Modal split and travel times in the western NSB corridor in Oslo

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Background

Hypotheses put forth by Downs (1962), Thomson (1977) and Mogridge (1985, 1990, 1997) make up an important part of the background for the study presented in this paper. The point of departure for the argument of these researchers is the fact that the consequences of increased urban traffic in terms of travel speeds are opposite for car traffic and public transport[1]. Whereas more congestion and lower speeds on urban roads are consequences of increased car traffic, a higher patronage of public transport may facilitate more frequent departures and may also create an economic surplus enabling the transit company to invest in faster and more comfortable vehicles. In other words, the collective transport operator gains economies of scale, contrary to the *diseconomies* of scale characterizing the flow of cars on the road network (cf. Figure 1). In traffic corridors with a high density of cars, vacant road capacity will, according to Downs, Thomson and Mogridge, tend to be utilized until the traffic density on the roads has increased to a level where the speed of car traffic (measured from door to door) is similar to that of public transport. If the traffic density on the roads increases beyond this level, the speed of car traffic will drop below the speed of transit, and in its turn cause some motorists to change to the transit mode. The traffic load on the roads will gradually stabilize at a level where average door-to-door travel speeds are about the same for car as for transit. Accordingly, the level of this *equilibrium speed* is determined by the speed of the public transport system.

If the above arguments are correct, the most efficient way of increasing travel speeds (including the speed of car traffic) will be to reduce door-to-door travel times by public transport. Increasing road capacity in congested conditions will, according to Mogridge, be counter-productive. With increased road capacity, some previous transit riders will change to automobiles, resulting in a lower patronage for public transport. Sooner or later this will force the transit companies to reduce their services[2], for example by reducing the frequency of departures (resulting in longer average waiting times). The future equilibrium speed will thereby be lower than it was before the construction of new road capacity, and paradoxically, this results in lower travel speeds also among those who go by car.

So far the arguments of Downs, Thomson and Mogridge. Their reasoning is based on several assumptions. Firstly, they assume that a large proportion of the travelers are in a situation where they can choose between car and public transport. For «captive riders», e.g. travelers without access to a car, or who need to use the car for official trips during the workday or for errands on their way to or from the workplace, the mode of transport will not be influenced by variations in the travel speeds of car and transit. Secondly, it is assumed that the travelers are «rational actors» whose choice of mode is determined by what is most time-saving, and not by, e.g., their ideas about which mode gives the highest status or is most comfortable. The theory assumes that travel time makes up a substantial part of the «generalized costs of travel», although the latter may include a number of measurable and non-measurable circumstances in addition to the time spent during the trip. Thirdly, it is assumed that a large proportion of those who are in a situation where they can choose among modes (i.e. the «non-captive riders»), are attentive to marginal changes in the speeds of either of the modes and adjust their travel behavior accordingly. Fourth, the theory assumes that the total traffic trough the transport corridor is sufficiently high that the curves indicating how travel speeds of car and transit vary with

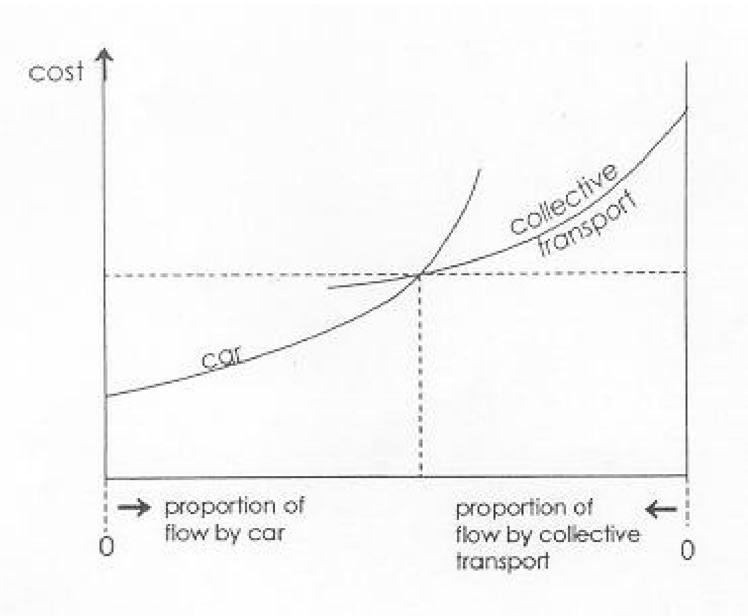
[1] The argument mainly refers to public transport running on separate lanes, i.e. subways, trains, and buses and streetcars with a separate lane.

[2] Or increase the transit fares. Such an increase in the costs of traveling by transit will, however, add to the generalized travel costs of the transit mode and is likely to influence the modal split in a similar way as reduced transit services.

the traffic density on the roads and the patronage of public transport, are actually crossing each other (cf. Figure 1)[3].

In order to illustrate the above questions, a research project is currently beeing conducted in cooperation between Norwegian Institute for Urban and Regional Research and Martin Mogridge Assosiates in London. The overall purpose of this study is to illuminate "virtuous circles" and "vicious circles" in urban transport, seen from the perspective of energy minimizing and reduction of emissions. What are the effects of road and transit investments, respectively, in terms of modal split and travel speed?

