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'New urbanism' or metropolitan-level centralization?

A comparison of the influences of metropolitan-level and neighborhood-level urban form characteristics on travel behavior

Petter Næss
Aalborg University, Denmark [a]

Abstract: Based on a study in the Copenhagen Metropolitan Area, this paper compares the influences of macro-level and micro-level urban form characteristics on the respondents' traveling distance by car on weekdays. The Copenhagen study shows that metropolitan-scale urban-structural variables generally exert stronger influences than neighborhood-scale built-environment characteristics on the amount of car travel. In particular, the location of the residence relative to the main city center of the metropolitan region shows a strong effect. Some local scale variables often described as influential in the literature, such as neighborhood street pattern, show no significant effect on car travel when provisions are made to control for the location of the dwelling relative to the city center.

Keywords: Residential location; travel; regional accessibility; centrality; neighborhood characteristics; rationales

1 Introduction

In the United States, research into relationships between land use and transport during recent years has been largely focused on the influence of local-scale urban structural conditions on travel behavior, comparing traditional suburban residential areas with areas developed according to the so-called 'New Urbanism' or 'Transit Oriented Development' principles (e.g. Cervero 1989; Krizek 2003). Often, studies comparing the travel behavior of residents living in different kinds of built environment do not take the location of the investigated neighborhoods into consideration. For example, among 38 research studies reviewed in a recent American article Cao *et al.* (2009), only six included variables indicating the location of the neighborhood relative to the city center, and one of these studies was actually European. According to Boarnet and Crane (2001, 49),a relatively limited geographical scale (not much more than a census tract) was, when their book was published, typical of virtually all recent American empirical research into relationships between built environment characteristics and travel.

In a European context, research into relationships between land use and travel has focused much more strongly on the location of the residence relative to the main metropolitan center and sub-centers within the metropolitan-scale spatial structure. Studies in a number of cities in different European as well as Asian and South American countries have shown that residents living close to the city center travel less than their outer-area counterparts and carry out a higher proportion of their travel by bicycle or on foot (e.g. Mogridge 1985; Næss 2006b; Næss *et al.* 1995; Zegras 2010).

Based on a study in the Copenhagen Metropolitan Area, this paper compares the influences of macro-level and micro-level urban form characteristics on respondents' traveling distance by car on weekdays. The main results of the Copenhagen Metropolitan Area study[1] have been published elsewhere Næss (2005, 2006a,b, 2009b) and will therefore only be presented briefly here. The same applies to the theoretical background and the research methods used. These have been described in detail in the above-mentioned publications and in a separate paper in which the Copenhagen Metropolitan Area study is used as a reference case for a discussion of the ontological, epistemological and methodological basis of research into relationships between residential location and travel (Næss 2004). The present paper concentrates on a comparison of the effects of metropolitan-scale and

[1] This also includes the issue of residential self-selection, which has been examined in detail in Næss (2009a) and hence will not be a focus of the present paper.

[a] petter@plan.aau.dk

neighborhood-scale urban form characteristics on the amount of car travel, and an explanation of why the former variables turn out to be more influential.

In the next section, the theoretical background of the study is presented, followed by a section about the case urban region (Copenhagen Metropolitan Area) and the research methods. The empirical results are presented in sections 4–7.

2 Theoretical background

The so-called activity-based approach (Fox 1995; Jones 1990; Vilhelmson 1999) is a useful conceptual framework for our study. According to this approach, nearly all travel activity is derived from the need or wish to carry out other, stationary activities. Activities are carried out to fulfill physiological needs (eating, sleeping), institutional needs (work, education), personal obligations (childcare, shopping), and personal preferences (leisure activities) (Vilhelmson 1999, 178). In recent years, this view has been challenged by theorists who consider travel in late modern society to be increasingly a purpose in itself, rather than an instrument to move from one place to another (Steg *et al.* 2001; Urry 2000). This may be true to some extent for vacation and leisure trips, but the activity-based approach remains, in my opinion, a useful tool for understanding and analyzing daily travel behavior.

Hägerstrand (1970) distinguishes between three types of time-geographical restrictions on human activities: capability constraints, coupling constraints, and authority or steering constraints. Together, the different types of restrictions constitute a significant limitation on people's use of time and on the spatial distribution of their activities, in particular for workforce participants and pupils on workdays and schooldays. Hence, the scope for "free" activities on weekdays far from home is limited, in particular for those who do not have a private motor vehicle at their disposal. Therefore, there will be "distance decay" in the attractiveness of facilities (Maddison *et al.* 1996). The impact of a remote residential location in terms of longer traveling distances is therefore likely to be counteracted to some extent by a lower frequency of trips, at least for non-compulsory activities.

Based on Vilhelmson (1999, 181), trips can be classified into different categories, depending on how fixed or flexible they are in time and space. "Bounded trips" are those undertaken in order to reach activities for which both the time and geographical location are fixed and cannot freely be deviated from, e.g. journeys to work or school. According to Vilhelmson, the majority of trips on weekdays belong to this category. "Non-bounded" trips are those where the time of the activity is flexible and the location may vary. A heterogeneous intermediary group includes trips where the time of the activity is more or less fixed but the location may vary, and trips where the location is more or less fixed but the time may vary. The extent of space-time fixity varies substantially between individuals. For example, although the journey to work has a high degree of fixity for most workforce participants, some workers (e.g. service mechanics and builders) work at different places, and the duration of work at the same location may also vary.

For some facility types, we almost always choose the closest facility, because the various facilities are more or less equal (e.g. post offices) or have regulated catchment areas (e.g. local government offices). But for other facilities, qualitative or symbolic differences within each facility category may cause people to travel beyond the nearest facility to a more attractive one farther away. For cinemas and a number of other recreational facilities, many types of shops, and not the least workplaces, a number of features other than proximity are also important when choosing among facilities.

Despite decentralizing trends, most cities still have a higher concentration of workplaces, retail businesses, 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. For residents in the inner and central parts of the city, the distances to this concentration of facilities will be short. Downtown is usually also close to the geographical center of gravity of the workplaces and service facilities that are not themselves located to the city center (Nielsen 2002). Therefore, the average distance to the peripheral workplaces and facilities will also be shorter for those living close to the city center. Local-area densities are usually also higher in the inner parts of cities than in the peripheral suburbs. With a higher density of residences or workplaces in the local area, the population base for various types of local service facilities will increase. Hence, the average distance from residences to local services will also be shorter. Inner-city residents could thus be expected, on average, to make shorter daily trips than their outer-area counterparts to both local and more specialized facilities, and a high proportion of destinations might be easily reached on foot or by bicycle.

A large number of empirical studies conducted during the last couple of decades have concluded that the amount of travel and the proportion travel by car are higher among suburbanites than among inner-city residents. This relationship holds true when controlling for demographic and socioeconomic variables, and also in the cases where control has been made for transport attitudes or residential preferences (Fourchier 1998; Mogridge 1985; Newman and Kenworthy 1989; Nielsen 2002; Næss 2006b, 2010; Næss and Jensen 2004; Næss *et al.* 1995; Schwanen *et al.* 2001; Stead and Marshall 2001; Zegras 2010).

Local-scale urban design principles—such as street pattern, availability of sidewalks and bicycle paths, etc.—as well as aesthetic neighborhood qualities can influence the attractiveness of different travel modes and can for some travel purposes also affect trip destinations. As mentioned above, interest in such characteristics has been at the core of American studies of the influence of the built environment on travel behavior. For example, in their influential book Travel by Design, Boarnet and Crane (2001, 37) mention the following six urban features as urban form and land use measures that might influence travel behavior: density (residential or employment, or more complex accessibility measures); extent of land use mixing; traffic calming; street pattern; jobs-housing balance (or land use balance); and pedestrian features such as the availability of sidewalks. Handy *et al.* (1998) point to the fact that many neighborhood-scale studies focus on non-work trips, especially shopping, and how built environment characteristics can potentially reduce car travel—partly by encouraging walking as a substitute for driving, and partly by facilitating shorter car trips than would be necessary if a certain facility type were not available in the neighborhood. The built-environment features that can encourage walking include 'objective' factors (e.g., how close the facility is to the dwelling, or the availability of sidewalks) as well as more subjective factors (e.g. how pleasant and safe the walking route is perceived to be). Mixed land use is generally considered more conducive to reducing car dependency than monofunctional residential zoning. This includes local employment opportunities; the concept of local jobs-housing balance has been a prevailing planning ideal since the 1970s (Cervero 1989; Roundtable 2008; Weitz 2003).

