

A DECADE OF ROAD USER CHARGING – WHAT ARE THE EFFECTS?

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1. INTRODUCTION

This document presents results and experience from more than a decade of road user charging (RUC) in the Norwegian city of Trondheim. The presentation is based on work carried out as part of the PROGRESS project, under the EU financed Competitive and Sustainable Growth Programme, supported by the local public roads authorities.

1.1 A summary of the Trondheim history of road user charging

The Trondheim RUC scheme was introduced to raise revenue in order to finance a road construction package. Since the commencement in October 1991, the scheme has undergone a series of changes and revisions. From the outset the system comprised a single cordon with 11 toll stations around the central parts of the city. The toll system was based on automatic charging, using electronic read-only tags mounted in the vehicles, and only two of the toll stations were manned. At the unmanned toll plazas, tolls could be paid manually, using coin machines. Operating hours were Monday – Friday, between 06:00 and 17:00, levying inbound traffic only. The base toll level was NOK 10, and subscribers (i.e. tag holders) were offered a discount, varying by time of day, with discounts for morning peak-period being 20 %-points lower than for the rest of the charging period. The maximum discount to be obtained was -60 % per off-peak crossing.

During the first half of 1998, the single-cordon system was changed to a multi-cordon zone-based system with 18 toll stations, and operating hours were extended by one hour in the afternoon, to 18:00. The toll level and discount structure has been changed a number of times during the twelve years of operation, and at present the base toll is NOK 15, giving a total increase of 50 % since 1991. The time-differentiation in subscriber-discount has been maintained.

In November 2003 an “inner ring” will be added to the RUC scheme, with six new toll stations surrounding the CBD. The existing system was, in accordance with the legislation at that time, introduced to collect money for financing new road infrastructure. The 1998- and 2003-revisions are also motivated by the same funding needs. The RUC system will be operating until the end of 2005, when it is to be terminated according to political agreement. Based on new legislation, the city is now discussing road user charging as an instrument for future demand management.

