WILL IT BE POSSIBLE TO ACHIEVE A SIMPLER AND EFFICIENT FARE STRUCTURE? – CASE STUDY OSLO*

Truls Angell, Ruter AS, Oslo, Norway

Kjell Jansson, Møreforsking Molde AS, Norway

ABSTRACT

In many cities in the world zone systems are used for public transport fares. Such systems may very well approximately accord with economically efficient pricing. The reason is that zones can vary with size and location so that prices can approximately reflect the social marginal costs of journeys.

We believe, however, that many cities use an excessively large number of zones, which is not necessary and complicated for the passengers.

In this paper we hope to be able to demonstrate that such a complicated zone systems can be substantially simplified while maintaining or even improving economic efficiency.

We will describes how the zone fare structure in the city of Oslo can be improved, but also implementation difficulties including conflicting distribution issues etc. in the political process, The political aim is now to introduce the new system early in 2011. The basis for this paper is a work financed by Ruter AS, the public transport authority in the Oslo region (Oslo and Akershus), Norway. The result of the work is found in Ruter As (2008) and Jansson (2008).

Keywords: fare structure, zone system, efficiency, integration, simplification, distribution, political process

1 INTRODUCTION

The Oslo region comprises Akershus fylke (County), including the city of Oslo. The present fare structure is different for Akershus outside Oslo and for the city of Oslo respectively. The city of Oslo has had a flat fare for over 35 years. In Akershus outside Oslo there are in total 88 different zones and the number of zone passages for all routes in both directions are 2 242. This system has been regarded as too complicated. Besides zoning, also the present fare structure is fairly complex.

Until 2008 the Oslo region had two responsible public transport authorities, Oslo Sporveier for the city of Oslo and SL for Akershus outside Oslo. Then a common authority, Ruter, was established. Among other things it was then considered necessary to renovate the fare system, including better integration and simplification.

The objectives of a new structure were to achieve a common fare structure for the whole of the Akershus region, which is simpler and more understandable than the present one.

Section 2 describes the basis for the Oslo study. Section 3 includes a brief description of various discussed fare systems and the analysis of the proposed fare system. Section 4 summarizes principles for efficient pricing. Section 5 describes the political process and

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implementation issues and the main conclusions are drawn in section 6. The appendix includes a brief description of the computerized network model that was used.

2 BASIS FOR THE OSLO CASE STUDY

2.1 Study area, route network, revenues and costs

The area comprises the region (fylke) Akershus, which includes the city of Oslo. The area is approximately 5 014 square km, of which only 250 square km in urban areas, half of which within the city of Oslo. See the map below.