It is generally assumed that the greater the number of destination choices available within the neighborhood, the greater the likelihood that a destination within the neighborhood will be selected. However, as Handy *et al.* (1998, 10) point out, the availability of a greater number of choices outside the neighborhood, may also increase the likelihood that a destination outside the neighborhood will be selected.

Empirical studies suggest that neighborhood characteristics such as higher residential densities and the presence of mixed land uses do promote walking as a travel mode in connection with non-work activities (see Boarnet and Crane 2001; Chatman 2005; Handy *et al.* 2005; Handy and Clifton 2001; Handy *et al.* 1998; Rajamani *et al.* 2003). The impacts in terms of reduced vehicle miles traveled are, however, generally found to be quite moderate. Moreover, in many of the studies of relationships between local built-environment characteristics and travel behavior, no effort has been made to control for the location of these neighborhoods within the metropolitan structure, i.e. in relation to major concentrations of workplaces and services. To some extent, a higher local jobs-housing balance has been found to reduce commuting distances among the residents of the areas where new jobs have been established and among the employees of businesses in the areas where new housing has been added (Frank and Pivo 1994; Nowlan and Stewart 1991). However, this does not necessarily mean that higher local jobs-housing balances have reduced commuting distances at a metropolitan scale. Employment growth in predominantly residential suburbs may result in longer commutes for those employees who are not local residents. If the workplaces in question are specialized and recruit employees from a wide catchment area, this effect may well outweigh any reduction in commuting distances among the local residents.

3 Case area and methods

The Copenhagen Metropolitan Area (population: approximately 1.8 million) is one of the largest urban areas in northern Europe and a major node for international air and rail transport. Although it now encompasses several smaller cities that previously were largely autonomous, the Copenhagen Metropolitan Area is today a conurbation functioning largely as a single city and as a continuous job and housing market.

According to some authors, historical urban cores have lost much of their dominant position during the past 30 to 40 years. For example, Sieverts (1999) holds that cities can no longer be fitted into a hierarchic system according to central place theory and should, instead, be understood as networks of nodes, where there is a spatially more or less equal, scattered distribution of labor with spatial-functional specializations. Such net-like cities or city regions have polycentric rather than monocentric or hierarchic center structures. However, the Copenhagen Metropolitan Area does not fit this description (which may also be of limited validity in a wider European context; cf. Newman and Kenworthy 1989; Nielsen and Hovgesen 2006). The inner city of Copenhagen still has an unchallenged status as the dominant center of the city region. The central municipalities of Copenhagen and Frederiksberg, making up only 3.4 percent of the total area of the Copenhagen Metropolitan Area, are home to a third of the inhabitants and an even higher proportion of the workplaces. This implies that people whose residences are located close to downtown Copenhagen travel, on average, considerably shorter distances to most facility types than those who reside in the outer suburbs (Næss 2006b). The center structure of Copenhagen Metropolitan Area could be characterized as hierarchic, with downtown Copenhagen as the main center, the central parts of five formerly independent peripheral towns now engulfed by the major conurbation as second-order centers along with certain other concentrations of regionally oriented retail stores, and more local center formations in connection with, among others, urban rail stations and smaller-size municipal centers at a third level.

The study was carried out using a combination of qualitative and quantitative research methods. Apart from a registration of urban structural conditions, the data collection included a large travel survey among inhabitants of 29 residential areas (1932 respondents), a more detailed travel diary investigation among some of the participants of the first survey (273 respondents), and qualitative interviews with 17 households. The questionnaire surveys and the interviews were all carried out during the period from June to September 2001, avoiding the main holiday month of July. The chosen residential areas (Figure 1) include a wide range of urban structural situations, varying in their location relative to downtown Copenhagen and lower-order centers, as well as in their density, composition of housing types and availability of local green areas.

The qualitative interviews were (apart from a single case) conducted in the homes of the interviewees, usually lasting between 90 minutes and two hours. Nine interviewees were chosen from three inner-city areas (C1, C2, and C4 in Figure 1) and eight were recruited from two outer-suburban areas. Among the latter areas, one is located close to an urban rail station (La2) whereas the other suburban interviewee area (S4) has very poor accessibility by public transport. All interviews were audio-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, as well as the meaning attached to living in or visiting various parts of the city. As an important tool for the analysis an interpretation scheme was developed. By requiring the research team to make written interpretations of each interview in light of each of the detailed research questions, the interpretation scheme made us read and penetrate the transcribed interview texts more thoroughly than we would probably have done otherwise.

The questionnaires included questions about respondents' travel behavior, activity participation, socioeconomic characteristics, residential preferences, and attitudes to transport and environmental issues. The main survey included questions about the distances traveled via each mode on each day over the course of one week. The travel diary investigation covered the four-day period from Saturday morning to Tuesday night, and included detailed questions about each trip made (purpose, length, travel time, and travel mode). The concentration of respondents in a limited number of selected locations allowed for an in-depth accounting of contextual conditions in each of the chosen areas. This enabled us to record a large number of urban structural characteristics of each residential address within the selected areas and to include these characteristics as variables in the investigation. In total, 38 urban structural variables were measured for each respondent, including five variables measuring the location of the residence relative to the overall center structure in the metropolitan area, eleven variables indicating the location of the residence in relation to rail-bound public transport, seven variables measuring the density of the local area and the neighborhood, twelve variables measuring different aspects of service facility accessibility in the proximity of the dwelling, two variables measuring the availability of local green recreational areas, and one variable indicating the type of local street structure.

In addition to the urban structural variables, a number of individual characteristics of the respondents were recorded. In the subsequent multivariate analyses, 17 demographic, socioeconomic, attitudinal, and other 'non-urban-structural' variables were included as control variables[2]:

1. Four variables describing demographic characteristics of the respondent and the household to which he or she belongs (sex, age, number of household members below seven years of age, number aged 7–17 years)

2. Seven variables describing socioeconomic characteristics of the respondent (workforce participation, student/pupil, pensioner, personal income, driver's license, two dichotomous variables for type of education)

3. One attitudinal variable (index for transport-related residential preferences)

4. Five other control variables indicating particular activities, obligations or social relations likely to influence travel behavior during the period of detailed travel registration.

[2] I consider these control variables to be the most relevant among those recorded. Analyses have also been carried out with a larger number of control variables. The effects of the main urban-structural variables remain fairly stable across these various analyses. See Næss (2009a) for a discussion of the appropriateness of different control variables in studies of relationships between land use and travel.

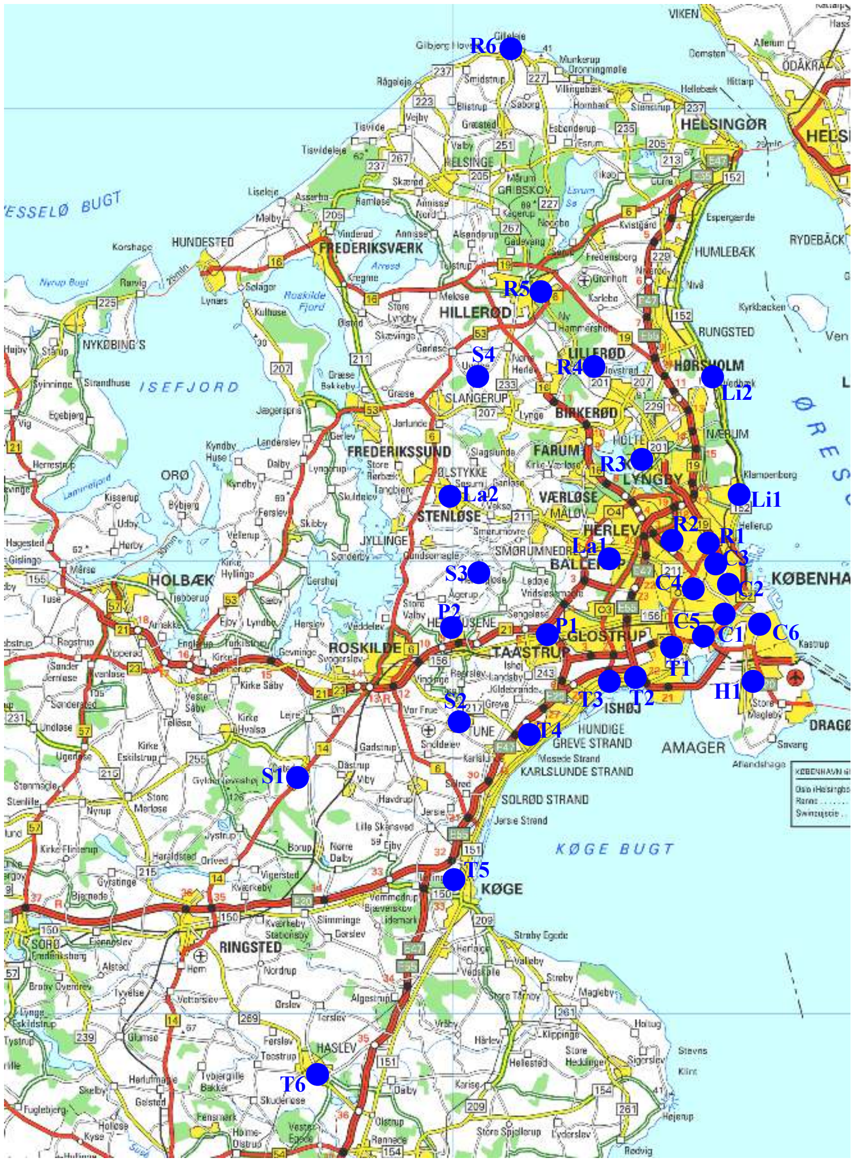

Figure 1: Location of the 29 investigated residential areas. Scale 1:750 000.