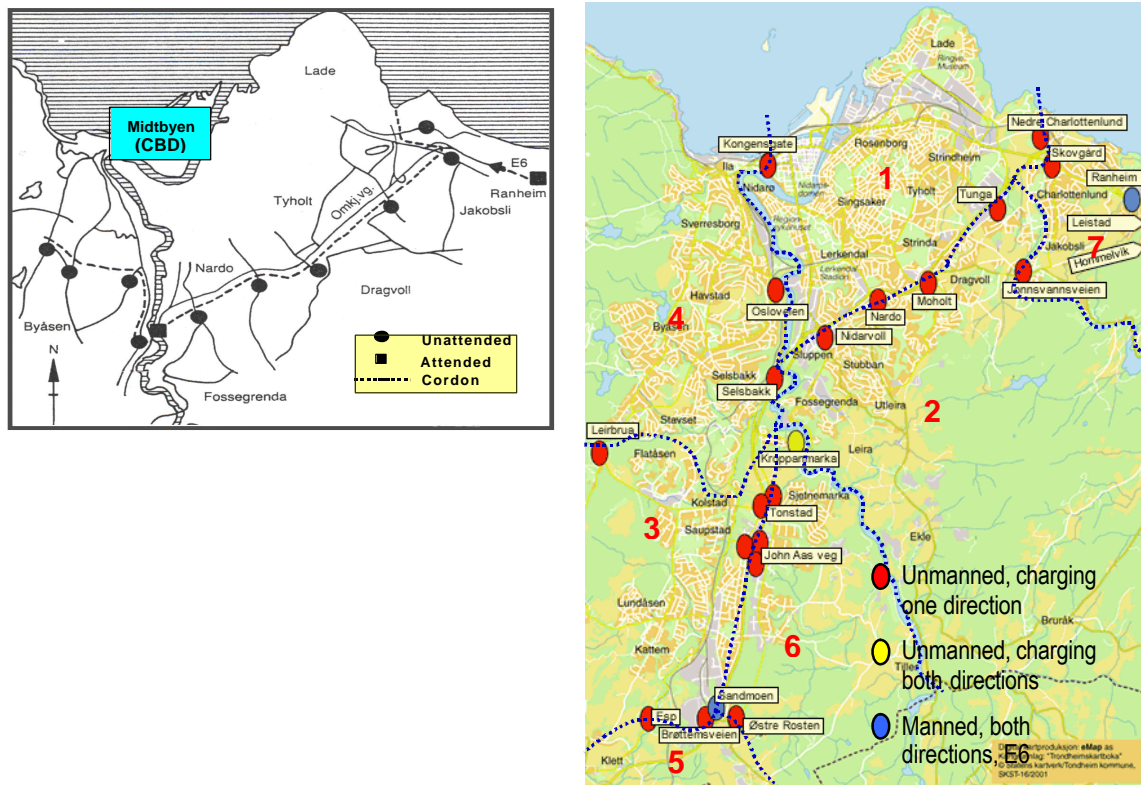


Figure 1: Charging points in the Trondheim RUC systems of 1991 (left) and 1998 (right)

2. SCHEME OPERATION

This chapter is mainly based on information from the RUC operator, Trøndelag Veifinans, and the local public roads administration (PRA).

2.1 Technology

The electronic tags used from the outset in 1991, had to be replaced in 2001, as international regulations required a change in communication frequency from 856 MHz to 5.8 GHz. The initial concession from the Norwegian Post and Telecommunications Authority expired in 2001, and the frequency used up till then, then was to be made available for future digital TV broadcasting. This led to the development of a new Norwegian standard for toll collection systems, called AutoPASS.

The AutoPASS system complies with the provisional European standard for a standard for wireless communication between vehicles and toll stations (ENV for

DSRC). In addition, full specifications are set up for all other elements needed in the Norwegian toll systems. This secures full technical interoperability.

For the time being, the AutoPASS can only be used in Norwegian AutoPASS toll sites and only as part of an individual agreement with each local toll company. The goal is to co-ordinate all toll systems so that electronic payment tags can be used in all toll sites. This will secure full interoperability, initially in Norway, and later throughout the Nordic region and the rest of Europe. The user then will have to sign only one agreement, covering electronic tolling at AutoPASS compatible toll sites. This will be of great significance, particularly for the transport industry.

2.2 Enforcement

The system security is a major concern. Though the system has no manual surveillance, no security problems have been experienced. The enforcement is based on a video system, triggered whenever a vehicle crosses a toll cordon without valid payment. The video picture is analysed and the number plate is read by a video recognition system. A bill with an extra fee is sent to the car owner. As an example of the size of the problem with illegal crossings: On May 6th 2003, extra fee was issued to 79 vehicle owners – 0.6 ‰ of the subscriptions.

2.3 Traffic flows over the RUC toll cordons

The number of vehicles crossing the cordon(s) has increased from close to 21 millions during 1992, the first full year of operation, to well over 36 millions in 2001.

Table 1: Number of vehicles crossing the toll cordon, 1992 – 2001

Year	Annual number of vehicles over cordon(s)			Average number of paying vehicles per charging day
	Total number	Number of paying vehicles during charging hours	% paying	
1992	20 965 761	10 194 785	48.6 %	40 397
1993	20 792 671	10 347 111	49.8 %	40 505
1994	21 099 409	10 561 013	50.1 %	41 743
1995	21 434 954	10 709 671	50.0 %	42 668
1996	22 162 491	11 195 076	50.5 %	44 521
1997	22 952 890	11 768 635	51.3 %	46 802
1998	31 853 376	18 007 096	56.5 %	71 362
1999	34 884 034	19 751 748	56.6 %	77 967
2000	35 655 190	20 155 562	56.5 %	79 666
2001	36 235 074	20 419 940	56.4 %	81 246

With the single cordon system which was operation until 1997, about half of all cordon-crossings were made during the charged hours. During the years 1992 to

1997, the average number of paying vehicles per charging day increased by 16 % from approximately 40 400 to 46 800.

The 1998-revision of the RUC scheme led to a major increase in traffic crossing the toll cordons, and also in percentage of vehicles being charged. The total traffic levels increased by roughly 30 %, adjusted for general traffic growth, and the corresponding increase in total charged traffic was some 34 %, resulting in a 6 %-points increase in paying share of total traffic flows. This increase was mainly due to the one-hour extension of the charging period. By 2001, the average number of paying vehicles was well over 81 200 per charging day – more than twice the number for the first year of operation.

2.4 Operating revenues and costs

The annual operating revenue for the Trondheim RUC scheme was mNOK 70 for 1992, the first full year of operation. There was a steady increase in revenue up to 1997, with mNOK 86. This year was the last one with the 1991-scheme. During the first months of 1998, the zone-based RUC-scheme was introduced, and the revenue increased by 46 % compared to the previous year. The increase in revenue for 2001 is due to a raise of the toll level.

