Inferring Variations in Values of Time from Toll Route Diversion Behavior

TERJE TRETVIK

The use of tolls to finance new road infrastructure has become widespread in many countries, and at many locations around the world the introduction of road pricing is being considered. The question of what values of time (VOT) should be used in toll road and road pricing studies has thus become increasingly important. Evidence is presented from a recent toll road diversion study, in which behavioral data were collected before and after a substantial price increase. The main emphasis is on the variations in willingness to pay for small time savings. Interesting changes over time in the relationships between background factors, and the difference between stated and measured time savings, are also discussed. VOT increased nearly linearly, but less than proportionately, with mean income. In general, short or frequent trips showed lower values than long or infrequent ones. Most drivers revealed a 2 to 4 percent increase in VOT corresponding to a 10 percent increase in their gross personal income. VOT was found to be a smaller percentage of the drivers' gross hourly wage rate as income increased. The ranges were 100 to 50 percent for commuting trips, 165 to 90 percent for business trips, and 175 to 75 percent for other trips.

The adoption of road user tolls to help finance interconnected or single sections of high-quality road infrastructure is common in many countries. The basic motivation is that government investment budgets are too tight and that users are willing to pay for time savings and better driving conditions. When there are alternative routes, however, the toll rates have to be set right for projects of this kind to be successful.

In the first section of this paper the general situation concerning the use of road tolls in Norway is outlined. Subsequently, detailed results from a toll road diversion study are given. Descriptive results about variations in toll road usage with background factors and new evidence concerning the relationships between stated and measured time savings are presented.

The last section addresses the question of modeling route choice under the influence of tolls. Logit models based on pooled data from 2 consecutive years are developed, and these are applied to study variations in values of time.

CHARGING FOR USE OF ROAD SPACE IN NORWAY

In Norway there is a long tradition of financing sections of road infrastructure, especially bridges and tunnels, by combining road user tolls and public funds. Most of the projects have no free-of-charge competitive routes in terms of distance or travel time. This is because the tolled sections either replace existing ferry crossings or establish new links in the road network. In times of steady traffic growth, the creation of enough revenues to defend the private sector involvement usually went according to plan. Often these types of projects generated trips exceeding the overall growth in traffic, and the charging period could in these instances be shortened.

Figure 1 shows the recent trend of increasing the private sector share of investments in national (state) highways. For 1991 the contribution from toll companies was expected to be 1.8 billion kroner, which is about one-third of the total investments.

One explanation for this large increase in private sector involvement is the introduction of the urban toll rings in Bergen (January 1986), Oslo (February 1990), and Trondheim (October 1991). The original political agreement was to raise extra private sector money, to be matched by extra government money, to fulfill urban road building programs in a much shorter time than was previously possible. The contents of the investment packages and the design of the schemes have, however, changed in line with increasing environmental awareness and developments in technology.

Although the focus of the original argument for the Bergen toll ring was entirely on road building, the emphasis widened to include infrastructure investments for public transport, cyclists, and pedestrians in the Oslo and Trondheim schemes. The Trondheim toll ring is the first scheme to have no monthly or yearly passes that allow an unlimited number of crossings. Tolls are charged per vehicle Mondays through Fridays from 6:00 a.m. to 5:00 p.m. for all inbound traffic. Charge levels during the morning peak are higher than they are later in the day, which indicates that the payment scheme is not entirely fiscal. It is also designed to influence car drivers' choice of mode and departure time.

As a result of a liberal credit policy and no government control on the issue of bonds, economically more marginal toll projects have been started. Some have even been financed entirely by borrowing. Others have been built in areas where competitive (old) free-of-charge routes existed.

The question of traffic diversion from the new route has thus become important. Environmental objectives of the new projects may not be met, and toll companies risk running into financial difficulties. This is exactly the case for the project that we now turn our attention to.

TOLL ROAD STUDY

The first tolled section was opened in 1988 on the E6 national highway route east of Trondheim in the direction of the air-

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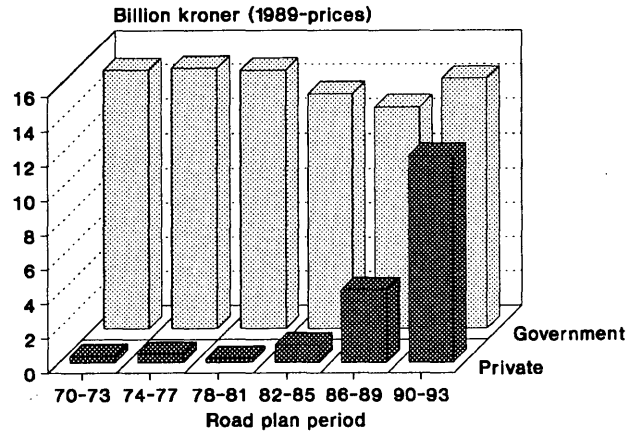

FIGURE 1 Private and government investments in national highways (*1*).

port. The motivation for building a new road was to divert through traffic from the heavily built-up area of the old route for environmental and traffic safety reasons and to provide a faster connection between the city and the airport.