A large number of travel behavior indicators were recorded for each respondent: total traveling distance, traveling distances by car, bus, train, and non-motorized modes, and the proportions of the total distance traveled by car, public transport, and non-motorized modes. Each of these eight aspects of travel behavior was recorded for the weekdays (Monday-Friday), the weekend (Saturday-Sunday) and for the week as a whole, resulting in a total of 24 travel behavior variables. In addition, annual driving distances of any cars belonging to the household were recorded, as well as flights and other long-distance holiday trips. Due to space constraints, in the following we shall concentrate on a single travel behavior variable: the distance traveled by car on weekdays. However, the relative strengths of the influences of different urban structural variables on the remaining travel behavior variables are fairly similar to the strength of their influence on traveling distance by car on weekdays (Næss and Jensen 2005, 353-371).

First, simple bivariate correlations between traveling distance by car and each urban structural variable will be shown. Second, results of analyses where each of these relationships has been controlled for the influences of the 17 non-urban-structural variables as well as the location of the dwelling relative to the city center of Copenhagen will be presented. Thereupon, material from our qualitative interviews will be used in order to explain why metropolitan-level urban structural variables exert a stronger influence on travel behavior than neighborhood-scale urban characteristics do. Finally, the results of an analysis including only the four most influential urban structural variables and the 17 non-urban-structural control variables will be presented.

4 Bivariate correlations

As mentioned in the introduction, neighborhood-scale street pattern is an urban structural variable often used in American studies investigating relationships between urban built environment and travel behavior. Compared to the curvilinear and cul-de-sac street patterns typical for suburban neighborhoods planned according to modernist principles, grid-shaped street networks facilitate more direct access to local destinations and can thus bring a larger number of local facilities within acceptable walking (or biking) distance (Handy *et al.* 1998). Street patterns in the neighborhood were recorded in the Copenhagen Metropolitan Area too. Among the 29 investigated residential areas, nine were located in neighborhoods characterized by a (more or less) grid-shaped street pattern, whereas the remaining 20 residential areas were located in neighborhoods characterized by other kinds of street patterns (curvilinear streets or some sort of hierarchical street layout based on recommended driving speeds, with cul-de-sac access roads and separation of motorized and non-motorized traffic). Figure 2 shows an example of investigated neighborhoods with street patterns belonging to the grid and the non-grid categories.

In line with what has been found in several American studies (e.g. Cervero 2003) (e.g. Cervero, 2003; Frank, 2003), the amount of car travel is lower among residents living in neighborhoods characterized by grid-shaped than by other types of street patterns. As can be seen in Figure 3, mean traveling distance by car during the weekdays from Monday through Friday is only 86 km among the respondents living in a neighborhood with grid-shaped street pattern, compared to 153 km among the respondents living in local areas with other types of street

However, the correlation between street pattern and amount of car travel does not necessarily reflect any causal relationship. Admittedly, grid-like street patterns may offer better connectivity between different locations within the neighborhood and may thus facilitate shorter local traveling distances, especially compared to cul-de-sac-based street patterns. The shorter local traveling distances may also be conducive to non-motorized travel, since people who rely on their own muscles for transportation are usually sensitive to travel distance and often change to motorized modes if the distance exceeds a comfortable level. Nevertheless, the differences in traveling distances resulting from the local street patterns are probably not very large, since the investigated neighborhoods are themselves of a limited size. Arguably, the location of the neighborhoods relative to concentrations of workplaces and other facilities matters more. Figures 4 and 5 provide some preliminary indication of this. Here, the respondents have been subdivided into four groups of approximately equal size, depending on how far from the Copenhagen city center they live. As we can see from Figure 4, the respondents living far from the city center travel, on average, considerably farther by car than their counterparts living in the inner distance belts, especially those living less than six kilometers away from the city center. Among the latter group of respondents, the mean traveling distance by car over the five weekdays is 66 km, compared to 176 km among respondents living more than 28 km away from the city center of Copenhagen. Figure 5 shows mean trip distances for journeys to work/education as well

Figure 2: Examples of investigated residential areas with grid and non-grid street patterns. Amager North (top) and Holmene (bottom).

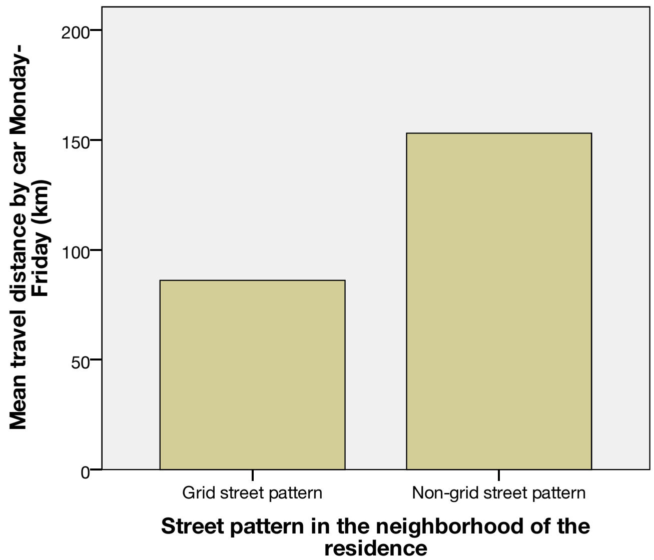

Figure 3: Mean traveling distances by car during the weekdays (Monday-Friday) among respondents living in residential areas with grid and non-grid street patterns. $N = 1810$, of which 603 in grid-type and 1207 in other street environments.

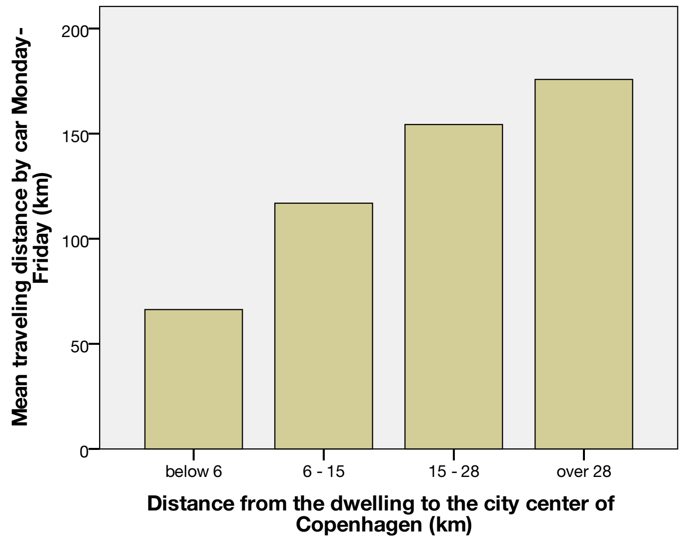

Figure 4: Mean weekday (Monday-Friday) traveling distances by car among respondents living within different distance intervals from the city center of Copenhagen. $N = 1810$, varying from 405 to 530 per distance belt.

as several other trip purposes.[3] The same pattern as for overall traveling distances by car are evident for the various categories of trips: suburbanites tend to make longer trips than inner-city dwellers do. On average, our respondents (including both workforce participants and non-participants) made 3.4 journeys to work or education during the week, 3.5 shopping/errand trips, 1.0 trip for bringing/picking up children, 1.3 visiting trips and 2.4 leisure trips.[4] Since journeys to work are, on average, longer than trips for any of the other purposes, these figures imply that much of the difference between inner-city dwellers and suburbanites in overall traveling distances (and traveling distances by car) is attributable to the longer commuting distances among respondents living in the outer parts of the metropolitan area.

