IMPACTS FROM DIFFERENT LAND-USE STRATEGIES ON TRAVEL DISTANCES

Linda Christensen & Mogens Fosgerau
Danish Transport Research Institute

1. BACKGROUND AND PURPOSE

This paper demonstrates the impact of urban structure on distances travelled by persons, both in total by all modes and by car. The findings illustrate the importance of policies designed to influence the urban structure as part of the tools available to control the demand for travel and hence reduce the environmental impact from transport.

1.1 Background

Taxes and charges such as fuel taxes are effective means to reduce the demand for travel and the ensuing environmental impact from transport. Increasing the costs of transport will induce consumers to reduce their transport demand, as transport becomes more expensive relatively to the benefits that the consumer obtains. However, controlling the demand for travel through pricing can carry a high cost in terms of loss for the consumers. If the objective is only to reduce CO_2 emissions from transport, taxes and charges may entail a relatively high cost compared to other potential means of reduction. Thus, calculations of the shadow price of alternative ways of reducing CO_2 emissions show that reducing CO_2 emissions in the transport sector through taxes carries a relatively high economic cost to society (Ministry of Transport 1997). There are other less costly potential reductions such as for example reducing energy consumption for heating in private households. It has also become apparent that it is politically very difficult to increase taxes enough as required to reduce the CO_2 emission from transport to the 1988 level – the CO_2 emission goal for transport in Denmark until it was given up last year. This provides a motivation to search for alternative ways of reducing transport volumes and the environmental impact of transport.

What makes urban structure particularly interesting is the potential for a double dividend, that is, if a measure intended to benefit the environment entails additional benefits such that the total benefits exceed the environmental benefits. This could happen if changes in urban structure makes it possible for consumers to participate in activities with less time and money being spent on travel. A first step in determining whether this potential exists is to investigate the demand for transport as influenced by urban structure.

The development of urban sprawl witnessed in all western countries has meant that people have to travel farther to reach the same activities as before. Although there is a benefit to the household in terms of more space available for housing, there is also a cost resulting from increased pollution and noise and potentially increased congestion. A driver behind the structural changes of the cities is the process of automobilisation. Increased car ownership and use has enabled people to reach more activities in shorter time. As many people have been willing to use this new good, companies have localised in attractive areas where they expect that the customers and workers are willing to attend them. As a consequence, small shops and other service facilities with few customers have been forced to close, which has resulted in longer travel distances and increasing car shares in the modal split for everybody. Thus, what may be rational economic decisions at the household level may turn out to be less than optimal decisions at the aggregate level because of externalities arising from market imperfections.

The change in transport behaviour has not been uniform. The supply of specialised activities is higher in central locations than elsewhere. Increasing travel has different environmental impacts as bicycling, bus and train are more feasible alternatives to the car in central areas than in peripheral areas.

1.2 Purpose

One of the best-known empirical works on the connection between land-use and the level of transport is *Cities and Automobile Dependence - An international Sourcebook* (Kenworthy and Newmann, 1989). It shows that the average distance travelled per capita decreases with the urban density. American cities are generally the least dense, resulting in the highest level of person kilometres. The Australian cities are slightly more dense than the American cities and the European cities even more so, which means that the Australian level of person kilometres is lower than the American level, but higher than the European level. The very densely populated cities of eastern Asia have the lowest level of person kilometres.

The arguments against this kind of approach (e.g. J. Short, 1996) have been that the differences between the transport levels in the cities are a result of the different income levels and not a result of density. The level of income has been shown to be one of the most important determinants for the level of transport within a society, and hence different levels of income could be a valid explanation for the differences between the cities too. This makes it necessary to show that the difference in transport levels exists independently of differences in income levels.

Research in the Nordic countries has shown that the level of transport depends on town size and localisation in the cities (Nyvig, 1982 for Denmark). This research was performed as a follow up on the first oil crisis in the second part of the seventies. The level of transport kilometres was lower in the centres of the bigger cities than in the suburbs and it was at its highest in the countryside, the small towns and villages. But again this research could be criticised for not taking into account the differences in income levels and other social differences in the population in different town sizes and parts of the cities.

A recent Danish research programme has followed up on this research. The purpose was to find the relations between urban structure, land use and the environmental impacts of these in order to find the best urban strategies and planning practise and thus obtain a more sustainable development in the long run. This paper is based on one of the two main projects under the programme; the paper presented to this conference by Hartoft-Nielsen (2002) is based on the same research programme.

The purpose of this paper is to show how the travel distances and car traffic depend on where residences and work places are located. We want to analyse and quantify the extent to which urban structure and localisation affect traffic volumes and modal split. Further, we want to show to what extent it can be explained from only the socio-economic background factors of individuals and households. This enables us to counter the arguments by Short (1996) against Kenworthy and Newmann (1989). Using micro-data of individuals and households we are able to control for income and other background variables and thus we can isolate the influence of urban structure from these influences.

The results of this analysis may contribute to the basis for decisions concerning land-use regulation and urban planning that incorporates considerations on environmental sustainability.

2. METHODOLOGY

2.1 Data

The data for the analysis come from the National Danish Travel Diary Survey (TU). The TU is an interview, recording a travel diary for the previous day for each individual interviewed. In addition, the interview records background information concerning the respondent and his/her household.

The survey includes information of the address zone of both the residence and the workplace of the interviewee (for those who work). From the TU data we have selected all persons living in the Copenhagen region, the rest of Sjælland and surrounding islands. Figure 5 at the end shows a map of the Copenhagen region. We have chosen observations from the period from April 1996 to the end of 2001 with a total of 38,200 interviews resulting for the analysis. Before 1998 the survey only included people between 16 and 74 years of age. From 1998 and forth the survey includes people between 10 and 84 years of age. All distances from the zone centroids to the centre of Copenhagen have been calculated in GIS. The maximal distance is 180 km.

2.2 Models

We employ a general model, which is applied in parallel to four different cases. The cases are differentiated by two factors as indicated in the table below. First, whether the location of the residence or the work place is taken as a reference to explain travel distances. Second, whether the total travel distance or the distance travelled by car is considered.

	Total travel distance	Travel by car
Place of residence	(1)	(2)
Place of work	(3)	(4)

The model has two independent parts. The first is a linear regression of the log of distance travelled by each individual. This regression is only carried out for those with non-zero travel distance. Thus the regression yields the expected log of travel distance conditional on the distance being greater than zero.