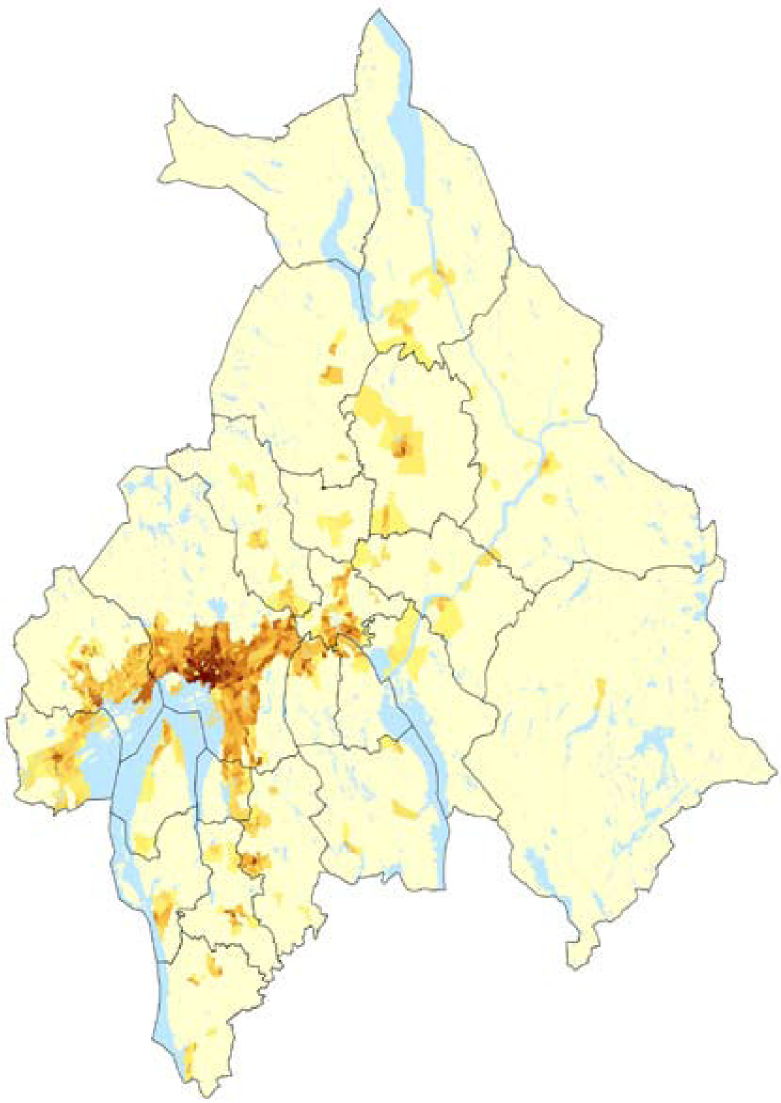

Figure 1 - The area studied

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The region is served by 450 bus routes, 6 tram routes and 5 metro routes, operated by the authority Ruter. The number of vehicle kilometers available to passengers per year is around 73 millions.

The region is also served by trains operated by the national state railways (NSB). All these train services have their start or end terminals far out of Oslo centre but they stop at the main railway station in Oslo and at a number of other stops within the Ruter area. Ruter has an agreement with NSB, which allows the passengers in the region to use the train services at the prices determined by Ruter, for which Ruter remunerates NSB.

All monetary figures in the paper are expressed in Norwegian kronor (NOK). 1 € is approximately 7.8 NOK (June 2010).

The total revenue in 2009 was around NOK 2 000 million and the total cost around NOK 3 500 million.

2.2 Purpose and objectives of the study

A number of fare structure alternatives were analyzed. The objectives of a new structure were to achieve:

- A simpler and more understandable structure,
- A common fare structure for the whole of the Akershus region,
- A minimum loss of passengers or revenues,
- An increase or only a small loss of socio-economic efficiency,
- A politically acceptable redistribution profile.

With several objectives inevitably conflicts will occur. In this study one objective was also to try to minimise such conflicts.

The commercial objective means to achieve unchanged (or more) passengers with higher (or slightly lower) revenues.

In order to measure the commercial objective we employ an index.

The index is the number of trips multiplied with the revenues, which is defined as 1 for the present situation. If this index is for example 0.998 for a fare structure alternative, it means that the alternative is 0.2 per cent below the present level. In other words, one could achieve the same number of trips with 99.8 per cent of the revenues, or the same revenues with 99.8 per cent of the trips, or a combination with somewhat higher revenues and somewhat fewer trips.

To achieve the same or more revenues with fewer zones is of course simple; it just means to raise the fares. However, in order to lose a minimum number of passengers at the same time, one must raise the fares in submarkets with relatively low price elasticity and maybe reduce the fares in submarkets with relatively high price elasticity, the well-know Ramsey pricing principle.

Empirical evidence suggests that price elasticity is lower for periodical travel cards (e.g., monthly passes, mostly used for peak travelling) and lower for short trips, especially to the city centre, than for long regional trips, since the car alternative is less attractive for short trips due to relatively high fixed costs such as parking costs. Finally price elasticity grows with the price itself.

Socio-economic efficient pricing means that the prices should reflect the marginal costs for passengers and the operator. This means that the prices should be higher when and where demand is high and capacity is exhausted. The passengers suffer from longer boarding times and in-vehicle congestion and the operator´s cost increases with boarding times, at least for bus service. In practice this typically means that the prices should be higher closer to the city centre where the capacity use (load factor) is higher.

A fare zone system should thus have successively smaller zones when moving from the periphery to the city centre. That prices are higher per distance unit close to the city centre thus accords with both commercial objectives and socio-economic efficiency. See some more details in section 4.

A politically acceptable redistribution profile may mean that some passengers may not suffer from “too high” price increases. In this case the political aim was not to harm travelers within the city of Oslo too much.

2.3 Method employed

Basically the network model Vips[1] calculated public transport travel time components and price in each O-D pair. On this basis and with car travel times calculated by the Emme/2 network model, the regional transport model RTM23 (see Rekdal et al. (2008)) produced travel matrices for peak and off-peak for the purposes work, school, other. Since the fare systems today are different in Oslo and the remainder of the county Akershus, the final matrices were, for peak and off-peak respectively, all in all 8 matrices[2]:

For peak and off-peak respectively:
- Oslo – travel card
- Oslo – single ticket
- Akershus, except Oslo – travel card
- Akershus, except Oslo – single ticket

For all simulations of effects of various zone structures, fare structures and fare levels the network model Vips was again employed. This model simultaneously deals with all routes and modes. Fares are specified per route, where all routes have zone fares. The model can apply different (convenience) ride time weights for each mode. After calibration the weights chosen were 1.05 for bus, 1.0 for tram, metro and boat, and 0.85 for train. Basic principles of the Vips model is fund in the appendix.

For the alternative fare systems only four matrices were needed since Oslo and Akershus should have the same fare structure.