Table 1 shows the bivariate relationships of each of the 38 urban structural variables with the respondents' distance traveled by car on weekdays, as well as partial correlations of each urban structural variable with the distance traveled by car,

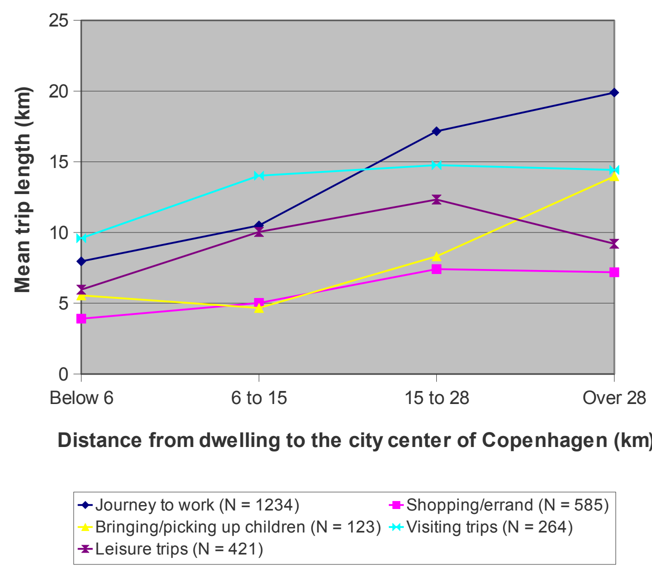

Figure 5: Mean one-way trip lengths for different purposes among respondents living within different distance intervals from the city center of Copenhagen.

controlling for the location of the dwelling relative to the city center of Copenhagen and 17 non-urban-structural variables.[5]

[3] Trips longer than 100 km have been excluded. Trip distances for journeys to work are based on workplace locations given by workforce participants who responded to the main survey, with distances measured along the road network by means of the GIS program ArcView. Trip distances for other purposes are based on the travel diary survey (273 respondents). The figures displayed in the diagram for non-work trips are weighted averages of trip lengths during weekdays and weekends.

[4] Trips home from any of these destinations are not included in these figures.

[5] These control variables are: sex, age, number of children younger than seven years of age in the household, number of children aged 7–17 in the household, personal income, possession of a driver's license for car, whether or not the respondent is a workforce participant, whether or not the respondent is a student, whether or not the respondent is a pensioner, whether or

Table 1: Relationships between various metropolitan-scale and neighborhood-scale urban structural variables and the respondents' traveling distance by car on weekdays (Monday- Friday).

	Bivariate correlations (Pearson's r)	Partial correlations
Location of the dwelling relative to the metropolitan-level center structure:		
Location of the dwelling relative to downtown Copenhagen (non-linear function)	0.233***	
Linear distance along the road network from the dwelling to downtown Copenhagen	0.201***	
Logarithmic dist. along the road network from the dwelling to the closest second-order center	0.210***	0.092***
Linear dist along the road network from the dwelling to the closest second-order center	0.177***	0.056*
Logarithmic dist. along the road network from the dwelling to the closest regional shopping mall	0.166***	0.019
Location of the dwelling relative to rail stations:		
Logarithmic dist. along the road network from the dwelling to the closest urban rail station	0.199***	0.072**
Linear dist. along the road network from the dwelling to the closest urban rail station	0.164***	0.062*
Linear dist. along the road network from the dwelling to the closest "well-serviced" junction station	0.159***	0.027
Linear dist. along the road network from the dwelling to the closest junction station	0.151***	0.053*
Linear dist. along the road network from the dwelling to any rail station	0.169***	0.097***
Residential location less than 500 m away from closest urban rail station (yes = 1, no = 0)	−0.094***	−0.019
Residential location less than 1000 m away from closest urban rail station (yes = 1, no = 0)	−0.124***	−0.016
Residential location less than 500 m away from any rail station (yes = 1, no = 0)	−0.089***	−0.022
Residential location less than 1000 m away from any rail station (yes = 1, no = 0)	−0.102***	−0.007
Residential location less than 500 m away from closest junction station (yes = 1, no = 0)	−0.113***	−0.034
Residential location less than 1000 m away from closest junction station (yes = 1, no = 0)	−0.117***	−0.036
Density in the surroundings of the dwelling:		
Density of inhabitants & jobs in the local area of the dwelling (inhab.+jobs within a radius of 800 m)	−0.203***	−0.071**
Population density in the local area of the dwelling	−0.191***	−0.048
Job density in the local area of the dwelling	−0.188***	−0.075**
Density of inhabitants and jobs in the narrowly demarcated residential area	−0.231***	−0.053*
Population density in the narrowly demarcated residential area	−0.234***	−0.054*
Dwellings per hectare in the narrowly demarcated residential area	−0.230***	−0.050*
Job density in the narrowly demarcated residential area	−0.120***	−0.019
Availability of service facilities in the proximity of the dwelling:		
Combined index for availability of service facilities in the proximity of the dwelling	−0.234***	−0.107***
Index for availability of shopping opportunities in the proximity of the dwelling	−0.217***	−0.095***
index for availability of primary schools, kindergartens and crèches in the proximity of the dwelling	−0.192***	−0.084***
index for availability of public-sector offices in the proximity of the dwelling	−0.175***	−0.075**
Number of grocery stores within 1.5 km distance from the dwelling	−0.204***	−0.077**
Number of special commodity stores within 1.5 km distance from the dwelling	−0.171***	−0.065*
Linear dist. along the road network from the dwelling to the closest grocery store	0.164***	0.075**
Linear dist. along the road network from the dwelling to the closest post office	0.122***	0.044
Linear dist. along the road network from the dwelling to the closest town hall	0.160***	0.070**
Linear dist. along the road network from the dwelling to the closest primary school	0.156***	0.065*
Linear dist. along the road network from the dwelling to the closest kindergarten	0.139***	0.01
Linear dist. along the road network from the dwelling to the closest crèche	0.233***	0.144***
Local green recreational areas:		
Availability of a recreational area of at least 10 hectares within 0.5 km distance from the dwelling	−0.041	−0.043
Availability of a recreational area of at least 10 hectares within 1 km distance from the dwelling	−0.041	−0.042
Local street pattern:		
Grid structure (1) or other street patterns (0)	−0.189***	−0.004

All the bivariate correlation coefficients have the expected signs: Traveling distances by car are higher among respondents living: peripherally in relation to various types of centers in the center structure of Copenhagen Metropolitan Area; in areas with a modest supply of local facilities; far away from urban rail stations; and in areas where population density and workplace density are low. There is also a (rather weak) tendency toward increased car travel among respondents who have poor access to local green recreational areas.

In line with the impression left by Figure 4, we find a quite strong bivariate correlation between distance traveled by car and location of the dwelling relative to the city center of Copenhagen, especially when the distance to the city center is transformed by means of a non-linear function[6] ($r = 0.233$). Some local-scale urban structural variables also show strong correlations with the amount of car travel, notably densities within the narrowly demarcated residential area, measured either as population density ($r = -0.234$), density of dwellings ($r = -0.230$) or as a combined population and job density variable ($r = -0.231$). There are also correlations of similar strength between the amount of car travel and, respectively, the distance from the dwelling and the distance to the closest crèche[7] provider ($r = 0.233$) and a combined index for availability of service facilities in the proximity of the dwelling[8] ($r = -0.234$).

As can be seen in Table 1, all urban structural variables show statistically significant bivariate relationships with the amount of car travel ($p < 0.001$) except the two variables indicating availability of green outdoor areas in the proximity of the dwelling. Local street pattern (see Figure 4) shows a fairly strong bivariate correlation with distance traveled by car ($r = -0.189$), but not as strong as with the location of the dwelling relative to the city center of Copenhagen. Car travel is also quite strongly correlated with logarithmic distance from the dwelling to the closest second-order center, local-area density of inhabitants and jobs, and logarithmic distance from the dwelling to the closest urban rail station.

5 Controlling for non-urban-structural variables and the location of the dwelling relative to the city center of Copenhagen

Controlling for the location of the dwelling relative to the city center of Copenhagen as well as for the non-urban-structural variables (Table 1, right column) considerably weakens the correlations of many of the neighborhood-scale urban structural variables with car travel. This is particularly true for street structure; the correlation between it and the amount of car travel becomes insignificant when we control for residential

not the respondent has completed advanced studies (more than six years following the standard nine years of primary school) in a technical field such as engineering or economics, whether or not the respondent has a short or medium-long education (less than six years following primary school) as a tradesman or industrial worker, transport-related residential preferences, whether or not the respondent has moved to the present dwelling within the previous five years, employment-related trips during the investigated week, overnight stays away from home more than three nights, number of days at the workplace or school during the investigated week, and regular transport of children to school or kindergarten.

