Designing Incentive Schemes for Public Transport Operators in Hordaland County, Norway

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Abstract

In 1999 the Hordaland County Council decided that the county should introduce so-called ”quality contracts” for public transport in the county. The main idea of this type of contract is that decisions on the level of service (routes and frequencies) are left to the operators while the fares are subject to regulation by the county. A basic ingredient of such contracts should be a remuneration scheme linked to the level of service. The purpose of the remuneration is to internalise the impacts on consumers' surplus caused by changes in the level of service. This impact is inadequately captured by the changes in fare revenue. Theory gives some guidance with respect to the principle of proper remuneration. A model was calibrated for each of the three main bus operators in Hordaland and used to estimate the rates of remuneration that would induce the operator to provide an optimum level of service based on maximisation of profit. Modelling indicated that the remuneration schemes should consist for fixed rates per revenue kilometre and vehicle hour of revenue service for basic services and additional peak services respectively. Due to substantial deviation between fare and marginal cost for peak passengers, two operators should also have a remuneration per peak passengers. Modelling also showed that the sum of fare revenue and remuneration per km, hour and peak passenger would imply excessive profits and that the contracts therefor should include the deduction of a fixed amount. This is a novel and promising approach to contracting for public transport services. The heavy reliance on modelling means that the stakeholders must have confidence in the model and the results produced. In year 2000, contracts were implemented in the County of Hordaland based on these principles and results from modelling.

Introduction

Two aspects of public transport makes the industry subject to increasing returns to scale irrespective of the economics of scale with respect to firm size. One aspect is due to the economics of vehicle size. Within certain limits the cost of the driver is a fixed element when the size or capacity of a unit increases. The other aspect comes from the demand side. When demand increases and capacity per route departure remains constant, frequencies or route density will increase if the load factor shall remain at an optimum level. Thus the average user cost will decrease due to shorter waiting times and/or walking distances.

Decreasing average cost makes a classic case for public subsidies and also for a situation where a competitive market may fail to produce the "usual" efficiency characteristics. In the absence of efficient road pricing, the case for public subsidies is strengthened in urban areas subject to congestion in the road network. This is due to the general "second best" argument in welfare theory. A counteracting force is the fact that public funds have a cost due to the distorting effect of high tax rates.

On the other hand, public subsidies and lack of a competitive market raises other issues of efficiency, notably X-efficiency in the firms that provide public transport services and market efficiency which is related to the quality and level of service provided in public transport. The problem of X-efficiency is clearly relevant for public transport operators that are public companies, but private companies exempted from competitive pressures may also tend to inflate costs. This leads to two crucial questions:

1. How should a market for public transport be organised?
2. What is the proper level of subsidies and how shall the subsidies be allocated?

So far no ideal answers seems to have emerged for these two questions and what we can observe, at least for local public transport, is a multitude of organisational forms and subsidy schemes.

This paper deals with novel approach recently implemented in the County of Hordaland on the western coast of Norway termed "incentive contracts" (Carlquist 2001).

The basic idea of the Norwegian "incentive contracts"

The starting point is that a public transport operator usually has the best and most detailed knowledge of the market he serves. A public authority responsible for public transport, will hardly be able to match the knowledge of the market possessed by an operator. An operator certainly also has a better knowledge of the cost structure for public transport services and should be able to accurately assess the cost of adding, deleting or changing routes, increasing or decreasing frequencies, changing timetables and so forth. Much of the information possessed by an operator familiar with an area or region will usually be unavailable for a public authority designing a route system that shall be subject to competitive tendering. Thus it can be argued that the design of a route system is best left to an operator familiar with the area to be served.