Figure 1: The Downs equilibrium. From Mogridge (1997): «The self-defeating nature of urban road capacity policy. A review of theories, disputes and available evidence.»



The empirical part of the study focuses on morning peak period commutes in two transport corridors of Western Oslo. In the theoretical part of the study, results will be compared across the two empirical cases and with previous empirical and theoretical studies. The conclusions of these comparisons will be used as elements in a broader discussion of factors influencing the competition between private and public transport in urban areas.

The two transport corridors in which commuting patterns are being investigated, are the corridor along the NSB railway line and highway between downtown Oslo and the suburb of Asker (below referred to as the *NSB corridor*), and the corridor from downtown Oslo to the suburb of Østerås (below referred to as the *Østerås line corridor*). In each of the cases, information from travel surveys among residents living in the corridor and working downtown will be combined with statistics on car traffic and public transport passengers during the last decades.

Thus, the overall design of the study is a multi-embedded case study (Yin 1994), including two cases (the NSB and the Østerås line corridors) in which different sources of information (both survey data,

[3] In Figure 1, the variable along the vertical axis is termed «cost», not «travel speed». However, as has been discussed above, the theory of equilibrium speed assumes that travel time makes up a substantial part of the costs experienced by an individual when making a trip.

archival records, interviews of transport planners and transit company officials, etc.) will be used. The survey data from the two cases will not be pooled, but utilized in separate analyses in each of the cases. The comprehensive comparison across cases will focus on the *conclusions* arrived at in each case.

In addition to the two main cases (the NSB and the Østerås line corridors), the effects on traveling patterns from certain important changes in the transportation system elsewhere in the Oslo region during the last decades will be analyzed. For these analyses, only already available data (traffic counts, statistics on transit patronage etc.) will be used.

Research questions

The main research question adressed in the study is the extent to which commuters' modal choice is influenced by door-to-door traveling times by car, compared to public transport. The investigation concentrates on the morning peak period. Journeys to work in the NSB corridor from Asker and Sandvika to downtown Oslo have been mapped. Our research questions are:
A) To what extent does the modal split of morning peak period commuting trips through the NSB corridor to downtown Oslo correlate with the relative competitiveness of car versus public transport as to door-to-door travel time?
B) Does the modal choice for commuting trips to downtown Oslo in the morning peak period correlate with the ratio of door-to-door traveling times with car and public transport, also when controlling for other factors (e.g. car ownership, income, sex, age) which may influence the choice of mode of transportation?
C) How high share of the morning peak period commuters are "captive riders" who have practically no other choice than the mode of transportation they actually use?
D) Approximately how high shares of the "mode choice riders" (i.e. non-captive riders) among the morning peak period commuters may be considered as "sheep" and "explorers" [4], respectively?
E) What is the magnitude of change in the proportions of car and transit commuters that could be expected from a given change in the door-to-door travel time ratio between car and public transport (e.g. from a situation where door-to-door travel time by car is 110 per cent of the corresponding travel time by transit, to a situation where the door-to-door journey by car takes only 90 per cent of the time required for a journey to work by transit)?
F) Does an "equilibrium speed" between car and public transport exist among the "mode choice riders"? I. e. that the "mode choice" commuters are relatively evenly distributed between car drivers and transit passengers, that average door-to-door travel time for each of these groups is approximately equal, and that the travel times of the individual respondents do not deviate much from the average door-to-door travel time (which is similar across modes) for the relevant commuting distance.
G) On average, how high are the proportions of commuters by car and transit, respectively, when the door-to-door travel time ratio between the two modes is 1.0? Is the distribution the same for the sample as a whole as among "mode choice riders" only?
H) To what extent is the modal choice influenced by the composition of the traveling time (the proportion of the total door-to-door travel time used for walking and waiting, and the number of transfers between different vehicles)? To what extent is door-to-door travel time a good indicator of "generalized traveling costs"?
I) How frequently do "non-captive riders" choose a mode of transportation leading to significantly (e.g. more than 20 per cent) increased door-to-door travel time, compared to the fastest alternative? What kind of reasons do the relevant respondents give for opting for a slower way of traveling? (For

[4] Downs (1962) separated people into «explorers» and «sheep», the former changing mode often to find the best mode for their journey, whereas the «sheep» did not.

example, do environmental considerations make many respondents choose public transport although car is faster?)

Method

The case study is mainly based on a survey investigation. To some extent we have also made use of statistics from the Oslo Municipality, Department of Transport.

The respondents are workforce participants living in the As ker/Høn area or the Sandvika/Blommenholm area, and working downtown Oslo. The persons included in the sample were identified by the Central Bureau of Statistics. The criteria for sample selection are presented in a Norwegian-language paper dated 12 May 1995. A copy of the questionnaire is available from the authors at request.

The data have been analysed by using the SPSS (Statistical Package for the Social Sciences), and we have espescially made use of the logit-model for multivariate regression.

