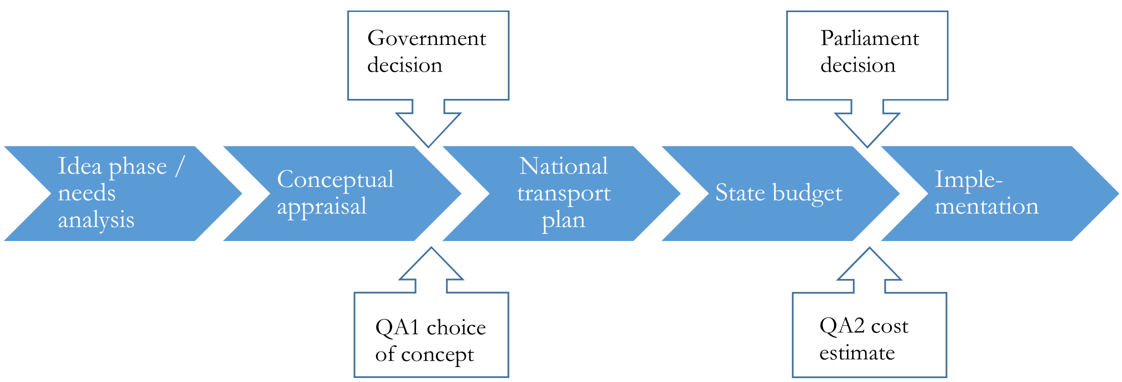

Fig. 2. The main planning phases in a Norwegian road project.

requires that local authorities pass municipal sector plans that include road alignment and other crucial details regarding construction. For projects with road tolls, the parliament approves the toll rates after a municipal council approval.

Throughout the process, a social cost benefit analysis (CBA) assesses the project's economic profitability. NPV and other outcomes from the CBA is of particular importance in the early stages of project development. The Government may reject a concept that delivers poor value for money at the first decision point. Here, the government decides to develop the concept into a project or not. As a part of the picture, the national transport plan (NTP) includes a list of projects considered as being desirable for strategic or political reasons. NPRA uses large resources on the social appraisal of projects. The CBA results have been extensively debated although Eliasson, Börjesson, Odeck, and Welde (2015) showed that a positive NPV did not affect the final project selection. The formal decision to fund and build each project connects with when the Government presents the state budget to the NP. Welde and Odeck (2017) argue that nearly all projects survive at this stage, even when the costs have escalated. This clearly indicates that the assumptions and the quality of the assessments in the front-end phase of the projects, when rejection of project proposals is still possible in practice, is of particular importance.

3. The costs of road tolling

No funding regime comes without costs, even to governments who usually have to finance their investments and operations through taxation. The extent to which different sources of finance may provide a more cost-efficient solution depends on the costs of collecting the funds and, more importantly, the impact on consumer behaviour.

Generally, taxes will cause consumers and producers to face different prices. A tax on a particular item will create a deviation from the market optimum where price equals marginal cost. The tax effectively drives a "wedge" between the price consumers pay and the price producers receive for a product. This represents a varying size of deadweight losses (DWL) in different markets, depending on the elasticity of demand and the item in question. In this paper, DWL_P due to taxation represents the welfare loss in the markets affected by the (marginal) taxation needed to fund a given project by means of public funds. In addition, there are costs imposed from running the tax collection system. These two elements added together represents the marginal cost of public funds (MCPF) which normally has the form of a multiplier. This means that the net public expenditure must be multiplied with MCPF in order to arrive at the true social cost of implementing a project. In practice, assessing the true level of MCPF can be quite complex, and hence the level is up for debate. For example, Ballard and Fullerton (1992) found that the MCPF varied with the object of taxation and that the marginal cost in some cases is below 1.0. The Norwegian government assumes, on a rather uncertain basis, an average MCPF of 1.2 (Finansdepartementet, 2014). This means that the proportion of government funds is multiplied by 1.2 in CBAs of projects funded at least in part by taxation. This assumes, of course, that taxes distort perfect competition. If this assumption does not hold, for example because of negative externalities, taxes can instead be welfare improving as discussed in Section 3.1.