2.4 Present zones and fare levels

The map in figure 2 below shows the present zone system. It consists of “rings” around Oslo centre, where each ring has a width of around 6 km. There are maximum 18 rings, but since

[1] The Vips model is no longer maintained but the basic algorithms are implemented in the network model Visum.
[2] In practice there is a number of fares within each of these categories, but we had to simplify to make the work manageable.

each ring is divided in sectors there are in total 88 different zones. The yellow lines mark zone boundaries.

The number of zone passages for all routes in both directions are 2 242, which has been regarded as "too many". The zone system has been regarded as too complicated by Ruter and the political levels in Oslo-Akershus, both for the passengers, the drivers and the administrators.

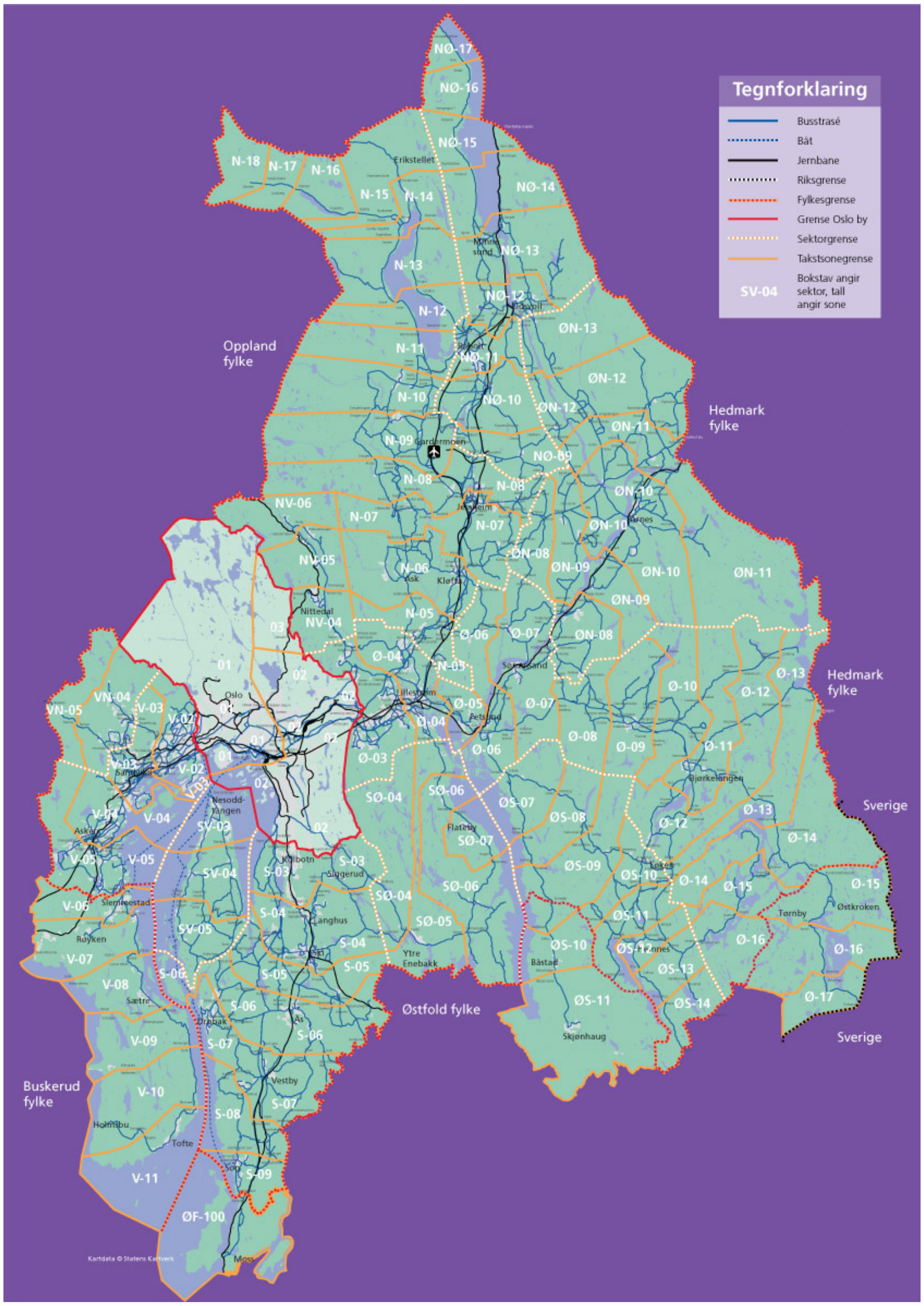

Figure 2 - Present zones

Besides zoning, also the present fare structure is fairly complex. All services within the Ruter area employ zone fares. Trains operated by the Norwegian state railways (NSB) employ kilometre fares, but a contract between Ruter and NSB allows passengers who board and alight within the Ruter area to use zone prices, at a financial cost for Ruter who pays NSB for an estimated revenue loss.