The toll project has since been in operation 24 hr/day, and drivers passing through the toll plaza located at the periphery of the city have to pay in both directions. The charge was 10 kroner (early January 1993: 1 U.S. dollar was equivalent to 7 kroner) for light vehicles and 25 kroner for heavy vehicles in 1988 and 1989. This was increased to 20 kroner and 40 kroner in 1990, in conjunction with the latest extension of the tolled route.

Choice Situations

A special feature of the payment scheme is that drivers can deposit money in their personal toll accounts and pass through the toll plaza without any delay, being identified as bona fide account holders by the identity of their personal electronic tag mounted inside the windscreen. Tag holders can also be billed via their bank at the end of each month according to actual use by direct debiting.

In 1989 a second section was opened, and the toll company offered motorists 12.5 km of motorway driving conditions. The old route had a much lower standard and passed through built-up areas with several local speed limits of 50, 60, or 70 km/hr. Its length was roughly equal to that of the new route, and it was available free of charge. Choosing the old route in the direction of the city during the busiest time of the morning peak also implied the risk of some queuing.

During 1990 the new motorway was lengthened by 7.5 km, thereby presenting long-distance traffic with the choice of "buying" larger time savings than in 1989, but at a higher price. The old route was still similar in length to the motorway route for long-distance traffic and was available free of charge.

Interview surveys were conducted on users of both routes in November 1989 and November 1990, and average driving times between key origins and destinations were measured. To cover most trip purposes during a week, questionnaires relating to the drivers' current trip were handed out at certain times during 3 consecutive days in both years (Sunday, Monday, and Tuesday).

Total average daily traffic on the two routes passing the cross section where the toll plaza is situated was around 18,000 vehicles in both interview periods. Two-thirds of the returned forms came from choosers, that is, time-versus-money traders, in the sense that the tolled route represented the shortest (measured) time route, given the drivers' own statements about origin and destination.

Time Savings and Costs for Light Vehicles

Time savings depended on the drivers' origins and destinations and on whether it was a trip during the morning peak toward Trondheim. A small time delay was imposed on drivers who did not possess a tag because of time that was, or would have been, spent in money transactions at the toll plaza.

Figure 2 shows that the number of minutes to be gained by choosing the tolled section was quite modest. For the choosers represented in the samples, the average time savings increased from 4.4 min in 1989 to 6.8 min in 1990. The mode of the distributions increased from 5 to 8 min.

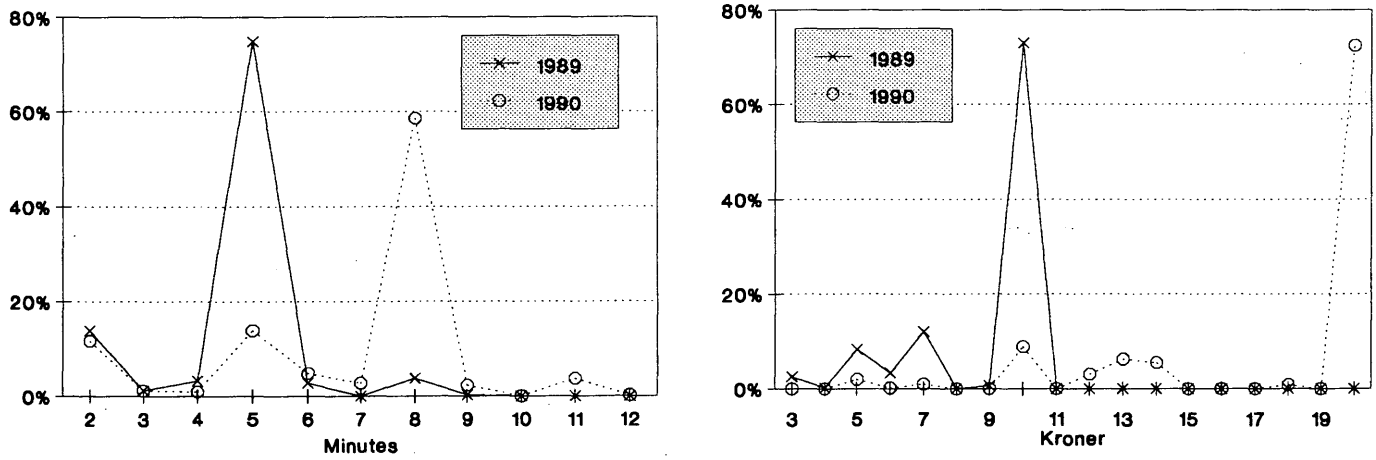

FIGURE 2 Distribution of actual time savings (*left*) and actual costs (*right*), rounded to whole numbers.