However, for an operator to design and operate a route system efficiently, the "correct" incentives must also be present. The main problem here is the following:

An public transport operator with a purely commercial objective (i.e. maximising profit) will look at the marginal trade-off's between the cost of improving the service and the additional fare revenue from improving the service. In a situation without proper incentives there are two important elements that will be missing in the operator's assessment:

- *Existing public transport riders will also benefit from an improved level of service due to reduced waiting time, shorter walking distances or a reduced number of transfers. This is a parallel to the fact that most of the benefits from improving a road system comes from existing road users.*
- *To the extent that car traffic is "underpriced", a transfer of riders from car to public transport due to an improved level of service will produce additional social benefits that are not reflected in the fare revenue from transferred riders.*

Thus, a proper system of economic incentives should attempt to internalise these benefits in the accounts of the operator. This is by no means straightforward. What is needed is a remuneration scheme related to some measure of the level of service and (possibly) the number of passengers. The level of remuneration must also sufficient to make the operator provide an optimum, but not excessive, level of service from a social point of view.

Nothing has so far been said about public transport fares. In a geographical area that is served by a monopolist public transport operator, it is natural to have a public body that regulates the fares. From economic point of view, the fares should ideally correspond to marginal cost with proper adjustment for the cost of public funds and – if relevant – second best considerations related to underpriced car traffic. In practice the level and structure of public transport fares will deviate more or less from the principles dictated by economic theory, be it for political or practical reasons. Still, irrespective of fares, the level of service remains a vital issue.

Modelling as basis for designing incentive schemes

In our work for Hordaland County one of the main tasks was to come up with recommendations with respect to economic incentives. The model used for this work was based on an adaptation and re-calibration of a model previously used for similar analysis related to the Oslo Public Transport Company (Larsen 1996 and 1999).

This model maximises social surplus for a public transport system with the relevant constrains applied to capacity, fares and total amount of subsidies. The model allows for inclusion of additional benefits related to transfer of car traffic. Formally it is a matter non-linear programming with non-linear constraints. The inclusion of a cost of public funds is also provided for.

In the model we distinguish between basic services that are operated with a fixed frequency all day and additional – and more costly – services that are provided only in peak periods. A model with diurnal peaks that distinguish between a basic (all day) service and additional service (higher frequency) in the peak periods was first presented by Jansson (1979, 1984).

On the demand side we distinguish between three categories of passengers:

1. Passengers in peak periods that use the sections of routes where the total need for capacity is determined.
2. Other passengers in peak periods.
3. Passengers in off-peak periods.

Benefits related to transfer of riders from car to public transport are assumed to be relevant only for category 1 passengers.

Practically any improvement in the level service from the passengers' point of view, apart from minor timetable adjustments and improved comfort, will involve an increase in revenue kilometres provided. Consequently there is a relatively close correspondence between the level of service as experienced by public transport passengers in an area and the number revenue kilometres provided per unit of time in the area.

As a simplification the model is therefor based on the assumption that the demand function for the three categories depends on the fare and the number of revenue kilometres per hour.

If we use Y^i as a symbol for category "i" passengers per hour, X^A and X^B as symbols for revenue kilometres per hour of additional and basic services respectively and q^i as symbol for average fare for category "i" passengers, the demand functions can be written as:

$$Y^i = D^i(q^i, X^A + X^B) \text{ for i} = 1,2$$
$$Y^i = D^i(q^i, X^B) \text{ for i} = 3$$

The arguments in the cost function are X^A, X^B, S^A, S^B and Y^i (i=1,2,3). S^A and S^B are average capacity per revenue kilometre.

The cost function can thus in general be put down as:

$$C = C(X^A, X^B, S^A, S^B, \sum_i Y^i)$$

The constraints on capacity can be stated as:

$$Y^1 - \beta^1(X^A S^A + X^B S^B) \leq 0 \quad \text{and}$$
$$Y^3 - \beta^3 X^B S^B \leq 0$$

There will always be sufficient capacity for passengers in category 2 and no constraint is therefor needed for this category.

The model produces results on an annual basis by multiplying the relevant variables by the number of hours per year.

In the most general case the model is used to maximise social surplus (SSP) defined as:

$$SSP = \sum_i q^i Y^i + \sum_i CS^i + B(Y^1) - C(X^A, X^B, S^A, S^B, \sum_i Y^i)$$

with respect to the 7 variables q^i (i=1,2,3), X^A, X^B, S^A and S^B and only with the constraints on capacity. CS^i is consumers' surplus for category "i" and $B(Y^1)$ is the benefits related to transfer for car travellers to public transport.