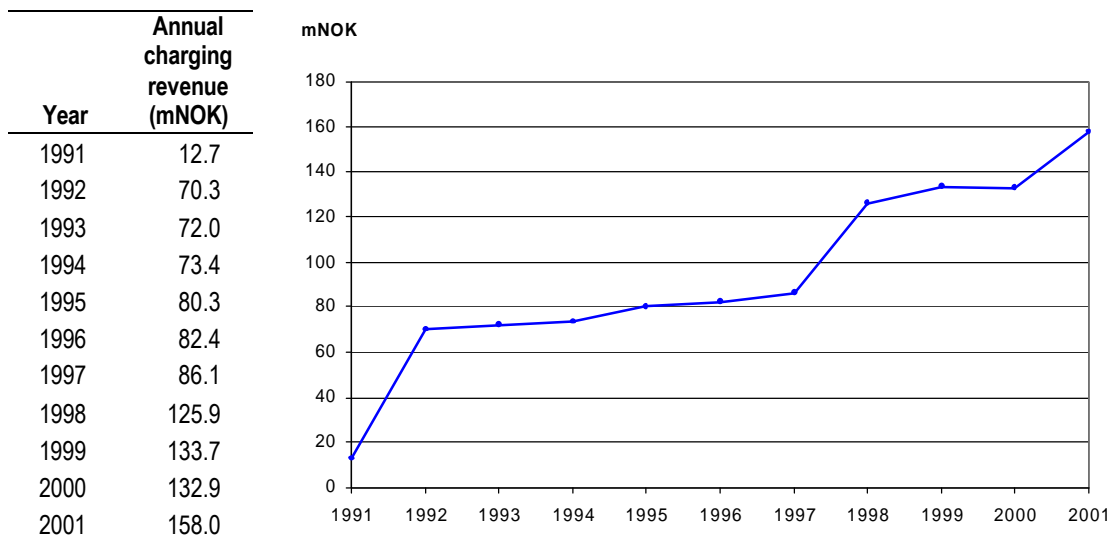


Figure 2: Annual charging revenue, Trondheim tolling system

Annual operation costs for the Trondheim RUC scheme have been roughly 10 % of the annual charging revenue throughout the decade of operation.

2.5 Subscriptions and exemptions

By May 2003 there was a total of 139 116 subscriptions to the Trondheim RUC system. The majority (94 %) was private customers, while 6 % were for vehicles belonging to companies. Some 5 % of the subscriptions were for heavy vehicles (> 3.5 tonnes), paying twice the ordinary toll level.

A total of 2 693 (1.9 %) subscriptions were exempt from paying. The exemptions to the tolling are handicapped with a parking permit, emergency vehicles / uniformed vehicles, public transport vehicles and electric vehicles. The exempt vehicles are dominated by the handicapped with a parking permit (57 %), followed by public transport vehicles (36 %), and uniformed or emergency vehicles (5 %). According to the toll operator, the number of exemptions has been stable over time, with only a modest growth due to increased issuing of parking permits for handicapped in the neighbouring municipalities of Trondheim. The vehicles from the toll are equipped with a regular tag for the tolling system, and the charging fee is set to 0. At present, there is no total overview of the number of crossings with exempt tags available, but in year 2000, the exempt crossings for the vehicles belonging to the local bus company, equalled a value of approximately 1.4 mNOK.

2.6 Use of pay options

Since the start of the toll ring in 1991, the road users in Trondheim have been automatically charged when passing the cordons in the toll system. When the RUC scheme was introduced, the electronic tags were distributed for free. This probably was a major factor in the successful introduction of a scheme based mainly on unmanned toll stations. During the first full year of operation, 80 % of all charged crossings were paid for by automatic charging. This share has been increasing steadily, and is now well above 90 %.