The mean costs were 8.85 kroner in 1989 and 17.63 kroner in 1990. Drivers with no tags had to pay the full price of 10 kroner in 1989 and 20 kroner in 1990. Slightly less than 30 percent of drivers in both years possessed a tag. These had variations in their cost per trip, depending on how many trips they had prebought. For instance, in 1990 the price per trip was reduced to 18, 16, 14, 12, or 10 kroner if the number of trips bought in advance was 25, 50, 100, 250, or 500, respectively.

If the driver stated on the questionnaire that others had, or would have, contributed to the payment (e.g., cost sharing with passengers or some kind of company car arrangement), the cost variable was reduced by 50 percent for nonbusiness travel purposes. The rationale for doing this was that company car usage for private purposes is taxed in Norway, so the marginal cost of a private trip is never zero. If the toll was paid by the employer and it was a business trip, the actual cost was not reduced, since for this trip purpose it is as much the employer's willingness to pay for time savings that is revealed.

It is suspected that the possession of a tag and the size of the rebate per trip for tag owners were related to income. The correlations between the final cost variable and gross personal income had the expected signs but were modest in size: -0.189 in 1989 and -0.214 in 1990. For the subsamples having a tag, the correlations were -0.162 in 1989 and -0.116 in 1990.

Choices

Figure 3 shows that usage of the tolled section dropped from 54 percent in 1989 to 40 percent in 1990. Groups labeled as "Commuting" and "Other" reacted more sharply to the price increases than did "Business." In general, drivers' reactions reveal that they did not find the extra time savings worth the double price.

In Table 1 usage of the tolled section by market segments is shown, together with the percentage distribution for each variable in brackets. The choices show a very clear pattern. First, in both years there is increased usage with (a) increased income, (b) lower frequency of traveling the section, (c) others paying, (d) owning a tag, and (e) increased length of the journey. Second, in each cell, usage is down in 1990 compared with that in 1989. It is evident from these results that travel-related factors, as well as income and details in connection with money transactions, play key roles in determining travelers' choice of route. We return to this point in another section.

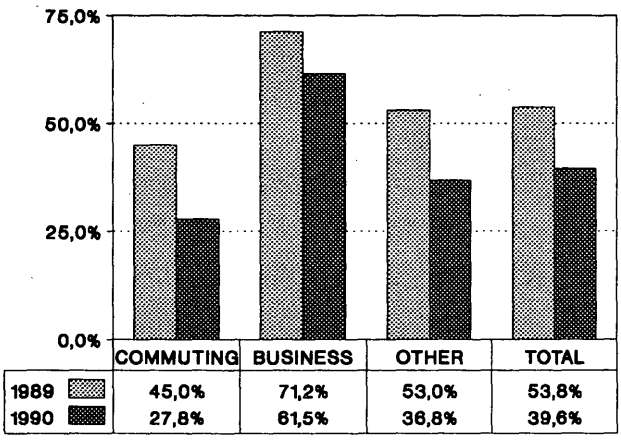

FIGURE 3 Usage of the tolled section in 1989 and 1990.

TABLE 1 Usage by Market Segments (Percentage of Observations in Brackets)

VARIABLE	1989	1990
INCOME GROUP (KRONER/YEAR)		
0 - 100 000	43.4 (16.4)	23.9 (15.9)
101 - 150 000	46.3 (19.7)	34.3 (18.0)
151 - 200 000	53.7 (33.9)	37.0 (32.3)
201 - 250 000	60.8 (15.9)	45.2 (16.9)
251 - 300 000	67.4 (7.6)	53.9 (9.1)
> 300 000	70.3 (6.5)	64.4 (7.8)
FREQUENCY OF CHOICE SITUATION		
Daily	46.1 (56.8)	30.7 (52.3)
Weekly	61.6 (18.7)	43.2 (19.0)
Monthly	69.1 (14.2)	51.3 (15.1)
More seldom	60.1 (10.4)	54.0 (13.6)
WHO PAYS THE TOLL?		
Car driver alone	47.2 (70.7)	29.8 (71.5)
Others, partly or completely	72.5 (29.3)	68.3 (28.5)
WAY OF PAYING		
Cash	44.0 (72.0)	29.4 (72.1)
Tag	80.6 (28.0)	67.4 (27.9)
TRIP LENGTH		
Short/local	44.8 (67.2)	30.0 (64.9)
Long	72.8 (32.8)	57.5 (35.1)

