Residential location, travel and energy use: the case of Hangzhou Metropolitan Area

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1. Introduction

This paper is based on a pioneering study of residential location and travel in an affluent Chinese urban region, viz. the Hangzhou Metropolitan Area (Næss, 2007). The results are compared to the conclusions of a similar study in Copenhagen Metropolitan Area, Denmark (Næss, 2006; Næss & Jensen, 2005). In important ways these two studies go beyond the scope of most previous investigations into the relationships between urban land use and travel. The traditional quantitative travel survey approach has been combined with qualitative interviews in order to identify the more detailed mechanisms through which urban structure affects travel behavior. Rationales for activity participation, location of activities, modal choice and route choice make up important links in these mechanisms. The statistical analyses include a broad range of urban structural, socioeconomic and attitudinal variables.

Hangzhou is the capital of the Zhejiang province and is located in south-eastern China, 180 kilometers south-west of Shanghai and is the economical and political centre of this province. The continuously built-up urban area of Hangzhou has 2 million inhabitants. Hangzhou Metropolitan Area includes 4 million inhabitants and is composed of one main city (i.e., the continuously built-up urban area), 2 second-order centers outside the city of Hangzhou and 6 local centers outside Hangzhou.

2. Theoretical background

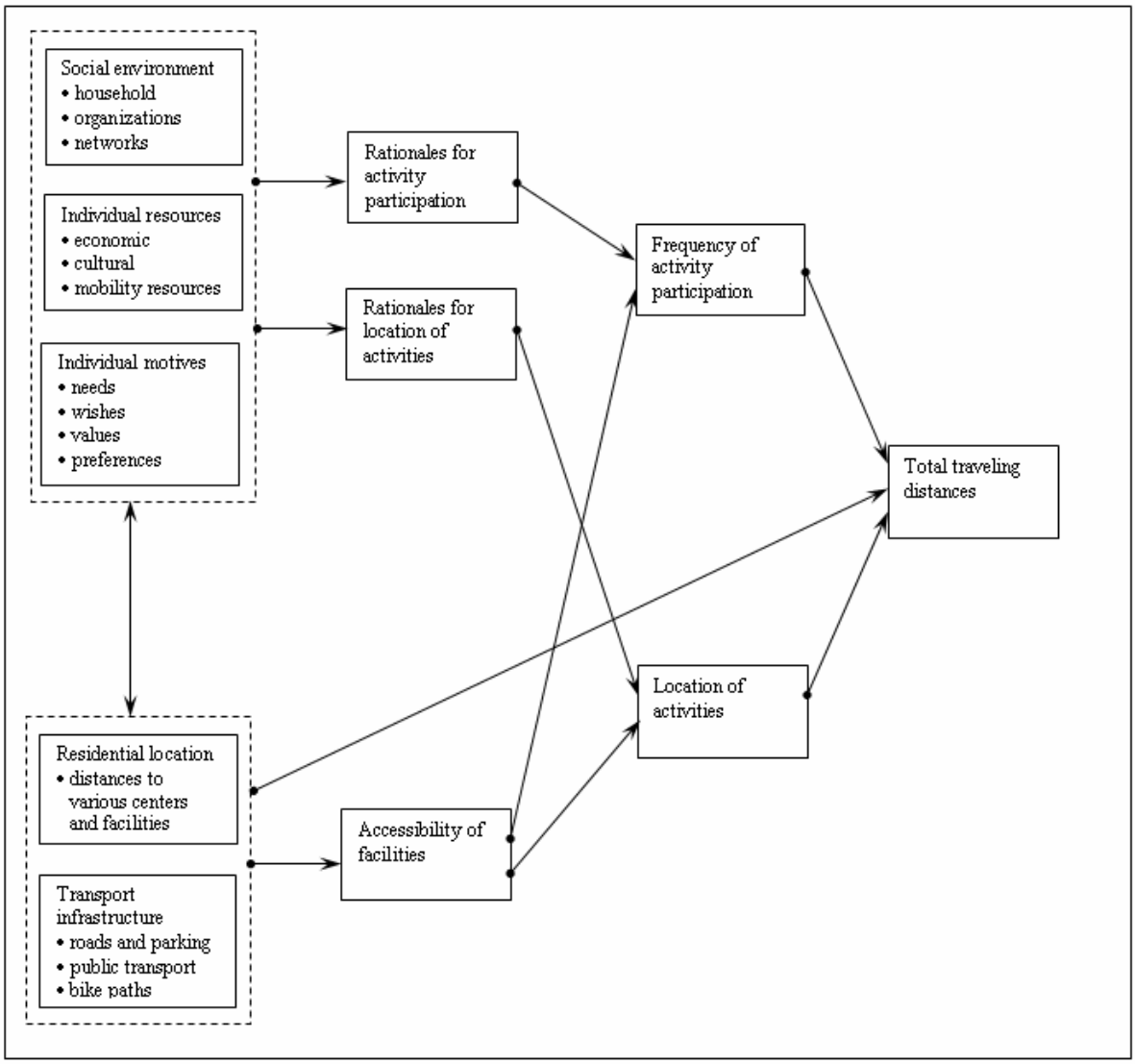
According to theories of transport geography and transport economy, the travel between different destinations is assumed to be influenced on the one hand by the reasons people may have for going to a place, and on the other hand by the discomfort involved when traveling to this location (Jones, 1978). By creating proximity as well as distance between activities, and by facilitating various modes of traveling, the urban structure makes up a set of incentives facilitating some kinds of travel behavior and discouraging other types of travel behavior. The causes of travel behavior of course also include personal characteristics of the travelers, such as age, sex, income, professional status, as well as their values, norms, lifestyles and acquaintances. The emerging transportation pattern (choices of destinations, modes of traveling and trip routes) is a result of people's resources, needs and wishes, as modified by the constraints and opportunities given by the structural conditions of society.