The costs of toll financing (CTF) consist of three elements: the costs of toll collection, the costs of capital and the allocation loss due to the impact of tolls (the deadweight loss from tolling, DWL_T). Public scheme operators are obliged to operate charging schemes efficiently, and private scheme operators have a duty to their shareholders to do the same, but meaningful data on toll system operating costs is hard to find. Even schemes similar in scope and purpose may exhibit large variations in their marginal costs of toll collection (Amdal et al., 2007; Hamilton, Pickford, & Welde, 2012). The latest available summary of Norwegian toll company performance showed an average cost/revenue-ratio of 7.9 per cent (Statens vegvesen, 2019).

Normally private finance requires an additional risk premium compared to public finance. However as Norwegian tolling companies are non-profit organisations and since local authorities normally guarantee their loans, their terms of borrowing are normally favourable. Currently, the average interest rate for Norwegian toll companies is 2.1 per cent.

The main cost of toll collection is normally the DWL_T connected with tolls exceeding social marginal costs for the traffic flows that are affected by the tolls. It is worth noting that DWL_T is different from the DWL_P caused by the provision of public funding described above. The starting point is that the benefits of road use are the area under the demand curve that is given by road users' willingness to pay, and that social surplus is maximised in the equilibrium between society's marginal willingness to pay and society's marginal cost. In the absence of externalities and other marginal costs in excess of existing marginal taxes on traffic, the correct price or toll is close to zero. Tolls will then lead to less traffic than what is optimal from an economic perspective (Fig. 3).

Low tolls reduce demand and consumer surplus as illustrated by the shaded triangle. The size of DWL_T depends on the size of the tolls. It increases over-proportionally as tolls increase – illustrated by the lightly shaded trapezoid. It also depends on the elasticity of demand. Fig. 4 illustrates the DWL_T in a situation where demand is inelastic to price changes. Low elasticities may be present where a high proportion of trips are long-distance travel and/or where travellers have no alternatives to the tolled road. The tolls may affect both elastic and inelastic traffic

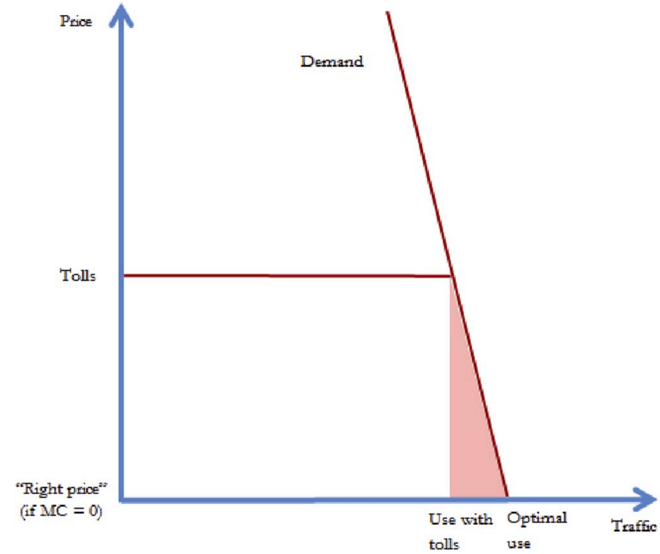

Fig. 4. Deadweight loss (DWL_T) with inelastic traffic.

flows, as illustrated in Figs. 3 and 4. Several studies have examined the sensitivity of demand with respect to tolls (see Littman, 2017, for a review of recent evidence). Most studies suggest an average elasticity of −0.5 or less, suggesting that an increase in generalised costs due to tolls of 10 per cent will lead to a reduction in traffic of 5 per cent. Odeck and Bråthen (2008) studied 19 Norwegian toll projects and found a short-run elasticity of −0.45 and a long-run elasticity of −0.82.

3.1. The trade-off between private finance and public funding

The discussion above illustrates that different sources of funding have different costs. Whether toll financing is more expensive in social terms than public funding is an empirical matter.