The distributions of the background variables were reasonably stable. A small shift toward higher-income classes can be noticed. Mean annual incomes in the samples increased by 3 percent from 183,000 kroner in 1989 to 189,000 kroner in 1990, which was close to the inflation rate that year (4 percent).

Subjective Versus Objective Time Savings

Choosers of both routes were asked to estimate the amount of time savings associated with use of the tolled section. Drivers on the old route were requested to estimate how many minutes of travel time they thought they would have saved if they had chosen the tolled route for their current trip. Drivers on the tolled route were asked how many minutes they thought they had saved by choosing the tolled route for their current trip.

Table 2 shows that all subgroups believed that the savings in travel time earned by choosing the tolled section were greater than they really were, as measured by observers using the car-following method.

In 1989 the average subjective time savings was 6.7 min, compared with the objective value of 4.4 min. This changed to 7.6 min subjectively in 1990, compared with 6.8 min objectively. The overestimation thus improved from +2.3 min to only +0.8 min—in percentage terms from +57 percent to +23 percent. We think that the effect of learning and possibly a more realistic view of the time benefits motivated

TABLE 2 Overestimation of Time Savings on Tolled Section by Subgroups

VARIABLE	1989 (minutes)	1990 (minutes)
FREQUENCY OF CHOICE SITUATION		
Daily/weekly	2.1	0.8
Less frequent	2.5	0.8
WHO PAYS THE TOLL?		
Car driver alone	2.8	1.2
Others, partly or completely	2.1	0.7
WAY OF PAYING		
Cash	2.1	0.7
Tag	2.6	1.1
TRIP LENGTH		
Short/local	2.1	0.9
Long	2.4	0.6
PURPOSE GROUP		
Commuting	2.1	0.7
Business	2.6	1.1
Other	2.2	0.8
CHOSEN ALTERNATIVE		
Old section	1.2	0.3
Tolled section	3.1	1.6

by the steep price increases are the main explanations for this improvement.

Drivers on the tolled section overestimated most seriously in both years, which indicates a sort of selection bias. It is almost surprising that 1990 toll road choosers did not overestimate even more, because of the effect of rationalizing their payment of twice the charge from the previous year.

People who travel the routes often or whose origins or destinations are local are bound to know better the attributes of the choice alternatives, and the results show that their estimates are more accurate. In addition, drivers who pay the toll completely out of their own pockets, or who have made the effort of acquiring a tag, are more likely to exaggerate their time savings. This phenomenon could be taken as evidence of attempts to correct the psychological strain referred to by Festinger (*2*) as cognitive dissonance.

Attempts at finding simple well-fitting linear relationships between objective and subjective time savings were not successful. Correlations (Pearson's R) between these two variables even for subgroups defined by travel purpose and year or choice were in general low. Groups labeled Commuting and Other segmented by either year or actual choice returned the highest coefficients, and these were around +0.4.

In Tretvik (*3*) simple binary logit models were estimated from 1989 data and applied in prediction exercises to forecast 1990 usage. Aggregate information about prices (+100 percent) and time savings (+50 percent) that would have been known in advance of the 1990 situation were used. The utility functions were

$$V_{\text{tolled route}} = \text{constant} + b_1 \times \text{actual cost} + b_2 \times \text{time saved (measured or stated)} \quad (1)$$

$$V_{\text{free route}} = 0 \quad (2)$$

The constants (b_1 and b_2) were estimated separately for each purpose group, and the probability for choosing the tolled route is given by the logit formula

$$P(\text{tolled route}) = 1/[1 + \exp(-V_{\text{tolled route}})] \quad (3)$$

The results showed that 1989 models using a stated time savings had a better fit than did the corresponding models using a measured time savings. This was to be expected because stated values measure people's perceptions much more closely than the more objective engineering values. However, whereas the 1989 objective models performed well in predicting 1990 usage, the 1989 subjective models seriously underestimated the actual 1990 demand. In short, the models did not respond well to the simple assumption that all drivers' perceived values for the time savings changed by +50 percent.