Response rate
Alltogether, 1000 questionnaires were sent to persons living in the NSB corridor, working in downtown Oslo. 500 questionnaires were sent to people in the Asker/ Høn area, 500 to persons living in the Sandvika/Blommenholm area. 543 (54 per cent) of the 1000 returned the questionnaire. Out of these 543, 269 questionnaires were for different reasons excluded; the respondent had moved, was on leave, had retired, started working somewhere else (outside downtown). Some of the excluded respondents had conducted errands on their way to work, which made their traveling times irrelevant for our analysis. Also, some of the repondents arrived too late to be considered traveling in the morning peak period. This arrival time-limit was set to 0939 for those going by public transport and 0938 for those going by car. Of the remaining 274, another 20 cases were excluded because they were car riders who used their car in work duty, and hence were not really free to choose traveling mode. In total, 253 (25 per cent of the total 1000) cases remained for the final analyses. Still, in the different analyses the number of cases (N) may vary, due to lacking information on some of the variables.

253 cases is a little below the 300 we hoped to include in the analysis. A broader discussion of the validity of the case study will be outlined in the final report from the project. So far, it is worth noting that the results reported in this working paper have shown to be statistically significant at an acceptable level.

Data and data preparation
The survey was carried out in weeks 39-42, 1995. Then there was still no snow on the ground, but getting colder. For the most of travels made by our respondents, walking or cycling probably were no alternatives, because of the long distance between home and work. According to the answers, none of the respondents walked or cycled. We therefore believe that the recorded modes of travel vary little over the year, and that the survey is valid not only for the weeks we investigated, but for the whole year.

The data in the forms were recoded into a SPSS file by the MMI (Markeds- og media-instituttet/Institute for market and media). Some of the data had to be processed before the analysis. This applies to the data concerning traveling times. For the respondents who had traveled by car, we needed to calculate traveling times as they would have been by public transport. For those going by public transport we had to calculate traveling times if going by car. In order to do this , each journey was divided into three parts:

1) Residential segment; the distance (measured in traveling time) from the residence to the bus stop/train station, or to the junction were the main road is entered.

2) The line haul segment; the distance carried out by the public transport mode, or by car on the main road. In the NSB corridor this is the highway E18.
3) Workplace segment; the distance between the stop/station where one leaves the public transport vehicle, and the entrance door at the work place, or the distance beween the junction where the car rider would leave the E18, and the parking place, and the distance between the parking and the entrance door at the work place.

The traveling times were calculated in the following way:
1) The residential segment: All respondents' home adresses were plotted on a map (scale 1:5000) with actual traveling times next to them. Car riders were plotted in blue, public transport riders in red. These actual travel times could be taken directly from the questionnaires. The traveling times in the residential segment could then be calculated by interpolating. For one who had gone by car, the theoretical walking time to the public transport vehicle was calculated by interpolating from the times the nearby living real public transport commuters had used. Correspondingly, we calculated theoretical times by car for those who went by public transport. For the public transport mode, waiting times were included in the walking time.

2) The line haul segment: For those who went by public transport, we had to calculate theoretical traveling times by car. This was based on speeds recorded in Prosam report no. 41 (Oslo municipality, department of transport, 1996). In the Prosam report, traveling times on the E18 highway have been measured every 15 minute between 0715 and 0845 in the morning peak period on the distance from Asker to Oslo central station. The measurement in 1995 took place in week 37 and 38. This made them quite comparable to traveling times for our respondents who recorded their journeys in weeks 39 to 42.

The respondents for whom we needed to calculate traveling times by car were divided into three groups: i) Those who arrived at their workplace before 0709, ii) those who arrived between 0709 and 0805 and iii) those who arrived between 0805 and 0939. Those who arrived later that 0939 were excluded because we consider them to travel after the morning peak period. The respondents were then given traveling times in the line haul segment calculated the following way:
Group i)
Based on the theoretical average speed in the Prosam report. This speed presume that traveling speed is equal to the speed limit. This speed has not been corrected for deviations due to curves, crossing, traffic lights (whitch there are none of on E18).
Group ii)
Based on the theoretical average speed and the observed traveling times in the Prosam report we presumed a linear increase in traveling time for the time between 0709 and 0805. The group was divided into four sub-groups and we calculated traveling times according to the presumed linear increase.
Group iii)
Based on the observed speeds in the Prosam report.

For those who actually went by car, traveling times by public transport was taken from the time tables for the most relevant public transport mode.

3) The workplace segment: All respondents' workplace adresses were plotted on a map (scale 1:5000) with actual walking times from public transport stop or parking lot respectively next to them. Car riders were plotted in blue, public transport riders in red. These actual travel times could be taken directly from the questionnaires. The theoretical traveling times in the workplace segment could then be calculated by interpolating similarly to what we did in the residential segment. In the case of calculating walking time from the car park to the work place, we also considered the distance to the

nearest parking house. Walking times were calculated by presuming a walking speed of four km/hour. In areas with long distances to parking houses, we assumed off street parking with seven or ten minutes walking distance, depending on the availability for such parking in the area.

Sources of error
Some of the respondents who went by public transport have recorded shorter traveling time by public transport than listed in the time table. These times have been corrected since we believe this is due to incorrect measurement by the respondent, rather than that the public transport mode went faster than described by the time table.

Those who went by a combination of car and public transport were recoded to have traveled by one of the modes, depending on what mode they used on the line haul segment.

