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Residential Location, Travel Behaviour, and Energy Use: Hangzhou Metropolitan Area Compared to Copenhagen

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Key Words
Residential location · Travel · Energy use · Qualitative · Quantitative · China

Abstract
This paper presents the results of a study of the influence of residential locations on travelling behaviour in the Hangzhou Metropolitan Area in China. Based on a combination of quantitative and qualitative research methods, the study shows that the location of a dwelling, relative to the centre structure of Hangzhou Metropolitan Area, can exert a considerable influence on the travelling behaviour of the respondents included in the survey. On average, people living close to downtown Hangzhou used less energy for transport. They travelled less in total and made a greater share of their journeys by bike or on foot.

The location of the dwelling relative to the closest second-order and third-order centre can also influence travelling, but not to the same extent as the location of the residence relative to the city centre of Hangzhou. The geographical differences in travelling behaviour exist independently of residential preferences and attitudes to transport and environmental issues and therefore cannot be explained by residential self-selection. Instead, a number of rationales for travel behaviour identified in the qualitative interviews showed important links in the causal mechanisms by which residential location can influence travel.

Introduction

The theme of this paper is how spatial planning in urban areas can be used to influence the amount of travel, the proportions carried out by different modes of conveyance, and the resulting energy use for transport. The paper is based on a pioneering study of residential location and travel in an affluent Chinese urban region, viz. the Hangzhou Metropolitan Area in the province of Zhejiang [1,2], and comparing these results to the conclusions of a similar study carried out in Copenhagen Metropolitan Area, Denmark [3]. The research study was funded by Volvo Research and Educational Foundation.

Until now, there has been a lack of valid and reliable knowledge about the influence of residential location on travel in East Asian cities. If Chinese cities are to follow the path that North American and many European cities have followed in their urban development and transport policies during the latter half of the 20th century, a very large increase in urban motoring must be expected, with

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associated problems of increased fuel consumption, air pollution, ill health, traffic accidents, and reduced accessibility to facilities for people who do not possess a private car. Therefore, it would be relevant for the policy makers to identify possible strategies for urban development that would reduce car dependency and provide the inhabitants with a greater accessibility to workplaces, service facilities, and other urban functions without having to rely on a high level of individual motorised transport.

Hangzhou is the capital of the Zhejiang province and is located in southeastern China, 180 km south–west of Shanghai and is the economic and political centre of this province. In 2002, the continuously built-up urban area of Hangzhou had 1.92 million inhabitants. Hangzhou Metropolitan Area had about 3.9 million inhabitants and is composed of one main city (i.e., the continuously built-up urban area), two second-order centres outside the city of Hangzhou, and six local centres outside Hangzhou.

Methods

Going beyond the scope of most previous investigations into urban land use and travel, the Hangzhou Metropolitan Area study combines the traditional quantitative travel survey approach with qualitative interviews in order to identify the more detailed mechanisms through which urban structure affects travel behaviour [3]. Rationales for activity participation, location of activities, modal, and route choices make up important links in these mechanisms. The statistical analyses include a broad range of urban structural, socio-economic, and attitudinal variables. Differences between population groups in the way urban structure affects travel behaviour have also been investigated.

Besides recording urban structural conditions by means of maps, aerial photographs, and visits to the investigated urban districts and residential areas, the investigation was also based on 28 qualitative interviews and answers from more than 3000 respondents participating in the questionnaire survey. The questionnaire included questions about a number of topics, among others: residential address, contacting detail, gender, age, type of residence, ownership of large items, household composition, income, responsibility for transporting children, driver's license, ownership/access to private car and other motor vehicles, perceived dependency on private motor vehicles, travel modes and distances for each day during the week of investigation, business travel, holiday travel, education, workforce participation, location of workplace/place of education, location of activities, frequency of activity participation, residential preferences, transport attitudes, and environmental attitudes. The respondents were recruited from residential areas that varied in their urban structural situation in terms of distance to downtown Hangzhou and local centres, 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 they represented typical inner-city neighborhoods, suburban locations as well as a location close to one of the second-order towns. The interviews were carried out by one of the members of the research team, based on an interview guide translated into Chinese from its original English-language version. Usually, the interviews took place in the homes of the interviewees, except for a few interviews carried out at the interviewee's workplace. All interviews were tape-recorded and transcribed. The Chinese-language transcriptions were subsequently translated into English.

As an important tool for the analysis an *interpretation scheme* was developed [1]. Because we had to make written interpretations of each interview in the light of each of the detailed research questions, we had to read and penetrate the transcribed interview texts in a far more thorough way than we would probably have done otherwise. In our opinion, this has contributed significantly to increase the validity and the reliability of our qualitative interpretation.

As is evident from the above, we have aimed at a "triangulation" [4], both regarding data sources (combination, among others, of questionnaire data and data from personal, qualitative interviews) and methods of analysis (statistical analyses and qualitative interpretation of interview material). We believe that this has given us a broader and more nuanced understanding of our research questions and contributed to more reliable and robust conclusions.

Results

Below, some of the major results of the study are presented. A more detailed account, focusing in particular on the influences of residential location on total travelling distance, the share of nonmotorised travel, and energy use for transport is available in Næss [2], where the research methods are also described more specifically.

Figures 1–5 show how the average total daily travelling distance on weekdays and the distances travelled by nonmotorised modes, electric bike, bus and car/taxi varied according to the distance belt from the city centre of Hangzhou where the respondents live. In the figures showing total daily travelling distances and travelling distances by nonmotorised modes, both arithmetic means and median values are shown. (Extreme travelling distances have been excluded from the analysis.) For the remaining travel modes, the figures only include arithmetic means, as less than half the respondents within each distance belt has travelled by car/taxi, bus, and train, and the median values of all these modes are therefore zero in each distance belt.