There are systematic differences in who travels on any given day. These differences are captured in a binary logit model, giving the probability for each individual of travelling. Combining the probability of travelling and the conditional expected travel distance yields the unconditional expected travel distance.

The combined model assumes that the error of the regression and the error of the logit model are uncorrelated. This is not necessarily a valid assumption. There are likely to be unobserved factors that affect both the probability of travelling and the expected travel distance. At a later stage the model could be extended to allow for correlation of the error terms, but the extension has not been included so far.

The same set of variables is used both for the regression and the logit model. The variables are divided into four groups: 1) variables related to localisation and urban structure, 2) variables related to car ownership, 3) socio-economic background variables and 4) a level parameter and the time of week.

1) Urban structure: The distance from the centre of Copenhagen, the distance to the nearest train station, and the type of the residence area (flats or low raise areas). Dummies for a city with 10-40,000 inhabitants, rural area, Copenhagen municipality, city centre of small cities, and of Copenhagen. These are the primary relationships of the model, as we want to describe the impact of urban structure on travel.
2) Car ownership: whether the individual has a driving licence, the number of cars in the household and the number of cars per person (to express the degree of competition for use of the car(s)).
3) Socio-economic background: sex, income, age, type of employment, no of children.
4) A constant term and a weekday/weekend dummy.

It can be discussed whether the variables for car ownership should be included in the model. The household decision regarding car ownership is partly determined by the location of the household within the urban structure. For instance, households in central Copenhagen have lower levels of car ownership, ceteris paribus. Thus it may be argued that either car ownership should be endogenous or the model should be in reduced form where car ownership does not enter as an explanatory variable. This issue is left for later consideration. It is however noteworthy that inclusion of these variables is likely to weaken our possibilities to find a significant relationship between distances travelled and urban structure, as car ownership is also correlated with both urban structure and travel demand. When we in the following find significant relationships between distances travelled and urban structure, we thus have good reasons to believe these relationships are actually causal relationships.

3. RESULTS FOR RESIDENCE

3.1 Total travel distance

The estimation results for total travel distance, given the place of residence, are shown in table 3 placed at the end of the paper. The parameter estimates for the regression of total travel distance are shown in column (a) with standard errors shown in column (b). As we model the log of the travel distances, the estimates and standard errors can be interpreted as percentages. Thus for example the distance travelled is 12 percent higher on weekdays than in weekends. All the included parameters are significant and most of them on a level better than 1 percent.

The socio-economic background factors are generally very significant. This illustrates the importance of incorporating such variables in the current analysis. Different types of households are unevenly spread across the city and the surrounding region and not controlling for individual and household characteristics would confound the relationship between travel demand and household location within the urban structure.

The daily travel activity is clearly dependent on the localisation factors. The parameters for the distance to the centre are very significant. Figure 1 illustrates the dependency on the distance to the city centre. The top panel shows how the distance travelled, for those who travel at all, increases with the distance to the centre up to a distance of 50 kilometres, which roughly corresponds to the border of the Copenhagen region. Beyond this distance, the distance travelled decreases again to stabilise at a level above the level in central Copenhagen.

The result of the logistic regression on the probability of travelling is also shown in table 3, with parameter estimates in column (c) and corresponding standard errors in column (d). Only half of the parameters which are significant in the regression analysis are significant in the logistic regression. The significant parameters are some of the socio-economic parameters, whereas the linear distance to Copenhagen Centre and short distance to a station are the only significant structural parameters.

The signs of the parameters in the linear regression and in the logistic regression are often opposite, reflecting that frequent travelling is often associated with shorter travel distances.

The middle panel of figure 2 shows how the probability of travelling decreases with the distance to the centre. In other words, a person living in the centre of Copenhagen is more likely to travel on any given day than a person living some distance from the centre.

The probability of travelling modifies the conditional relationship in the upper panel somewhat. Still, the overall result is that people living around 50 kilometres from the city centre travel around 80 percent longer distances than do people living in the centre of Copenhagen. People living in the municipality of Copenhagen travel less than people outside. The municipality has a much more dense urban structure than the suburbs in the rest of Greater

Copenhagen. This means that distances to service facilities are shorter and the supply of for instance shops is larger and more differentiated.

Hence, the model reveals very large differences in the amount of daily travel depending on the distance to the centre, even after controlling for socio-economic differences. This strengthens considerably the case for the existence of such relationships.

In addition to the dependency on distance to Copenhagen, other dependencies on the urban structure are found through the various dummies estimated (summarised in table 1). People living in the rural areas and villages of the Copenhagen region travel 17 percent more than what they would have done, had they lived in the suburbs or towns and the people living in the rural areas outside the Copenhagen region travel 34 percent more. Conversely, people living in the cities around Copenhagen travel 17 percent less. Outside the Copenhagen region only people living in the centre of the cities travel less.

Table *Error! Unknown switch argument..* **Structural dependencies, residence, total kilometres**

	Copenhagen region	Outside Copenhagen region	
			City centre
Provincial town	- 16%	- 2%	- 17%
Rural area	+ 19%	+ 40%	

Other findings include the dependency on the distance to a rail station. People who have less than a 10 minutes walk to a rail station travel 8 percent less, and if they have more than 15 minutes they travel 5 percent more. An explanation for this might be that many shopping centres are situated in the neighbourhood of a train station.

3.2 Car traffic

Table 4 and figure 2 repeat the above analysis of travel distance, now instead looking at car kilometres. The analysis is performed for the sub-sample of people who did travel. The interest of this analysis is both the mode choice and the distance.

The effects for car kilometres are similar to those found for the total distance travelled. Some of the parameters included in total daily kilometres are excluded from the analysis of car kilometres, as they are not significant. Thus all included parameters are significant most on a level less than 1 percent.

Columns (c) and (d) show the parameter estimates and standard errors from the logistic regression of driving by car given that the person is travelling. The probability of travelling by car follows the tendencies of the distance by car (similar signs in the two models) and most of the structural parameters are significant. The bottom panel of figure 2 shows the overall car kilometres including the probability to travel. The exclusion of some of the parameters means that most of the rest parameters are significant, also for the probability to travel.