We also recoded missing answers for some questions. This included missing answers on the question about wether they were doing errands or not and those missing on the question about wether they were using the car for work duty during working hours. The missing answers on these yes/no-questions were coded into "no" answers, as we believe that they probably did not answer the question because they did not find it relevant if they had no errands or did not need the car for work duty during working hours. We have carried out the multiple regression analysis with and without this recoding, and there is little difference in the results.

Results so far

Below we will present some of the results so far available from the study. We are not yet able to answer all of the research questions above. Nevertheless, the results at this stage include several interesting observations.

Descriptive statistics

The study shows that door-to-door traveling times by car and by transit are relatively similar among residents in the Asker and Sandvika areas who are working downtown Oslo. On average, door-to-door traveling speeds are about ten per cent higher by car than by transit. For about 65 per cent of the commuters, car was the fastest option.

Even though car was on average slightly faster than transit, nearly 80 per cent of the commuters of our sample traveled by public transport. Only among travelers who would spend more than twice as long time for the journey to work by transit than by car, the proportion of car commuters was above 50 per cent.

18 per cent of the respondents had sufficient parking conditions near by the work place, a factor that is likely also to influence modal choice. About one fourth did errands on their way back from work , wich may have forced them to go by car. Only 5 per cent of the respondents have the economic expences of their journeys to work covered by their employees, and are in this way economically encouraged in any direction when choosing traveling mode.
The average age among the respondents was 46, with an standard deviation of 12, and minimum of 23 and maximum of 75. Males are slightly dominating the group of respondents, with 54 per cent. However, this may still imply a overrepresentation of women, compared to the universe of commuters in the NSB corridor. On average, the respondents belong to high income groups, with 272 000 Norwegian kroner (NOK) as the average income per adult household member. But, there are large standard deviations from this mean, +/-135 000 NOK. Also, these numbers were asked for by referring to categories ranging from 50 000 to 850 000 with intervals of 100 000, which make the

mean only roughly correct. Half of the group had at least 7 years of education in addition to 9 years of compulsory school, and 7.5 per cent did not hold a driver's licence. Three of the households had 2 cars per adult household member, and 26 per cent had one car per adult household member. The average number of cars per household member was 0.6.

Which factors influence the modal split?

Reasons for using the logistic regression model

A linear regression model requires that the dependent variable is continuous and unlimited. In our model this is not the case. The dependent variable is dichotomous and takes either the value one (going by car) or zero (going by public transport). Hence, we have to use another statistical prediction model than the linear regression. The *logistic regression model* handle dichotomous variables in a satisfactory way, and this is the model we have used in our analyses.

The model we have been using in the regression analysis contains the following variables (table 1):

Table 1   Variables in the model

dependent variable	**value**
traveling mode	1 (car), 0 (public transport)

independent variables	**value**
errands on the journey home from work	1 (yes), 0 (no)
age	years of age
ratio of length (in minutes) of within-vehicle public transport journey, by the total length of the door-to-door public transport journey	ratio
household gross income per household member above 18 years of age	income in Norwegian kroner
sex	1 (male), 0 (female)
door-to-door travel time by car divided by door-to-door travel time by public transport	ratio
parking facilities at the work place	1 (adequate parking facilities), 0 (scarse, expensive or no parking within acceptable walking distance)
travel expences paid by the employer	1 (yes), 0 (no)
years of education after 9 years of compulsory school	1 (7 years or more), 0 (6 years or less)
interaction variable, interaction between cars per household member above 18 years old and holdership of a driver's licence	