In spite of decentralizing trends, most cities – in China as well as in Western countries – 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 (cf., among others, Newman and Kenworthy, 1999:94-95; Yuanyuan, 2004). This also applies to the Hangzhou metropolitan area.

Figure 1 shows a simplified behavioral model of the ways in which individual, urban structural and other social conditions are assumed to influence daily-life traveling distances through accessibility to facilities, rationales for activity participation and location of activities, frequencies of activity participation and actual location of activities[2]. The location of the residence relative to various centers and facilities, combined with the transport infrastructure on the relevant stretches, determines how accessible these centers and facilities are from the dwelling.

The residents' individual resources, motives and social environments influence their rationales for activity participation and location of activities. Combined with the accessibility of various facilities, these rationales influence the frequency of activity participation as well as the actual locations chosen for the various activities. The total distance traveled is a consequence of the geographical locations chosen for the activities in which the resident participates, the distance along the transport infrastructure network from the residence to these locations, and the frequencies at which the various activities are carried out.

Figure 1 *Behavior model showing the assumed links between urban structural, individual and social conditions, accessibility to facilities, rationales for activity participation and location of activities, actual activity participation and location of activities, and total traveling distances.*



3. Methods

Besides recording urban structural conditions by means of maps, aerial photographs and visits in the investigated urban districts and residential areas, the investigation was based on 28 qualitative interviews and answers from 3154 respondents participating in the questionnaire survey. The respondents were recruited from residential areas varying in their urban structural situation in terms of distance to downtown Hangzhou and local centers, density, availability of local facilities etc.

The qualitative 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. The interviewees were recruited from five of the investigated residential areas, and represented typical inner-city neighborhoods, suburban locations as well as a location close to one of the second-order towns. All interviews were tape recorded, transcribed and translated into English.

4. Typical mobility patterns in different parts of the metropolitan area

Figures 2 to 4 show how the average total daily traveling distance during the investigated week, the distance traveled by car/taxi, and the proportion of the total distance traveled by non-motorized modes vary according to the distance belt from the city center of Hangzhou wherein the respondents live.

Figure 2
Mean and median daily traveling distances during the whole week among respondents living within different distance belts from the city center.

N = 2829, with 791, 700, 683 and 655 respondents, respectively, in the innermost, second inner, second outer and outermost distance belt. 225 respondents with zero or extreme traveling distances (above 37.2 km daily) have been excluded from the analysis.