Tolls alone has financed only a few Norwegian toll projects. The government usually provides a share of the total cost, usually in the

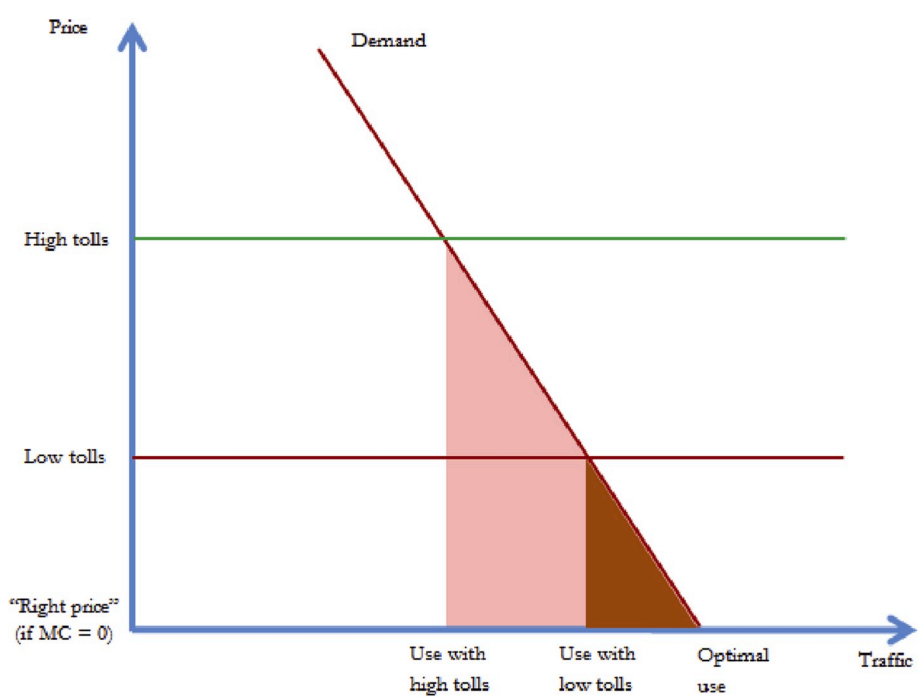

Fig. 3. Deadweight loss (DWL_T) in traffic.

range of 10–50 per cent of the cost of construction. This means that the cost of financing a project through tolls consists of four parts:

1) the DWL_P from general taxation in order to provide public funding for parts of the project,
2) toll collection costs,
3) the DWL_T for the traffic flows affected by the tolls, and
4) the collection costs of public funds. We illustrate the trade-off between the two sources of finance mathematically below.

The starting point is that the costs of funding a road project with a cost *I* by government funds is equal to the construction cost multiplied by the marginal cost of public funds, λ. This λ consists of element 1) and 4) in the preceding paragraph. We ignore the road's operating and maintenance costs, because there are no reasons to assume that these elements will not be similar for different types of funding. However, some projects may affect subsidies or revenues for operators such as ferry companies, public transport operators or toll companies operating in other parts of the network. Hence, this may affect the total cost of a project to the government. We express the different elements in the trade-off between private finance and public funding as:

$$\text{The costs of public funding: } C_P = \lambda^*(\text{I-R}) \quad (1)$$

R is the discounted change in public revenues (like tax income) that the project may generate.

Toll financing implies other cost components:

$$\text{The costs of tolls: } C_T = \alpha^*\text{I} + DWL_{T\alpha} + c_i \quad (2)$$

α is the share of the project financed by tolls, $DWL_{T\alpha}$ is the summed deadweight loss due to tolls (element 3) in the preceding paragraph) which depends on the elasticities of the different user segments and the share of toll financing, cf. Figs. 3 and 4 c_i is the cost of toll collection. Hence C_T consists of element 2) and 3) in the preceding paragraph. In this study, we calculate the net $DWL_{T\alpha}$ with the use of transport models as described in Section 5. This means that the model subtracts the inefficiency of excess traffic on the nodes where congestion occurs, from the DWL_T from tolls. In cases of more or less severe congestion, it follows that the net DWL_T could be neutral or even negative. In the equations below, net $DWL_{T\alpha}$ is used.