When $B(Y^1) \equiv 0$ we get the standard "first best" case with fares equal to marginal cost and an optimum level of service. The amount of subsidy (fare revenue less cost) is in this case usually close to 40 per cent of cost.

The problem of finding proper economic incentives can within the framework of this model be stated as follows:

Assume that we have found a solution to the problem of maximising social surplus with the relevant constraints (which may also involve constraints on fares and total amount of subsidy). Let this solution be $\{q^*, X^*, S^*\}$ *(in vector notation).*
Find estimates of subsidy per passenger (q') and per revenue kilometre (t) such that the solution to the problem:

$$\underset{X,S}{maximise} \quad \Pi = (q^* + q') \cdot Y + t \cdot X - C(X,S,Y)$$

$$subject\ to:$$

$$Y^1 - \beta^1 (X^A S^A + X^B S^B) \leq 0 \quad \text{and}$$

$$Y^3 - \beta^3 X^B S^B \leq 0$$

is equal or approximately equal to $\{X^*, S^*\}$*.*

That is, find a remuneration scheme for revenue kilometres and (if necessary) passengers that will induce a profit maximising operator to provide the socially optimal level of service.

It turns out that in all the cases where we applied the model, it has been possible to find such estimates {q',t}. In many cases it has also been possible to find a solution with q' $\equiv$ 0. This is an advantage because it allows for a simpler incentive scheme that also is easy to monitor for a public authority.

However, it also turns out that this type of incentive scheme (i.e. a fixed remuneration per revenue kilometre for different types of services and – if necessary - combined with a fixed remuneration for different categories of passengers) may allow for a excessive profit. Thus the schemes must be supplemented by a deduction in the subsidies calculated on basis of revenue kilometres and passengers, but this deduction should not affect the remuneration "on the margin".

Economic incentives based on this principle should be a main ingredient in a long term contract between a public authority responsible for the provision of local public transport and public transport operators. This will mean that the public authority can concentrate on pricing policy and the design of a proper remuneration scheme and leave the supply side to the operator. However, any long term contract should also contain clauses related to aspects of service quality that are not covered adequately by the remuneration scheme.

Full scale performance contract in Hordaland County

The principles indicated above was first applied in a model for Oslo Public Transport Company (Larsen 1999). OPTC is owned by the Municipality of Oslo and the close links between owner and operator not does constitute an ideal environment for an incentive contract. The agreement finally reached between the municipal authorities and OPTC was far from a full scale incentive contract and did only partly adhere to the principles.

In March 1999, Hordaland County Council decided that “the principle of quality contract” should form the basis for all contracts relating to public transport in Hordaland as from 1. January 2000[1]. In this respect a “quality contract” signifies a incentive based contract, similar in principle to the scheme initially proposed in Oslo. There are some differences between Oslo and Hordaland that are important for the design of contracts.

1. While the company involved in Oslo is owned by the municipality, there are three private companies providing services in Hordaland. One company (GAIA) operates in the City of Bergen and two regional companies[2] operate commuting services to Bergen and rural and school services in the region.
2. The initial level of subsidy was extremely biased in Hordaland. GAIA had 65 per cent of the passengers and 13 per cent of the subsidies. Our study showed that an optimum distribution of subsidies should reduce this imbalance. However, the financial constraints faced by Hordaland County would only allow for a minor adjustment.

Using the model in Hordaland meant that the model had to be calibrated to each of the companies. This was considered an important task. In order to have confidence in the results produced by the model, all participants in the process should be able to recognise and relate to the results. They should also accept the key assumptions of the model with respect to unit costs, the distribution of revenue kilometres between basic and additional peak services and the distribution of passengers between categories (with school children as an additional category).

Thus the initial work consisted finding a set of consistent assumption and parameters that was accepted both by the operators and county’s transport authority. An important check was that these inputs should make the model reproduce the benchmark situation (1999) with respect to passengers, fare revenue and cost. However, some allowance was made for the fact that the final figures for 1999 were still not known at that time.