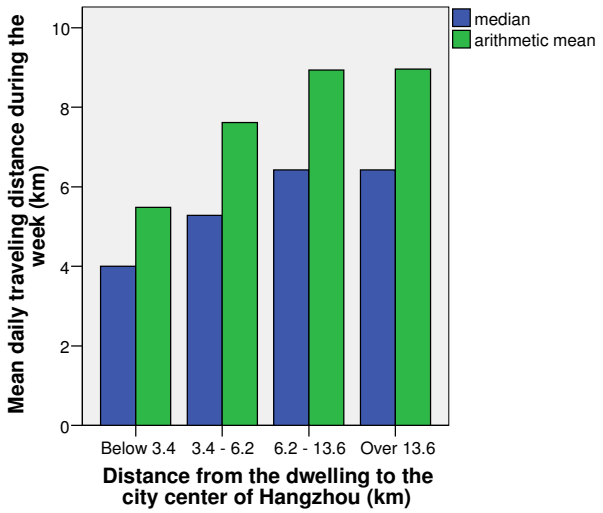
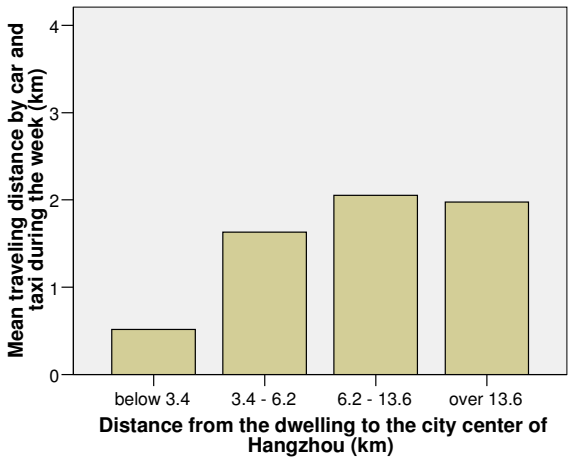


Figure 3
Mean daily traveling distances by car or taxi on weekdays (Monday-Friday) among respondents living within different distance belts from the city center of Hangzhou.

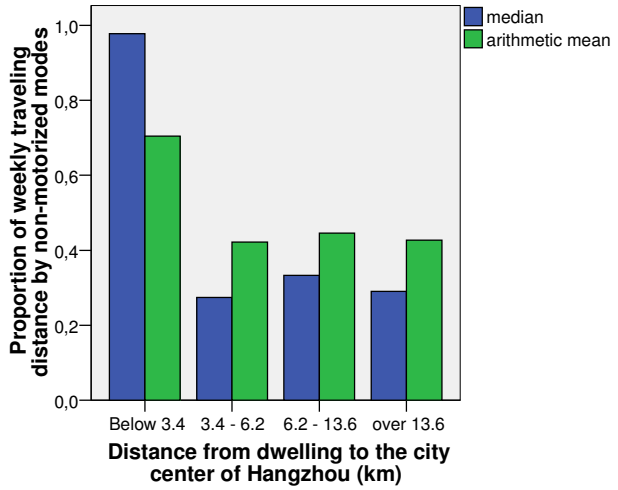
N = 2829, with 791, 700, 683 and 655 respondents, respectively, in the innermost, second inner, second outer and outermost distance belt. 225 respondents with zero or extreme traveling distances (above 37.2 km daily) have been excluded from the analysis.



We see a clear tendency to shorter traveling distances among respondents who live close to the city center of Hangzhou (Figure 2). In particular, this applies to travel by car or taxi (Figure 3), where respondents living less than 3.4 km from the city center of Hangzhou travel on average less than a quarter of the average distance traveled by car/taxi among the remaining respondents. Respondents living close to the city center of Hangzhou travel shorter distances than those living more peripherally also by other motorized modes (bus and e-bike).

Figure 4
Mean and median proportions of weekly traveling distances by non-motorized modes among respondents living within different distance belts from the city center of Hangzhou.

N = 2829, with 791, 700, 683 and 655 respondents, respectively, in the innermost, second inner, second outer and outermost distance belt. 225 respondents with zero or extreme traveling distances (above 37.2 km daily) have been excluded from the analysis.