[6] The city center 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 the city center of 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) + EXP(− (centafs×0.18 − 2.85))) − (0.00068×(centafs − 42)×(centafs − 42) − 2.8) where ASTFUN = the transformed distance from the dwelling to the city center and centafs = the linear distance along the road network, measured in km.

[7] "Crèche" describes childcare for children under the age of three years.

[8] The service index was constructed as a weighted sum of z-scores for three other indices also included in the analysis: an index for availability of shopping opportunities near the residence, an index for availability of primary schools, kindergartens, and crèches in the environs of the dwelling, and an index for availability of public-sector offices in the proximity of the dwelling. The weighting between the sub-indices was based on data from Norwegian (Vibe 1993, 35) and Danish (Christensen 1996, 9) national travel surveys on the frequencies of different trip purposes. Given a weight sum of 100, this implied the following weights: Shopping opportunities, 60; schools, kindergartens and crèches, 27; and public offices, 13. The three latter indices were constructed as follows: The shopping opportunity index was constructed by adding the z-scores for number of grocery stores within 1.5 km of the dwelling, number of special commodity stores within 1.5 km of the dwelling, and distance from the dwelling to the closest grocery store (with the sign of the z-score changed for the latter factor in order to make a high index value signify a high accessibility for all the sub-elements of the index). The index for availability of primary schools, kindergartens and crèches was based on the measured distances from the dwellings to the closest facilities in these categories, with a weighting based on considerations about the number of years the children spent in each type of institution and the propensity of parents to follow their children to the various types of institutions. Again, the sign of the index value was changed in order to make a high index value signify high accessibility. The index for availability of public-sector offices was constructed in a similar way, based on the assumption that residents go to the town hall to make use of public services about as often as they visit the post office.

location relative to the city center. In this study, all the investigated residential areas having a grid-like street pattern are located in the inner part of the Copenhagen Metropolitan Area, no more than 9 km from downtown. The correlations of car travel with the location of the dwelling relative to lower-order centers as well as with the various local-area and residential-area density variables are also weakened, but these correlations are still statistically significant, at least when density is measured within a local area larger than the narrowly demarcated residential area.

The weakened correlation coefficients of several neighborhood-scale variables reflect the fact that there are considerable internal correlations between the different urban structural variables. Population densities, workplace densities, accessibility to public transport, and availability of service facilities near the residence are generally higher the closer to the city center of Copenhagen the residence is located (see Table 2). Many of the bivariate correlations between neighborhood-scale urban structural variables and car travel are therefore attributable to the location of these neighborhoods within the overall urban structure, rather than to the proximity of each residence to local service facilities.

The various service index variables also have statistically significant correlations with the amount of car travel when non-urban-structural variables and the location of the dwelling relative to the city center are taken into account. The correlation between car travel and the distance from the dwelling to the closest crèche is especially strong. However, proximity to a crèche is hardly an important determinant of the amount of car travel among the respondents. Only a minority among the respondents follow children to and from crèches, and the average length of such trips is considerably shorter than, for example, journeys to work.[9] Rather, this variable serves as a proxy for other urban-structural conditions, notably proximity to a second-order or third-order center where many other facilities than crèches are available. Moreover, as there is a strong correlation between the distance from the dwelling to the closest crèche and the distance to the city center, the former variable may 'steal' some of the effect of the latter variable when both are included in the same analysis. These two variables are equally strongly correlated with the amount of car travel when control is made for non-urban-structural variables, and the "theory-blind" way that the statistical software used in this research carries out the multivariate calculations implies that there is always a risk that a theoretically less-well- founded variable may mask some of the relationship between a dependent variable and a theoretically more plausible independent variable.

Needless to say, the location of the dwelling relative to the city center of Copenhagen has not been included in the table, as this is one of the control variables. However, if we instead use the variable showing the second-strongest relationship with car travel when controlling for non-urban-structural variables (i.e. the combined index for availability of service facilities in the proximity of the dwelling) as the urban structural control variable, the correlation coefficient between the amount of car travel and the location of the dwelling relative to the city center of Copenhagen is still as high as 0.132, with a level of significance of 0.000.

With the exception of proximity to crèches, the local-scale urban-structural variables tend to become less strongly correlated with car travel when the analysis includes control for the location of the dwelling relative to the city center of Copenhagen. In the next section, we shall draw on qualitative interviews data that may help explain why this is so. We also note (in the right column of Table 1) that some of the service index variables are more strongly correlated to car travel is more strongly correlated to some of the service index variables than to local area density or to the location of the dwelling relative to second-order centers. In the analyses presented in Section 5, we have still preferred to include the latter variables instead of any of the service indexes. This is because we believe that the service indexes act, to some extent, as proxy variables for the latter variables—which are, in our view, more appropriate as the centers include not only concentrations of service facilities but also concentrations of workplaces, and offer high accessibility by public transport.

6 Rationales influencing travel behavior

Why does travel behavior in the Copenhagen Metropolitan Area depend more on metropolitan-scale than on local-scale built environment characteristics? Material from the qualitative interviews illuminates some important rationales on which people base their travel behavior. The relative importance of metropolitan-scale and neighborhood-scale built environment characteristics to travel behavior depends, in particular, on people's rationales for choosing the locations of the activities in which they participate.

The interviewees' choices of locations for their activities are made as a compromise between two competing desires: the

[9] Among the respondents of our main survey, 62 percent reported trips to a workplace or place of education at least four times during the week of investigation, whereas only 12 percent reported regularly bringing children to and from kindergarten, childcare, or school. In addition, mean commuting distances are more than four times as long as trips from home to kindergarten/crèche.

Table 2: Mean values for some urban structural characteristics of the respondents' residences, grouped into four distance intervals from the city center of Copenhagen. $N = 1932$ respondents of the main survey.

Urban structural factor	Distance interval from the city center of Copenhagen			
	<6 km (N=435)	6–15 km (N=461)	15–28 km (N=557)	>28 km (N=457)
Distance from residence to downtown Copenhagen (km)	3	9.7	21.9	41.8
Distance from residence to closest second-order urban center (km)	2.2	5.7	7.6	10.1
Distance from residence to closest urban rail station (km)	1.4	2.3	3	11.2
Local area population density (inhabitants/ha)	85	24	14	10
Local area workplace density (jobs/ha)	66	11	7	5
Distance from residence to closest grocery store (km)	0.13	0.51	0.97	0.68
Number of grocery stores within 1.5 km distance from the dwelling	150	18	12	8
Number of specialized stores within 1.5 km distance from the dwelling	218	16	15	15
Distance from residence to closest primary school (km)	0.51	0.85	1.5	1.2
Distance from residence to closest kindergarten (3-5 years) (km)	0.31	0.52	0.65	0.77
Distance from residence to closest crèche (0-3 years) (km)	0.32	0.72	1.08	2
Distance from residence to closest post office (km)	0.74	1.09	1.56	0.98
Distance from residence to closest town hall (km)	2.8	2.8	4	3.7
Proportion of residences with a green recreational area of at least 10 ha within 1 km distance (%)	36	60	55	42

desire to limit travel distances and the desire for the best facility. Depending on the trip purpose, the balance between these desires may vary somewhat. Our interviews suggest that each resident establishes an individual threshold value for the longest acceptable travel distance within each category of destination.

Among the different travel purposes, travel related to employment and higher education, along with visits to friends and relatives, are the purposes for which the longest distances are accepted. Because the workplace or school/university is usually visited each weekday, while long trips for social purposes are far less frequent, journeys to work or education account for the largest proportion of the travel distance on weekdays. The acceptable travel distance to work or education appears to be greater for travelers with more specialized work qualifications, those with more mobility resources at their disposal, and those living further from the largest concentrations of work and education opportunities.

For example, one interviewee, a computer engineer now living in the peripheral suburb of Uvelse, told that his present job was chosen without much consideration of the distance from their dwelling at that time:

> "No, I just thought that I wanted employment, and then we would have to see where to go. And it did not matter where the workplace was located." (Male computer engineer living in the suburb of Uvelse, 30 years old.)