The cost of toll financing will thus depend on the share of the investment financed by tolls, α. We express the total cost of toll financing, C_T, as:

$$\text{The cost of toll financing: } C_T = \alpha^*\text{I} + (1\text{-}\alpha)^*\lambda^*(\text{I-R}) + DWL_{T\alpha} + c_i \quad (3)$$

For toll financing to be welfare improving compared to public funding, the sum of expression (3) must be lower than the cost of funding the project by taxes alone:

$$C_T < C_P \quad (4)$$

The cost of capital will not be discussed further in this paper. It may vary over time and between countries whether funding infrastructure through borrowing in the capital market or by the use of public funds give the most expensive solution. Equations (1)–(4) forms the basis for the model runs conceptually described in Section 4 and with results presented in section 5.

4. Data and methodology

An important purpose of this study is to quantify the effect of tolls on economic profitability. We use data from four projects where tolls are being or have been collected. In order to do so, we use a transport network model system, consisting of two models. One is for regional and urban trips and the other for long-distance trips. Hereafter we refer to these levels as 'the regional model' and the 'national' model. The first generation of the model is from 2003 whereas the current version is from 2013. This is a conventional four-step approach where we model trips between zones for different travel purposes and modes. For a thorough description of four-step modelling, see Ortúzar and Willumsen (2011). The model system uses data on network characteristics, travel speeds and costs together with register data on workplaces, employment and households. Travel survey data gives information about travel patterns for various segments of the population. Rekdal, Larsen, Løkketangen, and Hamre (2013) and Rekdal et al. (2014) describe the model structure for the regional and national models, respectively. The models are designed to reproduce current travel behaviour (measured by traffic counts) and to model scenarios where network layout and various toll schemes can be simulated and assessed. The advantage of using transport models for quantifying the effects of tolling one specific link in an infrastructure network is that it allows us to capture effects for a range of users in different geographical locations and in different parts of the economy. Fig. 5 illustrates the main structure of the transport model.

Transport models as well as the data that they rely upon have uncertainties. One such uncertainty is connected with the demand modelling, which is based on the national travel surveys in order to predict how people behave and react to changes in the transport system that affects components in the generalised travel costs. As an example, the demand model may predict how a 35 years old female driving licence holder with two children, access to a car and living in a small city will adapt her transport activities to characteristics in the transport network and to changes in this network, e.g. a new and/or improved transport link. As shown in this paper, the calibrated models have been able to fit well with the actual outcome of network changes. However, larger changes to the network could increase the uncertainty in demand estimates.

We study the effects of tolls in four projects that opened for traffic in the years from 2007 to 2013. Three of the projects are fixed link projects where bridges and tunnels have replaced former ferry services across fjords whereas one project is a traditional highway improvement where a new built dual carriageway follows a roughly parallel course to a sub-standard single carriageway. The sample of projects is too small to generalise the findings to a wider population, but as the projects are typical of toll projects in non-congested areas, we suggest the *approach* should be relevant to other and future projects in Norway and elsewhere, whereas the *results* serve as examples of policy-relevant effects. Table 1 provides some basic information about the projects.

The Eiksund Subsea Tunnel connects four island municipalities with their maritime industries to the mainland where a university college, an airport and a hospital is located. Before the tunnel opened, a ferry service that carried on average 850 vehicles per day served the connection. The area that is directly affected by the area has some 50,000 inhabitants.

The Atlantic Subsea Tunnel connects the town of Kristiansund to a municipality in the south-west direction. Kristiansund links to the mainland in south-west through two bridges and a tunnel, but lacked a fixed link to the south. The total influence area has some 35,000 inhabitants.

The Hardanger Bridge is a suspension bridge across the Hardanger Fjord. The bridge is the 10th longest of its kind in the world. The purpose of the bridge was to improve the road connection between Bergen with surroundings on the west coast of Norway and the Oslo area – a distance of some 460 km. There are five competing routes between the Bergen and Oslo, so the Hardanger Bridge is likely to have a certain amount of route selection sensitivity.