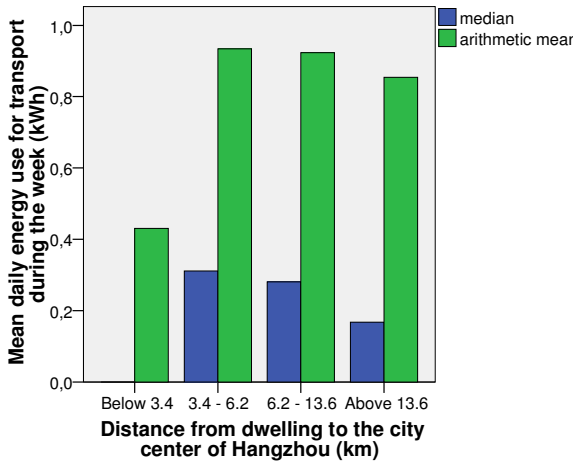


In contrast to that, the average traveling distance by non-motorized modes is about 20% longer among the respondents of the innermost distance belt than among the remaining respondents (Figure 4). As a result, non-motorized modes account for 70% of the distance traveled among the respondents living less than 3.4 km away from the city center of Hangzhou, compared to 43% among the remaining respondents.

Based on the information about the respondents' traveling distances by different modes of conveyance, their energy use for transportation during the investigated week has been calculated. As can be seen in Figure 5, respondents living in the most central distance belt use on average less than half the amount of energy for transport consumed by the respondents living in the three outer distance belts. There are only small differences in energy averages between the three outer distance belts. Actually, energy use is a bit lower in the outermost distance belt than in the two middle distance belts, but still considerably higher than among the inner-city respondents. Interestingly, this tendency to reduced energy use among the most peripheral respondents is more evident when comparing median values than arithmetic means.

Figure 5
Mean and median daily energy use during the investigated week among respondents living within different distance belts from the city center of Hangzhou.

N = 2829, with 791, 700, 683 and 655 respondents, respectively, in the innermost, second inner, second outer and outermost distance belt. 225 respondents with zero or extreme traveling distances (above 37.2 km daily) have been excluded from the analysis.



This suggests that a relatively high proportion of the most peripherally residing respondents work and have their other daily destinations locally, at the same time as a fairly considerable minority of the most peripheral residents travel long distances, notably to workplaces in the city of Hangzhou. The zero median energy use among the respondents living less than 3.4 km from the city center implies that more than half of the respondents of the innermost distance belt have not been traveling by any motorized mode during the entire week of investigation.

5. Rationales influencing travel behavior

In order to substantiate that a peripheral residential location is a (contributory) cause of a higher amount of travel and more extensive car driving than what is the case among inner-city dwellers, we must show the basic mechanisms by which residential location influences travel behavior. Examples showing the *rationales* on which people base their frequency of participation in out-of-home activities, the location of these activities, the modes of travel used to reach these locations, and the routes followed make up important elements in this endeavor. In order to explore these rationales and mechanisms, we shall now turn to the material from the qualitative interviews. Below, we will focus in particular on the rationales for location of activities and choices of travel modes, and deal only briefly with the two remaining categories of rationales.

Rationales influencing the location of activities. The interviewees' choices of locations for their activities seem to be influenced by two main, competing rationales which are balanced against each other in different ways, depending on a number of circumstances:

1) Choosing the best facilities, including sub-rationales of

- Choosing facilities where the instrumental purpose of the activities can best be met
- Choosing facilities where social contacts can be maintained
- Choosing facilities matching the interviewees' cultural, esthetic and symbolic preferences
- Variety-seeking

2) Minimizing the friction of distance, including sub-rationales of

- Minimizing the spatial traveling distance
- Minimizing travel time
- Minimizing the stress or physical efforts of traveling to the destination
- Minimizing economic expenses associated with the trip.

A high emphasis on choosing the best facility implies that relatively long traveling distances will be accepted if necessary, whereas a high emphasis on minimizing the friction of distance implies that less-than-ideal facilities are accepted if facilities of the desired quality are not available within a low threshold for acceptable traveling distance. The following circumstances tend to contribute to a high priority attached to the rationale of choosing the best facility, compared to distance minimizing: Specialized job skills, specialized leisure interests and 'exclusive' cultural taste, much time available, high mobility resources, many facilities available in the local area of the dwelling, and short distance from the local facilities to the closest competing concentration of facilities.

