The impacts of job and household decentralization on commuting distances and travel modes
Experiences from the Copenhagen region and other Nordic urban areas

1 Introduction

The main topic of this article is the influence of urban sprawl on commuting distances and modes of travel. This is an issue much debated in the urban planning literature. In particular, this discussion has been vivid as objectives of environmentally sustainable mobility appeared on planners’ agenda in the wake of the report from the World Commission on Environment and Development. More recently, the Kyoto protocol implies an obligation for the European Union to reduce greenhouse gas emissions by 8% within 2010, compared to the 1990 level. The internally agreed distribution of emissions between EU countries implies that some countries, such as Denmark and Germany, are obliged to reduce their emissions by more than 20 per cent. Obtaining these objectives may prove difficult unless current trends within the transportation sector are changed dramatically. For example, based on current transport policies, the emissions from the transportation sector will make up 32% of the internationally agreed limit for the total, national CO₂ emissions in Denmark in 2010, compared to 21% in 1997.

2 Are cities doomed to sprawl?

The focus of planners on the role of urban developmental patterns in influencing the amount of transport and the distribution between different means of conveyance rests on the assumption that it is possible to channel development to the types of areas identified as favorable, given a goal of reducing the greenhouse gas emissions and other negative environmental impacts from urban motoring. However, according to several authors, metropolitan-level decentralization of workplaces and residences is a strong and more or less general tendency in Europe. For example, Breheny holds that decentralization is the inevitable outcome of the expressed location preferences of people and firms. According to Sieverts, new development in German urban regions typically takes place in the “Zwischenland”, i.e. in the areas between the cities, and not within or immediately adjacent to the cities. In Sieverts’ view, cities can no longer be fitted into a hierarchic system according to central place theory. Instead, they should be understood as a network of nodes, where there is a spatially more or less equal, scattered distribution of labor with spatial-functional specializations. Such net-shaped cities or city regions have polycentric instead of monocentric or hierarchic center structures, and constitute larger, fragmented and very complex territories.

If nothing can be done to counteract the decentralization of jobs and households, then knowledge about the transport consequences of this decentralization will be of limited policy relevance. However, actual urban developmental trends in Europe are far more nuanced than what has been claimed by the most “decentralization-deterministic” debaters.

Empirical data show that population densities were reduced between 1980 and 1990 in a number of large European cities. Similarly, in a study carried out by the UN/ECE Human Settlements Division in 1998, urban sprawl is characterized as a dominant trend. However, urban development in recent years differs considerably across European national borders. In some countries, like Sweden and Norway, a long period of spatial urban expansion since the 1950s has been succeeded by a trend of reurbanization during the latest couple of decades. A considerable renewal of older housing areas and transformation of derelict and underutilized industrial and harbor areas has taken place, resulting in a substantial growth in the number of workplaces and dwellings in inner-city
areas. During the period 2000-2005, the average density of all Norwegian urban settlements has increased, in particular in the largest cities. In Oslo Metropolitan Area, with a total population of approx. 840,000 inhabitants, the population of the core municipality (the municipality of Oslo) has increased from 447,000 to 552,000 since 1985, with virtually no spatial expansion of the urban area.

The densification tendency of some Nordic countries is contrasted by the urban development currently taking place in the post-communist East European countries, where urban sprawl is proceeding “at a pace which leaves anything experienced in the west far behind”9. In other EU countries, including Denmark, Spain and the UK, there is also a spatial expansion of cities. However, in these countries the tendency of sprawl is more moderate and combined with considerable inner-city regeneration and densification.10 The growth of urban area in Danish cities dropped from 49 square kilometers annually in the period 1965-1982 to 30 square kilometers annually during the following 13 years. During the latest decade, the conversion of non-urban land into built-up areas has increased to a somewhat higher level again in Denmark.11

As can be seen, current urban development appears to follow different trajectories in different parts of Europe, depending on, among others, economic driving forces, cultural trends and political priorities. The fact that sprawl is not the inevitable and universal trend which some authors have claimed it to be, implies that there is scope for choice between different land use policy strategies.

Planners’ assumptions about the role of jobs and housing decentralization in influencing traveling patterns in urban regions also rests with the assumption that there are actually some centers from which workplaces and residents can be decentralized (or toward which they can be centralized, it such a strategy is found to be more favorable). As mentioned above, Sieverts describes urban regions as being more or less without any clear centers any longer. However, even the European regions where decentralization of workplaces and residences is a dominant tendency are characterized by a hierarchical intra-metropolitan structure with a main center and several lower-order centers, rather than being genuinely polycentric. Most European cities still have a higher concentration of workplaces, retail, public agencies, cultural events and leisure facilities in the historical urban center and its immediate surroundings than in the peripheral parts of the urban area.12 For example, in Copenhagen Metropolitan Area, the inner city of Copenhagen has an unchallenged status as the dominating center of the city region. The central municipalities of Copenhagen and Frederiksberg, making up only 3.4 % of the area of Copenhagen Metropolitan Area, have one third of the inhabitants and an even higher proportion of the workplaces.13 The conception of contemporary cities as polycentric and net-shaped regions with no clear center hierarchies does not fit with the general situation in European metropolitan areas, but describes at most a trend apparent in certain regions.

3 The influence of residential and workplace location on commuting: the case of Copenhagen Metropolitan Area

A comprehensive study of land use and travel in Copenhagen Metropolitan Area will be used as our main case. After a presentation and discussion of the findings of this study, the Copenhagen results will be compared to the results of other, less detailed studies from Nordic countries.

In a North European context, Copenhagen Metropolitan Area is a major city region of about 1.8 million inhabitants, with a concentration of workplaces and service facilities in the City of Copenhagen, but also with several secondary and local centers in the suburbs. The city has a well-developed public transport system with a network of urban rail lines as its backbone, along with several major arterial and ring roads.

In important ways the Copenhagen Metropolitan Area study goes beyond the scope of previous investigations into the relationships between urban land use and travel. In this article, only a brief account of the methodology of the study will be presented. More detailed information about the methods is available in an English-language book as well as in other journal articles.14 The study includes a
large travel survey among inhabitants of 29 residential areas, a more detailed travel diary investigation among some of the participants of the first survey, and qualitative interviews with 17 households.

Most of the questions about travel behavior focused on a specific investigation period (one week in the main survey and four days in the travel diary investigation). In addition, respondents who had moved during the latest five years were asked about any changes in travel behavior, activity participation and car ownership after moving from their previous residential address. The travel activities investigated included commuting as well as other travel purposes. Specified information about the commutes was recorded, and the data are therefore well suited to illustrate the influence of residential location on commuting patterns. Differences between population groups in the way urban structure affects travel behavior have also been investigated, as well as changes after moving from one residence to another.

Both surveys and all interviews were carried out during the period from June to September 2001. In the first survey, we received completed questionnaires from 1,932 individuals. In the travel diary investigation, 273 persons responded. The samples of the two surveys must be considered fairly well representative for the inhabitants of the Copenhagen area and the selected residential areas. The qualitative interviews were (apart from one single case) conducted in the homes of the interviewees, usually lasting between 1½ and 2 hours. All interviews were tape-recorded and subsequently transcribed in their entirety. The interviews were semi-structured, focusing on the interviewees’ reasons for choosing activities and their locations, travel modes and routes, the meaning attached to living in or visiting various parts of the city, and any changes in traveling patterns, activity participation and car ownership compared to previous places of residence.