Kløfta-Nybakk is a road-widening scheme on the E16, which connects the west coast of Norway with the east coast of Sweden, even if the road mainly serves local and regional traffic. The 10.5 km dual carriageway is one of five sub-projects, which totals some 60 km of road improvements. The road is in a relatively densely populated area with industrial growth due to the Oslo Main Airport Gardermoen, some 25 km to the south. Due to the population density and the relatively short distance to Oslo, we expect some congestion to be present. From the

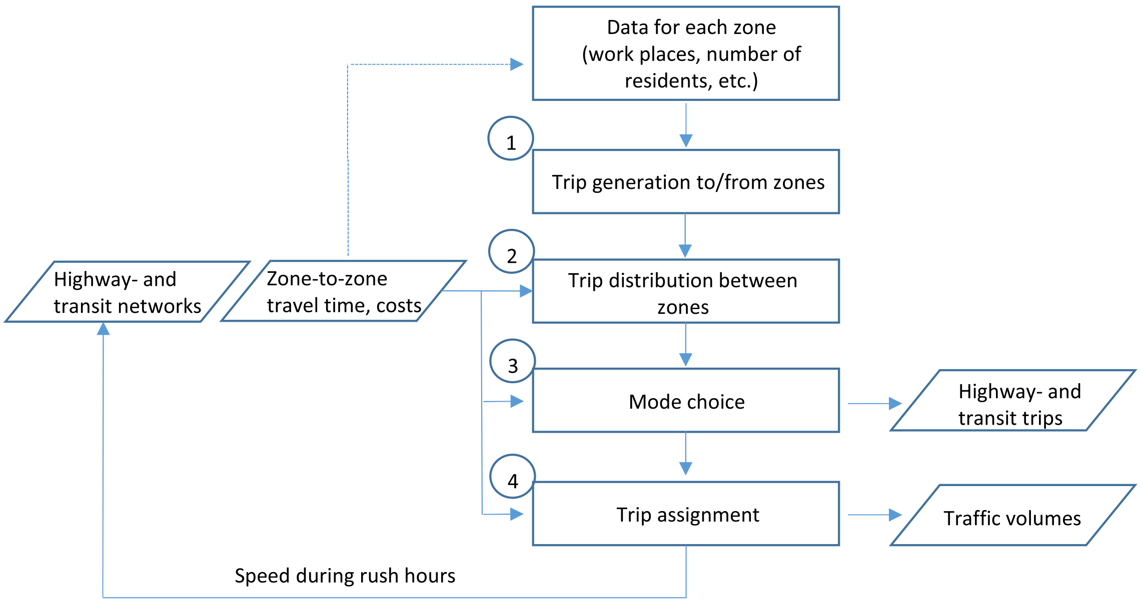

Fig. 5. The four-step transport network model.

Table 1
The projects in the sample.

Project	Share of investment financed by tolls	AADT[a]	Tolls (euros) small vehicle (<3.5 tonnes)	Construction costs (million 2017-euros)
The Eiksund tunnel	20%	2500	7.8	128
The Atlantic tunnel	70%	2000	8.7	102
The Hardanger bridge	60%	1700	15.4	280
E16 Kløfta-Nybakk	60%	9500	2.0	94

[a] AADT in Table 1 may differ somewhat from the model estimates in Table 2.

discussion above, this may influence the optimal toll level.

Fig. 6 shows the location of the cases.

Through model estimation, we seek to answer two questions for each of the four cases:

- What is the “optimal” average toll level, i. e. he toll level that gives the highest NPV and how does it compare with the present toll?
- How does the “optimal” toll level affect the NPV compared with the present toll?

Each of the cases have different characteristics with respect to e.g. alternative routes and the composition of the transport flow with respect to e.g. trip length and capacity constraints in the adjacent network. Our *a priori* assumption is that these effects should affect the findings. The next section will summarize the findings. We will also illustrate the model results in some more detail for one of the cases, namely the Hardanger Bridge.

5. Results

This section presents the modelling results for the four cases. Table 2 presents the main results.

First, the modelled traffic numbers (measured in average annual daily traffic, AADT) increase significantly when we remove the tolls. For the three fixed links, traffic may increase three-fold. It is worth noting that the models give this level as the final equilibrium after several iterations and possible behavioural effects has taken full effect. Therefore, traffic would not increase three-fold immediately, but over a period of probably 5–10 years after the removal of the tolls. Still, the AADT numbers with zero tolls are uncertain particularly in cases when the current situation is with high tolls.