The relationship between the amount of transport and the distance from the residence to the *main center of the urban region* tends to be strengthened in particular by the rationale of choosing facilities where the instrumental purpose of the activities can best be met, but also by the rationales of social contacts and cultural/esthetic/symbolic preferences, and (to a lesser extent) the rationales of variety-seeking, minimizing spatial traveling distance, minimizing travel time, and minimizing economic expenses. The former of these rationales 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 an approximate point of gravity for all peripheral destinations. The rationale of choosing facilities matching the interviewees' cultural, esthetic and symbolic preferences also contributes to strengthen this relationship, because several of the culturally, esthetic and symbolically most attractive areas are either located close to the downtown area or at locations easier accessible from the inner city of Hangzhou than from most of the outer parts of the metropolitan

area. The only identified rationale contributing to weaken this relationship somewhat is the rationale of minimizing the stress or physical efforts of traveling.

The relationship between the amount of transport and the distance from the residence to the *closest local center* tends to be strengthened in particular by the rationale of minimizing spatial traveling distance, but also by the rationales of social contacts, minimizing travel time, minimizing the stress or physical efforts of traveling, and minimizing economic expenses. This relationship seems to be weakened by the rationales of choosing facilities where the instrumental purpose of the activities can best be met, cultural/esthetic/symbolic preferences, and variety-seeking. These rationales all tend to increase the likelihood of choosing distant facilities rather than local ones.

For most travel purposes, our interviewees emphasize the possibility to choose among facilities rather than proximity. This means that the amount of travel is influenced to a higher extent by the location of the residence in relation to *concentrations* of facilities, rather than the distance to the *closest single facility* within a category. In particular, this is the case for workplaces and places of higher education, but also for cultural and entertainment facilities, specialized stores and, to some extent, also grocery stores. For leisure activities, the "atmosphere" and the esthetic qualities at the destination may also play a role, contributing to strengthen the attraction of Hangzhou's central parts.

Rationales influencing choices of travel mode. The interviewees' choices of travel modes are influenced by a number of different and interconnected rationales. These rationales could be classified into two main groups:

- Rationales concerning the *efficiency* of the movement from origin to destination
- Rationales concerning the *process* of moving from origin to destination

The first of these two groups includes concerns related the time consumption, economic costs and accessibility benefits of traveling by different modes. The second group includes concerns related to physically, psychologically and socially positive or negative aspects associated with traveling by a particular mode. Several of the rationales are hinted at indirectly through a criterion of *trip distanc*e as an important condition influencing the interviewees' choices of travel modes. Thus, trip distance appears to have the role of an *intermediate rationale* through which more basic rationales such as time saving and limitation of physical efforts influence modal choices. Since long trips will be very time-consuming as well as physically exhausting if they are made by non-motorized modes (in particular by foot), rationales of time-saving and limitation of physical efforts will logically imply a dependence of travel modes on trip distances. Similarly, the time-saving or reduction of physical efforts that may be obtained when driving car (or using other motorized modes) disappears for very short trips, where it may be faster and involve less physical efforts to walk or ride bike directly to the destination than walk to the parking place, start the car, park it again after a very short drive and then walk from the parking place to the destination. Living close to relevant trip destinations thus does not only contribute to shorter traveling distances, but also implies a higher propensity of using non-motorized modes.

The emphasis attached by the interviewees on the mode choice rationales appears to be influenced by a number of individual and contextual conditions, including the interviewees' mobility resources, social obligations, time-geographical constraints, and the purpose of the trip.

The relationship between the modal split and the distance from the residence to the *main center of the urban region* tends to be strengthened by rationales of time-saving, flexibility, expanding the radius of action, money-saving, frustration aversion, physical exercise, and en-

joyment of the surroundings along the route. This relationship seems to be weakened by a comfort rationale and to a lesser extent also rationales of relaxation, safety and habits. The relationship between the modal split and the distance from the residence to the *closest local center* tends to be strengthened by the rationales of money-saving, frustration aversion, physical exercise, and enjoyment of the surroundings along the route. This relationship appears to be slightly weakened by the rationales of comfort and safety.