Similarly, an economist living in the same suburb reported that he preferred to commute all the way to downtown Copenhagen instead of finding a less-challenging job in a municipality closer to the residence:

> "Surely, I would like something closer to home, but there are no such [relevant] jobs available to me here in the vicinity. Then it would have to be if I were interested in working in a municipal administration. ... But that would be such a small workplace, and I simply want some more challenges. ... Yes, for sure, most work opportunities for economists are in the city of Copenhagen." (Male economist, living in the suburb of Uvelse, 38 years old.)

One of the interviewees living in the inner-city area of Frederiksberg reported that both his own and his wife's workplaces were chosen primarily because they found the jobs interesting. Both had quite specialized job skills (civil engineer and pharmacology researcher). Due to the central location of their dwelling, they still succeeded in finding satisfactory jobs within a moderate distance from home. Asked whether they would have taken these jobs if the workplaces were located further away, for example in Roskilde (40 km away), the interviewee replied:

> "You see, we have never made long journeys to work. ... It would of course depend on the situa-

tion. If it was not possible to get a job closer to home, yes. ... Roskilde is pretty easily accessible, but you see ... I don't think that I would be willing to drive more than half an hour or so to get there, I really don't." (Male civil engineer, living in the inner-city area of Frederiksberg, 43 years old.)

Since primary schools, kindergartens and well-stocked grocery stores can usually be found closer to the residence than can jobs matching specialized work qualifications, the threshold values for acceptable distances to such facilities are usually shorter than for workplaces and higher education opportunities.

Distance limitation is included as an important (but not the only) rationale for most interviewees' choices of locations for daily-life activities. The desire to limit travel distances may be grounded on different reasons, often in combination, such as saving time, saving money, personal physical limitations with respect to walking and bicycling, and the desire to support the local community and maintain local social contacts.

Along with distance limitation, a desire for the best facility (judged against the instrumental purpose of the trip) is the most important rationale for the interviewees' choices among destinations. In a way, this is the most fundamental rationale, as the trips would simply not occur if no sufficiently attractive facility existed that might be visited. In practical locational choices, distance limitations and the desire for the best facility must be weighed against each other. What is considered the "best facility" will vary with the purpose of the trip and with the individual characteristics of the person in question. For workplaces, factors like job duties, qualification requirements, wages, and work environment are relevant. For specialized jobs, the catchment area from which employees are recruited typically includes considerable parts of the region.

Factors influencing the perceived quality of shops include, among others, the selection of goods available, prices, and possibly the availability of parking. When living in the periphery, the local grocer is often used only for "emergency purchases," e.g. when there is no coffee left in the house. Among those living in the central parts of Copenhagen, local shops are often well- stocked and are relied on to a higher extent for ordinary shopping. Among kindergartens, the reputation of the institution (pedagogy, etc.) and perhaps also the ethnic composition of the children may be influential factors.

The tendency to choose a facility other than the closest one is indicated in Figure 6, where lengths of trips made by parents when transporting their children to kindergarten or crèche are compared to the distances from dwellings to the closest such facilities. Although parents usually do not choose (nor are they offered places for their children in) kindergartens and crèches located very far away from the family dwelling, the facilities actually used are, on average, located more than four times farther from the home than the nearest kindergartens and crèches.[10] We still see a clear tendency toward longer trips to such facilities among respondents living farther from the center of the metropolitan area, reflecting the higher density of facilities in the inner city than in the outer suburbs.

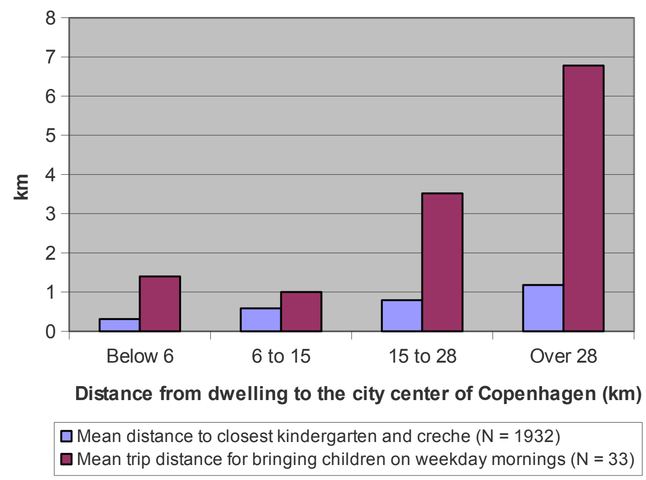

Figure 6: Mean trip distances for trips with the purpose of transporting children on weekday mornings (Monday-Tuesday) among travel diary survey respondents living within different distance intervals from the Copenhagen city center, compared to distances from home to the closest kindergartens and crèches among main survey respondents living in the same distance intervals. $N = 33$ travel diary trips and 1932 main survey respondents.

The destinations of visiting trips are defined entirely by the traveler's family relations and circle of acquaintances. When it comes to leisure trips, the choice among facility categories depends strongly on the interests and lifestyle of the person in question, but quality differences within each facility category matter as well. For example, when planning an outing, a forest that is distant but larger and more beautiful may be preferred to a local forest.

[10] The trip distances shown in Figure 6 are based on the follow-up travel diary survey, in which 273 of the original 1932 respondents participated. Among a total of 231 visiting trips carried out during the period Saturday–Tuesday, only trips on Monday and Tuesday were included, and only trips carried out as the first trip of the day, thus including only trips originating at the residence. When measuring average distances from dwellings to the closest kindergarten and crèche, the distances have been weighted in order to take into account the fact that trips to bring children to kindergartens are carried out about twice as frequently as trips to bring them to crèche.

Besides emphasizing the possibility of choosing the instrumentally best facility, the "atmosphere" and aesthetic qualities of the destination are important to many of our interviewees. In particular, this applies to trips such as visits to restaurants, cinemas, theaters, and other cultural facilities, as well as to shopping (particularly when purchasing non-grocery commodities). In contrast, people's choices of locations in which to seek employment are influenced to a much lesser extent by the "atmosphere" of the district where the workplace is located.

In quotidian travel, some trips are more fundamental, and their characteristics more fixed, than other trips. Often, such trips are part of a trip chain. Other travel purposes are then "linked" to this fundamental trip. For example, by choosing a well-stocked store along the route followed anyway on the way home from work, the rationale of distance limitation can be combined with the rationale of choosing the best facility. This can, to some extent, compensate for the longer distances to shops typical of residences in the outskirts of the city. This kind of adaptation is very common among our interviewees.

For most travel purposes, our respondents and interviewees emphasize the possibility of a choice of facilities over proximity. This means that the amount of travel is influenced to a greater extent by the location of the residence in relation to concentrations of facilities than by the distance to the closest single facility within a category. This is particularly evident for workplaces and places of higher education, but also for cultural and entertainment facilities, specialized stores and, to some extent, grocery stores. For leisure activities, the "atmosphere" and the aesthetic qualities of a destination may also play a role.

Thus, for most travel purposes, our interviewees do not necessarily choose the closest facility, but rather travel a bit farther if they can then find a better facility. They tend to emphasize a rationale of choosing the best facilities above a rationale of minimizing the friction of distance. This is especially true in regard to workplaces. Travel distances therefore depend more on the location of the dwelling relative to large concentrations of facilities than on the distance to the closest facilities. People who live close to the city center can access a large number of facilities within a short distance from the dwelling and therefore do not have to travel long distances, even if they are very selective as to the quality of the facility. Since the largest concentrations of workplaces, as well as other facilities, are in the city center and the inner districts of the city, the above-mentioned circumstances imply that the amount of quotidian travel is influenced by how far away the interviewees live from the city center rather than by the distance from their dwelling to lower-order centers.

Table 3 summarizes the impacts of the rationales identified in the qualitative interviews on relationships between residential location and travel .[11] These effects are attributable to the ability of the rationales to influence the relationships between residential location and concentrations of facilities at both local and metropolitan scales. The rationale of distance limitation has been divided into two aspects—limitation of geographical distance and limitation of time usage—because they appear to influence travel behavior differently.

The relationship between the amount of travel and the distance from the residence to the main center of the urban region is strengthened, in particular, by the rationale of being able to choose the best facility (judged against the instrumental purpose of the trip). The rationales of limiting geographical distance and limiting travel time also contribute to this relationship, to some degree, because the region's largest concentration of facilities serves as a local concentration of facilities for a large number of inner-city residents in the region's major city and because the urban center approximates the geographical center of gravity even for the more peripheral destinations that might—from a rationale of time-saving—be chosen by car drivers who want to avoid congested streets. The rationale of enjoying "atmosphere" and aesthetic qualities also increases the influence of the distance between the residence and downtown on the amount of travel. The relationship between the amount of travel and the distance from the residence to local facilities is based, first and foremost, on the rationale of limiting geographical distances; however, it is also affected by the rationale of saving time, as the local facilities will often be the ones that can be reached most quickly.