3.1 Commuting distances

Below, we shall first focus on the ways in which commuting distances are influenced by the urban structural situation of the dwelling. Thereupon, the influence of workplace location will be addressed.

Residential location

Figure 1 shows average trip lengths for journeys to work among respondents living within different distance intervals from downtown Copenhagen. The commuting distances have been measured accurately along the road network between the residential and workplace addresses of workforce-participating respondents. Residents of the outer parts of Greater Copenhagen have on average two and a half times as long journeys to work as those living less than 6 km away from the city center.

The strong relationship between residential location and commuting distances holds true also when controlling for demographic, socioeconomic and attitudinal variables. Table 1 shows the ten variables which, according to our material, influence commuting distances with effects satisfying a significance level (p value) of 0.15. Three of the ten variables are urban structural characteristics. The distance between the dwelling and the jobsite tends to increase the further away the residence is located from downtown Copenhagen as well as from the closest second-order urban center and the closest urban rail station. The location of the residence relative to downtown Copenhagen is the factor exerting the strongest influence of all variables on the distance between the residence and the workplace (Beta=0.327, p=0.000). The effects of the distances from the dwelling to the closest second-order urban center and the closest urban rail station are weaker (Beta=0.069 and 0.052, respectively, with p-values of 0.047 and 0.128).
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None of the effects of the three urban structural variables is surprising. The tendency to increasing commuting distances, the further away from downtown Copenhagen the residence is located reflects the location of a large proportion of the workplaces of the metropolitan area in the inner and central parts of Copenhagen. To some extent, the commuting distances to outer-suburban workplaces too will increase if the dwelling is situated far away from downtown Copenhagen. This will be the case for residents living in a different suburban sector (e.g. in the North) from the sector in which the workplace is located (e.g. the Køge bay corridor).

The second-order urban centers also contain a number of workplaces, attracting employees both from a local and regional catchment area. Some of those who live close to such a center may therefore find suitable jobs close to their residence. The effect of the distance to the closest urban rail station probably reflects the fact that the immediate surroundings of urban rail stations often contain a number of local service facilities and in many cases also a broader supply of workplaces. This local supply of workplaces will presumably be of a high importance to those groups of workforce participants with the least specialized jobs and/or lowest possibilities of making long journeys to work.

A number of previous investigations have shown that women more often than men combine a low degree of professional specialization with non-access to a car for daily use and hence have lower average commuting distances. The impact of sex is therefore in line with our expectations. The same applies to the effect of schoolchildren in the household, where childcare and activities together with the children may put constraints on the parents' opportunity to spend time on long daily commutes. A high income, on the other hand, enables respondents to spend more money on traveling and thus increases the respondents' general radius of action, including the possibility of choosing workplaces and residences spaced a long distance apart. The effect of income may also be due to the choice of some respondents to accept longer commuting distances in order to obtain the most well-paid employment. The longer average commutes among respondents who have moved relatively recently to their present dwelling reflects the fact that many other criteria are often considered more important than proximity to the workplace when people move to a new residence. After the move, some people may try to find a

### Table 1

Results from a multivariate analysis of the influences from various independent variables on the daily one-way commuting distance (km) of workforce-participation respondents

(Only variables with a level of significance of 0.15 or lower are included; n=1 026 respondents from 29 residential areas in Copenhagen Metropolitan Area; adjusted R²=0.203)

<table>
<thead>
<tr>
<th></th>
<th>Unstandardized coefficients</th>
<th>Standardized coefficient</th>
<th>Level of significance (p value)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B Std. error Beta</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location of the residence relative to downtown Copenhagen (non-linear distance function, values ranging from 0.66 to 3.80)</td>
<td>3.326 0.351 0.327 0.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex (female = 1, male = 0)</td>
<td>-2.598 0.767 -0.102 0.001</td>
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<td></td>
</tr>
<tr>
<td>Number of household members aged 7 - 17</td>
<td>-1.384 0.488 -0.087 0.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has moved to the present dwelling less than 5 years ago (yes = 1, no = 0)</td>
<td>2.139 0.770 0.080 0.006</td>
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<td></td>
</tr>
<tr>
<td>Personal annual income (1000 DKK)</td>
<td>0.0044 0.018 0.076 0.017</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logarithm of the distance (meters) from the residence to the closest urban rail station (log values ranging from 1.90 to 4.47)</td>
<td>2.452 1.296 0.069 0.059</td>
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<td></td>
</tr>
<tr>
<td>Age (deviation from being „middle-aged“, logarithmically measured)</td>
<td>-2.635 1.330 -0.063 0.048</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Index for transport attitudes (high value = car-oriented attitudes, values ranging from -17 to 11)</td>
<td>0.127 0.066 0.057 0.055</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logarithm of the distance (meters) from the residence to the closest second-order urban center (log values ranging from 2.49 to 4.46)</td>
<td>1.239 0.814 0.052 0.128</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long technical or economic education (yes = 1, no = 0)</td>
<td>1.948 1.117 0.051 0.082</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-4.495 4.472 0.315</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
job closer to the new residence, but since this can take some time, the likelihood of living far away from the workplace is higher among recent movers than among those who have lived in their present dwelling for several years. The effects of the three remaining non-urban-structural variables are also in line with expectations. Middle-aged respondents with high technical or economic education and car-oriented attitudes tend to be more able and willing than other respondents to commute a long distance.

Keeping non-urban-structural variables constant at mean variables, the average distance between the home and the workplace is 16 km longer among the respondents of the two most remote investigated areas (Gilleleje and Haslev) than among the respondents of the inner-city area of Vesterbro (Fig. 2). This differential is larger than the bivariate difference between residential areas in the respective distances from downtown Copenhagen (14 km).

Similarly, a separate analysis among the proportion of our respondents who are students/pupils shows that the distance between the residence and the place of education increases clearly, the further away from downtown Copenhagen the dwelling is situated. In spite of the quite small size of this sub-sample (n=124), the effect has a high degree of statistical certainty (p=0.000).

The above results are in line with the information given by the participants of the qualitative interviews. Those interviewees who had moved to a more peripheral dwelling had most often experienced increased commuting distances, while the opposite was the case for those who had moved inward. The answers to retrospective questions in the travel surveys about changes in the amount of travel due to moving show a similar pattern: although many respondents, in particular among those who had changed their distance from downtown only marginally, have experienced no significant change in the amount of travel, there was a clear tendency to increasing amounts of transport when moving outwards and decreasing when moving closer to the city center.

Figure 2
Average, expected one-way commuting distance (km) among workforce participants living in each of the 29 investigated areas, based on the respondents’ actual values on each of the three urban structural variables of the regression model, and with all other independent variables kept constant at mean values (n=1 026, p=0.000)

Figure 3
Spatial distribution of respondents’ workplaces (n=1 319 workforce participants among 1 932 respondents participating in the main survey)
The look at the spatial distribution of the respondents’ workplaces illustrates why we find such large differences in commuting distances between respondents living in the central and peripheral parts of the urban region. In Figure 3, the map to the left includes the whole north eastern part of the Zealand, whereas the right part of the figure zooms in on the inner part of the Copenhagen area. Although a considerable number of respondents work in semi-peripheral and outer parts of the region, in particular in the sub-regional centers of Hillerød, Roskilde, Køge and Tåstrup, the main concentration of respondents’ workplaces is clearly in the inner and central parts of Greater Copenhagen.