Table 2: Charged traffic, ratio with subscription, 1992 – 2001

Year	Annual paying vehicles over cordon(s)			% subscribers
	Subscribers	Manual payment	Total paying vehicles	
1992	8 189 589	2 005 196	10 194 785	80,3 %
1993	8 538 377	1 808 734	10 347 111	82,5 %
1994	8 897 799	1 663 214	10 561 013	84,3 %
1995	9 228 944	1 480 727	10 709 671	86,2 %
1996	9 840 459	1 354 617	11 195 076	87,9 %
1997	10 478 942	1 291 401	11 768 635	89,0 %
1998	16 601 294	1 405 802	18 007 096	92,2 %
1999	18 451 401	1 304 799	19 751 748	93,4 %
2000	18 909 520	1 246 042	20 155 562	93,8 %
2001	19 010 700	1 409 240	20 419 940	93,1 %

3. TRAVEL PATTERNS

This chapter is mainly based on data from three travel surveys carried out in Trondheim in the years 1990, 1992 and 2001 respectively. There was a change in survey instrument for the 2001 data collection, which may have caused an under-reporting of short, non-motorised trips for this survey.

3.1 Trip generation

There is no evidence that the RUC has caused an overall decrease in number of car trips.

The RUC targets the car driver trips, and the figures from the travel surveys give no indication that there has been a drop in the use of cars as a consequence of the RUC scheme. The initial evaluation of the 1991 RUC scheme (Meland, 1994) found that the decrease in number of cars crossing the cordon was lower than the general decrease in car trips in the Trondheim area. The long term trend from 1992 to 2001 is a general increase in number of car trips, and the increase was larger for OD-relations with a cordon-crossing (+ 9.3 %), than for relations which were not directly affected by the 1998 RUC-scheme (+7.8 %).

3.2 Spatial and temporal distribution of trips

The overall temporal and spatial travel patterns have remained stable throughout the decade of road tolling in Trondheim. There is no clear evidence that the RUC schemes has led to changes in overall temporal and spatial travel patterns, away from the charged relations and periods.

The 1991- and 1998 tolling schemes affect specific OD-relations, mainly in one direction, towards the city centre. The trips in each of the three travel surveys have been categorized into four groups by their relation to the toll cordons in the two tolling schemes, taking into account whether or not the trip type has undergone a change in relation to tolling:

- Group A holds the trips which are not charged in any of the two charging schemes, either because there is no cordon, or because the cordon is crossed in free direction or outside the charged hours.
- Group B holds the trips crossing a cordon in charged direction during charged hours in both schemes.
- Group C holds the trips which were not subject to charging with the 1991-scheme, but which are crossing a cordon in charged direction during the charged hours with the 1998-scheme.

- Group D holds the trips which were crossing the cordon in charged direction during the charged hours with the 1991-scheme, but which are not subject to charging with the 1998-scheme.

Although rough, this grouping provides a useful tool for studying aggregated effects of the tolling system with regard to the distribution of trips in time and space, and has been applied in the following analysis.

The relative distribution of trips between the groups is constant across the three travel surveys: Half of the trips are on relations with no toll cordon at all, while a further fifth of the trips cross a cordon in free direction or during free hours. An additional tenth of the trips do not involve charging, as these trips did not cross a cordon with the 1991-scheme, and crosses the 1998-cordon for free. In total, the trips with no cordon or free cordon crossings (Group A) represent 83 % of all trips in each of the three surveys. Only 8 % of the trips are on relations with cordon charging, during the charging hours for both RUC schemes (Group B), while an additional 8 % of the trips changed from free to charged with the 1998 RUC scheme (Group C). The 1998 revision changed 1 % of the trips from charged relation to free or without a cordon (Group D).

3.3 Mode choice

Although the general trend is an increased use of car, the data suggests that both the 1991-introduction and the 1998-revision of the RUC-scheme has affected the modal split on the relations and time periods which were directly affected by the change.

The data from the travel surveys show that car generally has become an increasingly important mode of travel in Trondheim. As the RUC scheme targets the car trips only, an expected effect would be a reduction or lower increase in car driver share for trips crossing the cordon in charged direction during the charging hours, than for the other categories of trips.

Findings from the evaluation of the initial 1991 RUC scheme indicated that there was a shift in mode choice during the charged hours for the trips affected by the charging, with a drop in car trips during the entire charged period, an increase in use of two-wheeled modes during the high-toll period, and an increased use of public transport during the low-toll period. Did the 1998-revision of the RUC-scheme give similar effects?

Figure 3 gives a picture of the changes in car driver share for each of the four groups of trips (Groups A – D) from 1990 to 2001. As the travel surveys only provide data for the years 1990, 1992 and 2001, the remaining years have been interpolated. This clearly is a very rough approach, and thus the graphs should

be interpreted with caution. The main function of the figure is to provide a basis for comparison between the four groups of trips.