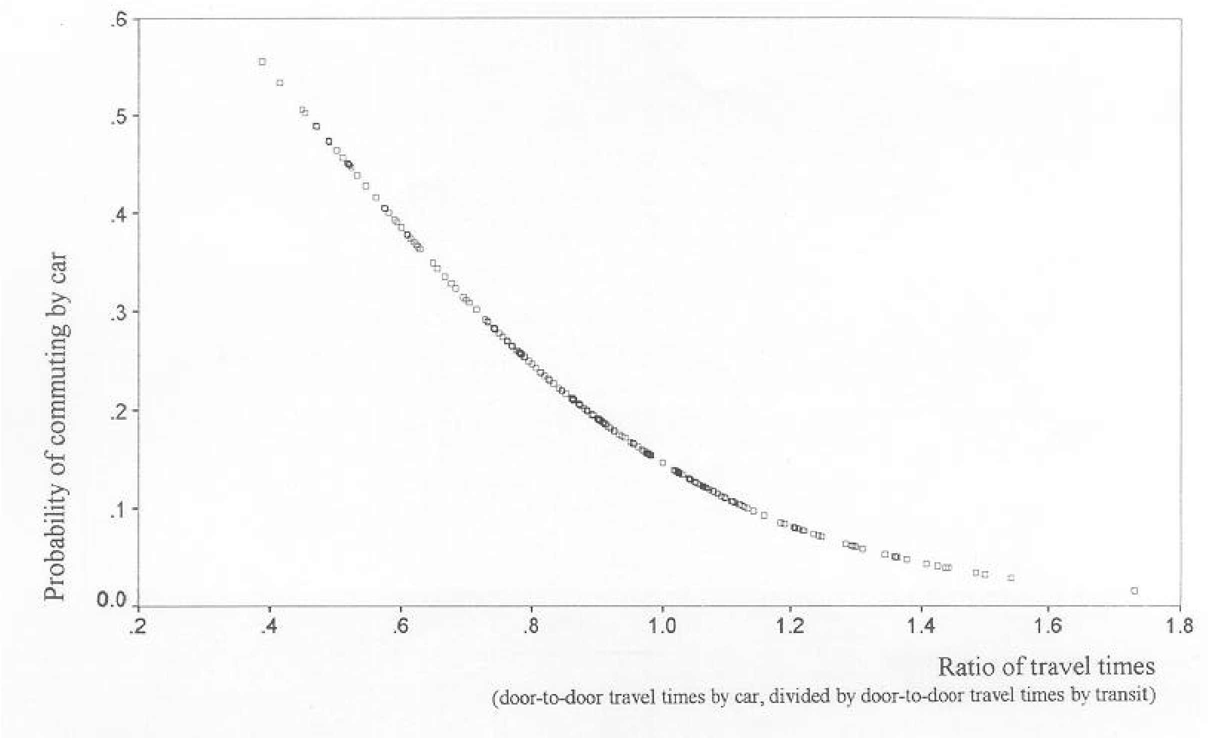
Bivariate regression

figure 2 shows the bivariate logistic regression curve, indicating how the likelihood of commuting by car varies with the ratio of door-to-door travel times by car and by transit.

Bivariate regression coefficients were calculated in order to check for multicollinearity. We found no such collinearity. Neither the VIF (variance inflation factor) test revealed multicollinearity.

Figure 2 *Probabilities of commuting by car at varying ratios of door-to-door travel times by car and by transit. Bivariate logistic regression, without controlling for other variables.*

N = 253 employees living in the Asker or Sandvika areas and working downtown Oslo.



Multivariate regression

The results of the logit analysis are presented in tables 2, 3 and 4.

a: Likelihood ratio test (Goodness of fit)
In the logistic multiple regression analysis, the likelihood ratio is used a test parameter for the null-hypothesis. It is analogous to the F statistics in the linear multiple regression.
In our model the chi square is equal to 62.217, and significant (Table 2). We then can reject H_0-hypothesis that all coefficients are equal to zero, or that none of the independent variables show a relationship with modal choice.

Table 2 *Results from the logit analysis with modal choice as dependent variable:*

1) Log likelihood

-2logL0	244.750
-2logL1	182.533
[(-2logL0)-(-2logL1)]= ^{2}	62.217
Significance level, df=10	0.0000
N	253

b: How well does the model predict the outcome?
Our model predicts 84.84 per cent of the outcomes correct (Table 3). The modal percent is 79.4 per cent. The outcome is hence improved by app. 5 percentage points, with a total possible improvement of 21 percentage points (based on 100 per cent prediction).

Table 3 Results from the logit analysis with modal choice as dependent variable:

2) Predicted vs. observed outcomes

	Predicted		**Per cent correct**
Observed	*public transport*	*car*	
public transport	185	10	94.87%
car	27	22	44.90%
Overall			84.84%

c: Logit coefficients

In table 4 can we see that four of the 10 independent variables show significant relationship with modal choice at a 5 per cent level . These are the following variables: ratio of the door-to-door travel times by car and by transit, parking conditions at the workplace, commuting expenses paid by the employer, and the interaction variable car ownership by driver's licence holding. From the sign of operation of the coefficients we can see that a long traveling time by public transport, satisfactory parking conditions at the work place, commuting expenses paid by the employer and holding a driver's licence and at the same time having a high number of cars in the household, all increase the probability of going by car. The directions of the relationships are as expected from theoretical considerations we did beforehand. Conducting errands on the way back from work is almost significant on the 5 per cent-level, and also increases the probability of going by car. None of the remaining variables investigated (age, the proportion of the door-to-door travel time by transit spent within the vehicle, income level, sex, and education) appear to exert any influence worth mentioning on the modal choice.

Table 4   Results from the logit analysis with modal choice as dependent variable:

3) Relationship between the independent variables and modal choice: Logit coefficients, standard error and significance levels

independent variables	logit-coefficient B	standard error S.E.	significance Sig
errands on the journey home from work	0.7507	0.4452	0.0918
age	-0.0158	0.0174	0.3650
ratio of length (in minutes) of within-vehicle public transport journey, by the total length of the door-to-door public transport journey	-2.6327	1.8448	0.1535
household gross income per household member above 18 years of age	1.12E-06	1.611E-06	0.4856
sex	0.0691	0.4126	0.8669
door-to-door travel time by car divided by door-to-door travel time by public transport	-3.2350	0.8939	0.0003
parking facilities at the work place	1.5094	0.4340	0.0005
travel expences paid by the employer	2.7037	0.8336	0.0012
years of education after 9 years of compulsory school	-0.0148	0.4131	0.9713
interaction variable, interaction between cars per household member above 18 years old and holdership of a driver's licence	1.3758	0.5399	0.0108
constant	1.6433	1.5520	0.2897