In Figure 4, the respondents’ workplaces and places of education have been distributed according to their distances from downtown Copenhagen. The figure shows the number as well as the density of respondents with workplace/place of education within concentric, 1 km wide belts around the center of Copenhagen. In spite of the fact that the inner belts cover areas of a far less size than the outer belts, more than one sixth of the respondents’ workplaces and places of education are located within the two innermost kilometer belts, and one half is located less then 10 km from the city center. If we instead consider the density of respondents’ workplaces and places of education (which is more reasonable since what we want to compare is the concentration of such trip destinations), the difference is enormous, ranging from more than 300 workplaces and places of education per 10 square kilometer in the inner ring (i.e. up to 1 km from the City Hall Square), 20 in the distance belt from 5 to 6 km, and lower than 1 in all distance belts from 16 km and outward.

 Needless to say, the distances to these centrally located trip destinations will be longer if you live in the peripheral parts of the metropolitan area than if you live in one of the two central municipalities (Copenhagen and Frederiksberg). An important part of the explanation of the geographical differences in the respondents’ amounts of travel shown in the previous sections probably lies in these circumstances.

Even though the dwellings in the metropolitan area also show a higher concentration in the inner parts, this concentration is stronger for the respondents’ workplaces than for their residences. Whereas 26% of our working respondents live within 6 km from downtown Copenhagen, 39% of the respondents’ workplaces are located within this zone. If respondents working more than 70 km away from downtown Copenhagen are excluded (a delimitation which seems reasonable, given the fact that none of the respondents’ dwellings is located more peripherally than that), the respondents on average live 19.5 km away from the city center of Copenhagen, whereas their workplaces are on average situated 15 km from downtown. The corresponding median values are 15 km and 10 km, respectively. Two thirds of the respondents work closer to downtown Copenhagen than where they live, while only one third work more peripherally than their place of residence.

### Workplace location

Whereas we find a clear impact on commuting distances from the location of the dwelling relative to downtown Copenhagen, the impact of the distance from the workplace to downtown is less clear. Similar to Figure 3, Figure 5 shows average commuting distances among employees working at workplaces located within different distance belts from downtown Copenhagen. Employees at inner-city workplaces have on average somewhat shorter journeys to work than their outer-area counterparts, except for the outermost distance belt,
where the average commute drops to a level slightly below that of the most central of the distance belts (12.6 km, 14.2 km, 14.7 km and 11.9 km, respectively, in the inner, second inner, second outer and outer of the four distance belts). It should be noted that the number of respondents’ workplaces is considerably higher in the inner distance belts than in the two outer, with nearly 40% of all the workplaces located in the innermost of the belts (cf. fig. 3, 4).

Nevertheless, the correlation between commuting distance and the linear distance from the workplace to downtown Copenhagen is far from being statistically significant (p=0.654). This is also true if we transform the distance from the residence to downtown by means of a non-linear function similar to the way the distance from the residence to downtown Copenhagen was measured. Apparently, a slight quadratic curve provides the best description of the correlation between the commuting distance and the distance from the workplace to downtown Copenhagen (R Square=0.008).

Controlling for the same non-urban structural variables as in Table 1, but without making any control for the location of the residence22, we find a slight tendency to reduced commuting distances among respondents working at the most remote workplaces. This tendency is, however, not statistically significant (p=0.228).

Discussion

The stronger influence on commuting distances from residential location than from workplace location is probably due to the different combinations of mechanisms by which the location of residences and workplaces, respectively, influence the distances of journeys to work (see Table 2). Firstly, in Copenhagen Metropolitan Area (like many other urban regions), there is a higher concentration of residences and workplaces in the inner than in the outer part of the region. This contributes considerably to shorter average commuting distances among inner-city dwellers as well as among employees of inner-city workplaces. Secondly, downtown is located much closer to geographical point of gravity of the city’s stock of buildings than most suburban locations are.23 Downtown is also a major node for the public transport lines, and transit travelers going from one suburb to another often start the trip taking an inward line before changing to an outward line at a more centrally located junction. The more coarse-meshed street networks in the outer areas also imply that car drivers traveling from one suburb to another suburban location must often first travel some distance toward the center before they reach a relevant ring road. Trips from a residence or workplace in one suburb to a random destination in another suburb will for the above-mentioned reasons on average be longer, the further away from downtown the residence or workplace is located.24 Although not very strong, the mechanisms emerging from the role of downtown as a transport node and approximate point of gravity contribute to some extent to shorter average commuting distances both among inner-city residents

Table 2

<table>
<thead>
<tr>
<th>Different characteristics of the urban structure of Copenhagen Metropolitan Area:</th>
<th>Contribution to the relationship between residential location and commuting distances:</th>
<th>Contribution to the relationship between workplace location and commuting distances:</th>
</tr>
</thead>
<tbody>
<tr>
<td>The higher concentration of workplaces and residences in the inner than outer part of the metropolitan area</td>
<td>Contributes considerably to shorter commuting distances among inner-city dwellers</td>
<td>Contributes considerably to shorter commuting distances among employees of inner-city workplaces</td>
</tr>
<tr>
<td>Downtown as an approximate point of gravity for the housing stock and the workplace, and as a major node in the transport network</td>
<td>Contributes to some extent to shorter commuting distances among inner-city dwellers</td>
<td>Contributes to some extent to shorter commuting distances among employees of inner-city workplaces</td>
</tr>
<tr>
<td>The more centralized location of workplaces than of residences</td>
<td>Contributes considerably to shorter commuting distances among inner-city dwellers</td>
<td>Contributes considerably to longer commuting distances among employees of inner-city workplaces</td>
</tr>
</tbody>
</table>

Figure 5

Mean trip length for journeys to work among respondents working within different distance intervals from downtown Copenhagen (n=1,161)
and among people working in the central part of the metropolitan area. Thirdly, the workplaces of Copenhagen Metropolitan Area are located in a more centralized pattern than what is the case for the residences of the region (cf. above). This creates a scarcity of jobs compared to the number of inhabitants in the outer areas, and a scarcity of inhabitants compared to the number of jobs in the inner city. As a result, a mechanism exists by which commuting distances tend to increase, the further away from downtown the residences are located and the closer to downtown the workplaces are located.

Seen together, the above circumstances imply that all the three mechanisms mentioned contribute to reduced commuting distances among inner-city residents. In comparison, only two of the three mechanisms contribute to shorter commuting distances among employees at centrally located workplaces, and one of these two mechanisms (the one based on the role of downtown as a transport node and approximate point of gravity) is arguably quite modest. On the other hand, the surplus of jobs in the inner part of the region, compared to the number of inhabitants, makes up a strong counteracting mechanism. The total influence of the three mechanisms is therefore that the length of commuting trips varies only to a little extent with the distance from downtown Copenhagen to the workplace.