This result, and the previous discussion about the biases in people's perceptions about the actual time savings, underlines observations made by Small (*4*) about the problems of using stated values in prediction models. Even if reported values accurately measure the perceptions that determine choice, the resulting models cannot be used for prediction, unless one can predict how a given change will alter those perceptions.

GENERALIZATIONS ON THE VALUES OF TIME

In this section the focus is on variations in the car drivers' willingness to pay for perceived marginal time savings, rather than forecasting future demand. The 1989 and 1990 samples are added together, and we use stated instead of measured time savings as the explanatory variable. Figure 4 shows that the range is wider than that for measured time (Figure 2).

A rounding effect is noticeable in peoples' estimates of the time savings, causing distinct peaks at the values of 5, 10, and 15 min. Notice that small minorities (5 percent) of the Commuting and Other groups have the impression that there are no time savings associated with the tolled route. Figure 4 also shows that drivers with the purpose labeled as Other have the highest propensity for paying the full charges and that drivers with the purpose labeled as Commuting have the lowest propensity for paying the full charges.

The pooled sample allowed the estimation of more complete model specifications. The questionnaire did not contain variables such as sex, household composition, personal occupation, or age group. However, it was possible to take into account the effects of the length of the trip, whether the driver was a frequent traveler in the area, and whether he or she covered the cost privately. The effects of income were modeled by segmentation into six gross personal income groups.

Table 3 gives the results for the whole sample and for each purpose group. All parameters are attached to the utility function of the tolled alternative. The utility is specified in such a way that all parameters having names like "+ Cost if . . ." are additive corrections to the base actual cost parameter. This way of specifying the effects of income group on the cost variable is adopted from the Dutch value of time study (*5*).

Purpose group differences between the base actual cost parameters and between the stated time-savings parameters are modest. Differences in preferences between purpose groups are mainly accounted for by the additive cost parameters. A test statistic for the null hypothesis (H_0) of no taste variations across the purpose group segments can be computed as twice

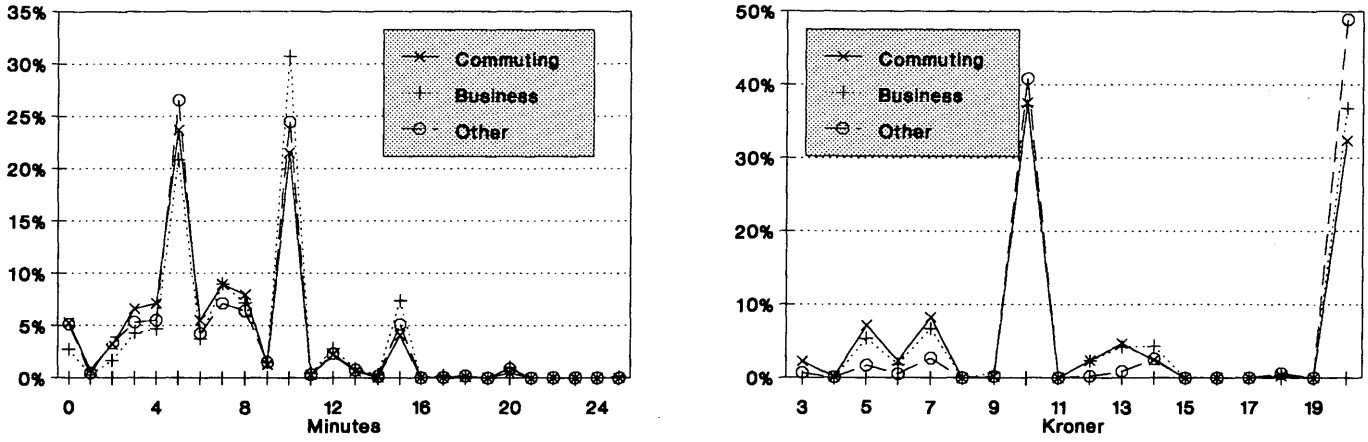

FIGURE 4 Distribution of stated time savings (*left*) and actual costs (*right*), rounded to whole numbers.

the difference in final likelihoods between the whole sample and the sum of likelihoods for the segments (*6*). It is χ^2-distributed with, in this case, $3 \times 11 - 11 = 22$ degrees of freedom. χ_{test} works out at 95.0, compared with $\chi_{22,.01} = 40.3$, so H_0 can be firmly rejected at the 1 percent level.

In Table 4 implied values of time resulting from the estimations are shown. Values for each income segment are calculated, with additive and independent percentage adjustments for the effect of other factors.

The values in the top section of Table 4 thus apply for travelers that are on a short trip, travel in the area often, and pay the toll themselves. These conditions are satisfied by 62 percent of the commuters but only by 11 percent of the drivers on business trips and by 13 percent of the drivers with other purposes. At the bottom of Table 4 average computed values across each sample are given, both per vehicle and per person in the vehicle.