Rationales influencing route choice and activity participation. According to some debaters (e.g. Urry, 2000; Steg et al., 2001), travel in the late modern society is predominantly a purpose in itself, rather than an instrument to move from one place to another. This might undermine key assumptions about the influence of urban structure on travel. However, the rationales for *route choice* imply that the interviewees are not apt to make long detours from the shortest route to daily-life destinations. The rationales for route choice thus provide general support to the activity-based approach to transport analyses. Our interviews indicate that people's *activity patterns* are to some extent adapted to the availability of facilities in the proximity of the dwelling. The interviewees still rarely give up activities completely as a result of moving to a different urban structural situation. "Distance decay" in the form of reduced activity participation when living far away from relevant facilities is not very pronounced among our interviewees and survey respondents.

6. Multivariate statistical analyses

In order to distinguish differences in travel behavior caused by urban structural conditions from differences caused by individual characteristics of the residents, we have conducted multivariate statistical analyses. The following three urban structural variables were included in these analyses:

- The location of the dwelling relative to the city center of Hangzhou
- The location of the dwelling relative to the closest second- order center
- The location of the dwelling relative to the closest third- order center.

These urban structural variables were chosen from theoretical considerations as well as iterations based on preliminary analyses of the empirical data. For all three variables, the distances measured in kilometer were transformed by means of non-linear functions. The location of the dwelling relative to the city center of Hangzhou tells something about the situation of the residence relative to the concentration of workplaces and service facilities found in the city of Hangzhou, especially in its inner and central parts. The closer to this concentration a respondent lives, the easier it will be for her/him to find a workplace matching her/his qualification within a short distance from the dwelling, and the shorter will be the distance to special commodity shops and a number of cultural and entertainment facilities. On the other hand, if the distance to the city center of Hangzhou is too long, many residents will prefer more local job opportunities and service facilities even if these jobs and services are, apart from the traveling distances, less attractive than the central ones. The relationship between traveling distances and the distance between the residence and downtown Hangzhou is therefore not likely be linear, but could rather be expected to follow a curve reflecting a lower propensity to use facilities in the city of Hangzhou when living in the peripheral parts of the metropolitan area.

The location of the dwelling relative to the closest second-order and third-order centers tells something about the accessibility of more local concentrations of job opportunities and services. Here, too, 'distance decay' in the form of lower propensity to use facilities in a second- or third-order center when living far away from such a center could be expected.

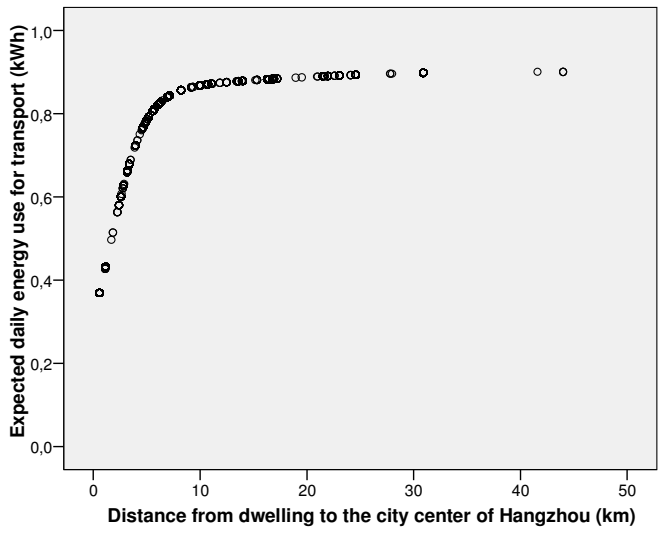
In addition to the three above-mentioned urban structural variables, the regression model included 17 demographic, socioeconomic, attitudinal and other non-urban-structural variables[3].

Below, we shall focus in particular on the influences of residential location on energy use for transport. Besides its obvious relevance to the discussion on environmentally sustainable urban structures, energy use is also a variable summarizing key aspects of travel behavior, as it depends on both traveling distances and travel modes. In a situation where space constraints prohibit a thorough account of the relationships between residential location and all aspects of travel behavior, energy use is thus well suited as an indicator of the relationship between residential location and travel.