By the end of the calibration process the model produced the results in Table 1. The first four rows are estimates inputs (acceptable to all parties), while the remaining rows are results produced by the model and also accepted as accurate estimates of expected results for 1999 by the operators and the transport authority in Hordaland.

We can see marked difference between GAIA that mainly serves the densely populated area of the City of Bergen and the three regional companies that operates long commuting routes to Bergen and also have a high share of school children as passengers.

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[1] Hordaland County in Western Norway includes the city of Bergen, and has a total population of about 450,000.

[2] The analysis was carried out for three regional companies, but two of them merged before our study was finalised.

While revenue kilometres in additional services amounts to 10 per cent of the basic services for GAIA the regional companies have percentages ranging from 29 to 56. By itself a high percentage of additional services tends to increase average cost per revenue kilometre. On the other hand, average speed is lower and unit costs are higher for GAIA than for the other companies.

GAIA is by fare the largest company in terms of revenue kilometres and number of passengers, but average length of trips are shorter than for the regional companies.

Table.1: Expected results for 1999

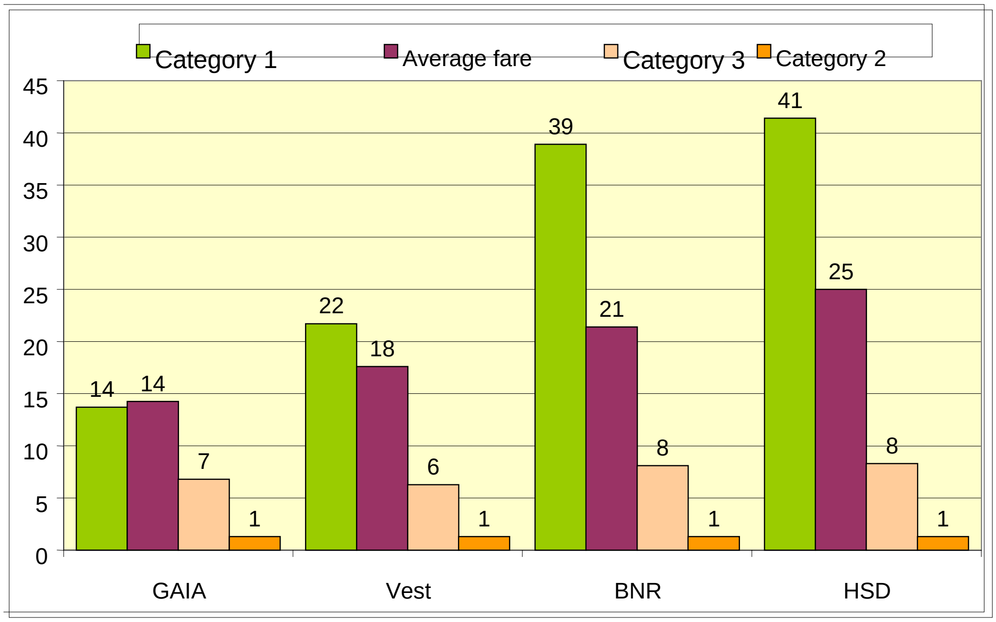
	GAIA	VEST	BNR	HSD
Basic services , Mill rev. km/y	11.50	4.10	2.84	6.46
Additional peak, Mill rev. km/y	1.39	1.98	1.58	1.89
Revenue/pass. ordinary NOK	*14.25*	*17.60*	*21.40*	*25.00*
Revenue/pass. school NOK	10.40	12.30	18.40	19.70
Passengers (Mill/year):				
Category 1 pass.	4.9	1.81	0.52	0.68
Category 2 pass.	2.5	0.60	0.17	0.23
Category 3 pass.	14.0	2.98	0.68	1.44
School children	1.5	1.07	0.80	1.65
Total number of passengers	22.9	6.46	2.18	4.00
Costs (Mill NOK/year)	352.2	153.8	87.7	153.7
Fare revenue (Mill NOK/year)	320.5	107.9	44.2	91.3
Deficit (Mill NOK/year)	-31.7	-45.9	-43.5	-62.4
Deficit in per cent of cost	9.0	29.9	49.6	40.6

The model was initially run for all four operators with the "first best" assumptions in order to get an indication of the differences between fare and marginal cost for different categories of passengers. The results are shown in Figure 1. It is only for GAIA that the fare exceeds marginal cost for all categories of passengers. The regional companies seem to have substantial deficit for marginal commuting passengers. The main explanation is probably the substantial discounts for seasonal passes.