In Norway, officially recommended values of time per person in the vehicle for use in cost-benefit analyses are given as standard percentages of the average wage rate in industry; 35 percent for Commuting trips, 134 percent for Business trips, and 20 percent for Other trips (*7*). This average wage rate was 90 kroner in the first quarter of 1990. The behavioral values revealed in this study, expressed in similar fashion, are

TABLE 3 Pooled Estimation Results (*t*-Values in Brackets)

VARIABLES AND KEY STATISTICS	WHOLE SAMPLE	COMMUTING	BUSINESS	OTHER
Constant	0.4071 (4.6)	0.4870 (3.4)	0.8105 (4.4)	0.1863 (1.3)
Actual cost on the tolled section (base)	-0.2488 (-31.7)	-0.2744 (-21.6)	-0.2452 (-15.5)	-0.2259 (-14.7)
Stated time saving on the tolled section	0.2355 (27.4)	0.2408 (17.4)	0.2424 (13.5)	0.2226 (15.7)
+ Cost if income ≤ 100 000	-0.03432 (-5.7)	-0.02971 (-2.6)	-0.00886 (-0.6)	-0.03146 (-3.7)
+ Cost if income 101 - 150 000	-0.00424 (-0.7)	-0.00177 (-0.2)	0.01167 (1.0)	-0.00866 (-1.0)
+ Cost if income 201 - 250 000	0.01039 (1.7)	0.02355 (2.0)	0.00222 (0.2)	0.00507 (0.5)
+ Cost if income 251 - 300 000	0.03758 (5.0)	0.05795 (4.2)	0.02291 (1.8)	0.03472 (2.8)
+ Cost if income > 300 000	0.03954 (4.8)	0.05921 (3.4)	0.04310 (3.4)	0.01284 (0.9)
+ Cost if on a long distance trip	0.05882 (14.4)	0.06782 (8.3)	0.03688 (4.8)	0.06475 (10.7)
+ Cost if infrequent traveller in the area	0.07129 (16.2)	0.07347 (7.4)	0.05708 (6.7)	0.06825 (6.5)
+ Cost if others contribute to toll payment	0.06420 (13.7)	0.01117 (0.8)	0.06390 (8.0)	0.03959 (3.8)
Sample size	8197	3464	2051	2682
Final likelihood	-4073.6	-1575.2	-997.3	-1453.6
Rho-squared (0)	0.2830	0.3440	0.2985	0.2181

TABLE 4 Values of Time (kroner/hr) per Vehicle (Percentage of Observations in Brackets)

	COMMUTING		BUSINESS		OTHER	
Base values by gross personal income group (kroner/year):						
0 - 100 000	47.51	(18.5%)	57.25[a]	(6.7%)	51.90	(22.4%)
101 - 150 000	52.32[a]	(18.5%)	62.28[a]	(13.2%)	56.94[a]	(21.8%)
151 - 200 000 (base)	52.65	(33.9%)	59.31	(32.6%)	59.12	(29.8%)
201 - 250 000	57.60	(15.2%)	59.85[a]	(21.6%)	60.48[a]	(14.3%)
251 - 300 000	66.75	(8.2%)	65.43	(11.5%)	69.85	(7.2%)
> 300 000	67.14	(5.6%)	71.96	(14.4%)	62.69[a]	(4.6%)
Adjustments for other factors:						
Trip length						
Short/local (base)	...	(76.9%)	...	(57.4%)	...	(59.8%)
Medium/long	+32.8%	(23.1%)	+17.7%	(42.6%)	+40.2%	(40.2%)
Frequency of choice situation						
Daily/weekly (base)	...	(88.1%)	...	(40.1%)	...	(18.1%)
Less frequent	+36.6%	(11.9%)	+30.4%	(59.9%)	+43.3%	(81.9%)
Who pays the toll?						
Car driver alone (base)	...	(87.4%)	...	(31.9%)	...	(89.2%)
Others, partly or completely	+4.2%[a]	(12.6%)	+35.3%	(68.1%)	+21.3%	(10.8%)
Average value across the sample per vehicle	73		138		120	
Average value across the sample per person in the vehicle	52		89		53	

[a] *Estimate not significantly different from base group (|t| < 1.8)*

smaller for Business trips (99 percent), larger for Commuting trips (57 percent), and considerably larger for Other trips (59 percent).

CONCLUSIONS

The data that were available for this study made it possible to establish that systematic variations existed in car drivers' willingness to pay for small time savings, with purpose group, income, and some key characteristics of the journey.