A relatively high proportion of the respondents (36%) had not at all used motorized modes of transport during the week, and their energy use has accordingly been recorded as zero. In order to cope with this deviation from the requirements regarding dependent variables of regression analyses, we have, in line with the so-called sample selection method, carried out the analysis of energy use in two steps. First, a binary logistic regression analysis was carried out in order to identify factors influencing whether or not the respondents had at all traveled by motorized modes and hence used energy for this purpose. Thereupon, an ordinary regression analysis was carried out among those who have used energy for motorized travel. In order to assess the influence of residential location on the energy use for transport among the whole sample of respondents, the results of these two analyses were then combined. The results of this calculation can be seen in Figure 6. According to our data, respondents living more than 10 km away from the city center of Hangzhou could be expected to use more than two and a half time as much energy for transport within the metropolitan area as the respondents living closest to the downtown area.

Figure 6
Expected daily energy use for transport among respondents living at different distances from the city center of Hangzhou.

The graph is based on multivariate regression models of energy use among motorized travelers (N = 1245) and the likelihood of being a motorized traveler (N = 2201), respectively, and with the remaining variables of the models kept constant at mean values. p (two-tailed) = 0.0000.



7. Comparison with Copenhagen Metropolitan Area

Multivariate statistical analyses were conducted also in order to illuminate factors influencing total traveling distances, distances traveled by different modes and the proportion of non-motorized travel, with separate analyses addressing travel on weekdays, in the weekend as well as the week as a whole. Commuting distances were also analyzed. In table 1, the results of some of these analyses have been compared to corresponding results from a previous analysis of residential location and travel in Copenhagen Metropolitan Area (Næss, 2006; Næss & Jensen, 2005).

Both in Hangzhou Metropolitan Area and in Copenhagen Metropolitan Area, living in the central parts of the region contributes to shorter overall traveling distances, shorter commuting distances and a higher share of non-motorized travel. In particular, the location of the

dwelling relative to the main center of the region appears to influence traveling distances and modes in very similar ways. In both urban regions, the influences of the location of the residence relative to lower-order centers are weaker and less unambiguous than the location of the dwelling relative to the main city centers of the two urban regions. In the metropolitan areas of both Hangzhou and Copenhagen, living close to a second-order was found to contribute to a higher share of non-motorized travel in the weekend, but any similar effect on weekdays was only found in the Copenhagen area. In neither of the two metropolitan areas, proximity of the dwelling to a second-order center appears to influence traveling distances much, except for a slight tendency to shorter traveling distances on weekdays in Copenhagen Metropolitan Area and a slight tendency to shorter commuting distances among workforce participants of Hangzhou Metropolitan Area.

Table 1: *Main effects on selected transport variables from residential location relative to the main metropolitan center, the closest second-order center and the closest third-order center among respondents in the metropolitan areas of Hangzhou and Copenhagen.*

	Proximity to the main center of the metropolitan area		Proximity to a second-order center		Proximity to a third-order center	
	Hangzhou Metropolitan Area	Copenhagen Metropolitan Area	Hangzhou Metropolitan Area	Copenhagen Metropolitan Area	Hangzhou Metropolitan Area	Copenhagen Metropolitan Area
Total daily traveling distance on weekdays	Shorter	Considerably shorter	No clear effect	Somewhat shorter	Slightly longer	Somewhat shorter
Total daily traveling distance in the weekend	Shorter	Very slightly shorter	No clear effect	No clear effect	No clear effect	No clear effect
Commuting distance	Considerably shorter	Considerably shorter	Somewhat shorter	No clear effect	Longer	No clear effect
Non-motorized share of travel on weekdays	Considerably higher	Considerably higher	No clear effect	Considerably higher	No clear effect	No clear effect
Non-motorized share of travel in the weekend	Considerably higher	Considerably higher	Higher	Higher	Slightly higher	No clear effect
Energy use for transport during the week	Considerably lower	Considerably lower	Somewhat lower	No clear effect	Slightly lower	Slightly lower

Proximity to a third-order center shows a few somewhat surprising effects on traveling distances in Hangzhou Metropolitan Area, as respondents tend to travel somewhat longer on weekdays and make somewhat longer commutes the closer they live to a third-order center. Probably, this is due to these respondents' better access to public transport facilities than among the remaining outer-area residents, thus making it easier for those who live close to such a center to choose workplaces and service facilities outside the local district. The absence of any corresponding effects in Copenhagen Metropolitan Area is probably due to the much higher levels of car availability in the latter region. In the outer parts of Copenhagen Metropolitan Area, a large proportion of the residents are able to choose jobs and services outside the local district, even if they live in areas with poor public transport facilities.