For the present base situation and for all alternatives we have analysed in the project the rail kilometre fares are kept unchanged.

The present fare structure is different for Akershus outside Oslo and for the city of Oslo respectively. Akershus is the whole region including the city of Oslo. We distinguish between travel passes, which allow unlimited number of trips within a certain period of time, a month for example, and tickets, which are valid for one trip only. For calculation purposes we convert the price for a pass into an average price per trip. The fares were assumed to be as follows.

Table 1 - Present zone fares

Akershus, outside Oslo internal	
Zone fare Pass	**NOK**
Base, zone 1	13,46
Zone 2	13,46
Zone 3	16,87
Zone 4	18,33
Zone 5	20,16
Zone 6	21,62
Zone 7	23,25
Zone 8	24,76
Zone 9	26,36
Zone 10+	27,47

Akershus, outside Oslo internal	
Zone fare Ticket	**NOK**
Base, zone 1	19,86
Addition 2 zones	7,28
Addition 3 zones	6,23
Addition 3 zones	6,23
Addition 3 zones	6,23
Addition 3 zones	7,52
Addition 7-20 zones	5,87
Max 20 zones	141,44

Oslo internal		Oslo internal	
Zone fare Pass	**NOK**	**Zone fare Ticket**	**NOK**
Base, zone 1	8,80	Base, zone 1	17,50
Zone 2	8,80	Zone 2	17,50

There are also tickets and passes that allow passengers to use both the areas. All in all the system has a large number of fares and is evidently complicated.

3 ANALYSIS OF PROPOSED FARE SYSTEM

A large number of alternative zone structures and fare levels were analysed. We will here present the results only of the alternative (number 3) that was the most politically acceptable of the ones that in the study were considered as the most efficient ones from economic efficiency point of view. First we give a brief verbal description of advantages and disadvantages of all alternatives.

3.1 Brief description of all alternatives

The maps below show the zones for each of the studied alternatives.

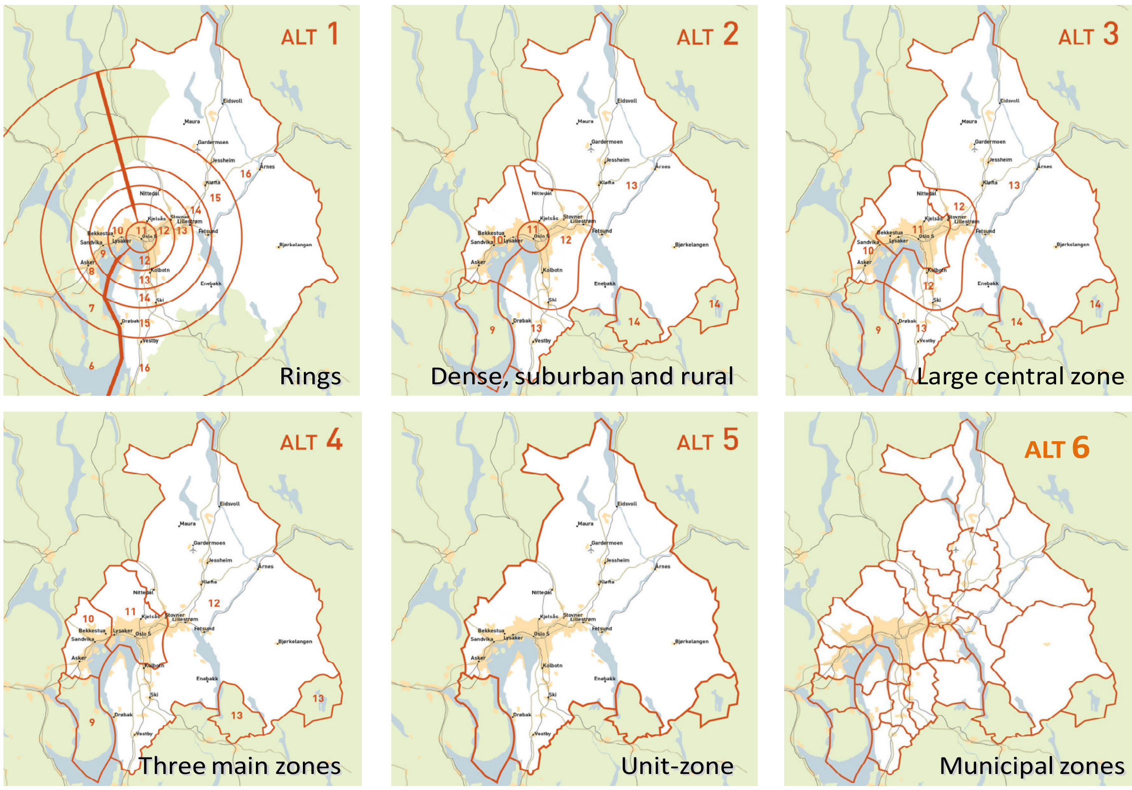

Figure 3 - all alternatives studied

Main advantages and disadvantages of the alternatives, of which number 3 is chosen:

1. **Rings**. – Small loss of revenue
    - Smaller “price-jumps” between zones
    - Less conflict with railway-pricing outside the Ruter-area.
    - Seems rather complicated, especially compared to the other five “finalists”
    - Introduce three zones within Oslo city. Even though many get cheaper price, some get much higher price.