The results concerning private trips confirm a trend found in recent Norwegian studies from which values of time can be deduced, namely significantly higher values for Commuting and Other trips than the ones that are recommended officially. The results are also consistent with a summary of international empirical studies in Small (*4*). He concludes that 50 percent of the gross wage rate is a reasonable average for a journey to work, that business travel seems to have a higher value than commuting travel, but not necessarily equal to the wage rate, and that Other travel may have a value higher or lower than Commuting. He also notes that values on weekends are higher than values on weekdays, and that observation suggests one reason for the relatively high values for Other trips found in this study: because Sunday was one of the three interview days, we have picked up a large share of weekend social and recreation trips.

Figure 5 shows the average values of time per vehicle hour across the samples for mean incomes in the income segments. In the first three boxes, values are segmented by trip length and frequency of the choice situation. Values of time per vehicle hour are seen to vary with income in the range 50 to 200 kroner. In general, short or frequent trips have lower values than long or infrequent ones.

In the last box of Figure 5 the average values for each purpose group are plotted, and fitted linear regression lines are shown. The data give good support to a hypothesis about a straight-line relationship between value of time and income. The regression lines for value of time (VOT) in kroner/vehicle hour as a function of gross personal annual income in thousands of kroner were given by Equations 4, 5, and 6 for Commuting, Business, and Other, respectively:

$$\text{VOT} = 59 + 0.084 \times \text{income} \qquad R^2 = 87.1\,\text{percent} \qquad (4)$$

$$\text{VOT} = 89 + 0.226 \times \text{income} \qquad R^2 = 89.8\,\text{percent} \qquad (5)$$

$$\text{VOT} = 100 + 0.122 \times \text{income} \qquad R^2 = 91.9\,\text{percent} \qquad (6)$$

Values of time per vehicle for purpose groups, expressed as percentages of the gross hourly wage rate, are shown in Figure 6. In cases in which there is a lack of information about the respondent's working hours, the wage rate for each individual is computed as the reported annual income divided by 2,000. The values are decreasing percentages of income as income increases, and the ranges are 100 to 50 percent for Commuting, 165 to 90 percent for Business, and 175 to 75 percent for Other.

Equations 4, 5, and 6 imply that VOT increases less than proportionately with income. In Figure 7 the variations in percentage change in VOT, for a 10 percent change in income, are shown. Most travelers reveal an increase of 2 to 4 percent in VOT for a 10 percent increase in their gross income.