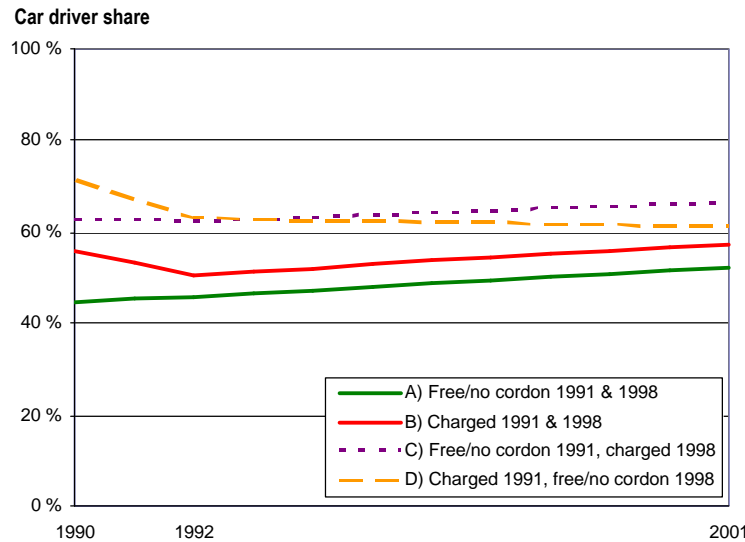


Figure 3: Car driver share, groups of trip categories, 1991- and 1998 RUC schemes (Travel surveys of 1990, 1992, 2001)

The most striking features of the figure are the trend-break captured in the 1992-survey for the trips exposed to charging in 1991 (groups B and D), with a clear drop in car driver share, and the parallel trend from 1992 to 2001 for the two groups which were not directly affected by the 1998-revision of the RUC scheme (Groups A and B). As the trips in group D were “relieved” from charging with the 1998-revision, one could expect a larger increase in car driver share for this group of trips, but this does not seem to be the case. However, as mentioned above, this group of trips represent only 1 % of the total number of trips, and the results are thus less reliable than for the other groups of trips. The graph for group C – the trips which were mainly affected by the 1998 change in RUC-scheme - does not clearly reveal a trend-break for the 1998-scheme, similar to the effect of the 1991-scheme, but this does not necessarily mean that there was none. The 1991-scheme was “embedded” by travel surveys one year before and one year after the introduction, while the 1998-revision must be captured by surveys from six years before and three years after the scheme was revised. Thus, any effects of the 1998-scheme are blended with more long-term general trends, making it harder to identify scheme-specific effects. However, the more modest increase in car driver share from 1992 to 2001 for group C suggest that this group of trips is worth a closer examination:

A study of the mode choice for trips directly affected by the 1998-revision of the RUC scheme, suggest that the revision indeed may have had an effect on the travel patterns, similar to what was found for the 1991-scheme.

Table 3: Mode choice, trips affected by 1998-revision of RUC-scheme (Travel surveys of 1992 and 2001)

Trips crossing no cordon in 1991-scheme, crossing cordon in charged direction in 1998-scheme										
Mode	Monday - Friday									
	06:00-10:00		10:00-18:00		18:00-06:00		Weekend		Total	
	1992	2001	1992	2001	1992	2001	1992	2001	1992	2001
Car driver	61 %	62 %	62 %	68 %	58 %	71 %	50 %	71 %	58 %	68 %
Car passenger	12 %	6 %	17 %	10 %	29 %	15 %	34 %	23 %	23 %	14 %
Public transport	13 %	16 %	11 %	11 %	4 %	5 %	5 %	1 %	9 %	8 %
Two wheels	10 %	10 %	4 %	5 %	4 %	6 %	4 %	3 %	5 %	6 %
Pedestrian	3 %	4 %	5 %	4 %	5 %	2 %	6 %	2 %	5 %	3 %
Other mode	0 %	1 %	1 %	1 %	0 %	0 %	1 %	2 %	1 %	1 %
Total	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %

For the OD-relations which were without a cordon in the 1991-scheme, but which cross a cordon in charged direction with the 1998-scheme, there was a total increase in car driver share from 58 % in 1992 to 68 % in 2001. This increase was however not uniform throughout the day and week. For the high-toll period (Mon-Fri, 06:00-10:00), there was hardly any change at all, and also for the low toll period (Mon-Fri, 10:00-18:00) the increase was more modest than for the free periods in the evenings (Mon-Fri, 18:00-06:00) and weekends. For the morning peak period, the data suggests an increase in the use of public transport.