2. **Dense, suburb and rural**.
    - Introduces three zones within Oslo city
    - Rather big “price-jumps” between zones within Oslo city

3. **The chosen**: **Big central zone**. – Easy to understand
   - Do not make any (significant) changes for the great number of travelers within Oslo city
   - Gets the whole metro within the central zone
   - Rather big “price-jumps” between zones

4. **Three zones**. – Easy to understand
   - Biggest “price-jumps” between zones
   - Bigger loss of revenue
   - Greater conflict with railway-pricing outside the Ruter-area.

5. **Unit-zone**. Extremely easy to understand
   - Bigger loss of revenue, but possible if acceptance for higher prices within Oslo city
   - Comprehensive conflict with railway-pricing outside the Ruter-area.
   - Stresses fairness even more than the others

6. **Municipal zones.** Small loss of revenue
   - Smaller “price-jumps” between zones
   - Less conflict with railway-pricing outside the Ruter-area.
   - Rather well-known units, at least for the decision makers
   - Though complicated because of “non-logical boundaries

3.2 The chosen zone structure with 3 rings

This alternative has only 6 zones and 36 zone passages compared to 88 zones and 2 242 zone passages in the present system. In practice it may be considered as even simpler since nobody pays for more than 3 zones[3].

The zone structure is seen in the figure 4 below, which apparently is much simpler than the present zone structure shown in figure 2.

[3] Eventually there might be a political decision on payment for 4 zones, if the wishes by NSB for higher prices within the Ruter area will be accepted. In June 2010 there still are negotiations going on. Backed by their owner – the National Ministry of Transport – NSB requires one extra zone in the north-east as well in the south. The circumstances make this to a possible solution, taking the fee up to 5 zones for single tickets and multi-ride tickets, but keeping max 3 zones payment for period-tickets.

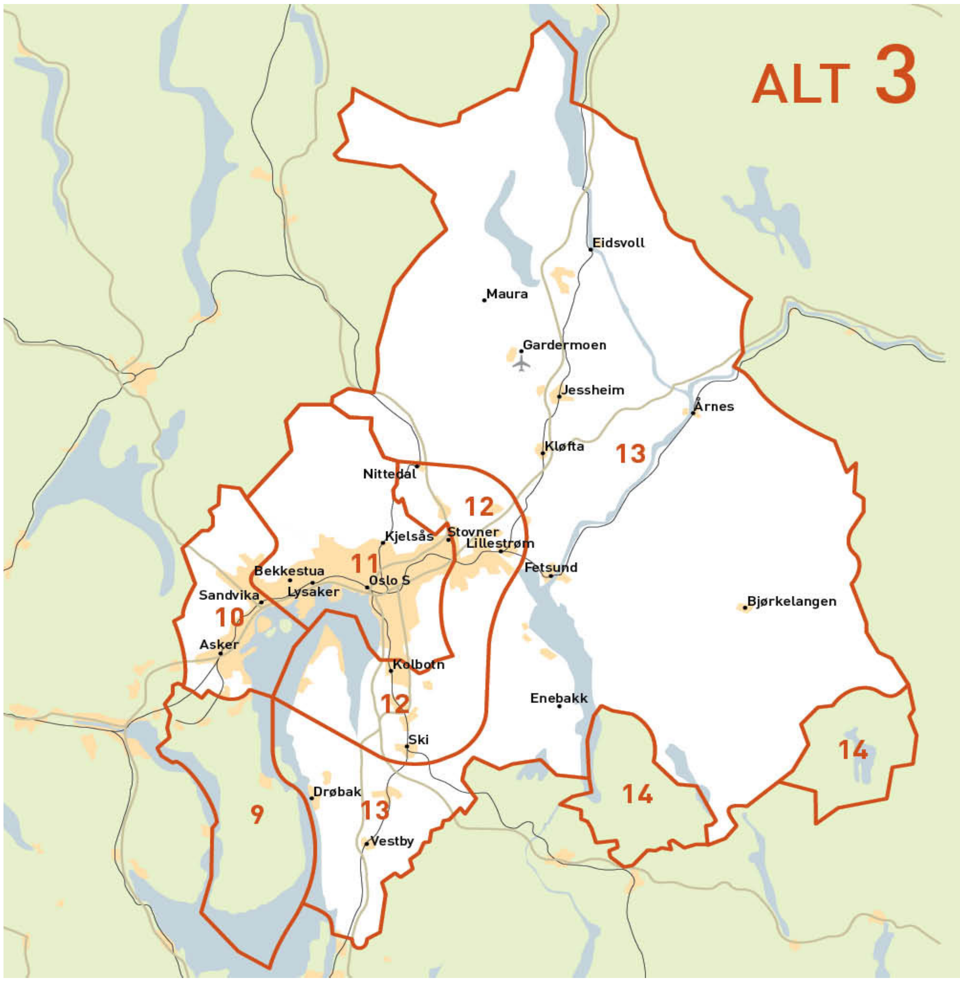

Figure 4 - Proposed zones

The proposed fare levels are as follows.