The overall effect of urban structure on car kilometres is both very significant and very strong. Figure 2 shows that car owners living about 50 kilometres from the Copenhagen City Centre drive more than two and a half time as much as car owners living in the centre. Non car owners are driving very little by car but decreasing with larger distance to the city centre. As the share of non-car owners is decreasing with distance to the centre they do not influence the overall result of car kilometres dependency of distance. Table 2 shows a stronger dependency of car kilometres from living in villages and rural areas, especially outside the Copenhagen Region. If the distance to a rail station is less than 5 minutes walk, car kilometres are reduced by 32 percent and if the distance is between 5 and 10 minutes walk, it is reduced by 23 percent compared to the longer distances.

Table *Error! Unknown switch argument..* **Structural dependencies, residence, car kilometres**

Percent	Copenhagen region	Outside Copenhagen region
Provincial town	- 26%	- 26%
Rural area	+ 42%	+ 52%

Thus again after controlling for a large number of socio-economic background variables, and including variables for car ownership, we find a strong and significant relationship between car traffic and urban structure.

4. RESULTS FOR WORKPLACES

In this section we repeat the analysis above. This time, however, focusing on the location of the workplace. Linear regressions have been performed for both daily travel distance and distance travelled by car on work tours regressed on the same variables as above, except that the locational variables now describe the workplace.

4.1 Travel Distance

The linear regression is carried out on the log of the travel distance conditional on this being greater than zero. This requires that the person has got a job and that he went to work at the day of the interview. The logistic regression is carried out on the probability of going to work given that the person has a workplace. The overall result from the combined models is the expected unconditional travel distance per workplace.

All the included parameters of the linear regression model (except the intercept) are significant on less than 1 percent level. When the same parameters are introduced to the logistic model only very few are significant on a high level and many are not significant. Most significant are two parameters for walking time to a train station (0-5 and 5-10 minutes) and the balance between workplaces and residences.

As above the socio-economic background variables contribute a great deal to the model, which provides further justification for the necessity of using micro-data for this type of analysis.

The linear regression shows that the conditional travel distance per workplace depends on the urban structure. But the dependency is much different from the dependency of residencies. The travel distance is lower the more distant from the city centre the workplaces are located. The travel distance stabilises at around 100 km from Copenhagen (at the opposite side of Sjælland).

In the Central Business District of Copenhagen the travel distance per workplace is extra high whereas it is much lower in the surrounding dense residential areas where many workplaces are typical local (i.e. hospitals, schools, kinder gardens and some few remaining manufacturing workplaces).

The findings are much different from Hartoft-Nielsen (2002) who has analysed the travel distance from large business and government offices, research institutes etc. His work shows increasing travel distance the more decentralised the offices are located. In a hope to reproduce these results we have introduced an interaction between distance from the city centre and the socio-economic variables as an indicator for the type of workplaces. Special interest has been paid to income and to high salaried employees. The calculations show a dependency between these variables and the travel distance of car owners but the travel distance for high salaried employees with high incomes still decreases with the distance from the centre up to around 80 kilometres from Copenhagen centre.

Workplaces located in rural areas and in cities outside Copenhagen have less influence on travel distance than observed for residences. On the other hand walking time to a station from a working place has some influence on the travel distance to work. It is reduced 10% within 5 minutes from the station.

4.2 Car traffic

An analysis has been carried out on travel distance by car. The results show similar decreasing car traffic at distances further from the centre.

For the travel distance by car we find strong impacts of locating the workplace near a rail station. Thus, a workplace less than 5 minute walk from a station decreases total car traffic on work trips by 51 percent, and 5-10 minutes walk from the station decreases car travel distance by 31 percent.

5. CONCLUSIONS

We have performed an analysis of travel distances using micro-level data correcting for a number of factors including income and car ownership. Nevertheless, we find strong correlations between the distances travelled and the urban structure expressed in terms of variables describing the location of the residence. Thus it is likely that the relationships found can in fact be attributed to the urban structure and are not due to socio-economic differences.

The analysis has shown that locating residences near the centre of the region can reduce transport volumes and car traffic considerably. The results further show that urban development at peripheral city centres reduces travel demand relative to development in suburbs and small tows. Development of rural areas and villages are likely to generate the highest level of traffic. Finally, location near rail stations has significant effect especially on car traffic.

The analysis has been repeated, this time letting variables for the urban structure determined by the location of the workplace. The conclusion from the analysis seems to be that workplaces ought to be decentralised in order to reduce the level of transport. The most likely reason for this conclusion is that residences are decentralised already. This means that workplaces near the residences might mean shorter distances between home and work for people on average. We do however feel that this conclusion need further consideration and are not prepared to give policy recommendations based on this.

The models include the effect of distance to a rail station. The result shows that the effect of locating a workplace within 5 minutes walk from a rail station decreases total travel by 10 percent and travel distance by car to 50 percent. The corresponding estimates for the location of the residence show a 7 percent reduction in total travel when the residence is less than 10 minutes away from a station and a 33 percent reduction in car travel when the residence is less than 5 minutes walk from a station. Hence, we conclude that a policy giving priority to locating workplaces near stations rather than residences is likely to contribute to reducing the demand for travel.

Of course this conclusion depends upon the actual density of the established areas. Offices and firms with few square metres per employee will typical have one employee per 30-50 indoor m^2. New residences will have one adult or big child (10-84 years old) per 40-70 indoor m^2. This means that the reduction in car kilometres from localising workplaces densely around rail stations related to residencies are even greater than the above calculated. Buildings with offices can normally be established more densely than residential areas which adds extra to the conclusion.

The strategic conclusion on the analysis must be that centralisation of residential areas and concentration of workplaces around rail stations will reduce travel and especially car traffic most substantially. A further effect of such policy will be a reduction of the CO_2 emissions. However, centralisation may entail more noise and air pollution in the dense areas. But serious planning of the road network and the detailed plan of the residential areas can reduce such problems.

Bibliography

Hartoft-Nielsen, P. (2002) Paper to EAT 2002.

Hartoft-Nielsen, P. (2001): Boliglokalisering og transportadfærd. By- og Landsplanserien nr. 15, Skov & Landskab (FSL), Hørsholm, 2001. 268

Kenworthy, J., Newmann, P. (1989): *Cities and Automobile Dependence - An international Sourcebook.* Gower Technical, Aldershot, UK.

Ministry of Transport (1997). CO2-reduktioner i transportsektoren. (CO2 reductions in the transport sector).