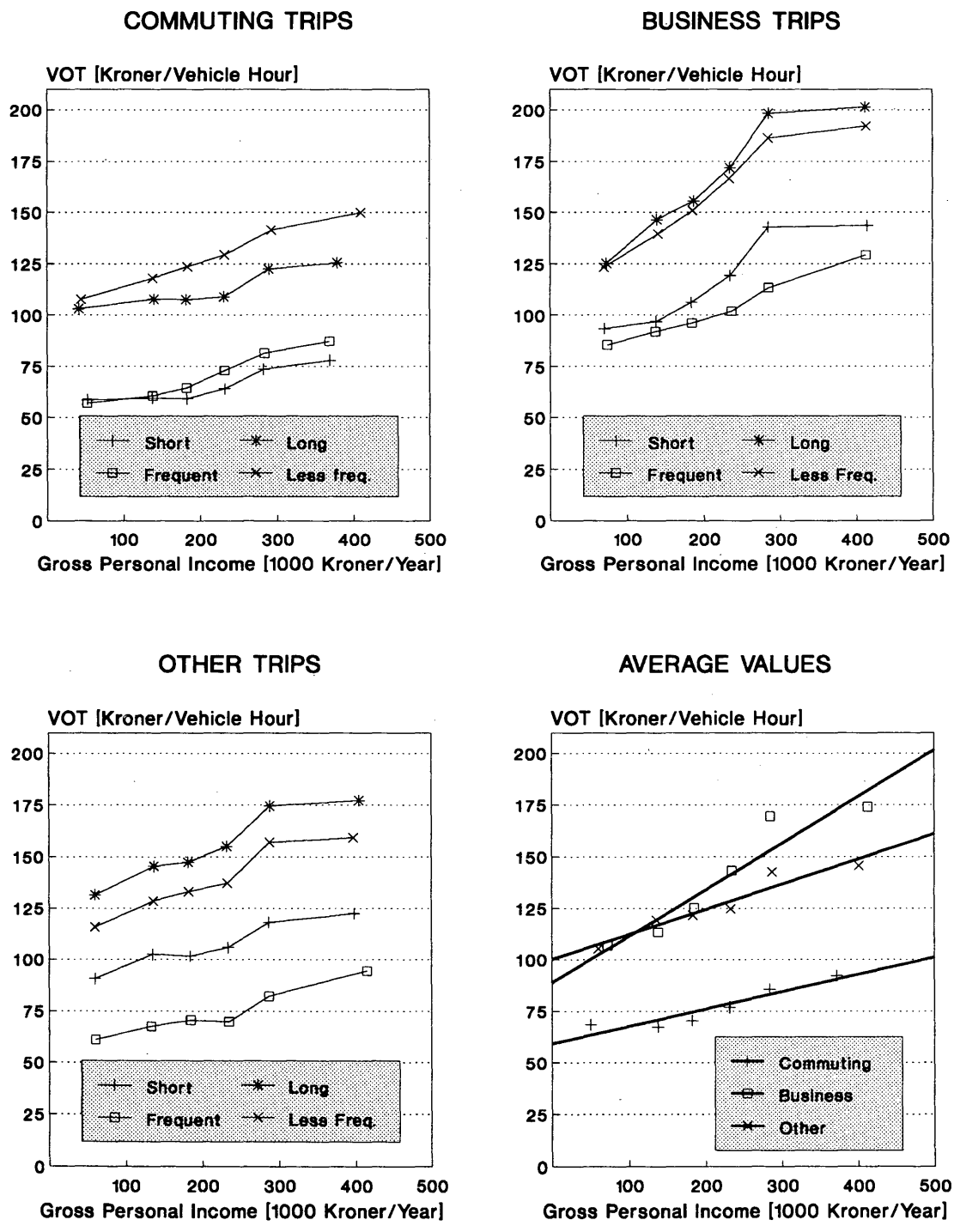

FIGURE 5 Variations in values of time with income.

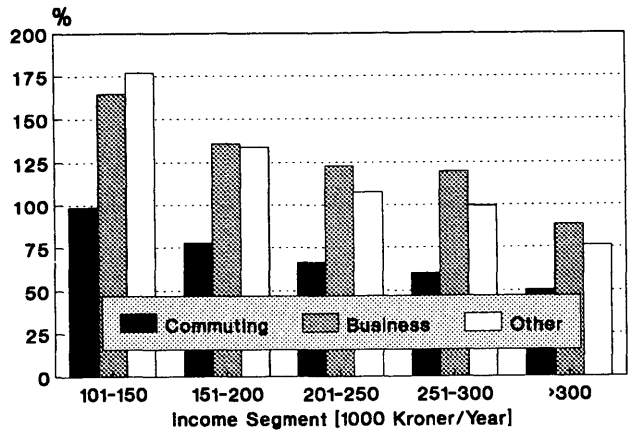

FIGURE 6 Values of time per vehicle as percentage of gross wage rate.

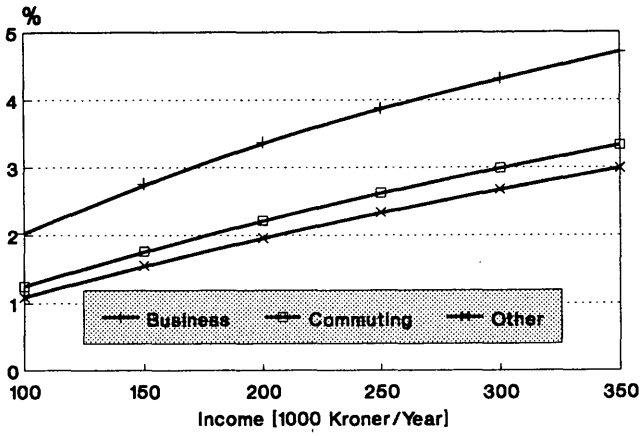

FIGURE 7 Percentage change in VOT per vehicle with 10 percent change in income.

Discussions are underway in Norway and among the Nordic countries, in preparation for coordinated efforts to supplement this and other recent studies of behavioral values of time. The aim is to provide a comprehensive body of evidence as a basis for recommending revised values for the assessment of transportation improvements.

ACKNOWLEDGMENTS

The writing of this paper was financed by PROSAF, a research program of the Royal Norwegian Council for Scientific and Industrial Research. The 1989 and 1990 data collections were planned and executed as a joint effort between ASPLAN Trondheim and SINTEF and financed by the Public Roads Administration. The author has benefited from the suggestions of Tore Sager of the Norwegian Institute of Technology.

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Publication of this paper sponsored by Committee on Transportation Economics.