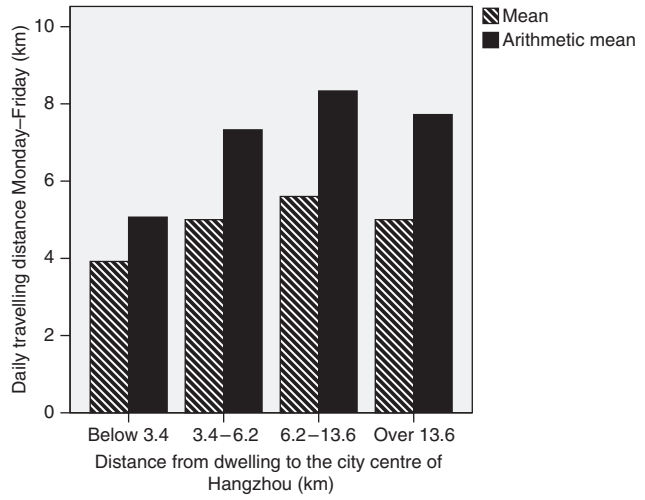

Fig. 1. Mean and median daily travelling distances on weekdays (Monday–Friday) among respondents living within different distance belts from the city centre. $n = 2798$, with 781, 697, 678, and 642 respondents, respectively, in the innermost, second inner, second outer, and outermost distance belt. 247 respondents with zero or extreme travelling distances (above 34.5 km daily) have been excluded from the analysis.

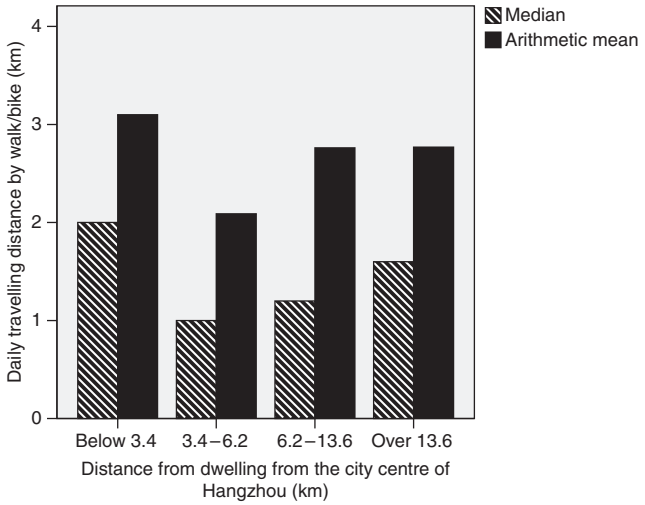

Fig. 2. Mean and median daily travelling distances by foot or by bike on weekdays (Monday–Friday) among respondents living within different distance belts from the city centre of Hangzhou. $n = 2798$, with 781, 697, 678, and 642 respondents, respectively, in the innermost, second inner, second outer, and outermost distance belt. 247 respondents with zero or extreme travelling distances (above 34.5 km daily) have been excluded from the analysis.

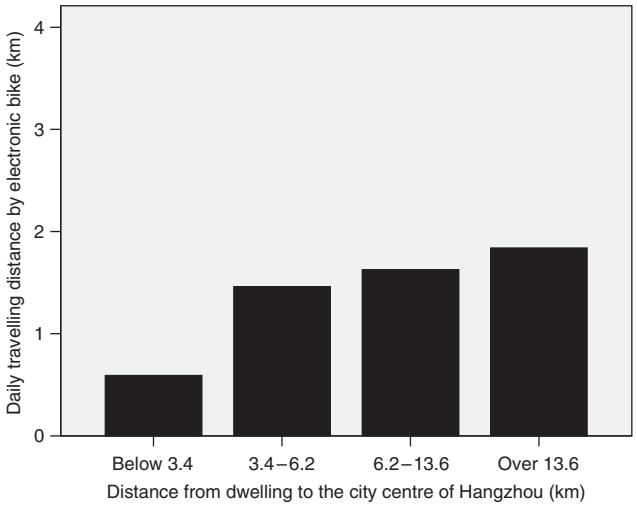

Fig. 3. Mean daily travelling distances by electronic bike on weekdays (Monday–Friday) among respondents living within different distance belts from the city centre of Hangzhou. $n = 2798$, with 781, 697, 678, and 642 respondents, respectively, in the innermost, second inner, second outer, and outermost distance belt. 247 respondents with zero or extreme travelling distances (above 34.5 km daily) have been excluded from the analysis.

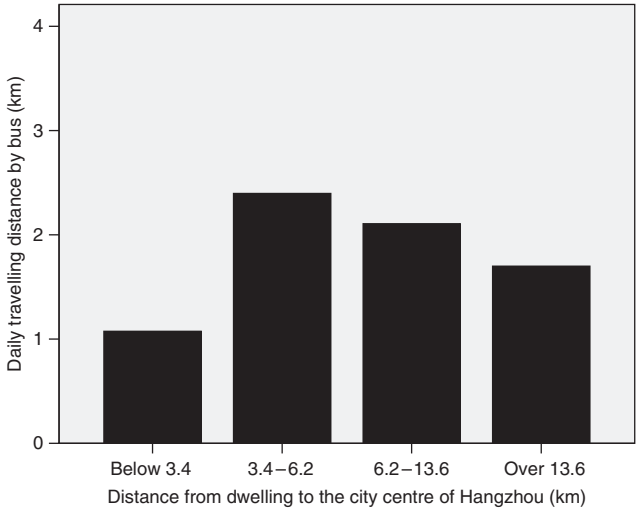

Fig. 4. Mean daily travelling distances by bus on weekdays (Monday–Friday) among respondents living within different distance belts from the city centre of Hangzhou. $n = 2798$, with 781, 697, 678, and 642 respondents, respectively, in the innermost, second inner, second outer, and outermost distance belt. 247 respondents with zero or extreme travelling distances (above 34.5 km daily) have been excluded from the analysis.

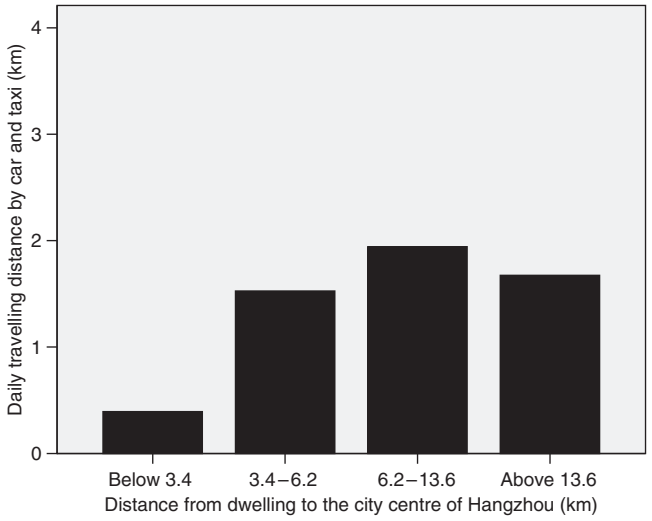

Fig. 5. Mean daily travelling distances by car or taxi on weekdays (Monday–Friday) among respondents living within different distance belts from the city centre of Hangzhou. $n = 2798$, with 781, 697, 678, and 642 respondents, respectively, in the innermost, second inner, second outer, and outermost distance belt. 247 respondents with zero or extreme travelling distances (above 34.5 km daily) have been excluded from the analysis.