To be more concrete about the effects from the different independent variables, we have looked at changes in the predicted probabilities of modal choices. This we have done separately for a continuous variation in travel time ratio, and with sufficient and not sufficient parking conditions. We have controlled for the effects of the other variables by keeping them constant, giving them the values (mainly based on means) as shown in Table 5:

Table 5 Values of the independent variables when calculating changes in predicted probability

independent variables	X	value
errands on the journey home from work	X_1	0
age	X_2	46
ratio of length (in minutes) of within-vehicle public transport journey, by the total length of the door-to-door public transport journey	X_3	0.58
household gross income per household member above 18 years of age	X_4	272058
sex	X_5	1
door-to-door travel time by car divided by door-to-door travel time by public transport	X_6	0.92 (or varying)
parking facilities at the work place	X_7	1 (or varying)
travel expences paid by the employer	X_8	0
years of education after 9 years of compulsory school	X_9	0
interaction variable, interaction between cars per household member above 18 years old and holdership of a driver's licence	X_{10}	1

The numbers in table 5 is calculated from the following equation, where Z equals:

$$Z= b_0+ b_1X_1+ b_2X_2+ b_3X_3+ b_4X_4+ b_5X_5+ b_6X_6+ b_7X_7+ b_8X_8+ b_9X_9+ b_{10}X_{10} \quad (1)$$

where *b* refers to the logit coefficient and *X* refers to the value set for the independent variable. In the case of the selection of respondents we have made with values for X_1-X_{10} and logit-coefficients (B_1-B_{10}) as set above, Z is expressed as follow:

$Z=1.6433+0.7507*0-0.0158*46-2.6327*0.58+1.12E-06*272058+0.0691*1-3.2350*X_6+1.5094*X_7+2.7037*0-0.0148+1.3758*1$

By first calculating Z for all cases and then putting this value in function (2) below, often called the

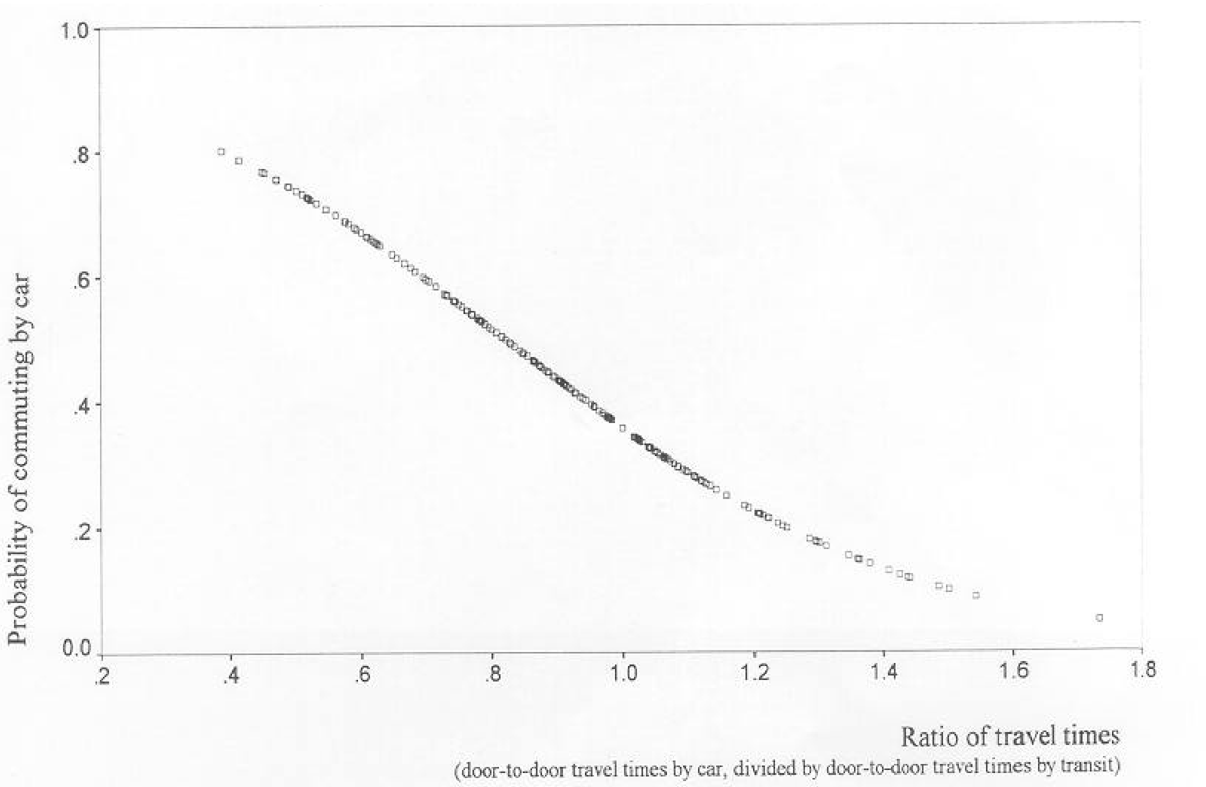
$P_i = 1/(1+\exp(-Z_i))$ (2)

where P_i is the probability for case number i, ranging from 0 to n and exp means the exponential function, the inverse of the log.

logistic function, we can calculate probabilities of modal choice for different values og traveling time ratio, while controlling for the other dependent variables (parking conditions held constant). The result can be seen in Figure 3.