Our qualitative interviews as well as our travel diary investigation show that the daily commutes are the most basic and fixed trips among workforce participants. Often, these trips make up the stock of a trip chain. Other travel purposes are then 'hitched' on this stock trip, e.g. shopping groceries along the route home from work. Taking the more basic character of the commutes into consideration, commuting trips make up two thirds of the distance traveled by workforce participating respondents on weekdays and nearly half their total weekly traveling distance.²⁵

3.2 Travel modes

The information about travel modes is based on the travel diary investigation, which included a considerably lower number of respondents than the main survey. Among the 273 respondents of the travel diary survey, 56 were not workforce participants, and another 33 were excluded from the analysis because the necessary information about their commutes was missing or their workplace was located at extreme distances from their residences (i.e. more than 70 km).

Residential location

Among the remaining 184 respondents we find a clear tendency to higher shares of car commuting and lower shares of journeys to work by non-motorized modes, the further away from downtown Copenhagen the residence is located (Fig. 6). In the diagram to the left, car drivers and car passengers have been combined, and similarly trips by foot and by bike have been combined in the figure to the right. Looking more closely at the data, we find that the correlations between residential location and commuting mode are stronger among
car drivers than among car passengers, and more pronounced among bicyclists than among respondents who walk to their workplace.

The proportion of commuting trips carried out by public transport is generally lower than the proportions carried out by car and by non-motorized modes (a total average of 10%, compared to 59% and 29%, respectively, for car and walk/bike). The use of public transport for journeys to work is slightly higher among respondents living in the central part of the region, but the relationship is not statistically significant. Looking more closely at the various types of public transport, we find more frequent commuting trips by bus among respondents living in the inner of the four distance belts, while the frequency of commuting trips by rail varies little with the location of the dwelling.

The relationships between the location of the residence relative to downtown Copenhagen and the propensities of commuting by car and by non-motorized modes, respectively, hold true also when controlling for other urban structural characteristics of the residence and the non-urban-structural variables included in the analyses of commuting distances. Table 3 shows the variables which, according to our material, influence the propensity of commuting by car with effects satisfying a significance level (p value) of 0.15. Since most respondents have either commuted entirely by car or not commuted by car at all during the investigated period, whereas only a minority of the respondents have combined car with other travel modes and thus made a proportion of their commuting trips by car, ordinal regression analysis has been used instead of ordinary least square analysis.26

As can be seen in Table 3, the location of the residence relative to downtown Copenhagen is the only urban structural variable showing an effect on the propensity of commuting by car (p=0.004). According to our analysis, transport attitudes and car ownership exert the two strongest effects. In addition, our material shows increasing propensity of car commuting from holding a driver's license, a low income, and having a short or medium-long education as a tradesman or industrial worker. The two latter effects probably reflect a stronger preponderance of a “car culture” among blue collar workers.

It should be noted that the two variables exerting the strongest effects (car ownership and transport attitudes) are both to some extent influenced by the location of the residence. People who live in the inner city often feel that they can reach most destinations without a car, and even though some residents of the central part of the

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Estimate</th>
<th>Std. error</th>
<th>Wald</th>
<th>Level of significance (p value)</th>
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<td>Proportion of commuting trips by car = 0.00</td>
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<td>1.449</td>
<td>3.144</td>
<td>0.076</td>
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<td>Proportion of commuting trips by car = 0.50</td>
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<td>1.457</td>
<td>4.544</td>
<td>0.033</td>
</tr>
<tr>
<td>Proportion of commuting trips by car = 0.72</td>
<td>3.155</td>
<td>1.458</td>
<td>4.684</td>
<td>0.030</td>
</tr>
</tbody>
</table>

| Location                                      |          |            |        |                                  |
| Index for transport attitudes (high value = car-oriented attitude, values ranging from -17 to 11) | 0.254    | 0.051      | 24.60  | 0.000                           |
| Number of cars per adult household member     | 3.014    | 0.761      | 15.68  | 0.000                           |
| Location of the residence relative to downtown Copenhagen (non-linear distance function, values ranging from 0.66 to 3.80) | 0.517    | 0.178      | 8.42   | 0.004                           |
| Possession of a driver’s license (yes = 1, no = 0) | 3.449    | 1.306      | 6.97   | 0.008                           |
| Personal annual income (1000 DKK)             | -0.00326 | 0.00154    | 4.46   | 0.035                           |
| Short or medium-long education as a tradesman or industrial worker (yes = 1, no = 0) | 1.338    | 0.680      | 3.87   | 0.049                           |

Table 3 Results from a multivariate ordinal logistic analysis of the influence from various independent variables on the proportion of commuting trips by car during the investigated period (n=167, Nagelkercke R2=0.570)
metropolitan area may want to have a car for recreational purposes and visiting trips, very few inner-city households feel a need for owning two cars (as distinct from the outer suburbs, where two-car households are common). Inner city residents whose neighborhoods are exposed to fumes and congestion from traffic generated elsewhere may also develop more negative attitudes to car travel than their outer-area counterparts, who usually live in much more protected neighborhoods and also often feel dependent on car travel to reach daily activities. Such influences of residential location on car ownership and attitudes could be observed in the qualitative interviews as well as in the statistical material of the Copenhagen Metropolitan Area study.\textsuperscript{27} The location of the residence relative to downtown Copenhagen thus exerts a certain indirect effect on the propensity of car commuting in addition to its direct effect shown in Table 3. (If car ownership and transport attitudes are omitted among the independent variables, the effect of residential location increases somewhat, and the level of significance improves to 0.000.)

Controlling for non-urban-structural variables, the propensity of commuting by non-motorized modes (Table 4) is influenced by the location of the dwelling relative to both downtown Copenhagen (p=0.032) and the closest second-order urban center (p=0.054).\textsuperscript{28} Transport attitudes exert the strongest effect, with lower proportions of biking or walking the more positive are the respondent’s attitudes toward car driving. Again, the fact that transport attitudes are themselves influenced by residential location should be noted. The indirect effects of residential location via transport attitudes imply that the actual influence of residential location on the proportion of walk/bike commuting is somewhat higher than indicated in Table 4.

The lower propensity of car commuting among inner-city dwellers and their higher propensity of biking or walking to the workplace are in line with what could be expected from theoretical considerations. For one thing, the average commuting distances are shorter when living in the central part of the urban region. Since traveling long distances by non-motorized modes is time-consuming and can make you physically exhausted, most people consider walking and biking as relevant alternatives only if the destinations are relatively close. In the qualitative interviews of the Copenhagen Metropolitan Area study, Table 4

| Results from a multivariate ordinal logistic analysis of the influence from various independent variables on the proportion of commuting trips by non-motorized modes during the investigated period (n=167, Nagelkerke R\textsuperscript{2}=0.378) |
|---|---|---|---|---|
| **Threshold** | **Estimate** | **Std. error** | **Wald** | **Level of significance (p value)** |
| Proportion of commuting trips by non-motorized modes = 0.00 | -2.341 | 2.233 | 1.099 | 0.294 |
| Proportion of commuting trips by non-motorized modes = 0.33 | -2.300 | 2.233 | 1.062 | 0.303 |
| Proportion of commuting trips by non-motorized modes = 0.40 | -2.260 | 2.232 | 1.025 | 0.311 |
| Proportion of commuting trips by non-motorized modes = 0.50 | -1.959 | 2.230 | 0.772 | 0.380 |
| Proportion of commuting trips by non-motorized modes = 0.67 | -1.914 | 2.229 | 0.737 | 0.391 |
| **Location** | | | | |
| Index for transport attitudes (high value = car-oriented attitude, values ranging from -17 to 11) | -0.214 | 0.044 | 23.58 | 0.000 |
| Location of the residence relative to downtown Copenhagen (non-linear distance function, values ranging from 0.66 to 3.80) | -0.430 | 0.200 | 4.61 | 0.032 |
| Personal annual income (1000 DKK) | 0.00297 | 0.00142 | 4.38 | 0.036 |
| Logarithm of the distance from the residence to the closest second-order urban center (values ranging from 2.49 to 4.46) | -1.337 | 0.693 | 3.72 | 0.054 |
| Regular transport of children to school or kindergarten (yes = 1, no = 0) | 0.886 | 0.583 | 2.32 | 0.128 |
some of the interviewees living in the inner-city pointed at the area within approx. five or six kilometers from downtown as the “bike city” where most destinations were considered to be within acceptable biking distance. Our statistical material also shows a clear correlation between trip lengths and the proportions of walk/bike travel. Secondly, the conditions for car travel are less favorable when living in the inner parts of the city, where narrow streets, many crossings, red traffic lights and a generally high congestion level frustrates car drivers and makes the car less competitive in terms of travel time.