Table 2 - Prices in alternative 3

Akershus and Oslo		Akershus and Oslo	
Alternative 3 Passes	**NOK**	**Alternative 3 Tickets**	**NOK**
Base, zone 1	9,50	Base, zone 1	20,00
Zone 2	14,50	Zone 2	30,00
Zone 3	19,50	Zone 3	40,00
Zone 4	24,50	Zone 4	50,00
Zone 5+	29,50	Zone 5+	60,00

Compared to the present situation travel pass fares for one zone are approximately the same and also the maximum fare level. For single tickets the fares are nearly unchanged for short journeys but less than half for long journeys.

3.3 Results for trips and revenues

The table below shows that the revenues are reduced with 0.5 per cent and that the number of trips is reduced with 0.3 per cent, or something in between. The commercial loss in terms of revenues multiplied with trips is 0.9 per cent only.

Table 3 - Indices for revenues, trips and both for alternative 3

	Index		
	Revenues	Journyes	Rev.x Journeys
Base	1	1	1
A3	0,995	0,997	0,991

Below the same result is found in diagrammatic form.

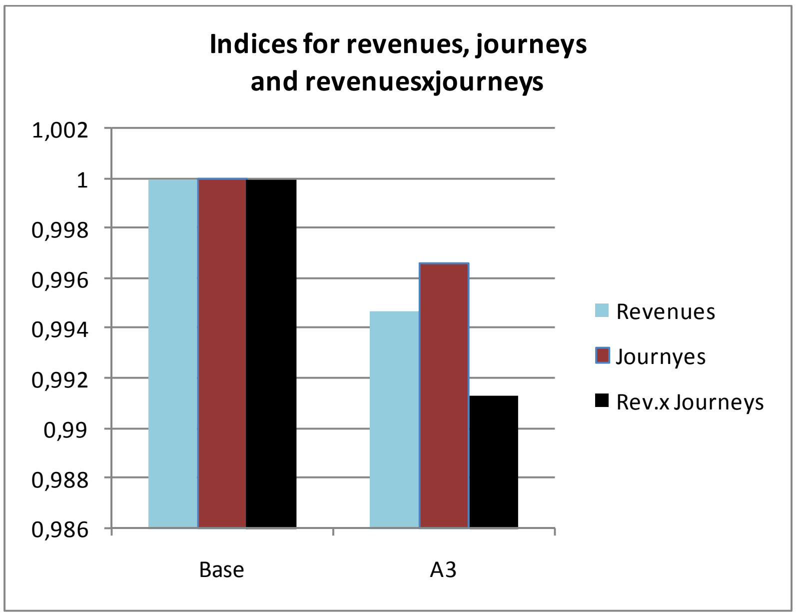

Figure 5 - Indices

3.4 Other concerns than economic efficiency

3.4.1 History and opinion

The city of Oslo has had a flat fare for over 35 years. Introduction of zone fares within Oslo is supposed to cause massive protests and is probably not politically feasible.

3.4.2 " Oslo's costumers subsidize the region "

Almost all proposals aiming at simplification and harmonization of prices mean higher prices for travelling within Oslo. The controversy is that travellers within Oslo, who will hardly experience any simplification, would have to pay for simplifications and lower prices for travellers outside Oslo.

3.4.3 New prices"over-night"

During the course of the project there was a political decision to reduce the price of the monthly card within Oslo. Even if the financial deficit was covered it meant a larger price increase to the zone boundaries outside Oslo. This meant another reality than the one the project assumed, which in turn causes more insecurity of the results of the study.

3.4.4 Requirements on simple service in the underground

The Oslo region has for many years investigated, and tried to implement, 100 % electronic ticketing system. It is supposed that the whole metro-system within the first zone would be easier to implement and communicate. In principle the best zone system shall be chosen irrespective of technical solution but this issue has been substantially debated.

3.4.5 Revenue loss for the Norwegian Railway (NSB)

Fare reductions for long journeys will cause revenue losses for NSB, which have to be covered by Ruter. In addition NSB claims that it will also lose significant money outside the Ruter responsibility area.

4 PRINCIPLES FOR EFFICIENT PRICING OF PUBLIC TRANSPORT

One basis for the work was to make the fare system efficient.