Discussion

We saw a clear tendency to shorter travelling distances among respondents who lived close to the city centre of Hangzhou. In particular, this applied to travel by car or taxi, where respondents living less than 3.4 km from the city centre of Hangzhou travelled on average less than a quarter of the average distance travelled by car/taxi among the remaining respondents. Respondents living close to the city centre of Hangzhou travelled shorter distances than those travelled by the people living more peripheraly using other motorised modes (bus and e-bike). In contrast to that, the average travelling distance by nonmotorised modes was about 20% longer among the respondents of the innermost distance belt than among the remaining respondents. As a result, nonmotorised modes accounted for 74% of the distance travelled on weekdays among the respondents living less than 3.4 km away from the city centre of Hangzhou, compared to 47% among the remaining respondents.

Statistical analyses including a number of non-urban-structural factors influencing travel behaviour showed that residential location could affect travel behaviour, when taking into consideration the socioeconomic and the attitudinal differences among the inhabitants. The statistical analyses will be discussed in detail below. Although the specific influences of urban structure can vary between population groups, the location of the residence in the urban structure of the Hangzhou Metropolitan Area affected the travel behaviour within all our investigated subgroups.

Overall, our analyses showed that the location of the dwelling relative to the centre structure of Hangzhou Metropolitan Area exerted to a considerable influence on the travel behaviour of the respondents. On average for all our respondents, living close to downtown Hangzhou contributed to less travelling, a lower share of car driving, and more journeys by bike or on foot. Conversely, living in the peripheral parts of the metropolitan area contributed to a higher amount of transport and a lower share of travel by nonmotorised modes. In particular, the length and the travel mode of the journeys to work were influenced by the location of the dwelling relative to the city centre of Hangzhou. In general, higher concentration of service and leisure facilities in the inner and the central parts of the metropolitan area also implied shorter average travelling distances for nonwork purposes, the closer to downtown Hangzhou the residence was located. The location of the dwelling relative to the closest second- and third-order centre also had an influence on travelling behaviour, but not to the same extent as the location of the residence relative to the city centre of Hangzhou.

Our data indicated that a residential location close to the city centre of Hangzhou contributed to:

- shorter overall travelling distances on weekdays as well as at weekends,
- considerably higher likelihood of using nonmotorised modes during weekdays as well as weekends, but somewhat shorter travelling distances by foot and bike than the average among users of these modes,
- lower likelihood of travelling by bus both during weekdays and at weekends, and shorter travelling distances by bus than the average among users of this mode,
- lower likelihood of using car or taxi during weekdays and to some extent also at weekends, and shorter travelling distances by car and taxi than the average among users of these modes,
- lower likelihood of using an e-bike especially at weekends but also during weekdays,
- considerably higher proportion of the total travelling distance carried out by nonmotorised modes during weekdays as well as at weekends,
- considerably shorter commuting distances.

Residential location close to any of the two second-order centres (Xiaoshan and Yuhang) contributed to:

- higher likelihood of using nonmotorised modes during weekdays as well as at weekends,
- lower likelihood of travelling by bus at weekends and to some extent also during weekdays,
- slightly higher likelihood of using an e-bike during weekdays,
- higher proportion of the total travelling distance during weekends by nonmotorised modes,
- somewhat shorter commuting distances.

Residential location close to any of the six third-order centres appeared to contribute to

- slightly longer overall travelling distances on weekdays,
- somewhat higher likelihood of using nonmotorised modes during weekdays as well as at weekends,
- shorter travelling distances by foot and bike than the average among users of these modes on weekdays, but somewhat longer at weekends,
- lower likelihood of travelling by bus during weekends,
- lower likelihood of travelling by car or taxi during weekends, and slightly shorter travelling distances by car and taxi than the average among users of these modes,
- slightly higher likelihood of travelling by electronic bike during weekends,
- somewhat higher proportion of the total travelling distance during weekends by nonmotorised modes,
- longer commuting distances.

Most of these tendencies are in line with what could be expected from theoretical considerations and are also in line with the mechanisms and rationales identified in the qualitative interviews (see below). There were, however, some effects that may appear surprising, notably the tendencies to travel longer commuting distances and the overall travelling distances on weekdays when living close to a third-order centre. Better accessibility to job opportunities outside the local area when living close to the public transport connections usually available in a third-order centre might be an explanation. In particular, such a tendency appeared to exist among women. More research is still needed in order to uncover the reasons for the tendencies found towards a higher amount of travel on weekdays when living close to a third-order centre.

Our study did not show any tendency to ''compensatory travel'' in the form of longer travelling distances at weekends among respondents living at locations making it possible to manage on a low amount of travel on weekdays. In Europe, a hypothesis of compensatory travel [5–7] has gained much attention, and in our investigation in Copenhagen Metropolitan Area, certain indications of such travel could be found among residents of dense urban districts [3,8]. In Hangzhou Metropolitan Area, there is, even at weekends, a fairly strong and certain tendency to travel longer distances the further away from downtown Hangzhou the respondents live.

Our interviewees' *rationales* for location of activities, choice of transport modes and route, made up important links in the mechanisms by which urban structures can influence travel behaviour.

The rationales are partialy interwoven. Usually, the choice of an individual was not based on one single rationale, but on a combination of (and a trade-off between) several rationales. Most of the rationales identified either contributed actively to strengthen the relationships between residential location and travel, or were neutral, as regards these relationships. A few of the rationales form the base of ''compensatory'' mechanisms, which may contribute to weaken the relationships mentioned.