There is also an increase in the annual net benefits. The toll collection period is normally limited to 15 years. Assuming a modest annual traffic growth of one per cent through this period of time, the discounted economic value added will be in the area of 22–85 MEUR for the three fixed links.

The “optimal” toll level appears to be significantly lower for the fixed links as compared with the current tolls. However, there is some uncertainty regarding this, and the toll could be anywhere between EUR 0 and EUR 2 for the Eiksund and Atlantic Tunnels. Odeck (2017) also concluded that the toll funding reduced te economic profitability for the Eiksund Tunnel, but the main reason for this was that the investment cost had increased, although he identified some reduction in the net user benefits as well. For the Hardanger Bridge, the optimal tolls seem to be well above zero (EUR 5.2–12.7), but still significantly lower than today’s level of EUR 15.4. The reasons for this appear to be that traffic diverts from other routes, giving a reduction in producer surplus on these routes. The interval for optimality is rather wide here, because the diversion effects vary in a rather complex manner with the toll level in the Hardanger Bridge, i.e. diversion takes place from different routes depending on the toll levels. We illustrate the route choice effects for the Hardanger Bridge below because they are significant and hence of particular interest to projects with similar characteristics.

As a sensitivity analysis for the Atlantic Tunnel, we simulated a situation with moderate congestion in the adjacent city of Kristiansund. The traffic from the tunnel runs through parts of the city and congestion causes external time costs. The results indicated that the “optimal” toll increased to be in the area of EUR 2.0–2.5. Different toll levels give very small route choice effects. For the Eiksund connection, there is no capacity constraints in the adjacent network, and the toll level has virtually no impact on the route choice.

For the fixed links, a reduction to the “optimal” toll levels will cause a distributive effect where the road users gain at the expense of the taxpayers in general. The net economic gain described above takes the increased cost of public funds into account because of the smaller contribution from toll funding.