The transport authority did not want to make any changes in the present level and structure of fares. An important argument in this respect was that the fare issue was politically very sensitive. Mixing a major revision of fares with the topic of contracts and incentive schemes could confound the political process.

Consequently the model was run with the present fares to produce the optimum level of service subject to this constraint. A cost of public funds of 0.25 was also applied.

Optimising the level of service with these constraints produced the results in Table 2.



Figur.1:Marginal cost per passenger for different categories and average fare.

The results in Table 2 indicate that there should be a major expansion of basic services in GAIA and VEST. Subsidies to GAIA should be increased substantially while the regional operators should face a moderate reduction in deficit (subsidies).

The initial low level of subsidies to GAIA probably reflects a regional bias in the County Council of Hordaland. It is a widespread opinion that subsidies to public transport are mainly needed in sparsely populated areas, while a minimum of subsidies would suffice for an urban area like Bergen. This is clearly a wrong assertion.

Table .2: Optimum derived from maximising social surplus with present fares

	GAIA	VEST	BNR	HSD
Basic services , Mill rev. km/y	20.51	7.92	1.91	4.58
Additional peak, Mill rev. km/y	1.71	0.97	1.71	2.53
Passengers (Mill/year):				
Category 1 pass.	5.4	1.72	0.52	0.69
Category 2 pass.	2.7	0.57	0.17	0.23
Category 3 pass.	17.3	3.89	0.55	1.20
School children	1.5	1.07	0.80	1.65
Total number of passengers	26.9	7.26	2.05	3.77
Costs (Mill NOK/year)	495.6	168.9	74.3	137.3
Fare revenue (Mill NOK/year)	378.1	121.9	41.4	85.6
Deficit (Mill NOK/year)	-117.5	-47.0	-32.9	-51.7
Deficit in per cent of cost	23.7	27.8	43.1	37.7

The next task is to design a remuneration scheme that induce the operators to produce approximately the same results as in Table 2 based on the objective of maximising profit. An exact solution can probably be found by solving a set of simultaneous non-linear equations based on the 1st order conditions for profit maximisation. However, we used a trial and error method. Starting from initial guesses and maximising profit, we adjusted the rates for revenue kilometres and peak passengers (Cat. 1) until the results in Table 3 were obtained.

The level of service in Table 3 corresponds very closely to the level of service in Table 2 and the differences have insignificant impacts on social surplus (the basic objective).

Table.3: Results with profit maximisation and remuneration scheme

		GAIA	VEST	BNR	HSD
Remuneration:					
Per revenue km, basic	*NOK*	10,00	7,20	5,50	5,10
Per revenue km, additional	*NOK*	18,00	12,00	10,00	9,00
Per passenger, Cat. 1	*NOK*	0,00	0,00	10,00	9,00
Level of service:					
Basic, Mill rev.km per year		20,4	8,01	2,32	4,53
Add. peak, Mill rev. km per year		1,7	0,97	1,70	2,52
Passengers (Mill/year):					
Cat 1		5,4	1,73	0,53	0,69
Cat 2		2,7	0,58	0,18	0,23
Cat 3 (off – peak)		17,3	3,91	0,61	1,19
School children		1,5	1,07	0,80	1,65
Passengers , total		26,9	7,29	2,11	3,77
Costs,	Mill NOK/year	496,0	170,2	77,9	136,9
Fare revenue	Mill NOK/year	378,1	122,4	42,8	85,4
Profits, excl. remun.	Mill NOK/year	-117,9	-47,8	-35,0	-51,5
Remuneration, basic	Mill NOK/y	203,6	57,7	12,7	23,1
Remuneration, add.	Mill NOK/year	31,1	11,6	17,0	22,8
Remuneration, Cat 1	Mill NOK/y	0,0	0,0	5,3	6,2
Total remuneration	Mill NOK/year	234,8	69,3	35,0	52,1
Fixed deduction[1)]	Mill NOK/year	-110,0	-20,0	0	0
Total subsidies	Mill NOK/year	124,8	49,3	35,0	52,1
Profits		6,9	1,5	-0,03	0,6