Figure 3 Probability of commuting by car at varying ratios of door-to-door travel times by car and by transit. Multivariate logistic regression.

N = 244 employees living in the Asker or Sandvika areas and working downtown Oslo. In the multivariate logistic regression, the influence of the following variables has been controlled for: Parking conditions, car ownership, driver's licence holding, income, education, sex, age, whether the employer covers commuting expenses, errands in connection with the journey home from work, and the proportion of the door-to-door travel time by transit spent within the vehicle. The figure applies to commuters who hold a driver's licence and belong to a household with one car per adult household member, and who have ample parking facilities at the jobsite.



According to Figure 3, the probability that an employee holding a driver's licence, belonging to a household with one car per adult household member, and having ample parking facilities at the jobsite will commute by car, is about 60 per cent when travel time by car is 30 per cent shorter than by transit, and the remaining independent variables are held constant. When both modes are equally fast, the likelihood of commuting by car is about 36 per cent.

Correspondingly, the probability of modal choice can be calculated for the two types of parking conditions. Keeping constant other variables (including the ratio of travel times), the likelihood of commuting by car is 42 per cent when parking facilities at the jobsite are ample, as compared to 13 per cent when parking conditions are poor (i.e. scarce, expensive or no parking within acceptable walking distance).

Conclusions

Answer to our research questions
The conclusions below refer to the research questions presented earlier:

A) To what extent does the modal split of morning peak period commuting trips through the NSB corridor to downtown Oslo correlate with the relative competitiveness of car versus public transport as to door-to-door travel time?
Answer: The percentage of transit riders increases clearly the more competitive the transit mode is as to door-to-door traveltime, compared to the private car. From the bivariate plot of mode choice probabilities (Figure 2), one can see that when the ratio of traveltime between travel car and transit is 0.6, the probability of travelling by car is about 38 per cent, as compared to about 5 per cent when the ratio is 1.4.

B) Does the modal choice for commuting trips to downtown Oslo in the morning peak period correlate with the ratio of door-to-door traveling times with car and public transport, also when controlling for other factors (e.g. car ownership, income, sex, age) which may influence the choice of mode of transportation?
Answer: According to Figure 3, the probability that an employee holding a driver's licence, belonging to a household with one car per adult household member, and having ample parking facilities at the jobsite will commute by car, is about 60 per cent when travel time by car is 30 per cent shorter than by transit, and the remaining independent variables are held constant. When both modes are equally fast, the likelihood of commuting by car is about 36 per cent.

C) How high share of the morning peak period commuters are "captive riders" who have practically no other choice than the mode of transportation they actually use?
Answer: About 20 per cent seem to be captive car riders, and 5 per cent captive public transport riders. This is when those doing errands to work and using the car in duty are excluded from the analysis.

D) Approximately how high shares of the "mode choice riders" (i.e. non-captive riders) among the morning peak period commuters may be considered as "sheep" and "explorers", respectively?
Answer: Hard to answer so far.
This will be analyzed later from a more in-depth look at the answers given to open questions questionnaire.

E) What is the magnitude of change in the proportions of car and transit commuters that could be expected from a given change in the door-to-door travel time ratio between car and public transport (e.g. from a situation where door-to-door travel time by car is 110 per cent of the corresponding travel time by transit, to a situation where the door-to-door journey by car takes only 90 per cent of the time required for a journey to work by transit)?

Answer: Reducing traveling time by car as described above would probably lead to a 14 per cent increase in car riders.

F) Does an "equilibrium speed" between car and public transport exist among the "mode choice riders"? I. e. that the "mode choice" commuters are relatively evenly distributed between car drivers and transit passengers, that average door-to-door travel time for each of these groups is approximately equal, and that the travel times of the individual respondents do not deviate much from the average door-to-door travel time (which is similar across modes) for the relevant commuting distance.
Answer: There is little evidence of an evenly distribution of "mode choice" commuters among car drivers and transit passengers. Neither there seem to be an "equilibrium speed" between the two modes. When car and transit are equally fast, the percentage of car commuters is 36 per cent, i.e. somewhat different from the 50-50 situation in the case of a perfect equilibrium speed situation. Furthermore, there is considerable individual variation in travel times among people travelling the same distance. The ratio of travel times by car vs. transit ranges from 0.4 to 1.7 among the individual employers, without any strong concentration of values around 1.0 as predicted by the hypothesis about an equilibrium speed.

G) On average, how high are the proportions of commuters by car and transit, respectively, when the door-to-door travel time ratio between the two modes is 1.0? Is the distribution the same for the sample as a whole as among "mode choice riders" only?
Answer: When the time-ratio is 1, there is a predicted 36 per cent probability of going by car. We have not yet been able to separate «captive» and «mode choice» riders.

H) To what extent is the modal choice influenced by the composition of the traveling time (the proportion of the total door-to-door travel time used for walking and waiting, and the number of transfers between different vehicles)? To what extent is door-to-door travel time a good indicator of "generalized traveling costs"?
Answer: We do not have a significant answer to this question. Still, there seem to be a negative relationship between proportion of travel on the main transit mode and total public transport travel time, and the probability of going by car. I.e. the longer time in the main mode, the less probability of going by car. The statistical significance for this is 0.1535.