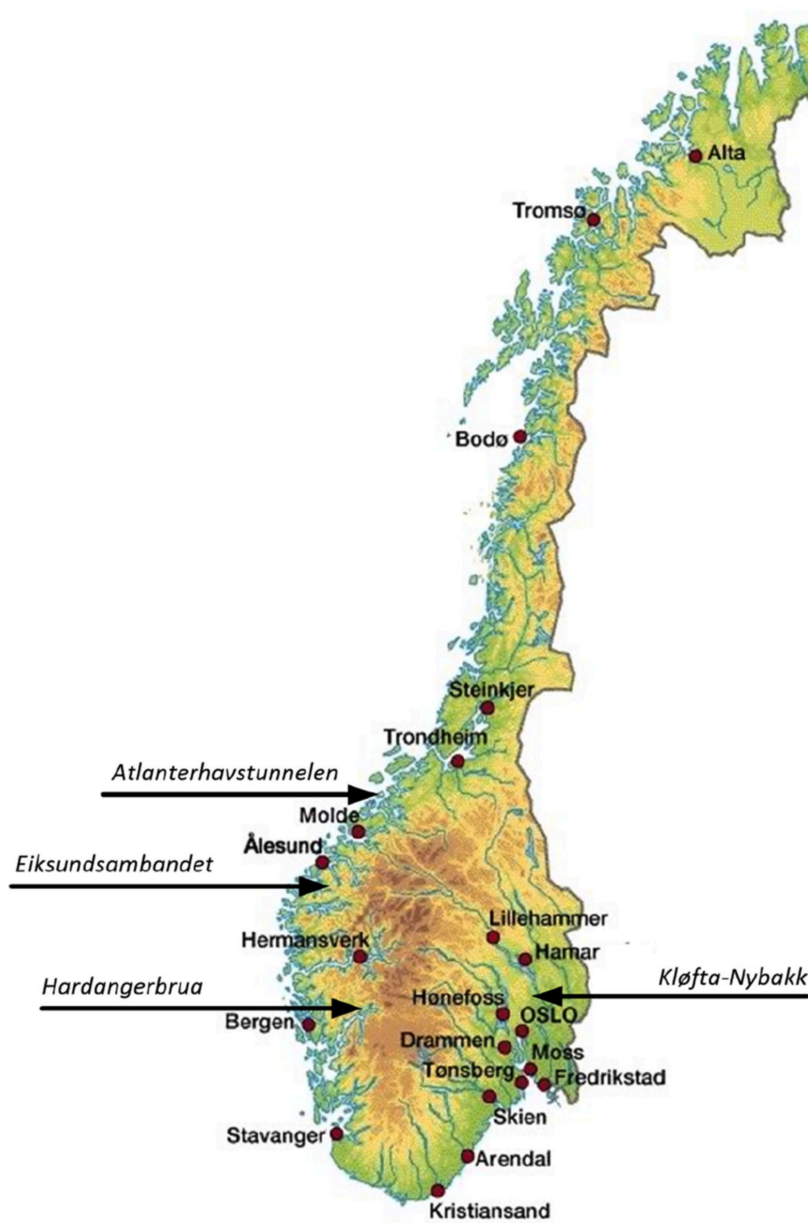

Fig. 6. Location of the four study cases.

Fig. 7 illustrates the route choice effect for the Hardanger Bridge if we reduce the tolls from EUR 15.4 to zero. The green lines show traffic increase (induced + transferred traffic), whereas the red lines illustrate a traffic reduction on other competing routes.

For Kløfta-Nybakk the story is a bit different. In contrast to the fixed links, this is a link with high capacity utilisation and with some but not severe congestion. Today's tolls seem to be well adapted to road users' willingness to pay, and the transport model identifies a loss if the toll is set to zero because of tendencies of congestion in the local transport network. This contrasts the findings in Odeck (2017), where the tolls reduce economic profitability significantly. We believe that this is mainly due to the difference in methodology, where the transport models are able to capture the network benefits from congestion relief.

6. Discussion and concluding remarks

It is apparent that road tolls are affecting the road users' benefits. They may in some cases, perhaps particularly where we observe high tolls on roads without congestion, limit the achievement of objectives with respect to regional integration/integrated labour markets. Some of the larger projects for regional integration where we may expect Wider Economic Impacts (see e.g. Venables, 2007) to exist, fall into this category. Furthermore, omitting user benefit effects that are caused by toll funding is highly likely to cause biased NPV estimates. This must be of considerable importance to the decision-makers.

Even if these case studies from Norway have limited direct transferability to other cases, the analytical relevance should still be of considerable interest, in terms of characteristics to look for in project appraisals word wide. High toll rates in relatively low-traffic projects, with short and more price-sensitive trips can significantly reduce value for money, compared with a significantly higher degree of public funding. In projects with a higher number of longer trips and competing existing routes, there may be threshold values that can give rise to large route choice effects. In a project like the Hardanger Bridge, where motorists have a choice between different routes, tolls that are marginally too high can reduce economic profitability significantly. The

Table 2
Model results (2018-values).

	The Eiksund tunnel	*The Atlantic Tunnel*	*The Hardanger Bridge*	*E16 Kløfta-Nybakk*
No tolls				
AADT	4500	5800	3600	11,000
Average toll (EUR)	**0**	**0**	**0**	**0**
Net benefits/year, relative to the present tolls (MEUR)	3.8	6.2	1.3	−0.8
System revenues/year, relative to the present tolls (MEUR)	**−3.8**	**−4.8**	**−14.9**	**−5.5**
Present[b] tolls				
AADT	1600	1600	1300	9100
Average toll (EUR)	**7.8**	**8.7**	**15.4**	**2.0**
Net benefits/year, relative to the present tolls (MEUR)	–	–	–	–
System revenues/year, relative to the present tolls (MEUR)	**-**	**-**	**-**	**-**
«Optimal»[a)] tolls				
AADT	3000–4500	3800–5800	1900–2500	9000–10,000
Average toll (EUR)	**0–2.0**	**0–2.0**	**5.2–12.7**	**1.5–2.6**
Net benefits/year, relative to the present tolls (MEUR)	1.4–3.8	2.5–6.2	1.7–2.2	+/- 0.1
System revenues/year, relative to the present tolls (MEUR)	**−3.8 to -2.0**	**−4.8 to -2.6**	**−8.5 to -1.2**	**−0.4 to + 0.3**

[a] “Optimal” refers to the toll level interval that gives the highest NPV.
[b] The toll collection period for the Eiksund tunnel ended in 2014.

calculations also show that tolls slightly above current rates lead to a sharp decline in the NPV. We underline that there is uncertainty in the numbers, but they still give realistic indications of the effects. One main finding is that the effects vary and there is a need to undertake thorough assessments in each project in order to optimize the design of the funding regimes.