Location of Activities

Our interviewees' choices of locations for daily activities were made as a compromise between two different concerns: a wish to limit travel distances and a wish for the best facility. For most travelling purposes, our interviewees emphasised that there was a possibility to choose between facilities rather than proximity. This means that the amount of travel was 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 was the case for workplaces and places of higher education, and also for cultural and entertainment facilities, specialised stores and, to some extent, also grocery stores. For leisure activities, the ''atmosphere'' and the aesthetic qualities at the destination could also play a role in strengthening the attraction of Hangzhou's central parts, in particular, the areas bordering the West Lake.

The longer overall travelling distances among outer-area residents than among inner-area residents were mainly a result of longer commuting distances. The given configuration of residences and workplaces resulted in a shortage of suitable jobs within a moderate commuting distance, when living in the outer parts of the metropolitan area. Outer-area residents therefore tended to make longer commutes, partly because local job opportunities often did not exist, and partly because jobs outside the local area were considered more attractive.

Although the distances to shops are usually longer when living in the suburbs, the outer-area interviewees often compensate for this by buying daily necessities along the route home from work. In this way, the rationale of distance limitation and the rationale of choosing the best facility can be combined for shopping trips and certain other errands.

Our interviewees' rationales for choosing modes of transportation usually contributed to a more extensive use of cars in the suburbs and a higher use of nonmotorised modes in the inner city. The rationales for route choice implied that the interviewees seldom made long detours from the shortest route to daily-life destinations, and thus provided general support to the activity-based approach to transport analyses.

Activity Participation

Our interviews indicated that the peoples' activity patterns were to some extent adapted to the availability of facilities in the proximity of the dwelling. The interviewees still rarely gave up activities completely as a result of moving to a different urban structural situation. According to our survey data, ''distance decay'' in the form of reduced activity participation when living far away from relevant facilities was not very pronounced among our respondents.

In general, the relationships between the residential location and the frequencies of activity participation were relatively weak. Our study also showed quite surprising tendencies of more frequent activity among respondents who live far away from the types of centres where the activities in question could usually be performed. Notably, this was the case for shopping, where the frequency of visiting shops tended to increase, the further away from downtown Hangzhou the respondents lived as well as from the closest second- or third-order centre. A plausible explanation might be that peripheral residents sometimes combined purchases of the most basic daily necessities in local stores (e.g., vegetable markets, fruit stands, and small supermarkets) with shopping in larger and more, well-assorted stores in Hangzhou in connection with commuting trips.

Our study showed that the propensity for using local facilities depended partly on which facilities that *exist* in the proximity of the dwelling, and partly on the *competition* from nonlocal facilities. In the districts next to the downtown area, a relatively broad supply of local facilities often exists, but at the same time there is a strong competition from facilities in the city centre. Conversely, the local supply of facilities is often more modest in the outer parts of the metropolitan area, and at the same time the long distance to the concentration of facilities found in central Hangzhou weakened the competition from the latter facilities. The two above-mentioned factors reflected the rationales for location of activities identified in the qualitative interviews. The wish to limit geographical distances and time consumption for travel motivated respondents to use local facilities, while the wish to choose the best facility pulled them out from the local areas, inducing them instead to choose facilities in the city of Hangzhou, particularly in its inner districts. The mutual prioritisation between the rationales, as well as the actual occurrence of local and competing external facilities, varied between different facility categories.

Differences Between Population Groups

Analyses where the respondents were divided into subgroups according to gender, age, household type, or socioeconomic characteristics showed that the residential location influenced travel behaviour among all these groups. In particular, this applied to travelling distances and the proportion of travel accounted for by nonmotorised modes. There are, however; some interesting differences across population groups in the ways in which residential location affected travel behaviour.

Travelling distances were influenced by residential location to a higher extent among men than among women, and to a lesser extent among childless households with two or more adults than among the remaining respondents.

Men's travelling distances tended to increase considerably when living far away from the city centre of Hangzhou, while women's amount of travel was also influenced by the location of the dwelling relative to the closest third-order centre, where proximity to such a centre tended to increase their travelling distances. This difference between men and women was to a large extent attributable to male suburbanites' choices of workplaces within a wider geographical area compared to their female counterparts. There were also somewhat stronger influences of residential location on travelling distances among respondents with a lower education background and income than among those with a higher education or income.

The influences of residential location on travelling distances varied between different household types in a quite complex way. In general, respondents with two or more adult members and no children living at home tended to be more locally oriented than the remaining household groups. This group included a relatively high proportion of pensioners, and this may explain why their travel behaviour appeared to be less influenced by the

distance from the dwelling to the workplace concentrations in the central parts of the region.

There were certain differences in the likelihood of using car or taxi according to age, household type and education level; where the likelihood of being a car or taxi user did not appear to be influenced by residential location at all among the younger half of the respondents, single persons, and respondents with education level above the median. Among respondents above the median age, respondents belonging to households with at least two adult members, and respondents with education level at the median or below, there is a lower likelihood of being a user of car and taxi when living close to the city center of Hangzhou. Among the older half of the respondents, living close to the city centre as well as living close to a third-order centre contributes to lower propensity of being a user of car or taxi. There were only small differences, between the investigated population groups, regarding the influence of residential location on the shares of nonmotorised travel.

The above-mentioned differences between population groups did not point to any clear and unambiguous direction in terms of the nature of the relationship between residential location and travel in Hangzhou in the future. On the one hand, education levels as well as income could be expected to continue to rise. According to our study, this could be expected to contribute to a slight reduction of the influence of proximity to downtown Hangzhou on travel behaviour. The same may be the case if the differences found between young and old respondents, represent cohort effects (i.e., lifestyles that the young generation will continue to practice also when they get older) as distinct from mere life-phase effects. On the other hand, if the development towards an increasing proportion of one-person households continues (like it has done in Western countries for several decades), the influence of the location of the dwelling relative to the city centre of Hangzhou on travel behaviour may increase. The same will apply if – as has been the case in Western countries – women increasingly adopt traditionally male types of travel behaviour.