Multivariate analyses of the propensity of commuting by public transport shows a slight tendency to reduced use of public transport the closer to a second-order urban center the respondent lives (p=0.073). This rather counter-intuitive results probably reflects the competition from non-motorized modes: many workplaces are located in the second-order centers (some of which are in the inner-city of Copenhagen, quite close to the downtown area), and many of those who live close to such a center prefer to cycle or walk to the jobsite (cf. Table 4).

Workplace location

According to our material, the respondents’ modes of travel for journeys to work are less influenced by the location of the workplace than by the location of the dwelling. This applies to car commuting as well as to commuting trips by public transport or non-motorized modes. For journeys to work by car and by non-motorized modes there is still a relatively clear pattern with lower proportions of car commuting and higher proportions of walking/biking among employees of centrally located workplaces (Fig.7). The tendencies to increasing proportions of car travel and decreasing proportion of non-motorized commutes the more decentralized the workplaces are located are, however, disturbed by unexpectedly high proportions of car commuting and correspondingly low proportions of commutes by non-motorized modes at workplaces in the second inner of the four distance belts. Looking more detailed at the data, we find comparatively high proportions of car passengers among the respondents working in the second distance belt and a similar high proportion of respondents who have walked to their workplaces in the third distance belt.

Given the limited size of the sample, these particularities may well be a result of coincidence. The correlations between workplace location and commuting as car driver and bicyclist, respectively, are somewhat stronger than in the analyses where car drivers and passengers have been combined into the car commuting category and walking and biking into the non-motorized travel category.

A closer look at the data shows that the relationship between modal split and travel modes are curvilinear rather than linear. This is also plausible from theoretical considerations, as congested driving conditions and scarcity of parking space are first and foremost occurring in the central part of the urban regions, whereas there is less difference in car accessibility between workplaces located in inner and outer

There is also quite strong evidence that a decentralized location of office workplaces contributes to increase the proportion of car commuters, compared to a central workplace location. The relationship between workplace location and commuting mode is less clear for other types of workplaces.
parts of the suburbs. Based on iterations, a nonlinear transformation of the workplace’s distance from downtown Copenhagen was found to yield the highest correlation with modal split (Pearson’s r = 0.173 for car commuting and -0.168 for commuting by non-motorized modes, with p values of 0.026 and 0.031, respectively).

However, the above-mentioned correlations disappear when controlling for car ownership, transport attitudes and the other socioeconomic and demographic control variables. When all the control variables mentioned in endnote 15 are included in a multivariate ordinal logistic analysis, the relationships between workplace location and travel mode turn out to be highly insignificant (p values of 0.773 and 0.684, respectively, for commuting by car and by walk/bike). Performing binary logistic analyses with an exclusion of respondents who have combined different travel modes yields similar results.

Above, the influence of residential location on car ownership and transport attitudes was mentioned. Arguably, these variables (along with environmental attitudes) are also to some extent influenced by the location of the respondents’ workplaces, and their inclusion as control variables might therefore be considered a kind of ‘over-control’. If car ownership, transport attitudes and environmental attitudes are removed from the multivariate analyses, the significance levels of the relationships between workplace location and travel modes are considerably improved, with p values of 0.069 and 0.074 for commuting by car and walk/bike, respectively. However, the relationships are still relatively weak and more uncertain than the corresponding relationships between residential location and travel modes for commuting trips.

Discussion

The lower influence of workplace location on commuting travel modes than that of residential location is probably due to several circumstances. Firstly, the use of non-motorized modes is highly sensitive to trip distances (cf. above). As we have seen, the commuting distances are on average considerably shorter among inner-city than among outer-area residents, whereas there is a much smaller difference in commuting distances between employees of centrally and peripherally located workplaces. This implies that the proportion of respondents who work within acceptable walking or biking distance from home is higher among inner-city residents than among employees of inner-city workplaces. Secondly, congested driving conditions in the inner city make up a disincentive against car commuting both for inner-city residents and for employees at inner-city workplaces. However, due to shorter average trip lengths, a larger proportion of the commutes of inner-city residents take place within the most congested area. Among the employees of inner-city workplaces, a majority travel through considerable non-congested stretches before they reach the congested central area. Actually, 69% of the respondents who live less than 6 km from downtown also work less than 6 km from the city center. In comparison, only 47% of the employees at workplaces located within 6 km from the center also live within this distance belt. Thirdly, parking facilities are often scarce in the inner city, and residents who do not have a private parking place at their disposal must often park at a considerable distance from the dwelling. This makes up a disincentive against commuting by car if other modes are feasible alternatives. Distinct from that, inner-city workplaces increasingly provide parking possibilities for their employees in a private garage, often at zero-cost for the individual car commuter.

4 Comparison with other studies

Like any study of a single case, the results of the Copenhagen Metropolitan Area study are context-dependent. Although the main mechanisms influencing commuting distances and travel modes will probably be present across a wide range of cities, the configuration and relative strength of these mechanisms will depend on the actual context. Let us therefore look at a number of other Scandinavian studies in order to assess the extent to which the findings in Copenhagen Metropolitan Area regarding the impacts of residential and workplace location on commuting patterns can be generalized to a wider Scandinavian context.

A problem for the comparison is the fact that most Scandinavian studies of relationships
between residential location and travel have focused on the total traveling during the chosen period of investigation (usually varying from a couple of days to a week), and not specifically on commuting trips. However, in Copenhagen Metropolitan Area, the differences between residents of peripheral and central areas in total traveling distances to a high extent reflect differences in commuting trip lengths. Studies where the relationship between residential location and total daily or weekly traveling distances has been addressed may therefore supplement the few studies focusing specifically on commuting, when assessing the possibilities of generalizing the Copenhagen Area results.

Among studies addressing relationships between workplace location and transport, most studies have focused precisely on commuting trips, whereas other trips to workplaces, such as freight and trips by visitors etc. have been covered to a much lesser extent. Here, we therefore have the opportunity to make direct comparisons of the Copenhagen Metropolitan Area study with a number of other investigations.