In projects with higher traffic and low tolls, one can achieve a good balance as compared with public funding, particularly in cases where congestion is or may become a problem. In such cases, the tolls is likely to have act as a corrective charge, internalising at least part if the externality, and this will contribute positively to the value for money.

One could point out other relevant and partly normative considerations as well:

- Overall, one should look for the most profitable projects in economic terms and avoid implementing projects with negative economic value to society. In cases where projects are desirable for equity reasons, one should provide transparent justifications for this.
- A decision-making regime for toll funding with strong emphasis on subsidiarity combined with “soft” public budget constraints may cause a political pressure for toll funding of unprofitable projects, resulting in overinvestments. Road tolls on economically unprofitable projects is highly likely to reduce the value for money even further.
- The menu of different funding options may affect the timing of infrastructure investments. If private sector funding allows a profitable earlier building of the project, this may add value that affects the partial allocation loss from tolls. This paper does not address this issue.
- Compared with public funding, tolls are causing equity effects for different groups in society. A transparent assessment of such effects is likely to add value to the outcome of the planning process. This may become even more important in the future as charging of transport use for regulatory reasons (like congestion relief and/or limiting the use of private cars) is likely to become a more common policy in urban areas.
- Funding by means of toll roads or cordons may not be the optimal way. Other designs, as GPS-based road funding schemes with a much higher degree of charge differentiation with respect to place, time of day, vehicle type, etc. is likely to be more precise. Such systems may allow for a more dynamic pricing in congested areas. The economic mechanisms pointed out in this paper will still be valid, though.

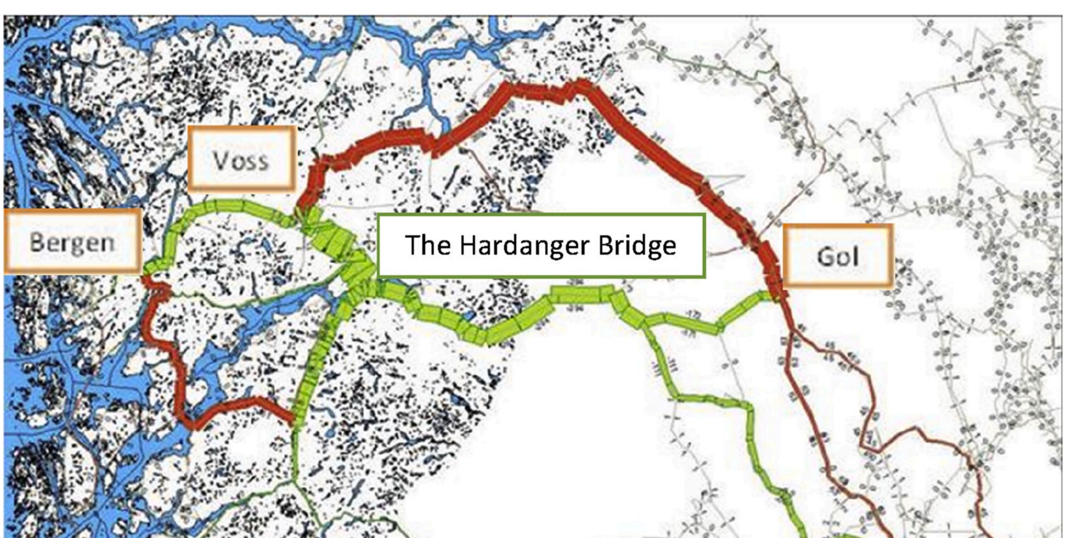

Fig. 7. The Hardanger Bridge and route choices – long distance travels with zero tolls.

Some of these points may perhaps inspire future research.

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