Nyvig (1982): *Bymønster, trafik og energi. Hovedresultater fra et forskningsprojekt om samspillet mellem bymønster, trafikal adfærd og persontrafikkens energiforbrug.* Ministeriet for Offentlige arbejder, Planlægningsafdelingen, Miljøministeriet, Planstyrelsen.

Short, J. (1996): *Transport Policy and the Environment.* In Lahrmann, H., Pedersen, L. H.: Trafikdage på Aalborg Universitet 19-20. august 1996. Supplementsrapport s 5-39.

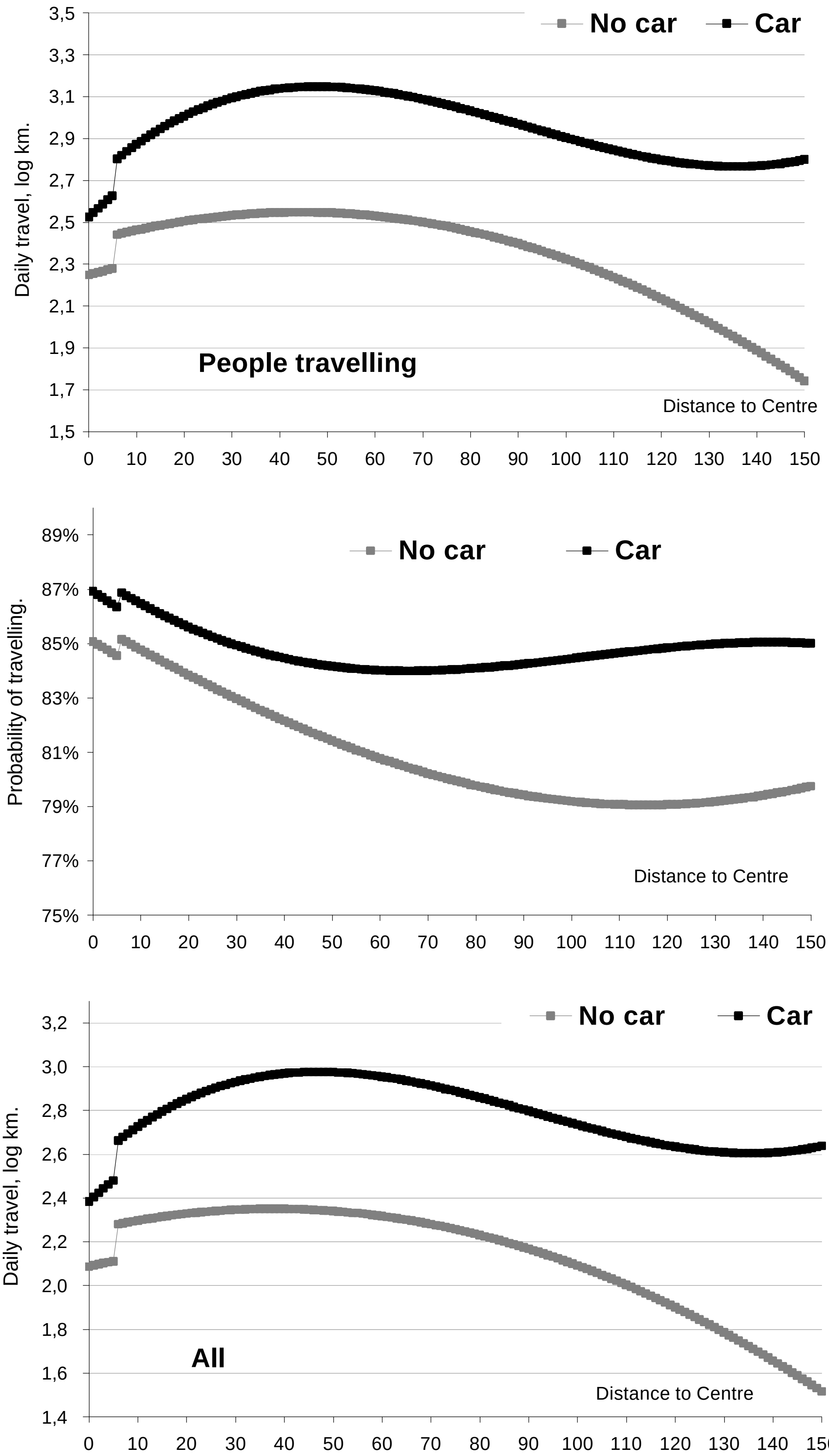
***Table** Error! Unknown switch argument.*. **Estimation results: Total travel distance given place of residence**

	Travel distance		Probability of travelling		
	(a)	(b)	(c)	(d)	(e)
	Estimate	Standard error	Estimate	Standard error	Change in probability
Intercept	2.42	0.050	1.662	0.089	
Weekdays	0.116	0.018	0.845	0.029	-0.115
Woman	-0.105	0.018	0.028***	0.032	
Old people	0.143*	0.040	0.281	0.062	0.038
Age^2	-1.51E-04	1.0E-05	-2.5E-04	1.7E-05	-0.000
Income, 1000 DKK	1.38E-03	8.5E-05	7.2E-04	1.6E-04	-0.000
Unemployed	-0.376	0.034	-0.583	0.058	-0.080
Unskilled worker	-0.326	0.032	-0.184*	0.061	-0.025
Skilled worker	-0.150	0.038	-0.212*	0.073	-0.029
Lower salaried employee	-0.157	0.024	0.089***	0.050	
Self-employed	-0.302	0.040	-0.642	0.067	-0.088
School child	-0.582	0.047	-0.089***	0.087	
Number of children	-0.107	0.010	-0.070*	0.020	-0.010
Driving license	0.293	0.024	0.397	0.039	0.054
Number of cars	0.164	0.028	0.086***	0.052	
Number of cars per adult	0.130*	0.045	0.085***	0.083	
Lives in low raise areas	0.061*	0.023	-0.144*	0.040	0.020
(Distance to centre)^3, car owner	1.13E-06	1.6E-07	-3.71E-07***	2.8E-07	
(Distance to centre)^2, car owner	-3.12E-04	3.7E-05	1.20E-04***	6.3E-05	
Distance to centre, car owner	0.022	2.3E-03	-0.010*	4.0E-03	0.001
(Distance to centre)^2, no car	-7.22E-05	1.3E-05	4.00E-05***	1.9E-05	
Distance to centre, no car	6.42E-03*	1.7E-03	-8.09E-03*	2.6E-03	0.001
Rural area	0.191	0.036	-0.102***	0.061	
Rural area outside Copenh region	0.186	0.046	-0.121***	0.075	
Municipality of Copenhagen	-0.157	0.031	-0.054***	0.054	
City of 10-40.000 inhabitants	-0.181	0.035	0.044***	0.060	
City of 10-40.000 inhabitants outside Copenhagen region	0.136*	0.052	0.096***	0.089	
City centre outside Copenh region	-0.173*	0.062	0.050***	0.110	
0-10 min walk to station	-0.062*	0.021	-0.121*	0.042	0.017
> 15 min walk to station	0.058**	0.026	-0.044***	0.054	
Goodness of fit	R^2 = 0.16		Rho^2 = 0.09		
Number of observations	30,230		36,950		