4.1 Other studies of residential location and travel

In line with the results of the Copenhagen Metropolitan Area study, in-depth studies of residential location and transport in the Danish cities of Aalborg and Frederikshavn show a clear increase in daily traveling distances the further away from the city center the dwelling is located. In both these urban areas, with populations of 160,000 and 35,000, respectively, a methodology similar to the present study was used, including travel surveys as well as qualitative interviews. In the Frederikshavn study, commuting distances were investigated in particular. Controlling for socioeconomic and attitudinal variables, the average one-way commuting distance was 6.5 km among Frederikshavn respondents living at the urban fringe or in satellite settlements, compared to 2.5 km among inner-city dwellers. Although statistically highly significant, this differential is modest compared to the corresponding difference of 16 km between residents of the most remote and most central parts of Copenhagen Metropolitan Area. This of course reflects the very different sizes of the two cities.

Longer traveling distances among suburbanites have also been found in the Danish city of Århus (population: 280,000) and the Norwegian capital Oslo (population: 840,000). According to the three different studies carried out in Oslo, the average daily traveling distance with motorized modes tends to increase from around 10-15 km to around 25-30 km when the distance between the dwelling and the city center of Oslo increases from a couple of kilometers to 15 km. Engebretsen has also investigated relationships between residential location and daily traveling distances in the Norwegian cities of Bergen and Trondheim (populations: 215,000 and 150,000, respectively) and found results very similar to those in Oslo. A clear correlation between central residential location and short daily traveling distances has also been found in Helsinki.

In Hartoft-Nielsen's study in Århus, the average length of commuting trips among medium-income workforce participants was found to increase from about 6 km close to the city center to about 20 km in residential areas located 15 km from downtown. Based on a regional-scale travel survey in the Oslo region in 1990, Hjorthol provides data referring specifically to commuting distances, yet with a very crude classification of residential locations. Among residents of inner-city Oslo, the average commuting distances of women and men were 5.3 km and 4.9 km, respectively. In the outer parts of the municipality of Oslo, the corresponding commuting distances were 7.5 km and 9.4 km, and among residents of suburbs outside the municipality of Oslo 11.9 km and 17.0 km, respectively.

Coarse-meshed data on the impacts of residential location on commuting distances are also available from Finland. In the larger Finnish urban areas, in particular in Helsinki, the average commuting distances are considerably longer among outer-area residents than among inhabitants of the inner cities. In the inner parts of Helsinki, people live on average about 5 km away from their workplace, compared to 15-20 km in the outer suburbs.

The finding that outer-area residents travel considerably more by motorized modes than their inner-city counterparts is not confined to the Nordic context. Such relationships have also been found in Paris.
London, New York and Melbourne, San Francisco, Dutch urban regions and British cities and Hangzhou Metropolitan Area in China. According to the latter study, average one-way commuting distances tend to increase from approximately 4 km among inner-city residents to about 7 km when the distance from the dwelling to the city center of Hangzhou exceeds 10 km. In these figures, control has been made for similar demographic, socioeconomic and attitudinal variables as in the Copenhagen Metropolitan Area study.

Thus, there appears to be a high degree of generality about our results, indicating that the dominating mechanisms through which residential location influences urban traveling distances (including commuting distances) are likely to be found across city sizes in a broad context of Scandinavian and European cities. Probably, this will also be the case at a global scale among cities where the mobility resources of the population are high. In cities where the population has a low access to fast modes of transportation a more decentralized urban structure might still be transport efficient. The influence of residential location relative to downtown is also likely to be weaker in high-mobility cities without any clear CBD, like Phoenix and Houston in the USA. Yet, even in such cities a central location is likely to generate less travel, as the point of gravity of the housing stock and the stock of workplaces in most cities is located relatively close to the city center. The average distance to all the other addresses of the city will even in a polycentric city tend to be shorter from a central than from a peripheral location.

The influence of residential location on the modal split between car, public transport and non-motorized modes of travel found in the Copenhagen Metropolitan Area study corresponds to findings in a number of other cities. In Aalborg as well as in Frederikshavn, the proportion of car travel was found to increase with increasing distances between the residence and the city center, whereas the proportion of walk/bike travel showed an opposite tendency. In Århus, Hartoft-Nielsen found an almost total dominance of car travel among respondents living more than 20 km from the city center. Residents living five kilometers from the city center traveled on average approximately 70% of their daily distance by car, with public transport and walk/bike accounting for roughly 15% each. In Oslo, a clear center-periphery gradient of the modal split between different means of transport has been found, with higher proportions of car trips among residents of peripheral suburbs than in the inner cities. Typically, cars accounted for 60% or more of the trips among residents of the outer suburbs, compared to only 25-30% among inner-city residents. Conversely, inner-city residents made about one half of their trips by bike or by foot, compared to only one fourth among suburbanites (in inner as well as outer suburbs). Studies in Bergen and Trondheim show similar tendencies.

4.2 Other studies of workplace location and travel
A previous study by Peter Hartoft-Nielsen of 52 office workplaces located in different parts of the Copenhagen Metropolitan Area shows slightly increasing average commuting distances with increasing distances from the workplace to downtown Copenhagen. Among the employees of downtown workplaces, the average commuting distance was 18 km, compared to 24 km when the workplace was located 25 km away from downtown. In Århus, Hartoft-Nielsen found a similar tendency. It should be noted that all the workplaces investigated by Hartoft-Nielsen are offices. Requiring relatively specialized skills, these workplaces recruit employees from wider catchment areas than the workplaces represented in our Copenhagen Metropolitan Area study. This is illustrated by the fact that the average one-way commuting distance in Hartoft-Nielsen’s Copenhagen area study is 21 km, compared to 14 km in our study, where workplaces within a wide range of white-collar and blue-collar trades are represented. With a lower general degree of specialization, the possibility to recruit employees locally is higher for the workplaces in our study than in Hartoft-Nielsen’s study. Given a higher degree of decentralization of blue-collar than white-collar jobs in Copenhagen Metropolitan Area, this may explain why the average commuting distances of peripheral workplaces are shorter in our study than in Hartoft-Nielsen’s investigation. A closer look at our data reveals that commuting distances among respondents with a high education are shorter among employees of
centrally located workplaces, with an average commuting distance of 10 km in the inner distance belt, compared to 13-15 km in the three outer (p=0.003). Among respondents with a low education, commuting distances are longer at centrally located workplaces, with average commuting distances decreasing from 17 km in the inner distance belt to 10 km in the outer of the four belts (p=0.000).

The modest overall variation in commuting distances among employees working at different distances from downtown Copenhagen corresponds to findings in some other Nordic cities. In Oslo, Næss & Sandberg found no clear difference in commuting distances between employees working at central and peripheral locations, except somewhat shorter commutes among employees of two semi-central workplaces. In the little Danish town of Frederikshavn, no influence on commuting distances was found from the distance between the workplace and the town center. In Trondheim, Strommen has found small differences between peripherally and centrally located workplaces in commuting distances, albeit with a slight tendency to longer commutes to jobsites on the periphery. A certain tendency to longer commutes among employees of outer-area workplaces has also been found in Finnish urban areas.

Compared to our study in Copenhagen Metropolitan area, some other studies show a stronger influence of workplace location on the modal split of commuting trips. Notably, Hartoft-Nielsen's study of 52 offices in Copenhagen Metropolitan Area shows that the proportion of employees commuting by car tends to increase from 40-45% at downtown workplaces to 80% when the distance between the workplace and downtown is 30 km. In addition, Hartoft-Nielsen has found a clear effect of proximity to urban rail stations. Thus, among the inner-city workplaces located closest to main urban rail stations, the proportions of car commuters was only 10-25%. In the outer areas, proximity to a junction urban rail station typically reduced the proportion of car commuters from 75-85% to 40-60%.