One might perhaps imagine that the rationales of inner-city residents would differ from those of suburban residents. However, no clear differences of this type emerged. The rationales were fairly similar across residential locations, but the need to emphasize one rationale at the cost of another was much less present among inner-city residents than among suburbanites.

Because their trips are often short, inner-city residents also make a higher proportion of trips by bicycle or on foot. This, and the generally higher level of public transport service in the inner city, helps to reduce the amount of car travel among inner-city dwellers.

[11] The rationales appear to be of a high generality across cultural and social contexts. For example, very similar rationales for location of activities were found in a study of residential location and travel in Hangzhou Metropolitan Area, China (Næss 2009a).

Table 3: The contributions of the various rationales for location of activities to the relationships between residential location and travel.

Rationales for activity location	Frequency of occurrence	Influence on the relationship between the amount of travel and the distance from the dwelling to the main center of the metropolitan area	Influence on the relationship between the amount of travel and the distance from the dwelling to local facilities
Limitation of geographical distances	Emphasized by all interviewees, in particular those without a car. Thresholds for acceptable distances vary between activity types and between individuals	Contributes to some extent to this relationship, both because the facilities in downtown Copenhagen are the closest opportunities for inner-city residents, and because of the shortage of facilities in the periphery	Contributes strongly to this relationship by increasing the likelihood of choosing local facilities rather than more distant ones
Limitation of time consumption	Emphasized by all interviewees, but thresholds for acceptable time consumption vary between activity types and between individuals	May induce some car drivers to choose, e.g., suburban shopping malls instead of central-city shops. Contributes nevertheless to some extent to the relationship between the distance from the residence to downtown and the amount of travel, due to the function of the urban center as geographical point of gravity	Contributes to this relationship because it will usually take a short time to go to local facilities. But because travel speeds will often be higher when going to e.g. a more distant shopping mall with ample parking space, the influence of this rationale is not as strong as the influence of the rationale of limiting geographical distances
Wish for the best facility (judged against the instrumental purpose of the trip)	Emphasized by all interviewees, but its importance varies between activity types and between individuals	Contributes strongly to this relationship by increasing the likelihood of traveling to the large concentration of facilities in the inner parts of the metropolitan area, but also because of downtown's role as a point of gravity for all peripheral destinations.	Contributes to a certain weakening of this relationship by increasing the likelihood of choosing distant facilities rather than local ones
Enjoying "atmosphere" and esthetic qualities	Emphasized by many interviewees, primarily for "non-bounded" trips	Contributes to this relationship by directing a higher number of non-work trips to the historical urban core	May contribute to a certain weakening of this relationship by making respondents bypass facilities in local centers where the "atmospheric" qualities are lower than in the downtown area

7 Multivariate analyses with main urban-structural variables and non-urban-structural control variables

Based on theoretical considerations, the information from the qualitative interviews about the interviewees' rationales for selecting activity locations, and preliminary analyses of the correlations of individual urban-structural variables with travel behavior, the following four urban-structural variables were included in the main statistical analyses of this study:

- Location of the residence relative to the Copenhagen city center
- Location of the residence relative to the closest second-order center
- Location of the residence relative to the closest urban rail station
- Density of inhabitants and workplaces in the local area surrounding the residence

These urban-structural variables offer the greatest explanatory power for interpreting travel behavior variables. Limiting the number of urban-structural variables to these four avoided problems of multicollinarity.

Table 4 shows the results of a multiple regression analysis of factors potentially influencing the distance traveled by car on weekdays, including the four above-mentioned urban structural variables and the seventeen non-urban-structural control variables used in the analyses presented earlier. Effects meeting the required significance level are evident for all four urban-structural variables. The effect of the location of the residence relative to the Copenhagen city center is, however, considerably stronger and more certain ($\beta = 0.130$, $p = 0.0001$) than the other three urban structural variables (absolute β values ranging from 0.048 to 0.062, with p values ranging from 0.07 to 0.08).[12]

The strong effect of the location of the dwelling relative to the city center does not, of course, imply that the city center itself (i.e. City Hall Square) is the destination of a large number of trips. The trip destinations reflected in the effect of residential location relative to the city center are the numerous workplaces and other facilities concentrated in and around the city center. In this sense, distance to the center is a proxy for other characteristics. The important point is that the area's central location supports the high concentration of facilities in this particular part of the metropolitan area. Centrality implies a high concentration of facilities, and vice versa.

Based on the results shown in Table 4, Figure 7 shows (by means of black dots) how the expected traveling distances among respondents living within each of the 29 residential areas varies with the distance from the residential area to the city center of Copenhagen when controlling for the non-urban-structural variables in the regression model. Expected travel distance by car over the five weekdays is nearly four times as long (187 km) in the most peripheral area investigated than in the most central area (50 km).

In addition, the triangles in Figure 7 illustrate the relationships between traveling distances by car and the distance from the residential area to the city center of Copenhagen when car ownership and attitudes toward car traveling are added to the other control variables. Several studies have shown that controlling for car ownership and attitudes toward car travel reduces the effects of urban-structural variables. As can be seen, this also applies to the Copenhagen case. There is still a fairly strong and statistically certain effect of residential location on the amount of car travel ($p = 0.000$), with predicted traveling distances twice as long in the outer suburbs as in the inner city. Moreover, our findings show that car ownership and, to some extent, transport attitudes are both influenced by residential location (see Næss 2009b for a thorough account). Treating car ownership and attitudes to car travel as exogenous control variables not influenced by urban structure will, therefore, lead to an underestimation of the impacts of residential location on travel. As long as socio-demographic variables and transport-related residential preferences have already been controlled for, it is my opinion that car ownership and attitudes to car travel should not be included as additional control variables. I therefore consider the black dots in Figure 6 to provide a more appropriate representation than the triangles of the influence of residential location on traveling distances by car.

As can be seen in the diagram, expected amounts of car travel in some of the residential areas are higher or lower than what would be the case if location relative to Copenhagen's city center was the only urban-structural variable influencing the amount of car travel. For example, two residential areas located about 35 km from the city center have consider-

[12] If only variables meeting a significance level of 0.05 are allowed to be included in the model, the location of the dwelling relative to the closest second-order center is excluded. The standardized regression coefficients and p-values of the remaining three urban structural variables are then as follows: Location of the residence relative to downtown Copenhagen: $\beta = 0.133, p = 0.0000$; local area density: $\beta = 0.088, p = 0.0048$; logarithmic distance from the residence to the closest urban rail station: $\beta = 0.067, p = 0.0067$.

Table 4: Results from a multivariate analysis of the influence of various independent variables on the distance traveled by car (km) on weekdays. Only variables with a level of significance of 0.15 or lower are included. $N = 1564$ respondents from 29 residential areas in Copenhagen Metropolitan Area. Adjusted $R^2 = 0.272$.

	Unstandardized coefficients		Standardized coefficient	Level of significance
	β	Std. error	β	(p-value, two-tailed test)
Occupational trips during the investigated week (yes = 1, no = 0)	85.65	9.54	0.21	0.0000
Index for residential location preference (1 = preference for residential location facilitating public transport, walking or biking, 0 = no such preference expressed)	−47.14	7.22	−0.143	0.0000
Possession of a driver's license for car (yes = 1, no = 0)	63.22	11.06	0.131	0.0000
Location of the residence relative to downtown Copenhagen (non-linear distance function, values ranging from 0.66 to 3.80)	17.28	4.32	0.13	0.0001
Personal annual income (1000 DKK)	0.088	0.019	0.119	0.0000
Overnight stays away from home more than three nights (yes = 1, no = 0)	53.56	13.41	0.087	0.0001
Long technical or economic education (yes = 1, no = 0)	44.96	12.02	0.086	0.0002
Workforce participation (yes = 1, no = 0)	26.73	9.18	0.07	0.0037
Short or medium-long education as a tradesman or industrial worker (yes = 1, no = 0)	29.47	10.61	0.064	0.0056
Density of inhabitants and workplaces within the local area of the residence (inhabitants. + workplaces per hectare)	−0.168	0.093	−0.062	0.0699
Logarithm of the distance (meters) from the residence to the closest second-order urban center (log values ranging from 2.49 to 4.46)	24.73	14.11	0.055	0.0799
Sex (female = 1, male = 0)	−17.88	7.82	−0.054	0.0224
Logarithm of the distance (meters) from the residence to the closest urban rail station (log values ranging from 1.90 to 4.47)	14.18	8.03	0.048	0.0776
Number of household members below 7 years of age				(p > 0.15)
Age (deviation from being "middle-aged", logarithmically measured)				(p > 0.15)
Number of days at the workplace or school during the investigated week[a]				(p > 0.15)
Number of household members aged 7 – 17				(p > 0.15)
Regular transport of children to school or kindergarten (yes = 1, no = 0)				(p > 0.15)
Pensioner (yes = 1, no = 0)				(p > 0.15)
Student/pupil (yes = 1, no = 0)				(p > 0.15)
Has moved to the present dwelling less than five years ago (yes = 1, no = 0)				(p > 0.15)
Constant	−135.91	49.85		0.0065

[a] The number of days a person is present at the workplace or place of education is directly related to the number of weekly trips. The weekly number of working hours was tried as an alternative control variable, but this variable, too, showed a statistically non-significant effect. Working hours were slightly negatively correlated with the distance from the dwelling to the city center, and including working hours among the control variables therefore yielded a slightly stronger effect of residential location relative to the city center on the traveling distance by car.