*Significant <1% level ** Significant <5% level. *** Not significant. Others significant <0,01% level

(a)-(b) is parameter estimates through linear regression on logarithm of daily kilometres. The table states how much the average daily distance is effected when the variables change value of one unity. (c)-(d) is parameter estimates through logistic regression of the probability of travelling. Column (e) states the change in probability of travelling when the variable changes marginally from the mean.

***Figure** Error! Unknown switch argument.* **Travel distance dependent on distance of residence to central Copenhagen**



Estimated daily travel distance depending on how far from the city centre of Copenhagen people live. The travel distance is shown in log kilometres for a mean person with and without car in the household. The top chart shows the distance travelled daily conditional on non-zero travel. The middle chart shows the probability of travelling and the chart at the bottom shows the expected distance travelled for all.

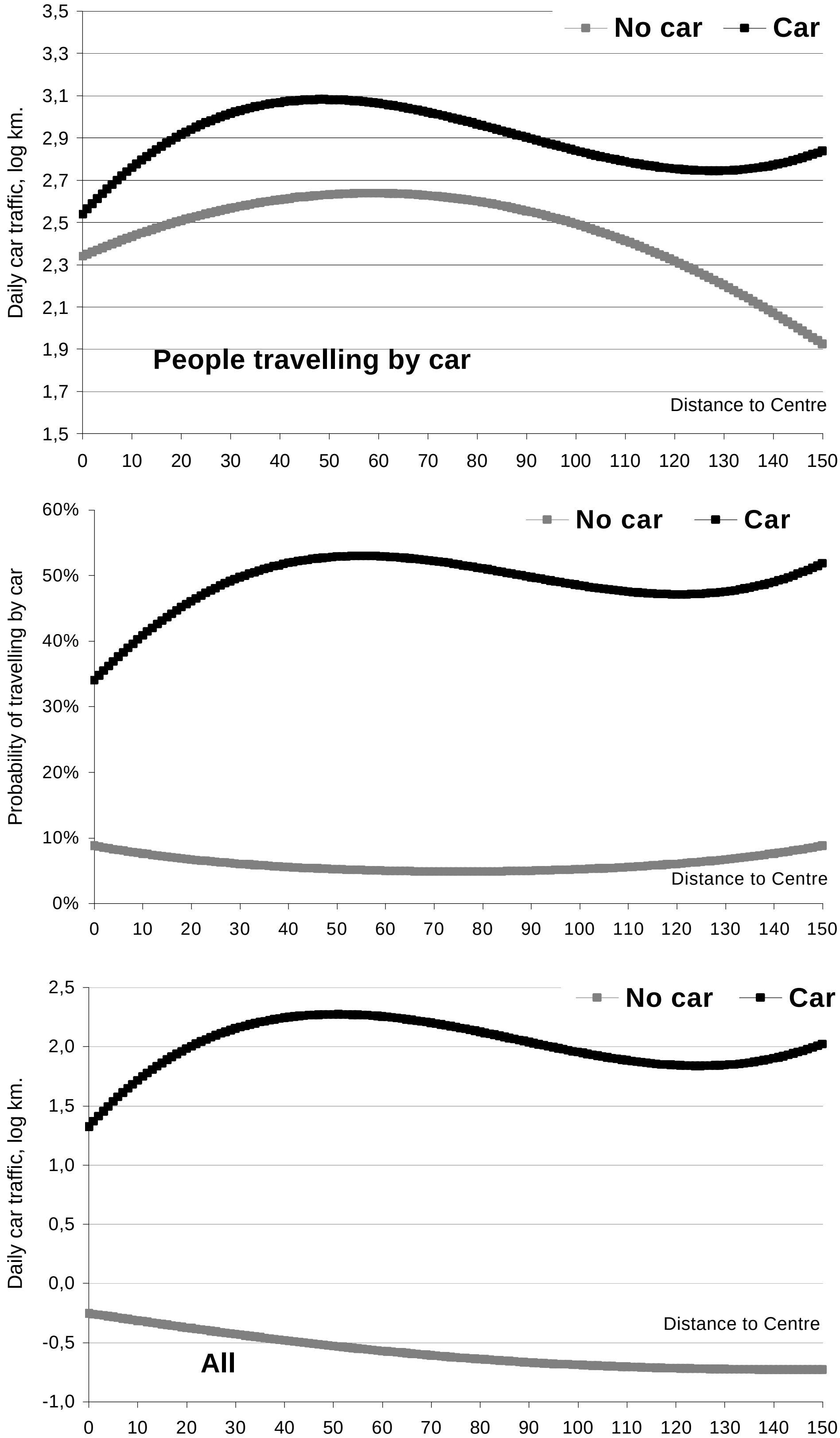
***Table** Error! Unknown switch argument.*. **Estimation results:**
Travel distance by car given place of residence