Again, the somewhat stronger center-periphery gradient in Hartoft-Nielsen's study than in our study may possibly be explained by the fact that all Hartoft-Nielsen's investigated workplaces were offices, whereas our study included a wide range of trade categories, some of which typically recruiting employees from a more local geographical context than what is usually the case for office workplaces. This may explain why the proportions of non-motorized commutes are higher and the proportions of car commuting lower among employees of outer-area workplaces in our study than in Hartoft-Nielsen's investigation. Actually, among our respondents with a low education, the proportion of car commuters is lowest and the proportion of walk/bike commuters highest at workplaces located between 15 and 28 km from downtown Copenhagen. Among our respondents with a high education, the lowest share of car commuters and the highest share of non-motorized commuting are found at workplaces located less than 6 km from downtown, similar to the distribution found in Hartoft-Nilsens study of employees at office workplaces. In the latter study, no statistical control was made for other factors influencing the modal split. The high comparability of the investigated workplaces in Hartoft-Nielsen's study still makes it plausible that the relationship between workplace centrality and travel mode is not spurious.

The lack of statistically significant relationship between workplace location and modal split in our multivariate analysis with all control variables included may, as already mentioned, be a result of "over-control", as both car ownership, transport attitudes and environmental attitudes may to some extent be influenced by the extent to which respondents may easily reach their workplace by other modes than the private car. Moreover, the low number of respondents in our travel diary investigation implies that quite strong relationships are required in order to obtain a high statistical certainty. The combination of a small sample size and the influence of locally-recruiting, low-specialized workplaces on the proportion of car commuting to outer-area jobs may thus explain why the levels of significance for the relationships between workplace location and travel mode were relatively weak in our study, even when car ownership and attitudes were excluded from the independent variables.
A study of workplace location and commuting in Greater Oslo shows results similar to Hartoft-Nielsen’s Copenhagen area study, with proportions of car commuting as low as 12-14% in the very downtown area, 40-60 per cent at a public transport junction 3.5 km outside the city center, and 70-90% in the outer suburbs. The relationship between the distance of the workplaces from downtown and the modal split was still strong when controlling for a number of other factors that may influence the commuting pattern, among others car ownership, sex and income. Studies in the Norwegian city of Trondheim have also shown clear effects on commuting modes from the location of the workplace relative to the city center, with proportions of car commuting around 30-45% in the downtown area compared to around 80% at the urban fringe some eight kilometers away from the city center. The investigations in Trondheim include studies of companies that have moved either from the city center to the outskirts or from a suburb to the downtown area. These before-and-after studies show clear effects of workplace location on travel modes, with an increasing proportion of car commuters after outward move and a decreasing proportion after moving from suburb to center. On the other hand, studies in the Danish cities of Århus, Odense and Aalborg show smaller differences between downtown and periphery in travel modes, with car proportions typically some 20 percentage points higher at workplaces in the outskirts than in the downtown area.

5 Concluding remarks

There is clear evidence from studies in Denmark, Norway and Finland that residents of peripheral parts of urban areas tend to commute longer distances than their inner-city counterparts do. This differential in commuting distances accounts for a high proportion of the higher overall traveling distances found among suburbanites, compared to their counterparts living in central districts of the city. Inhabitants of the outer parts of the urban regions also have a higher propensity of commuting by car than those who live close to the city center. Conversely, a high proportion of the latter residents commute by non-motorized modes. The share of the residents’ travel carried out by public transport typically does not differ much between inner and outer parts of the urban area. Inner-city residents usually have the best opportunities to travel by public transport, but on the other hand, their trip destinations are often close enough to make walking or biking more attractive alternatives than going by public transit.

Apart from a slight tendency to increased commuting distances among employees of peripheral office workplaces, the extent to which workplaces are located centrally or peripherally within an urban region does not appear to exert any strong influence on commuting distances. There is, however, quite strong evidence that a decentralized location of office workplaces contributes to increase the proportion of car commuters, compared to a central workplace location. The relationship between workplace location and commuting mode is, however, less clear for other types of workplaces. For workplaces with a low degree of specialization, such as warehousing, primary schools, kindergartens, grocery shops and institutions for elderly people, a decentralized location may well be compatible with a high share of non-motorized commuting, since such workplaces will often be able to recruit a high proportion of their employees locally. The latter four types of service functions anyway need to be located close to the population groups they are meant to service, so any centralization in order to reduce car commuting among the employees would probably be many times outweighed by increased transportation needs among clients and customers.

The above conclusions imply that urban sprawl is unfavorable if the aim is to reduce car travel and emissions from transport in urban areas. This applies to sprawl in the form of residential decentralization as well as workplace decentralization. Traditionally, many urban planners have believed in the idea of co-locating workplaces and residences, not only in the central part but also when developing new areas in the outskirts of the city. Such ideas of “mixed-use development” might imply the relocation of a number of inner-city workplaces to suburbs where there is a deficit of local job opportunities. However,
the higher the general mobility level grows, the less are people likely to prefer local jobs to more distant, but otherwise more attractive job alternatives. The qualitative interviews of the Copenhagen Metropolitan Area study show that most interviewees attach more importance to being able to choose the best facility than to minimizing traveling distances. With steadily increasing education levels among the population and specialization levels of jobs, the proportion of the population who are able or willing to be employed at local workplaces is likely to diminish. The commuting patterns characterizing office workplaces, where the companies typically recruit employees from all over the urban region, are therefore likely to apply to an increasing part of the workforce. Workplace decentralization will therefore probably to an increasing extent create criss-cross commuting patterns, and because the accessibility by car is generally higher and the accessibility by public transport lower in the suburbs, such a development is likely to lead to increasing shares of car commuting.

At an aggregate level, decentralization of workplaces as well as residences contribute to reduced urban densities, and hence also to increased average distances between the various functions of the city. Several studies – also in the Nordic countries – have demonstrated the link between low urban density and a high energy use for transport. The Nordic investigations show that this relationship is present also when controlling for a number of socioeconomic factors.67

Urban sprawl is of course not the only cause of the increasing commuting distances currently experienced in most European countries. Commutes have grown longer even in Norway and Sweden where sprawl has come to a halt, and in urban regions where a spatial expansion is still going on (like Copenhagen Metropolitan Area), only a limited proportion of the increase in commuting distances can be attributed to outward urban development.68 Still, land use is an important contributory factor, and other measures to curb the increase in car-based commuting will be less efficient and cause more negative welfare effects if residences and specialized workplaces continue to decentralize.