3.4 Vehicle occupancy

The overall shift in vehicle occupancy does not support the hypothesis that the RUC scheme has led to an increase in ride sharing.

The introduction and revision of the RUC-scheme could be expected to lead to an increase in number of persons per car. The travel surveys do however not give any evidence of such an effect. On the contrary, the data indicate a drop in vehicle occupancy, from 1.3 persons per car in 1990 and 1992, to 1.2 persons per car in 2001 – a reduction of 8 %.

3.5 Travel time

The overall shift in average travel time per trip for car drivers does not support the hypothesis that the RUC scheme has led to longer trips by car.

One possible effect of the introduction and revision of the RUC-scheme, could be that short trips by car would be dropped or replaced by longer trips, in order to avoid the toll cordon or “get value for the money” if the crossing is made. This does however not seem to be the case.

Table 4: Average travel time per trip by mode, all trips (Travel surveys of 1990, 1992, 2001)

	Survey year			Change		
	1990	1992	2001	1990 – 1992	1992 - 2001	1990 - 2001
All trips	19.5 min	20.9 min	18.5 min	+ 7 %	- 11 %	- 5 %
Car driver	17.3 min	17.3 min	15.3 min	- 0 %	- 11 %	- 12 %
Car passenger	23.3 min	23.8 min	22.1 min	+ 2 %	- 7 %	- 5 %
Public transport	33.8 min	36.2 min	31.4 min	+ 7 %	- 13 %	- 7 %
Two wheels	14.0 min	15.3 min	16.4 min	+ 9 %	+ 7 %	+ 18 %
Pedestrian	17.2 min	20.9 min	16.8 min	+ 22 %	- 20 %	- 2 %
Other mode	61.9 min	85.5 min	100.8 min	+ 38 %	+ 18 %	+ 63 %

The trend from 1990 to 1992 was increasing trip length for all mode alternatives except car driver, suggesting that the 1991-scheme did not make car drivers shift to destinations farther away in order to avoid the toll ring. Furthermore, the increase in car passenger’s travel time was more modest than for other modes.

From 1992 to 2001 there was a general drop in trip length as measured in travel time, with the exception of two-wheel modes and “other” mode. The change in travel time for car driver trips was not significantly different from the overall change in travel time, thus adding to the indications found for the 1991-scheme, that the RUC system has not lead to longer trips by car. The two-wheel alternatives differ from the other modes by an increase both in number of trips and in trip length, confirming that bicycles have become increasingly popular as a transport alternative during the last decade.

4. WHO PAYS?

This chapter focus on the share of the population paying tolls under the RUC-schemes, and geographical variations in “exposure” to the charging. One of the objectives for revising the Trondheim RUC scheme into a zone-based system in 1998, was to obtain increased “fairness”, in the term that more travellers should contribute to the financing of the local transport infrastructure investment plan.

The travel surveys of 1990, 1992 and 2001 give information about the travel patterns at the time of the survey, while the RUC scheme which is the main topic of this study, was introduced in 1991 and changed in 1998. This means that we do not know the exact effects of these events, only what the situation was like some time before and after. To try and capture differences in effects for residents in the various parts of the town, a rough approximation of the effects of the scheme has been made, assigning all changes in travel pattern from one survey to the next, to the time of the introduction/change in RUC scheme. This clearly is not realistic, as the travel patterns are affected by many other factors which

change over time, but this simplification provides a useful illustration of the differences between the geographical zones (1998 RUC-zones, see Figure 1).

4.1 Paying car drivers

The overall shift in share of paying car drivers does support the hypothesis that the 1998 revision of the RUC scheme led to an increase in “fairness” in terms of including a larger proportion of the car drivers.

In 1992, 19 % of all drivers’ licence-holders were paying road tolls for at least one trip per workday. In 2001, the corresponding share was 30 %, showing that the revision was a success in terms of making more people contribute.