	Travel length by car		Probability of travelling by car		
	(a)	(b)	(c)	(d)	(e)
	Estimate	Standard error	Estimate	Standard error	Change in probability
Intercept	1.89	0.10	-4.674	0.1132	
Weekdays	0.112	0.022	0.132*	0.035	3.1%
Woman	-0.260	0.022	-0.708	0.034	-16.8%
Age^2	-9.93E-05	9.9E-06	-5.90E-05*	1.6E-05	-1,4E-05
Income, 1000 DKK	1.08E-03	9.2E-05	1.92E-03	1.6E-04	4,5E-04
Unemployed	-0.291	0.038	-0.051***	0.061	
Unskilled worker	-0.207	0.038	-0.059***	0.061	
Skilled worker	-0.095**	0.038	0.243*	0.072	5.8%
Lower salaried employee	-0.118	0.028	-4.99E-02***	0.043	
Self-employed	-0.249	0.039	0.173**	0.079	4.1%
School child	-0.502*	0.149	-1.487	0.161	-35.2%
Number of children	-0.071	0.012	0.095	0.020	2.3%
Driving license	1.067	0.096	3.185	0.092	75.4%
Number of cars	0.101*	0.028	0.511	0.056	12.1%
Number of cars per adult	0.129*	0.044	1.813	0.089	42.9%
Lives in low raise areas	-0.104*	0.028	0.205	0.043	4.9%
$(\text{Distance to centre})^3$, car owner	1.36E-06	1.6E-07	1.68E-06	2.6E-07	4.0E-07
$(\text{Distance to centre})^2$, car owner	-3.61E-04	3.5E-05	-4.43E-04	5.9E-05	-0.01%
Distance to centre, car owner	0.025	2.2E-03	0.034	3.6E-03	0.8%
Distance to centre^2, no car	-8.60E-05**	3.8E-05	1.10E-04*	3.3E-05	2.6E-05
Distance to centre, no car	0.010*	3.9E-03	-0.017	4.0E-03	-0.4%
Rural area	0.139*	0.037	0.120***	0.069	
Rural area outside Copenh region	0.146*	0.046	0.188**	0.086	4.4%
City of 10-40.000 inhabitants	-0.158	0.034	-0.242	0.056	-5.7%
0-5 min walk to station	-0.165	0.037	-0.385	0.057	-9.1%
5-10 min walk to station	-0.143	0.026	-0.247	0.042	-5.8%
Goodness of fit	$R^2 = 0.11$		$Rho^2 = 0.40$		
Number of observations	14,420		30,260		

*Significant <1% level ** Significant <5% level. *** Not significant. Others significant <0,01% level

(a)-(b) is parameter estimates through linear regression on logarithm of the daily car kilometres. The table states how much the average daily distance by car is effected when the variables change value of one unity. (c)-(d) is parameter estimates through logistic regression of the probability of travelling by car given the person is travelling the actual day. Column (e) states the change in probability of travelling by car when the variable changes marginally from the mean.

Figure *Error! Unknown switch argument.* **Travel distance by car dependent on distance of residence to central Copenhagen**



Estimated daily travel distance by car depending on how far from the city centre of Copenhagen people live. The travel distance by car is shown in log kilometres for a mean person with and without car in the household. The top chart shows the distance travelled daily by car conditional on non-zero cartravel. The middle chart shows the probability of travelling by car given the person is travelling. The chart at the bottom shows the expected distance travelled by car for all, travelling and non travelling.

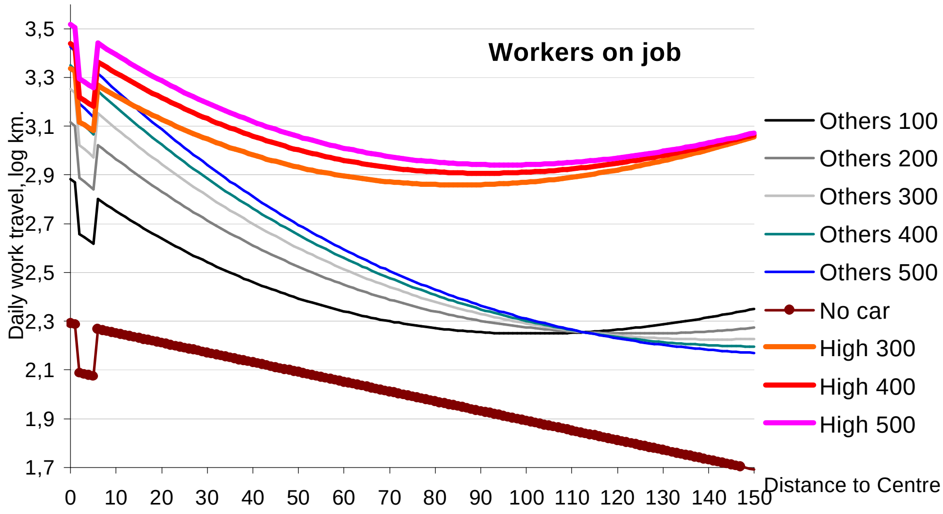
***Table** Error! Unknown switch argument.*. **Estimation results: Total travel distance given place of work**