In order to limit the growth in commuting distances and the use of car for commuting trips, urban land use policies should aim at densification rather than sprawl. In particular, locating a high share of new dwellings and white-collar jobs to inner cities is likely to contribute to lower car usage. Such urban strategies may seem contrary to trends in parts of Europe, but the experience from Swedish and Norwegian cities shows that reurbanization and densification is possible within a contemporary European context.
Notes

(1) World Commission on Environment and Development 1987
(2) Jespersen 2000, p. 107
(3) Breheny 1995, p. 87
(4) Sieverts 1995
(5) Newman & Kenworthy 1999
(6) UN/ECE Human Settlements Division 1998
(8) Statistics Norway 2005
(9) Schwedler 1999
(10) UN/ECE Human Settlements Division 1998
(11) Damsgaard & Olesen 2000
(12) cf., among others, Newman & Kenworthy 1999, p. 94-95
(13) Næss 2005
(14) Næss 2006a resp. 2005, 2006b and c
(15) 14 respondents with extreme commuting distances (one-way lengths ranging from 70–273 km) have been excluded from the analysis. The non-urban-structural control variables were the following: Sex, age, number of household members below 7 years of age, number of household members aged 7–17, personal annual income, whether the respondent holds a driver’s license, number of cars per adult household member, whether or not the respondent has a higher education within technical or economic subjects, whether or not the respondent has a short or medium-long education as a tradesman or industrial worker, index for attitudes to transport issues, index for attitudes to environmental issues, regular transport of children to school or kindergarten, and whether the respondent had moved to the present dwelling less than five years ago.
(16) Up to a turning point at a distance of 42 km from downtown Copenhagen, whereupon commuting distances are slightly reduced with further increases in the distance between the dwelling and downtown Copenhagen. Downtown was defined as the City Hall Square. Based on theoretical considerations as well as preliminary analyses of the empirical data, the location of the residence relative to downtown Copenhagen was measured by means of a variable constructed by transforming the linear distance along the road network by means of a non-linear function. This function was composed of a hyperbolic tangential function and a quadratic function, calculated from the following equation: Afstfun = ((EXP(centafs*0.18 – 2.85))/ (EXP(centafs*0.18 – 2.85) + EXP(- (centafs*0.18 – 2.85)) – (0.00068*(centafs – 42)*(centafs – 42) – 2.8)), where Afstfun = the transformed distance from the dwelling to downtown Copenhagen and centafs = the linear distance along the road network, measured in kilometer. A further account of the considerations and iterations on which the choice of this function was based is available in a working paper at Aalborg University (Næss, 2001, Danish-language only).
(17) Distances to the closest second-order center and the closest urban rail station were measured logarithmically, from an assumption that the influence of a one-kilometer increase in the distance within the relevant distance intervals (with averages of 6.5 km and 4.4 km, respectively) would be stronger if the distance is short at the outset than if it is already long.
(19) cf. Hägerstrand 1970
(20) Among our workforce-participating respondents, 18.5 % have both their residence and workplace within the inner distance belt (6 km from downtown Copenhagen). 20.5 % live more than 6 km from the city center but work within the inner distance belt, whereas 8 % live within the inner distance belt and work more than 6 km from the city center. The remaining 53 % both live and work more than 6 km from downtown.
(21) In addition to respondents with extreme commuting distances (cf. endnote 1), five respondents whose workplaces were located more than 70 km from downtown Copenhagen were excluded from the analysis.
(22) If we had also controlled for the urban structural situation of the dwelling, the effect of workplace location would refer to a situation where the respondents had chosen residences completely independent of the locations of their workplaces. In this hypothetical case, commuting distances would tend to be significantly shorter to the peripheral than to the centrally located workplaces (Beta = -0.280, p = 0.000). However, this is a highly unrealistic scenario – and from the point of view of reducing car dependency also an undesirable one.
(23) Within many cities, the historical urban core approximates the geographical point of gravity of the city’s stock of buildings (Nielsen, 2002). In Copenhagen Metropolitan Area, the downtown area is located close to the coast and is thus unevenly surrounded by built-up areas. The point of gravity of the building stock is therefore located a few kilometers to the west of the city center. Nevertheless, downtown is located much closer to this point of gravity than most suburban locations are.
(24) Nielsen 2000
(25) In these figures, respondents with extreme traveling distances on weekdays and in the weekend have been excluded. Some of the extreme traveling distances are due to long leisure trips, but many are work-related (long-distance commutes or official journeys).
Omitting respondents who have combined car with other travel modes, binary logistic regression may be employed as an alternative method. This yields results very similar to the original analysis, with significant effects of all the variables of Table 3. The significance level of the location of the dwelling relative to downtown Copenhagen is slightly weaker ($p=0.015$) than in the ordinal logistic analysis. Most likely, this is a result of a lower number of respondents (149) in the binary logistic analysis.

Excluding respondents who have combined walk/bike with motorized modes of travel, a binary logistic analysis shows effects on the propensity of commuting by non-motorized modes from the same variables as in Table 4. Compared to the original analysis, the location of the residence relative to downtown Copenhagen has a slightly stronger level of significance ($p=0.019$), while the level of significance of the distance to the closest second-order center is slightly weaker ($p=0.080$). Again, the reduced number of respondents in the binary logistic analysis should be borne in mind.

This curve has a turning point closer to downtown Copenhagen (28 km), compared to the curve for residential location (42 km). In addition, the slopes are gentler.

Among those respondents who both live and work within 6 km from downtown, 66% commute by bicycle or by foot and only 28% by car. The average commuting distance is 3.2 km among this group.

Studies of the impacts of new shopping malls on shopping trips are a main exception.

Among our respondents, blue-collar workers work on average 18 km away from downtown Copenhagen, compared to 14 km among the remaining workforce-participating respondents.
References

Andersen, A. K.: Commuting Areas in Denmark. – Copenhagen 2000. = Institute of Local Government Studies


Danish Government: Development with forethought. Denmark’s strategy for sustainable development. – Copenhagen 2002

Engelbreten, Ø.: Lokaliseringssønster og reisereraner i storbyene (Location pattern and travel habits in the major cities). Plan (2005) No. 5, pp. 54-61


Hartoft-Nielsen, P.; Forskningscenteret for skov og landskab: Boliglokalisering og transportafledning (Residential location and travel behavior). – Hørsholm 2001 (a)

Hartoft-Nielsen, P.; Forskningscenteret for skov og landskab: Arbejdspladslokalisering og transportafledning (Workplace location and travel behavior). – Hørsholm 2001 (b)


= Transportøkonomisk institutt (TØI) rapport 391/1998


Jespersen, P.H.,: Urban Structure Matters, Even in a Small Town. Journ. of Environmental Planning and Management 63 (2005) 2, pp. 167-257


Martamo, R.; M-Jönsministeriet: Työsköydentilastityö Suomessa (Distance between workplace and residence in Finland). – Markkantävingsavdelningen 1995


Næss, P.: Hyperbolske tangentialfunktioner i Hovedstadsområdet (Hyperbolic tangential functions in Copenhagen Metropolitan Area). – Aalborg University 2001 (Internal working paper)


Næss, P.: Are short daily trips compensated by higher leisure mobility? Environment and Planning B 23 (2006) (c)


Røe, P.G.: Storbymennskets hverdagsreiser. Sammenhenger mellom bosted, livsstil og hverdagsreisepraksis i et sønnmoderne perspektiv (The daily-life trips of the urbanite. Relationships between place of residence, lifestyle and everyday traveling practice in a late modern perspective).- (Diss.) Trondheim, Norges teknisk-naturvitenskapelige universitet 2001


Strømmen, K.: Rett virksomhet på rett sted – om virksomheters transportspende egenskaper (Right workplace at the right location – on the transport-generating properties of workplaces). (Diss.) Trondheim, Norwegian University of Technology and Science 2001