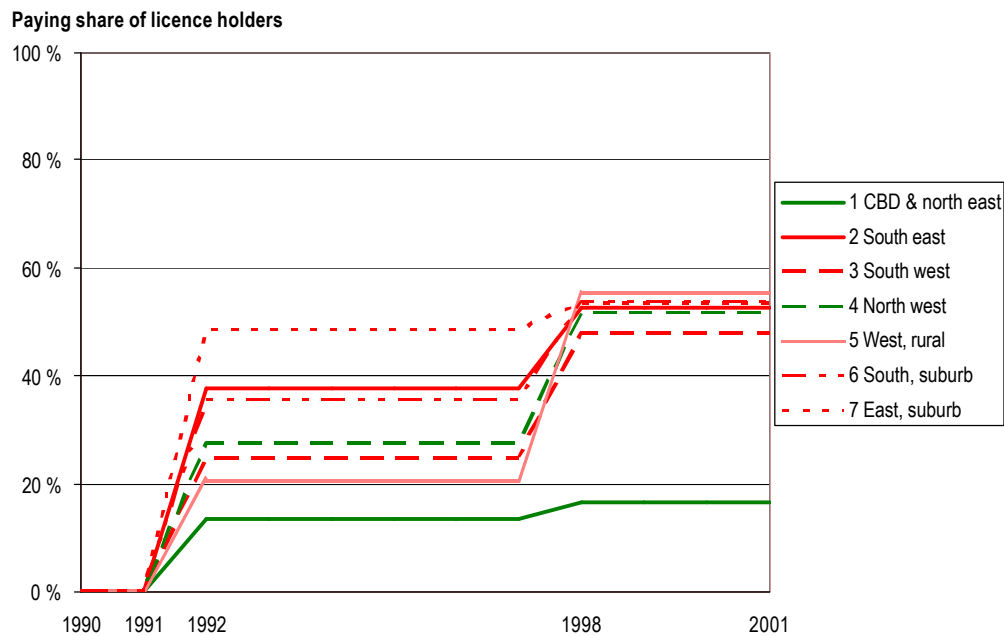


Figure 4: Share of paying licence holders per workday, residents in 1998-zones (Travel surveys of 1990, 1992, 2001)

The graphs in Figure 4 show that the share of paying licence-holders is lowest among the residents in the central area (CBD-zone). This is to some degree due to a generally lower car use in this area, but is also a result of the location of the toll stations in the RUC scheme. While the single cordon in the 1991 scheme affected the geographical areas in a varying degree, the 1998 revision led to an even clearer difference between the CBD zone and the remaining areas of the municipality. While 17 % of the driver’s licence holder in the CBD-zone pays road charges on any given weekday, the corresponding figures for the other zones vary from 48 % to 55 %. Thus, the 1998-revision of the RUC-scheme left the residents in the central areas of the municipality in an even more “privileged” position than before, with respect to exposure to the RUC scheme. However, the

forthcoming revision of the scheme during the autumn of 2003, with the introduction of six new toll stations surrounding the CBD, will alter this situation.

4.2 Charged trips

As shown above, there are differences in the share of licence-holders paying tolls, varying by residential zone. Naturally, the differences in number of trips being paid for follow the same geographical pattern.