1) Our suggestion

In order to get satisfactory results BNR and HSD needed a remuneration per peak passenger (Cat. 1) while GAIA and VEST could do without. The explanation is to be found in Figure 1. The big difference between average fare and marginal cost for Cat. 1 passengers for BNR and HSD makes it unprofitable to operate additional commuting services in the peak even with the remuneration per revenue kilometre estimated in Table 3. Increasing this remuneration without compensation for the difference between fare and marginal cost introduces other kinds of distortions.

The remuneration rates suggested by Table 3 will result in excessive profits for GAIA and VEST. A normal rate of return on capital is already included in the cost function.

Thus to avoid excessive subsidies we have suggested fixed deductions of NOK 110 Mill and NOK 20 Mill for GAIA and VEST respectively in Table 3.

The model is formulated in terms of revenue kilometres. This is mainly for convenience because it allows for the same units to be used both in the demand and in the cost functions. Differences between operators when it comes to unit cost per revenue kilometre can to a great extent be explained by differences in average speed for routes operated. Serving mainly a densely populated urban area, GAIA has the lowest average speed.

A more general remuneration scheme should use a combination of remuneration per revenue kilometre and revenue vehicle hour. In Table 4 the rates in Table 3 have been split between kilometres and hours. We see that the differences between operators now become much smaller.

Table .4: Remuneration rates based on revenue kilometres and vehicle hours, NOK

	Per revenue kilometre	Per rev. vehicle hour, basic	Per rev. vehicle hour, additional	Per Category 1 passenger
GAIA	3,50	130	300	0
VEST	2,50	130	250	0
BNR	1,50	130	250	10
HSD	1,50	130	250	9

The rates in Table 4 have formed the basis for the economic incentives included in the new contracts in Hordaland County. While being an important ingredient in the contracts they are only part of the story.

This paper focuses on the method that was used to come up with estimates of the rates that should be applied in the incentive scheme. Carlquist (2001) gives a more elaborate presentation of the actual contracts implemented and the experience gained so far.

Summary and conclusion

Assuming that a public transport operator familiar with a geographical area also posses the best knowledge of the market for public transport in the area and the cost of operating a system of routes in the area, this knowledge should be used to its best advantage. Lacking a compelling reason for thinking in other terms, we may also assume that the objective for the design of a public transport system is to maximise social surplus.

Given these assumption there is much to be said for an organisational form that allows for a regulated monopolist that faces economic incentives that makes the result of profit maximisation coincide with a social optimum when it comes to the level of service.

This idea has been used within the framework of a formal model and the results show that a proper remuneration scheme can be constructed to this end. A precondition for this approach to work is that the operators initially are performing efficiently. Otherwise a model calibrated on data from an actual operator may come up with excessive rates of remuneration.

In Hordaland County the model has been used to come up remuneration rates that have formed the basis for contracts. The operators in Hordaland County have for a decade been subject to hard pressures to reduce costs and there is by now no indication of poor X-efficiency. A modelling approach can therefor be used with some confidence.

The case of Hordaland represents the first example of a (near) full scale implementation of incentive based contract that relies so heavily on theoretical considerations and the experience gained there should be monitored carefully.

Apart from demonstrating a novel approach, the most remarkable aspect of the Hordaland case is in my opinion that local authorities have put so much faith in the experts and their abstract modelling. On the other hand, it also takes some courage on part of the experts to from abstract principles to very specific and detailed recommendations.

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