Influence of Residential Location on Energy Use for Transport

Based on the information about the respondents' travelling distances by different modes of conveyance, their energy use for transportation during the week investigated has been calculated. Based on average values of data from [9] and [10], energy use for travel by car has been estimated to be 0.528 kWh passenger km^{-1}. The same figure for taxi travel has also been adopted. According to [10], average energy use for travel by public transport in Chinese cities is 0.200 kWh passenger km^{-1} by bus and 0.057 kWh passenger km^{-1} by train. These figures were used as a basis for the calculation of energy use for public transport. Data on the energy use per kilometer travelled by electronic bike were obtained from [11]. According to this source, average energy use by e-bike is 0.014 kWh passenger km^{-1}. Compared to a European context, my Chinese energy data implies a lower energy use per passenger kilometer, especially by train but also by bus and to some extent by car too. For comparison, figures from Copenhagen Metropolitan Area showed 0.64 kWh passenger km^{-1} by car, 0.32 kWh passenger km^{-1} by bus, and 0.19 kWh passenger km^{-1} by train. Higher degrees of capacity utilisation (more crowded buses and trains in China) probably were the main explanation for these differences.

A relatively high proportion of the respondents (36%) had not used motorised modes of transport at all during the week, and their energy use was accordingly recorded as zero. This implies that the ideal requirements of ordinary least square regression analysis of normally distributed dependent variables was not met. In order to cope with this deviation from the ideal requirements of regression analysis, we have, in line with the so-called sample selection method, carried out the analysis of energy use by different modes in two steps. First, a binary logistic regression analysis was carried out in order to identify factors influencing whether or not the respondents had travelled at all by motorised modes and hence had used energy for this purpose. This analysis included the construction of a Heckman selection bias control factor (LAMBDA). This control factor was then added to an Ordinary Least Squares regression analysis of variables influencing the respondents' weekly energy use for transport. Control for selection bias was carried out according to the procedure described by [12]. In both analyses, respondents who had not travelled at all during the relevant investigation period have been omitted. Similar to the previous analyses (cf. Figures 1–5), respondents with extreme total travelling distances during the week have also been excluded.

Table 1 shows the results of the multivariate logistic regression analysis of factors potentially influencing the likelihood of having used energy for motorised travel during the week investigated.

In the table, the variables have been sorted in a descending order according to the strength and the certainty of their effects (cf. the Wald figures).

Table 1. Results from a binary logistic regression analysis of variables potentially influencing the likelihood of having used energy for motorised travel during the investigated week (the selection model)

	B	Standard error	Wald	Level of significance (p value)
Location of the dwelling relative to the city centre of Hangzhou (nonlinear distance function, values ranging from −0.23 to 1.00)	1.211	0.151	64.70	0.0000
Education level (professional secondary school or higher levels = 1, otherwise 0)	0.628	0.102	38.21	0.0000
Logarithm of personal annual income (¥1000RMB)	0.803	0.146	30.11	0.0000
Availability of private car in the household (yes = 1, no = 0)	1.222	0.386	10.02	0.0016
Whether or not the respondent has moved to the present dwelling less than 5 years ago (yes = 1, no = 0)	0.405	0.141	8.23	0.0041
Possession of driver's license for car (yes = 1, no = 0)	0.411	0.146	7.90	0.0050
Overnight stay away from home four or more nights during the week of investigation (yes = 1, no = 0)	0.860	0.335	6.60	0.0102
Attitudes to transportation issues (car-oriented = high value, values ranging from −17 to 6)	0.040	0.016	6.54	0.0105
Constant	−1.390	0.216	41.61	0.0000

Note: $n = 2315$ respondents living in different parts of Hangzhou Metropolitan Area; Nagelkercke's $R^2 = 0.204$.

The following 12 variables of the original regression model failed to meet a required significance level of 0.05 and were therefore omitted in the final model: overnight stay away from home for four or more nights during the week of investigation ($p = 0.974$), regular transport of children to/from kindergarten or school ($p = 0.965$), number of preschool children (less than 7 years) in the household ($p = 0.814$), location of the dwelling relative to the closest third-order centre ($p = 0.669$), whether or not the respondent was a workforce participant ($p = 0.575$), number of children aged 7–17 in the household ($p = 0.563$), transport-related residential preferences ($p = 0.482$), number of household members above 18 years of age ($p = 0.358$), location of the dwelling relative to the closest second-order centre ($p = 0.301$), whether or not the respondent was a student ($p = 0.297$), attitudes to environmental issues ($p = 0.153$), and age ($p = 0.071$).

Table 2 shows the results of the multiple ordinary linear regression analysis of factors potentially influencing the amount of energy use. In the table, the variables have been sorted in a descending order according to the strength of their effects (cf. the absolute values of the standardised regression coefficients). The following 13 variables of the original regression model failed to meet a required significance level of 0.05 and were therefore omitted in the final model: transport-related residential preferences ($p = 0.992$), number of household members above 18 years ($p = 0.988$), number of children younger than 7 years of age in the household ($p = 0.984$), number of children aged 7–17 in the household ($p = 0.976$), whether or not the respondent was a student ($p = 0.973$), regular transport of children to/from kindergarten or school ($p = 0.967$), sex ($p = 0.948$), location of the dwelling relative to the closest second-order centre ($p = 0.907$), age ($p = 0.869$), education level ($p = 0.854$), whether or not the respondent was a workforce participant ($p = 0.848$), attitudes to environmental issues ($p = 0.807$), and overnight stay away from home for four or more nights during the week of investigation ($p = 0.711$).

Based on the results shown in Tables 1 and 2, the predicted energy use depending on the distance from the dwelling to the city centre of Hangzhou has been calculated. 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 centre of Hangzhou could be expected to use about four times the amount of energy for transport within the metropolitan area than the respondents living closest to the downtown area. First and foremost, this reflected a considerably higher propensity of inner-city dwellers to carry out all their transport during the week by nonmotorised modes (cf. Table 1). To some extent, those who travelled by motorised modes also tended to use somewhat more energy, the further away from downtown Hangzhou they live, but this effect is much more modest. A separate analysis among the users of motorised modes (not shown here) revealed weak tendencies of increasing energy use, the further away from the closest second- and third-order centre the respondents lived; however, none of the latter urban structural variables showed any effect on the propensity of being a

Table 2. Results from a multiple linear regression (the substantial analysis) of the influence from various independent variables on the respondents' mean daily energy use for transport (kWh)