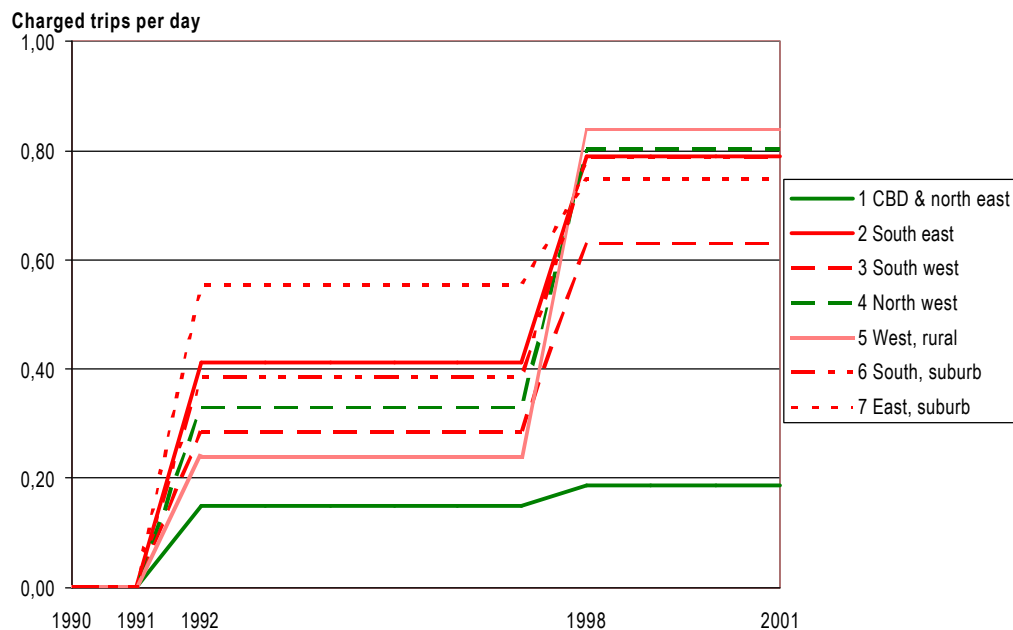


Figure 5: Average number of charged trips per licence holder per workday, residents in 1998-zones (Travel surveys of 1990, 1992, 2001)

In 1992, the first full year of charging, geographical the number of charged trips per weekday for each holder of a driver's license varied from 0.15 for the CBD-zone, to 0.56 for zone 7, the eastern suburb. These were the extreme values – for the other zones, the number of charged trips per day varied from 0.24 to 0.41. While the residents in the CBD-zone clearly were less affected by the 1991 scheme, the effect for the other of the two zones located inside the 1991 cordon (zone 4) did not differ much from most of the areas outside the cordon.

As mentioned, one of the motives for introducing the 1998-scheme, was to obtain a fairer charging system, and one of the criteria was the geographical effects of the RUC. Whether or not this was obtained, can clearly be a matter of discussion. The overall effect was an increase in number of trips subject to charging, but as illustrated above, the changes did not reduce the geographical differences. While the number of charged trips increased by 26 % to 0.19 for residents in the CBD-zone, the corresponding figure for the western rural zone (zone 5) was 248 %, to

0.84 charged trips. However, apart from the CBD-zone, the 1998 revision of the scheme reduced the geographical variation in number of charged trips per licence holder.

5. OTHER EFFECTS

5.1 Social exclusion

The high number of subscribers to the RUC system suggests that most residents in the Trondheim area do have an economic situation which allows them to subscribe, either by prepaying a certain amount of money, or by being admitted a post-payment-agreement.

However, in 1995 occasional users in the tolling systems (non-subscribers) were interviewed (Foss, 1995), and when asked about reasons for not being a subscriber, 6.4 % stated that they found it difficult to get a subscription. To get a subscription, you would either have to pay a given amount of money in advance to get a prepayment subscription, or be found credit-worthy to be granted a post-payment subscription. For households with little or no income, either of these criteria could be difficult to meet.

5.2 Effects for retailers

The Chamber of Commerce in its own study concluded that the 1991 toll ring hardly had any effect of on trade at all. During the first months of 1992 there was evidence of some businesses located inside the toll ring losing trade, but from the summer of 1992 on, no distortion of competition due to the toll ring could be read out of the trade statistics.

5.3 House prices

Based on the data available, it is not possible to conclude that the toll ring has had any effects on house prices in different parts of Trondheim. The statistics gives the same picture for the different parts of Trondheim and for the large cities in Norway.

6. CONCLUSIONS

The main purpose of the introduction of the Trondheim RUC scheme was to raise money for new road infrastructure. This has also been the motivation for the expansion of the scheme in 1998, and the forthcoming expansion in November 2003. In a town with a current population of 150 000 people, the scheme has raised more than NOK 1 000 million spent on road infrastructure for cars, public transport, bicyclists and pedestrians, and measures to reduce environmental problems generated by road traffic. The funding raised through road user charging is being matched with a similar amount of money from public grants.

Traffic management was not the main purpose of the scheme, and there are no indications that the RUC scheme has affected the overall traffic levels. However, the introduction of the 1991-scheme led to a temporal shift, away from the charged hours, towards evenings and weekends, and the data available suggest similar effects of the 1998-revision for the trips directly affected by the changes in the scheme.

During the autumn of 2003, the Trondheim RUC-scheme will be enhanced with six new toll stations in order to meet the needs for final funding of the infrastructure investments planned. According to political agreement, the system will be operating until the end of 2005, when it is to be terminated. Based on new legislation, the city is now discussing road user charging as an instrument for future demand management.

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PROGRESS Deliverable 6.2 Evaluation results (forthcoming). EU Competitive and Sustainable Growth Programme.