I) How frequently do "non-captive riders" choose a mode of transportation leading to significantly (e.g. more than 20 per cent) increased door-to-door travel time, compared to the fastest alternative? What kind of reasons do the relevant respondents give for opting for a slower way of traveling? (For example, do environmental considerations make many respondents choose public transport although car is faster?)
Answer: Hard to answer so far. This will be analyzed later from a more in-depth look at the answers given to open questions in the questionnaire.

Discussion of results
In our data, there is a close relationship between the ratio of door-to-door travel times by car and transit, and the modal choice of the commuters of our investigation. This holds true also when controlling for other relevant variables. So far, our data support the case that increased road capacity on urban major roads should be avoided if increased car commuting and reduced transit ridership is considered undesirable.

To some extent, the theory of equilibrium is supported at an aggregate level. Still, there are some anomalies, as car is on average somewhat faster, and there is no 50-50 distribution of «mode choice» commuters between the modes when both modes are equally fast. (Under such conditions, 64 per cent go by transit and 36 per cent by car.). Furthermore, there are large individual variations in travel times among people traveling the same distance, and the travel time ratios cover a broad range (from 0.4 to 1.7), instead of clustering around 1.0 as predicted by the theory.

The above deviations from the theory may reflect that several other aspects than travel time influence the modal choice of commuters. Some of these are parts of the generalized traveling costs other than travel time (cf., among others, Hammer and Nordheim 1993). In our corridor, none of the respondents had to change between two or more means of public transport. Walking and waiting times vary, but this variation does not appear to exert any influence on the modal choice apart from the obvious fact that the travel time increases the longer you have to walk or wait (cf. the low and uncertain effect of the variable X_3 in the logistic regression).

Therefore, some other factors than those usually included when calculating the generalized traveling costs are probably exerting influence. There is a larger proportion of the «mode choice riders» who go by transit even when this is slower than car, than people who go by car in spite of transit being faster. Some of the commuters who go by transit in spite of losing time doing this, may choose this mode for environmental reasons. Others may prefer transit because this mode enables them to read or write on the train or bus. Others again enjoy walking to and from the transit stops and consider this a health-bringing daily motion activity. Conversely, some dedicated car drivers prefer to go by car even if transit is faster. These commuters may include persons who like listening to radio or car stereo while driving, and people who feel that driving a car (notably an expensive one) increases their social status. Guro Berge's studies identify several cultural and social factors that may cause people to behave in seemingly «irrational» ways, seen from the perspective of travel time minimizing (Berge 1994).

This would imply that in addition to those usually identified as captive riders, there may also be some riders who are «captive» for cultural or other reasons. Or perhaps a nuanced hypothesis about the equilibrium speed could be formulated this way: For each individual, there exists an «equilibrium» rate of door-to-door speeds between car and transit, but the actual level of this ratio varies from individual to individual. For people who do not have strong ideological or other preferences for any of the modes, the equilibrium ratio is likely to be close to 1.0, but for those whose norms (ethical as well as hedonistic) result in the preference of one particular mode, this mode must be considerably slower if a shift to the otherwise not preferred mode should take place.

At an aggregate level, the equilibrium speed ratio would then be 1.0 if few people have an à priori preferences for any particular mode, or if the groups dedicated to car and transit, respectively, are about equally large. If more people are sympathetic to transit than car commuting, the aggregate equilibrium speed ratio (i.e. travel time by car divided by travel time by transit) would be likely to be less than 1.0. The data from the NSB corridor suggest that the proportion of respondents who prefer transit commuting for commuting by car, other things equal, is higher than their counterparts who are more inclined to chose the automobile.

The above interpretation is well in accordance with the theorist of science Jon Elster. According to Elster's book «Nuts and bolts for the social sciences» (Elster 1989), human behavior is, within the range of possible actions, mainly influenced by rational choices and social norms. What is rational for an individual must of course be seen in relation to his or her preferences. However, given a set of preferences and constraints, some alternatives of action will be rational, and others will not. Unless the rational actions are in conflicts with social norms respected by the individual, he or she is likely to choose the rational alternatives of action, rather than the irrational ones.

For our sample of respondents, this would imply that people who choose a mode of transport slower than the alternative mode, either have stronger preferences connected to other aspects of the journey than to time saving, or they respect social norms that make up a deterrent against choosing the fastest mode. Even for these types of respondents, however, changes in the speed of either of the two modes might lead to changed transport behavior. This might occur if the change of speed of a mode is sufficiently great to increase the travel time ratio beyond this individual's particular equilibrium speed ratio. This also means that transportation investments in either transit or road capacity, does not only affect the travel behavior of those ideologically or emotionally neutral, but to some extent also by those who have a general preference for one particular mode.

Another reason for this «irrational» choice may be insufficient or lacking knowledge about travel times on different modes among the travelers. This leads to the hypothesis that many public transport riders perform as «sheep» according to Downs' vocabulary (Downs 1962), i.e. they stick to their habitual mode and do not explore other modes in order to improve travel conditions.

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