A number of works on determination of efficient prices of public transport have been presented over the last decades. A common conclusion therein is that optimal price falls short of average variable operator cost. Mohring (1972), Turvey and Mohring (1975), J. O. Jansson (1979), (1980) deal with price and service frequency, using models which are most relevant for frequent urban services and assuming constant exogenous demand from one passenger group. Nash (1978) optimises price and output in terms of miles operated for frequent urban bus services, contrasting maximum profit and maximum welfare solutions and taking demand as dependent on price and bus miles operated. These works regard demand from all passengers, or from one representative group travelling the average distance, with no concern for where passengers board and alight. K. Jansson (1991) considers and contrasts frequent and infrequent services on a route where demand is a function of fare and frequency.

The efficient price, p*, can be expressed in two ways, which have to be fulfilled simultaneously.

$$(1) \quad p^* = F\frac{\partial C}{\partial X} + X\frac{\partial T}{\partial X}$$

$$(2) \quad p^* = \frac{FC}{X} - \frac{Fy}{X}$$

Where F is service frequency per hour, C is operating cost, X is demand per hour, T is travel time, y is the marginal benefit to passengers of frequency increase.

Equation (1) shows that optimal price equals the marginal costs imposed on the operator and the passengers, with respect to an additional passenger.

Equation (2) shows that optimal price equal the average operating cost minus the marginal benefit to passengers of frequency increase.

Equation (1) also implies that the optimal price increases with the number of passengers per departure (and of course with the time they travel where there is in-vehicle congestion). This means that a zone system can be employed to approximate optimal prices. Assume that the price is comprised of a boarding charge and a charge per passage of each zone boundary, which is a common design of zone fares. Since in-vehicle congestion typically is higher in and close to city centres the zones should be smaller here than in the outskirts. The figure below illustrates this principle for a route from the outskirts of a city to the central city. The thickness of the line illustrates schematically the in-vehicle congestion and thus also the price for various sections of the route.

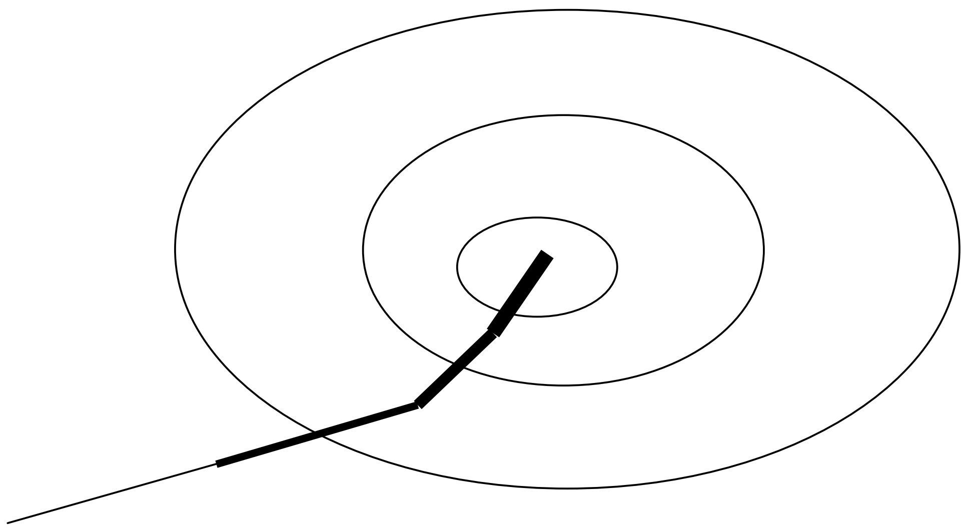

Figure 6 - Principal fare differentials and zones

5 THE POLITICAL PROCESS AND IMPLEMENTATION CONCERNS

5.1 Political process

The proposed system was appreciated both by politicians and the general public, especially due to its simplicity.

A critical issue has been that the system is supposed to cost NOK 180 million more than today, which is about 5 per cent of the cost and 10 per cent of the present subsidy level. The politicians could accept a subsidy increase of NOK 90 million. The Ruter officers mean that the remaining NOK 90 million can be obtained by a small increase of fares within Oslo, which seems to have gained political acceptance.

In June 2010 it seems as if the new system can be implemented early in 2011. However, a critical point is the deficits that NSB claim they will experience, which may require central Government financing. Further assessments continue during the summer 2010.

5.2 Technical implementation

A requirement is that a new ticketing system must be able to handle the new fare zone system early in 2011, which is a technical challenge.

5.3 Quality control

By use of observed travel pattern and ticket use, a method employed since 1991, it seems as if the subsidy may be 30 per cent higher than what the simulations in the project found. This can, however, be managed by the extra NOK 90 million mentioned above. The critical issue is still the revenues losses of NSB, which has to be dealt with by the central Government.