	Unstandardised coefficients		Standardised coefficients	Level of significance
	B	Standard error	Beta	(p values, two-tail)
Availability of private car in the household (yes = 1, no = 0)	4.455	0.286	0.348	0.0000
Possession of driver's license for car (yes = 1, no = 0)	1.434	0.137	0.202	0.0000
LAMBDA	0.609	0.128	0.109	0.0000
Logarithm of personal annual income (1000 yuan renmimbi)	0.642	0.061	0.105	0.0000
Location of the dwelling relative to the city centre of Hangzhou (nonlinear distance function, values ranging from −0.23 to 1.00)	0.968	0.178	0.098	0.0000
Whether or not the respondent has been outside Hangzhou Metropolitan Area during the week of investigation (yes = 1, no = 0)	1.026	0.194	0.091	0.0000
Attitudes to transportation issues (car-oriented = high value, values ranging from −17 to 6)	0.070	0.016	0.079	0.0000
Whether or not the respondent has moved to the present dwelling less than 5 years ago (yes = 1, no = 0)	0.394	0.130	0.052	0.0024
Location of the dwelling relative to the closest third-order centre (nonlinear distance function, values ranging from −0.93 to 1.00)	0.267	0.103	0.045	0.0096
Constant	−1.245	0.305		0.0000

$n = 2156$ individuals living in different parts of Hangzhou Metropolitan Area. Adjusted $R^2 = 0.395$.

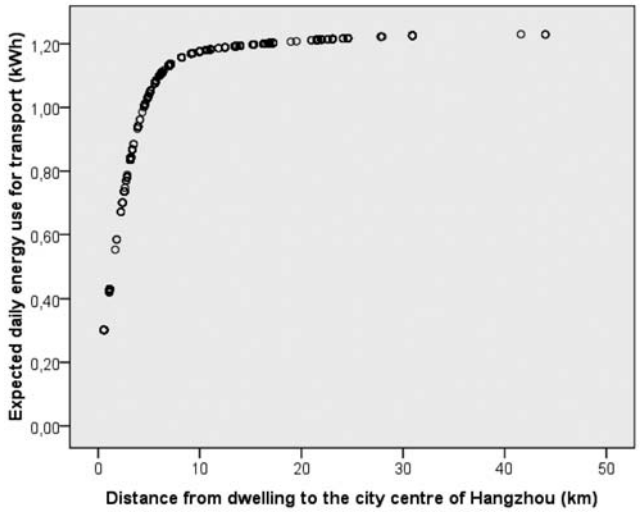

Fig. 6. Expected daily energy use for transport among respondents living at different distances from the city centre of Hangzhou ($n = 2156$).

user of energy for motorised travel. Seen together, the location of the residence relative to the city centre of Hangzhou therefore exerts a much stronger influence on energy use for transport than the location relative to lower order centre categories.

Among the non-urban-structural variables, energy usage appeared to be influenced in particular by availability of a private car in the household, income, and possession of a driver's license. We also find effects of whether or not the respondent has been outside Hangzhou Metropolitan Area during the week of investigation, transport attitudes, and whether or not the respondent has moved to the present dwelling during the past 5 years. Energy used for transport tended to increase if the respondent had a car at her/his disposal, if the respondent held a driver's license, if the respondent's income level was high, if the respondent had been outside the metropolitan area during the week, if the respondent had car-oriented transport attitudes, and/or if she/he had moved to the present dwelling during the last 5 years. Neither of these effects was surprising. The Lambda factor reflected the effect of all the unmeasured characteristics, which were related to the residential choice/transport decision. The coefficient of this factor therefore captured the part of the effect of these characteristics, which was related to energy used for transport [12].

Comparison with the Copenhagen Metropolitan Area Study

Table 3 shows the impact of the location of the dwelling relative to different categories of urban centres in the metropolitan areas of Hangzhou and Copenhagen, respectively, on five main transport variables: total travelling distances on weekdays and at weekends, commuting distances, and proportions of nonmotorised travel on weekdays and at weekends. For Copenhagen Metropolitan Area, the influences of the location of the dwelling relative to the main city centre and the local area

Table 3. The main effects on selected transport variables due to residential location relative to the main metropolitan centre, the closest second-order centre, and closest third-order centre among respondents in the Metropolitan Areas of Hangzhou and Copenhagen

	Proximity to the main centre of the metropolitan area		Proximity to a second-order centre		Proximity to a third-order centre	
	Hangzhou Metropolitan Area	Copenhagen Metropolitan Area	Hangzhou Metropolitan Area	Copenhagen Metropolitan Area	Hangzhou Metropolitan Area	Copenhagen Metropolitan Area
Total daily travelling distance on weekdays	Shorter	Considerably shorter	No clear effect	Somewhat shorter	Solightly longer	Somewhat shorter
Total daily travelling distance at 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-motorised share of travel on weekdays	Considerably higher	Considerably higher	No clear effect	Considerably higher	No clear effect	No clear effect
Non-motorised share of travel at the weekend	Considerably higher	Considerably higher	Higher	Higher	Somewhat shorter	No clear effect

density were combined in order to make the Copenhagen results more comparable to those of Hangzhou. There is a considerable overlap between the local area density and the distance from the dwelling to downtown Copenhagen, as most of the high-density areas are located in the inner city or relatively close to it. It should be kept in mind that the residential locational variables of the Copenhagen area study are somewhat different from those of the Hangzhou area study. For example, both the second- and third-order centres of the Copenhagen area study should probably be considered more local (i.e., belonging to a somewhat lower order in the hierarchy of centres) than the second- and third-order centres of Hangzhou Metropolitan Area, as nearly 20 second-order and almost 80 third-order centres were defined in the Copenhagen Metropolitan Area study, compared to only two second-order and six third-order centres in Hangzhou Metropolitan Area. We still think that the juxtaposition of results from the two studies shown in Table 3 provides a useful background for comparison of the findings.