The rationales on which the interviewees of the two studies base their travel behavior are also very similar across national contexts. In both Hangzhou Metropolitan Area and Copenhagen Metropolitan Area, the interviewees' choices of locations for their activities (work, shopping, leisure etc.) are based on a balancing between a wish to minimize traveling distances and/or travel time, and a wish for choosing the best and most suitable facility. And in both areas, the prioritization of the "best facility" rationale compared to the "distance minimizing" rationale appears to be stronger the more specialized is the activity and the higher are the interviewees' mobility resources.

The above many similarities between the results of the studies in Hangzhou Metropolitan Area and Copenhagen Metropolitan Area might leave the impression that traveling patterns among inner- and outer-area residents of Hangzhou Metropolitan Area are quite similar to

those of residents living in the corresponding parts of Copenhagen Metropolitan Area. However, residents of Hangzhou Metropolitan Area travel in general only a small fraction of the distance traveled by Copenhagen Metropolitan Area residents. Moreover, whereas traveling distances and energy use do not appear to increase to any extent worth mentioning when the distance from the dwelling to downtown Hangzhou increases beyond some 8 – 10 km, the curve of Copenhagen Metropolitan Area levels out at a distance from the city center of more than 40 km. These differences across national contexts obviously reflect the far higher car ownership rates in Denmark than in China. Among the respondents of Copenhagen Metropolitan Area, 75% belong to a household having a private car at its disposal. Among the Hangzhou Metropolitan Area respondents, the corresponding figure is 6%.

9. Concluding remarks

Apart from being highly consistent with the findings of the Copenhagen Metropolitan Area study, the results of our study are well in accordance with the conclusions from studies in Paris (Mogridge 1985; Fouchier 1998), London (Mogridge, ibid.), New York and Melbourne (Newman & Kenworthy 1989), San Francisco (Schipper et al. 1994), Oslo (Næss, Røe & Larsen, 1995), Dutch urban regions (Schwanen et al., 2001), English cities (Stead & Marshall, 2001), Danish provincial cities (Hartoft-Nielsen, 2001; Nielsen, 2002; Næss & Jensen, 2004), and Santiago de Chile (Zegras, 2006). Our results thus seem to be of a high generality, indicating that the dominating mechanisms by which residential location influences urban travel will be present across city sizes and considerable contextual differences.

Admittedly, some previous studies have concluded that only weak relationships or no relationship at all exist between urban structural characteristics and the inhabitants' travel behavior (see, e.g., Williams, Burton & Jenks (2000), where some of these studies are referred). However, the empirical studies concluding that urban structure has no influence worth mentioning on travel behavior have usually investigated other aspects of travel (e.g. trip frequencies or travel time) and/or focused on other urban structural conditions (e.g. detailed neighborhood design) than those which, according to our investigations, exert the strongest influences on traveling distances and modal split. Moreover, a common feature of many of the publications from the above-mentioned studies is an absence of theoretical discussion of the reasons why urban structure could be expected to influence travel, which characteristics of the urban structure could be expected to exert the strongest influence on travel behavior, and which aspects of travel behavior could be expected to be influenced by urban structure. Among theoretically informed, empirical, multivariate investigations into the influences on travel from the location of residences within the urban area, the converging conclusion is that living close to the city center does contribute to reduce traveling distances and the use of motorized modes of travel, especially cars.

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Notes

[1] With partial positions at Institute of Transport Economics, Oslo, and Oslo University College.

[2] The figure does not show conditions influencing the travel modes used, which make up another important aspect of the study. Travel modes could be expected to be influenced indirectly by the factors shown in Figure 2 through their influence on traveling distances, and directly by individual resources and motives, transport infrastructure and social environments.

[3] These variables were: Sex; age; number of children younger than 7 years of age in the household; number of children aged 7–17 in the household; and number of adult persons in the household; education level; personal income; car ownership; driver's license for car; whether or not the respondent is a workforce participant, and whether or not the respondent is a student; attitudes to transport issues; attitudes to environmental issues; whether or not the respondent had moved to her/his present dwelling less than 5 years ago; regular transport of children to/from kindergarten or school; whether or not the respondent has been outside Hangzhou Metropolitan Area during the week of investigation, and whether or not the respondent has stayed overnight away from home four or more nights during the week of investigation.