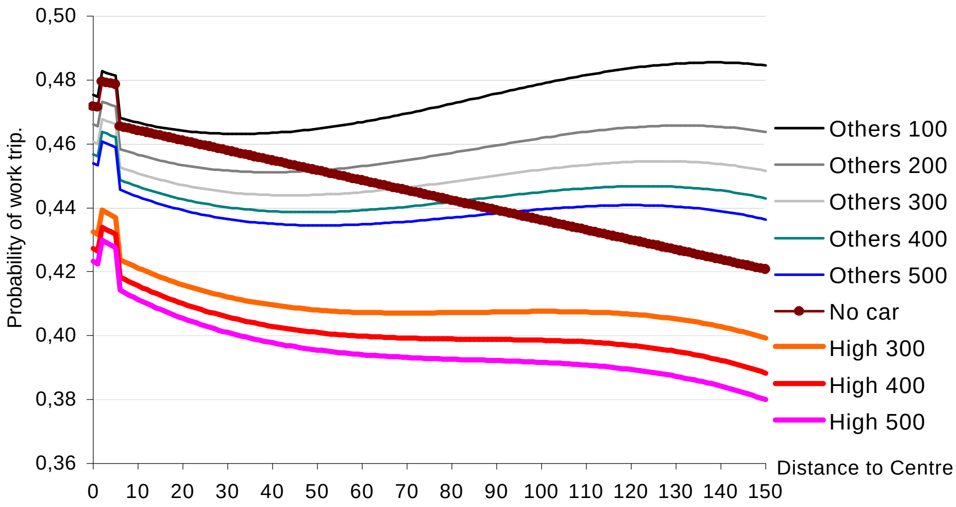
	Work travel distance		Probability of work travel	
	(a)	(b)	(c)	(d)
	Estimate	Standard error	Estimate	Standard error
Intercept	0.119***	0.151	-1.553	0.190
Weekday	0.239	0.041	2.598	0.038
Woman	0.489*	0.126	-0.098***	0.163
Age^2	-1.4E-04	1.4E-05	-5.1E-05*	1.8E-05
Log income in 1000 DKK * woman	-0.122	0.024	4.0E-05***	0.031
Log income in 1000 DKK, higher salaried employee	0.414	0.026	-0.074**	0.034
Log income in 1000 DKK, other employee	0.399	0.027	-0.054***	0.035
Skilled worker	0.128*	0.045	-0.079***	0.059
Medium salaried employee	0.181	0.035	-0.222	0.044
Apprentice	0.443	0.085	0.073***	0.120
Student	0.273	0.052	-0.497	0.065
Self-employed	-0.291	0.058	-1.013	0.062
School child	-0.666	0.079	-0.273*	0.103
Number of children	-0.081	0.014	-0.067	0.017
Driving license	0.147	0.035	-0.033***	0.046
Number of cars	0.280	0.036	-0.043***	0.045
Number of cars per person	0.248	0.061	-8.2E-04***	0.077
Lives in low raise area	0.385	0.029	0.016***	0.037
$(\text{Distance to centre})^3$, car owner	-1.3E-07*	4.0E-08	-1.5E-07*	4.8E-08
$(\text{Distance to centre})^2$, car owner	8.8E-05	1.3E-05	4.0E-05**	1.7E-05
(Log income in 1000 DKK, higher salaried employee) * (Distance to centre, car owner)	-2.1E-03	2.4E-04	-5.7E-04***	3.1E-04
(Log income in 1000 DKK, other employees) * (Distance to centre, car owner)	-3.0E-03	2.2E-04	-4.5E-04***	2.8E-04
Distance to centre, no car	-4.0E-03	7.2E-04	-1.3E-03***	8.8E-04
Rural area	0.137*	0.043	-0.190*	0.052
Copenhagen city centre	0.197	0.044	-0.034***	0.058
Copenhagen municipality	-0.196	0.033	0.052***	0.043
0-5 minutes from station	-0.238	0.035	0.253	0.047
5-10 minutes from station	-0.129	0.026	0.217	0.034
Balance between workplaces and residences	0.298	0.038	0.182	0.046
$(\text{Balance between workplaces and residences})^2$	-0.027	0.006	0.020*	0.007
Goodness of fit	$R^2 = 0.18$		$Rho^2 = 0.20$	
Number of observations	12,689		26,505	

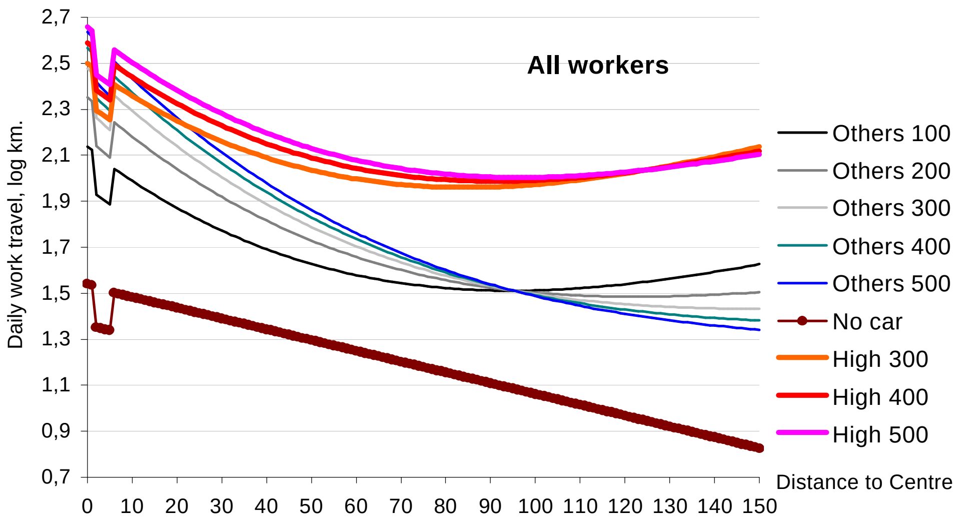
*Significant <1% level ** Significant <5% level. *** Not significant. Others significant <0,01% level

(a)-(b) is parameter estimates through linear regression on logarithm of daily kilometres to work. The table states how much the average work distance is effected when the variables change value of one unity. (c)-(d) is parameter estimates through logistic regression of the probability of travelling to work.

***Figure** Error! Unknown switch argument.* **Travel distance dependent on distance of work places to central Copenhagen**







Estimated daily work travel distance depending on how far from the city centre of Copenhagen workplaces are localised. The travel distance is shown in log kilometres for households without a car and for households with a car specified after high salaried employees and other employees with different incomes (in 1000 Dkr). The top chart shows the distance travelled daily conditional a work trip. The middle chart shows the probability of travelling to work and the chart at the bottom shows the expected distance travelled for all workers.

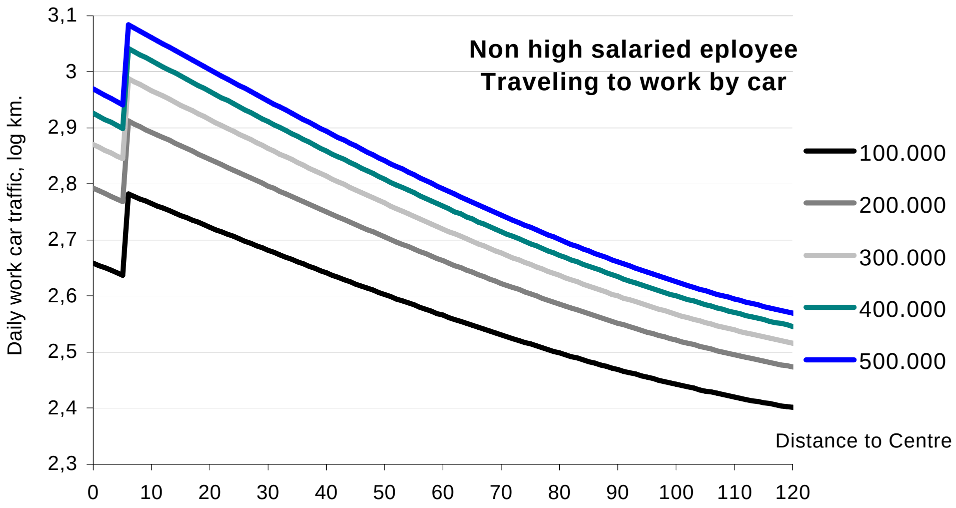
Table *Error! Unknown switch argument.*. **Estimation results: Total travel distance given place of work**