In general, there are considerable similarities between the findings of the two studies. Both in Hangzhou Metropolitan Area and in Copenhagen Metropolitan Area, living in the central parts of the region was found to contribute to shorter overall travelling distances, shorter commuting distances, and higher share of non-motorised travel. In particular, the location of the dwelling relative to the main centre of the region appeared to influence travelling distances and modes in very similar ways. Moreover, both in Hangzhou Metropolitan Area and in Copenhagen Metropolitan Area, the influences of the location of the residence relative to lower order centres were weaker and less unambiguous than the location of the dwelling relative to the main city centres of the two urban regions. In the metropolitan areas of both Hangzhou and Copenhagen, living close to a second order centre was found to contribute to a higher share of nonmotorised travel at the weekend, but any similar effect on weekdays was only found in the Copenhagen area. In neither of the two metropolitan area, did proximity of the dwelling to a second-order centre appear to influence travelling distances much, except for a slight tendency to shorter travelling distances on weekdays in Copenhagen Metropolitan Area and a slight tendency to shorter commuting distances among workforce participants of Hangzhou Metropolitan Area.

Proximity to a third-order centre showed a few somewhat surprising effects on travelling distances in Hangzhou Metropolitan Area, as respondents tended to travel somewhat longer on weekdays and make somewhat longer commutes, the closer they live to a third-order centre. It should be noted here that the influence of the peripheral location of all the third-order centres has already been accounted for by the variable measuring the location of the dwelling relative to the city centre of Hangzhou. The travel-increasing effects of living close to a third-order centre therefore did not simply reflect the long distances from these centres to the workplaces and the service facilities found in the inner parts of the metropolitan area. Instead, the effect probably reflected the better access to public transport facilities compared to the remaining outer-area, thus making it easier for those who lived close to such a centre to choose workplaces and service facilities outside the local district. The absence of any corresponding effects in Copenhagen Metropolitan Area was probably due to the much higher levels of car

availability in this region. In the outer parts of Copenhagen Metropolitan Area, a large proportion of the residents were able to choose jobs and services outside the local district, even if they lived in areas with poor public transport facilities.

There are also considerable similarities between the Hangzhou and the Copenhagen study in the different ways that residential location influenced travel among different population groups. In particular, this applies to gender differences. The difference in travelling distances between inner- and outer-area respondents was considerably smaller, among women than among men, suggesting that, lower accessibility to private motorised vehicles for women had led to a confinement of the geographical job markets of suburban women, compared to those of men.

The rationales, on which the interviewees of the two studies had based their travel behaviour, are also very similar across national contexts. In both Hangzhou Metropolitan Area and Copenhagen Metropolitan Area, the interviewees' choices of locations for their activities (working, shopping, leisuring, etc.) were based on balancing between a wish to minimise travelling distances and/or travel time, and a wish to choose the best and most suitable facility. In both areas, the prioritisation of the "best facility" rationale appeared to be stronger, the more specialised was the activity and the higher were the interviewees' mobility resources. As a result, this had led, for example, to the above-mentioned longer commuting distances among women than among men.

The rationales for the choices of modes of travel are also similar in the metropolitan areas of Hangzhou and Copenhagen. Notably, in both areas, the rationale to limit physical efforts had led to lower shares of nonmotorised travel for longer trips, and hence, lower shares of walk/bike travel in the parts of the urban region where distances from the dwelling to relevant facilities are longer. The interviews in Hangzhou Metropolitan Area focused on rationales for activity participation, location of activities, travel modes, and route choices, somewhat more in-depth than the Copenhagen area study. Thus, some new or more detailed rationales were encountered in the qualitative interviews of the present study, therefore giving an even more detailed account of the various mechanisms by which residential location had influenced travel behaviour.

For example, a rationale for variety-seeking was found to influence the location of activities as well as the route choices of some of the respondents. This contributed to increased travelling distances beyond what would have been the case if the closest facility or shortest route matching personal quality criteria were always chosen. However, occurrence of this rationale did not weaken the relationship between residential location and travel, as the possibility of choosing alternative routes or facilities without increasing the lengths of the journeys would be significantly higher in inner-city dense environments than in the more thinly populated outer areas.

Another difference between the Hangzhou and the Copenhagen study was the strong emphasis placed by many Hangzhou interviewees on social contact as a rationale for activity participation as well as location of activities. Often, the interviewees of Hangzhou Metropolitan Area carried out various types of leisure activities (e.g., visits to cinemas, restaurants, cafes, or parks) not so much for the activities themselves, but in order to use the activity as a facilitator of social contact. The locations for such activities were to a greater extent based on which would be the most convenient and easily accessible for the group of friends as a whole, rather than judged from an individual perspective or based on, for example, the quality of a restaurant. In the Copenhagen Metropolitan Area study, no corresponding emphasis on social contact as a rationale for activity participation and location was found.

The above similarities between the results of the studies in Hangzhou Metropolitan Area and Copenhagen Metropolitan Area might create the impression that travelling patterns among inner- and outer-area residents of Hangzhou Metropolitan Area were quite similar to those of residents living in the corresponding parts of Copenhagen Metropolitan Area. However, as can be seen in Figure 7, residents of Hangzhou Metropolitan Area travelled, in general, only a small fraction of the distance travelled by Copenhagen Metropolitan Area residents. Although outer-area residents in both metropolitan areas travelled longer than their inner-city counterparts, the difference between the Chinese and the Danish respondents was considerably larger than the average differences between respondents living in the different parts of each metropolitan area. Thus, during weekdays inner-city respondents of Copenhagen travelled on average nearly four times longer than the outer-area respondents of Hangzhou Metropolitan Area. Moreover, whereas travelling distances did not appear to increase to any extent worth mentioning when the distance from the dwelling to downtown Hangzhou increased beyond some 8–10 km, the curve of Copenhagen Metropolitan Area leveled out at a distance from the city centre of more than 40 km. It should be noted that the curves in Figure 7 showed only the influences of the distances from the dwelling to the city