6 CONCLUSIONS

The study indicated that it is possible to substantially simplify a zone fare structure and make it more efficient, while at the same time keep demand and finances virtually unaffected.

However, reality has addressed two problems. One is the political opinion that travelers within Oslo must not lose too much. The other is new data that indicates the subsidies have to increase more than the study found.

The prime proposed system means substantial price reductions for longer journeys, while increasing the prices within Oslo only marginally. In order to solve the financial dilemma one may have to slightly increase the prices within Oslo and add two zones.

The politically necessary compromise between efficiency and distribution aspects still means that the proposed fare system would imply great improvements from efficiency and simplicity points of view.

Finally, the general public has been positive and the political process has been fairly smooth given the complexity of changing the system substantially, and it seems as if the new system can be implemented early in 2011.

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APPENDIX: PRINCIPLES OF THE VIPS NETWORK MODEL

A1 Introduction

The model Vips assumes that travellers know the timetables. The model works in one simultaneous step for lines and modes, where all feasible combinations of lines and modes are taken into account, and where each line has a specific ride time and price (kilometre, zone, or stop-stop based). Each passenger segment can then have a specific price structure for each mode and service within mode. The price in each O-D pair for a specific group is then calculated endogenously by the program as the weighted average of the prices of all combinations of lines and modes.

The passengers in each origin zone are assigned to various stops with various services and modes.

The model allows a) substantial segmentations for passenger categories with respect to different values of time, b) that services and modes are given specific characteristics in terms of comfort, price etc., which may differ between passenger categories.

Since the model takes into account a number of combinations of services and modes, the number of travel paths (each with a combination of services and modes from origin to destination) can be very large.

A. 2 Principles

When departure times of all lines are known all lines and stops are considered simultaneously, but all cannot be acceptable. Assume that different lines ^{j} have travel times R^j and headway H^j. Expected wait time is then not $H^j/2$. Expected wait time when the timetable is known is the difference between ideal and actual departure time. The basis for choice of acceptable lines is the time to reach the boarding point plus travel time after boarding, here denoted R^j, plus all of the headway, H^j. Assume that line 1 is best, has the lowest value R^1+H^1. Other lines m are acceptable if $R^m < R^1+H^1$. This means that it is not worthwhile to choose a line that has travel time only that is longer than travel time plus the whole headway of the best line.

The RDT approach is based on two assumptions. It uses the stochastic element x, difference between actual and ideal departure time, often called schedule delay. This delay is here based on expected delay based on average frequencies of services and not on exact departure times. It is thus assumed that (x^1, x^2) has a uniform distribution on $[0, H^1]\times[0, H^2]$, exemplified by two alternatives. This assumption is thus based on the mentioned assumption that the modeller does not now anything about the true distribution about ideal departure times for the period of time (a whole day, peak hours or non-peak hours for example) we are analysing. Secondly it is also assumed that departure times of alternative lines/modes are uniformly distributed.

Notation

H^1 headway of line 1.

H^2 headway of line 2.

R^1travel time (including price expressed in minutes) of line 1.

R^2 travel time (including price expressed in minutes) of line 2.

x^1 time to departure of line 1.

x^2 time to departure of line 2.

The joint generalised cost, is then:

$$G = E\left[\min\left[R^1 + x_i^1, R^2 + x_i^2\right]\right]$$

It has been shown, see Jansson, Lang and Mattsson (2008) and Hasselström (1981), that the probability of choice of alternative 1, Pr(1), is:

$$\Pr(1) = \frac{1}{H^1 H^2} \int_0^{H^1} \int_0^{H^2} h\left[R^2 - R^1 + x^2 - x^1\right] dx^2 dx^1$$

where h(s) is the heaviside function defined by:

$$h[s] = 1 \quad if \quad s > 0; 0 \quad if \quad s \le 0$$

Note that the probability for choice of a specific line depends on travel times, prices and intervals of all acceptable lines.

Note that R^1 and R^2 may have a different weight in relation to the weight of the headway. Jansson, Lang, Mattsson (2008) and Hasselström (1981) also show that the expected wait time, V, is:

$$V = \frac{1}{H^1 H^2} \int_0^{H^1} \int_0^{H^2} \left(h\left[R^2 - R^1 + x^2 - x^1\right]\left(x^1 - x^2\right) + x^2\right) + dx^2 dx^1$$

The average expected travel time when there are several acceptable lines is found by the weighted travel time for all lines where the weights are the calculated probabilities. If there are j acceptable lines and the travel time for line j is R^j and the probability of choice of line j is denoted Pr(j), the average expected travel time, R, is:

$$R = \sum_{j=1}^{k} \Pr(j) R^j$$

The generalised cost is simply the sum of the joint expected wait time and the average expected travel time: G=V+R.

More details on the principles are found in Jansson et al. (2008). Some details of the implemented Vips model are found in Jansson and Ridderstolpe (1992).