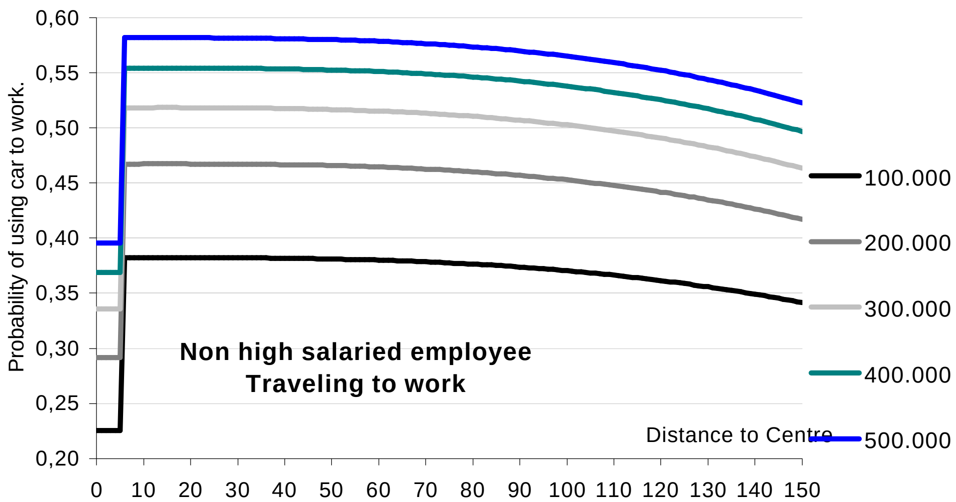
	Work travel distance		Probability of work travel	
	(a)	(b)	(c)	(d)
	Estimate	Standard error	Estimate	Standard error
Intercept	0.371***	0.255	-7.8628	0.3639
Weekday	0.111**	0.047	-0.556	0.0974
Age^2	-1.2E-04	1.6E-05	-8.90E-05*	3.00E-05
Log income in 1000 DKK * woman	-0.025	0.005	-0.072	0.010
Log income in 1000 DKK. higher salaried employee	0.212	0.029	0.562	0.052
Log income in 1000 DKK. other employee	0.206	0.031	0.539	0.056
Skilled worker	0.106	0.045	0.340*	0.093
Medium salaried employee	0.126**	0.039	0.170**	0.072
Self-employed	-0.276*	0.055	0.509	0.130
School child	-0.538	0.268	-1.553	0.343
Number of children	-0.049**	0.015	0.067**	0.030
Driving license	1.570*	0.197	3.879	0.226
Number of cars	0.134	0.036	1.104	0.085
Number of cars per person	0.144*	0.056	2.199	0.141
Lives in low raise area	0.266**	0.033	0.228*	0.063
(Log income in 1000 DKK. other employees) * $(\text{Distance to centre. car owner})^3$	1.3E-08	0.0E+00	-1.17E-08**	5.24E-09
(Log income in 1000 DKK. other employees) * (Distance to centre. car owner)	-9.2E-04	1.1E-04	7.92E-06***	1.95E-04
Copenhagen municipality	-0.149	0.036	-0.755	0.062
0-5 minutes from station	-0.332	0.046	-0.659	0.078
5-10 minutes from station	-0.131	0.032	-0.474	0.058
Balance between workplaces and residences	0.175	0.039	0.101***	0.083
$(\text{Balance between workplaces and residences})^2$	-0.012	0.005	-3.32E-04***	1.35E-02
Goodness of fit	$R^2 = 0.10$		$Rho^2 = 0.42$	
Number of observations	5,689		12,689	

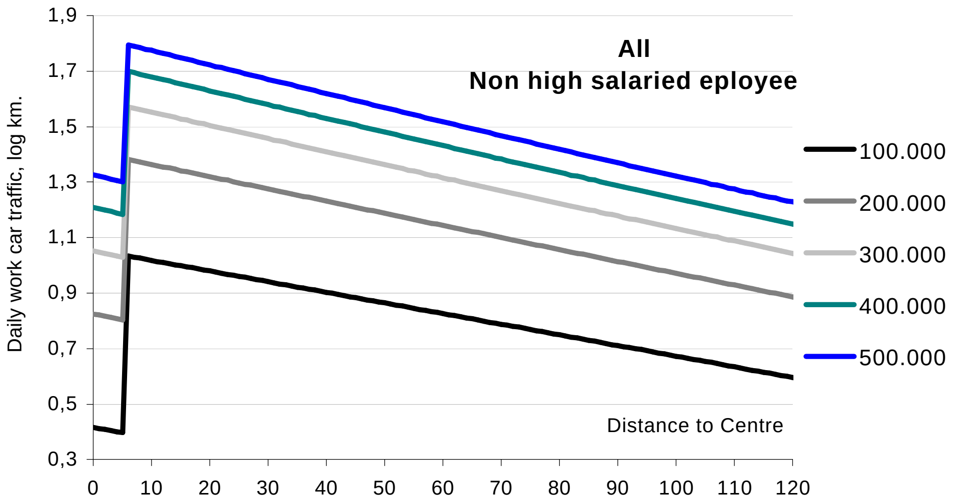
*Significant <1% level ** Significant <5% level. *** Not significant. Others significant <0,01% level

(a)-(b) is parameter estimates through linear regression on logarithm of daily kilometres to work by car. The table states how much the average work travel distance by car is effected when the variables change value of one unity. (c)-(d) is parameter estimates through logistic regression of the probability of travelling by car to work, given the person go to work the actual day.

***Figure** Error! Unknown switch argument.* **Travel distance dependent on distance of work places to central Copenhagen**







Estimated daily work travel distance by car depending on how far from the city centre of Copenhagen workplaces are localised. The car travel distance is shown in log kilometres for households with a car specified after other employees than high salaried with different incomes (in Dkr). The top chart shows the distance travelled daily by car conditional a car trip to work. The middle chart shows the probability of travelling to work by car and the chart at the bottom shows the expected distance travelled by car for all non high salaried employees.

Figure *Error! Unknown switch argument..* **Map of the Copenhagen region** with all the urban zones from which the distances are calculated. The size of the map is about 80x120 km^2. The map also shows daily car kilometres per person in the zones (16-74 years, data for 1995-97).