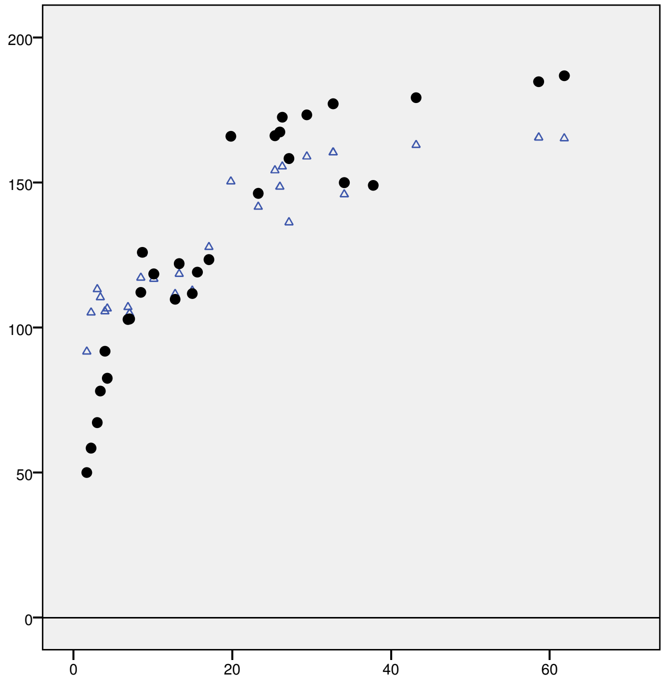

Figure 7: Average expected travel distances by car (km) over the five weekdays for each of the 29 investigated areas. The black dots are based on the actual values of each urban-structural variable in the regression model, with socioeconomic variables, demographic variables, and residential preferences kept constant at mean values, cf. Table 4. ($N = 1564$ respondents, $p = 0.0000$.) The blue triangles are based on a regression analysis that includes, in addition to the variables in Table 5, car ownership and attitudes toward car driving ($N = 1476$, $p = 0.0000$).

ably lower expected traveling distances by car than the other peripheral residential areas. This reflects the fact that both these areas are located near second-order centers (the towns of Hillerød and Køge) and are also fairly close to urban rail stations. Conversely, expected car usage in one residential area located about 20 km from the city center is clearly higher than in the other residential areas located at similar distances from the city center. This reflects the fact that the area in question has a particularly low local-area density and is located far from the closest second-order center and the closest urban rail station.

8 Concluding remarks

Our study shows that metropolitan-scale urban-structural variables generally exert stronger influences than neighborhood-scale built-environment characteristics on traveling distances by car during weekdays. In particular, the location of the residence relative to the main city center of the metropolitan region shows a strong effect on the amount of car travel.[13] We also find that the amount of weekday car travel is affected by the location of the dwelling relative to the closest second-order center and to the closest urban rail station, as well as the density of population and jobs within the local area (a two-square-kilometer zone around the residential area). Compared to these four variables, the effects of local-scale urban characteristics are generally weaker. For example, when we control for the location of the dwelling relative to the city center, density measured at the level of the narrowly demarcated residential area is not as strongly correlated with traveling distances by car as density measured within a larger geographical area. Similarly, the distance from the dwelling to the closest facility within a category is generally less important to traveling distances than proximity to concentrations of facilities. Since the highest concentrations of service facilities and workplaces are found in the central and inner parts of the metropolitan area, inner-city residents generally have better possibilities of finding suitable jobs, shopping opportunities, and leisure facilities without having to travel long distances.

The finding that metropolitan-scale built-environment characteristics exert a stronger influence on travel behavior than neighborhood-scale characteristics is not limited to weekday car travel. Similar results have been obtained for total traveling distance on weekdays and weekends, and for the proportion of total distance traveled by car (Næss 2006b; Næss and Jensen 2005).

The obvious interpretation of these results is that the four higher-level urban-structural variables influence travel behav-

[13] An examination of 485 respondents who had moved from one residence within the Copenhagen Metropolitan Area to another during the previous five years gives additional support to this claim. These respondents were asked whether they, according to their own judgment, had experienced a change in their amount of travel due to the move. The phrasing of the question was: "If you have moved – has moving from your latest to your present residence caused any changes in your amount of travel?" The answer alternatives were: a) Yes, moving has had the consequence that I now travel more b) Yes, moving has had the consequence that I now travel less c) No, moving has not led to any changes in my amount of travel worth mentioning. The answers to these questions show a clear tendency toward increased travel when moving outward (Wald = 33.259, $p = 0.0000$) and decreasing when moving closer to the city center (Wald = 22.147, $p = 0.0000$).

ior through the accessibility of various types of facilities. Because the variables measuring accessibility to different facilities only capture the travel purposes associated with the facility categories in the respective indices, their effects are weaker than the effects of the variables representing the location of the residence relative to the main centers of the metropolitan area. Accessibility indices that include a greater number of facility categories generally exhibit a stronger relationship with travel behavior. Thus, traveling distances by car are more strongly correlated with the index for availability of shopping opportunities near the dwelling than with the index for distance to the closest grocery store, and stronger with the combined index for availability of service facilities near the dwelling than with the index for shopping opportunities.

Arguably, an equal or even higher statistical 'power of determination' (adjusted R^2) might have been obtained by replacing the variables measuring distances to various types of centers with measures of accessibility at local, district, and metropolitan scales Bhat and Guo (2007); Krizek (2003). However, as guidance for urban planning, it is probably more interesting to know how the location of the dwelling relative to various types of centers affects travel behavior than to know the relationship between travel behavior and, for example, the 'mean opportunity distance.'

The moderate effect of local-area density on traveling distances by car should not lead us to believe that neighborhood-scale density is unimportant to travel. Apart from influencing the provision of local services and public transport, local area densities add up to the overall density of the city. The higher the population density of the city as a whole, the lower will be the average distance between the residences and the downtown area. In this way, local area densities indirectly influence the urban-structural variable that, according to our studies, exerts the strongest influence on the travel behavior of individuals and households, namely the location of the residence relative to the city center.

Interestingly, any relationship between the local-level street structure and traveling distance by car disappears with the introduction of statistical control for the location of the residence relative to downtown Copenhagen. This gives rise to a suspicion that the corresponding relationship seen in research carried out in the United States might reflect the location of the residential areas rather than the shape of the local street network. In most of the American studies that have attached a great importance to the shape of the local street pattern, control for the location of the residential area relative to the higher-level center structure seems to be missing.

The results of this study are in line with the findings of a number of studies in other cities in Europe and Asia, as noted in the introductory section. The Copenhagen study findings are also in accordance with evidence from some American studies, such as (Ewing and Cervero 2001) and (Zegras 2010), both of which found regional accessibility to be more important than local built-environment characteristics to the number of vehicle miles traveled. A clear difference in the amount of car travel between suburban/rural residents and residents living close to the Central Business District—also after control for socioeconomic and attitudinal factors—was also found in a study by (Zhou and Kockelman 2008).

The lesson for spatial planners aiming to facilitate more environmentally friendly travel patterns in city regions is that urban containment is more conducive to this end than the development of new suburban neotraditional housing areas. In particular, densification close to the main center of the metropolitan area contributes to a reduction in traveling distances and encourages the use of travel modes other than the private car. From the perspective of sustainable mobility, metropolitan-level centralization is thus more favorable than decentralized development according to 'New Urbanist' principles. Today, fortunately, many European and American cities have considerable opportunities for inner-city densification and regeneration due to the strong deindustrialization processes that have been going on during recent decades in most Western cities.

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