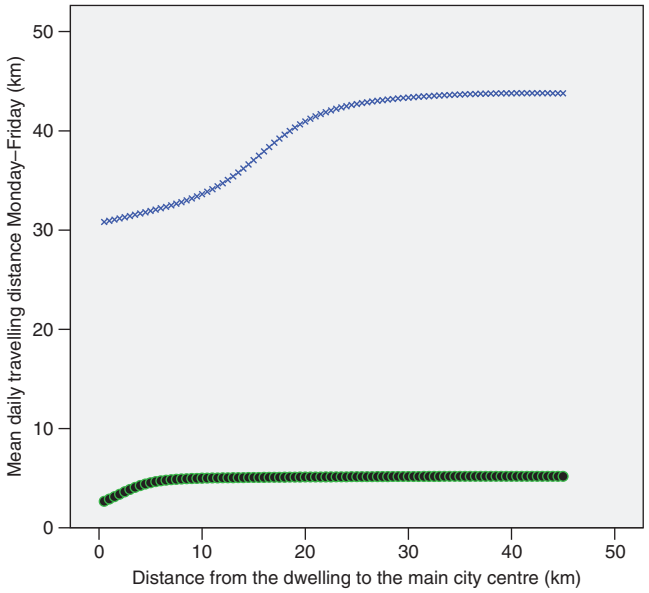

Fig. 7. Expected daily travelling distances on weekdays among respondents living at different distances from the city centres of Hangzhou (lower curve) and Copenhagen (upper curve), controlled for demographic, socioeconomic, attitudinal, and other non-urban structural variables. $n = 2305$ (Hangzhou Metropolitan Area) and $n = 1414$ (Copenhagen Metropolitan Area), $p = 0.0000$ in both cases.

centres of Hangzhou and Copenhagen, respectively. The other urban structural variables have been kept constant at mean values. Since inner-area residents of Copenhagen Metropolitan generally lived closer to second-order centres than their outer-area counterparts, this implied that the travelling distances of inner-city residents of Copenhagen tend to be somewhat exaggerated in Figure 7.

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% had a private car at their disposal. Among the Hangzhou Metropolitan Area respondents, the corresponding figure was 6%. Although car ownership as well as the availability of company cars for private use has been increasing rapidly in China, currently with a doubling of the car ownership rate every 5 years, there is still a considerable difference between China and Denmark in terms of car ownership and usage. Since the rationales influencing travelling behaviour were found to be pretty much the same among the interviewees of the two studies, we might, however, expect that the curves showing the relationship between residential location and travelling distances in Hangzhou would show an upward trend as car ownership increases, and the distance from the city centre of Hangzhou at which the curve begins to level out, would show a rightward shift. In a sustainability perspective, such a development would be highly problematic. An energy-conscious spatial planning should therefore be combined with transport policy measures to limit urban motoring while improving accessibility by public transport. The new metro line currently under construction in Hangzhou would be an important contribution to the latter. However, at the same time strong efforts are being made in Hangzhou Metropolitan Area to increase road capacity to keep up with expected traffic growth (sometimes involving the conversion of bike lanes into car lanes). The latter developments do not point in the direction of an environmentaly sustainable development of the Hangzhou region.

Conclusions

Nearly one half of the World's current construction of buildings is taking place in China, especially in the growing metropolitan areas along the eastern coast. In Hangzhou, 20-year-old housing areas are considered old. This illustrates the rapid pace of change. Compared to cities in Europe and America, where it usually takes several decades to bring about a significant change in the urban form, the much higher pace of construction in Chinese cities implies that the increase in building stock during the next couple of decades may change the spatial structures of these cities dramatically. Thus, there is a high potential for influencing the urban form of Chinese cities in a medium-term perspective (15–20 years) depending on the urban planning and the developmental strategies pursued. Whether the spatial development of Chinese cities takes place in a way contributing to a higher amount of individual motorised transport, or in a way more conducive to public and nonmotorised travel modes, will have an important imprint on China's oil consumption; and hence also on China's degree of self-supply with energy. Of even greater salience is the importance of urban planning in China in the context of global carbon dioxide emissions. In Europe and America, there has been a considerable debate about the impacts of different urban development strategies on energy use and carbon dioxide emissions, and in some countries (e.g., Norway and Sweden) this debate has contributed to a reversal of long-lasting trends of urban sprawl. Due to the higher pace of construction in China, the impacts on the greenhouse gas emissions from alternative urban development strategies are even more important in China than in Europe. From a global climate perspective, energy-efficient urban developmental

strategies for Chinese cities should therefore be among the top items of the agenda.

The results of the Hangzhou Metropolitan Area study showed that it is crucial to avoid urban sprawl if China is to avoid an uncontrolled increase in motorised daily-life travel. In general, accommodating growth in the building stock by means of densification instead of outward expansion is preferable from a transport energy point of view. In particular, densification close to the main centre of the urban region can contribute to reduce the amount of travel and increase the proportion of nonmotorised travel. To some extent, densification close to the centres of second- or third-order towns may also be favorable, in particular if these towns are connected to the main city by means of high-standard public transport lines rather than new motorways.

However, it is important to be aware that densification should not be pursued in isolation, but be accompanied by restrictions on urban motoring (e.g., road pricing), improved public transport services, better conditions for bicyclists and pedestrians, and provision of sufficient green areas and elements. In spite of the high proportion of bike travel in Hangzhou, the conditions for bicyclists are considerably poorer than in Copenhagen. Here, Hangzhou and other Chinese cities might preferentially gain a lot from implementing some of the schemes for bike paths and lanes, similar to those existing in cities like Copenhagen and Amsterdam. Moreover, the recommendation for densification must not be interpreted as a recommendation for converting centraly located parks and hills (e.g., the areas adjacent to the West Lake) into development sites. Although highly important, goals of limiting energy use and motorised urban transport are not the only environmental concerns necessary to be taken into consideration in urban planning.

Compared to the level of affluence among the inhabitants, the present urban form of Hangzhou Metropolitan Area may be considered largely favorable from a perspective of environmentally sustainable transport. Although the residential floor space per capita in Hangzhou Metropolitan Area is more than half that of their Danish counterparts, the inhabitants travel on average only about one-eighth of the daily distance travelled by residents of Copenhagen Metropolitan Area (cf. Figure 7). Admittedly, some of the recent development areas (notably some economic and technological developmental zones) have a location and density that is not very favorable, seen from the perspective of minimising transport energy. However, Hangzhou is still on average a dense city, and most of the outward urban expansion that has taken place in Hangzhou and in the second-order towns has been at fairly high densities, very different from the one-story single-family home development so typical for urban expansion in many American cities.

The main challenge for Hangzhou Metropolitan Area (and other similar Chinese urban areas) is not to make the built-up areas even denser than they are already (although such density increases may also be relevant, in particular in the most central parts); but rather to avoid adopting the low-density, sprawling form of development, typical for American urban regions, and in a more moderate form also for European urban regions during the second half of the 20th century.

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