

The dynamic land use-transport connections and the impacts on travel behaviour: evidence from China

Abstract

There seems to be a consensus on the interdependence between the built environment and transport among academics and practitioners: the evolution of transport could lead to changes in urban form, and the changes in land use could also result in transport consequences. However, there is quite little empirical evidence to verify the hypothesis. In this paper, we aim to examine the dynamic relationship between built environment and transport system, using the case study of Nanjing metropolitan area in China where unprecedentedly fast pace of economic, social and spatial transitions have taken place. Through a comparative study based on the cross-section data of Nanjing Residents Travel Survey (NRTS), 2008 and 2011, it is found, on the one hand, fast motorization and huge investment in public transport have caused the urban form of Nanjing transforming toward low densities expansions with spread-out opportunities; on the other hand, the changing built environment has resulted in enlarged daily travel distance and considerably increase in the use of private cars and the ridership of public transport at the expense of non-motorized transport modes. The paper also finds that the impacts of the built environment are even pronounced in determining travel behaviour in 2011 while the 'classic' socio-demographics of individuals show attenuated impacts.

Keyword: Built environment; Travel behaviour; Dynamic relationship; Urban China

1. Introduction

Urban China is now experiencing unprecedentedly fast pace of economic, social and spatial transitions (Logan 2011; Friedmann 2005; Ma and Wu 2005). The fast economic growth with more than 8% rise every year (CSB 2000-2011) has greatly facilitated individual affluence. According to statistics, the average income of urban resident tripled in the last five years (CSB 2000-2011). Alongside the income rises, car ownership also rapidly increases. From 2005 to 2009, the car ownership ratio has raised from 3.4% to 10.9% in China. The increase in income and car ownership might lead to substantial changes in travel behavior as showed by studies conducted in western countries (Giuliano and Narayan 2003; Susilo and Maat 2007).

Economic growth also resulted in some social consequences. The first is the increasing social inequality caused by the widening gap in income. While majorities have improved their economic status a lot, some minorities, especially the urban poors slid further into economic despair, reflecting the nation's great economic polarization (Wang 2004; Ma and Wu 2005). Another change is 'rise of the individual and the consequential individualization of society' (Yan 2010, p.489). Individuals in Chinese society are getting more free from most previous social categories, such as family, kinship, gender, etc., and show more individualistic traits, such as self-reliance and pursuit of personal interests (Inglehart and Baker 2000). These transformations supported by higher income and car ownership will be expressed in more

differentiated and diversified lifestyles of the individuals which will eventually influence people's travel behaviour.

Besides economic and social transitions, some spatial changes are also observed. The most prominent result is the accelerating urbanisation and expansions of cities. Statistics show that yearly about 12 millions people flood into Chinese cities (CSB 2000-2011). In order to accommodate those huge new urban residents, cities expand rapidly. Taking Nanjing for example, from 2005 to 2009, the city expanded with 85 km² (NSB 2006-2011). Secondly, the fast motorization of transport has fuelled suburbanisation. Emerging luxury villas and gated communities have been built for a growing class of car-driving homeowners in the suburbs (Feng and Zhou 2005). Thirdly, the affluent society also provides people new options and activity opportunities, such as big shopping malls in the suburbs as well as specialized shopping, eating and entertainment districts (Wang and Jones 2002), for instance, *Xintiandi* in Shanghai.

Urbanization and development of functional specialization have offered urban residents more choices opportunities. However, in the meanwhile, they also induce dramatic increase in travel demands and therefore place intense pressures on the urban transport system (Shen 1997; Ng et al. 2010). To alleviate the tension, Chinese cities have encompassed a broad range of urban and suburban public transport investments including subway, light rail and rapid bus transport. It is reported that from 2009 to 2015, China will construct 87 mass transit rail lines, totalling 2,495 km, in 25 cities at the cost of 98.9 billion EUR (Business Sohu 2010). It is to be expected the fundamental changes in the built environment and transport supply will have large consequences for destinations and modes choice.

All three macro transitions, the economic, social and spatial changes, as mentioned above, will have important implications on travel behaviour. We might expect that travel distance will be considerably enlarged and the share of car and public transport use will increase dramatically at the expense of non-motorized transport modes as a consequence of the macro transitions. To date, most of existing literature about the determinants of travel behaviour draws on analyses of cross-sectional data gathered at a single point in time from Western countries. Quite little is known about the dynamic relationship between the built environment and travel behaviour *over times*, especially for the unique context of China where unprecedentedly fast and voluminous changes is occurring, which is never seen in Western countries. The study aims to understand the meaning of the changes of socio-demographics and built environment on travel behaviour, particularly with the expectation it can gain a richer, deeper and perhaps more general understanding of the true nature of the built environment-travel connections.

Drawing on data from the repeated cross-section data of Nanjing Residents Travel Survey (NRTS), 2008 and 2011, this paper will trace the trends of mode choice, daily travel distance and time in Nanjing metropolitan area and examine the impacts of the changing social-demographics and the built environment on above travel behaviour over time. The remainder of the paper starts with a review of relevant literature on the dynamic linkage between built environment and transport in section 2. An overview of the data and methods used is presented in section 3. Then we turn to some descriptive empirical results in section 4, which is followed by a discussion of regression analyses in section 5. The results will be further discussed in the concluding section 6.

2. The dynamic linkage between built environment and transport

There seems to be a consensus on the interdependence between built environment and transport in the transport and geography academia (Giuliano 1986; Badoe and Miller 2000; Wegener and Furst 2009). It is widely believed that the evolution of transport could lead to changes in urban form, and the changes in land use could also result in transport consequences. The most famous case could be Muller's four-stage model of intrametropolitan transport eras and associated urban growth patterns, which demonstrates the persistently strong relationship between the intraurban transport system and the spatial form of the metropolis of the US urban history in the past two centuries: walking-housecar era, the electric streetcar era, the recreational automobile era and the freeway era (Muller 1995). A similar classification could also be found in Newman and Kenworthy's (1996) research, who put forward three types of cities throughout urban history concomitant with the dominant transport modes that is, the walking city, the transit city and the automobile city. This classification again confirmed the closely inter-linked urban form and transport connection.

Actually, the dynamic linkage between transport and land use could be decomposed into two directions: the impacts of urban form on transport and the effects of transport on land use (Wegener and Furst 2009). For the influence of urban form on transport, the land use locations of activities in space, together with the transport resources connecting them, impact people's daily activity (travel) pattern which is expressed as flows on the transport network, therefore affects the transport system. And for the effects of transport on land use, it is the characteristics of the transport systems which configure accessibility-the ease of moving one place to another-through which the locations of activities and the land use pattern are influenced (Giuliano 1986). Jointly, these two directions form the so called 'land-use transport feedback cycle' which is commonplace in the planning literature (Handy 2003; Wegener and Furst 2009).

Both of the two directions have attracted numerous attentions from researchers. With respect to the influence of the built environment on transport, in the last few decades, a spate of studies originating from a diversity of sources and encompassing a variety of geographic scales and locations has contributed to this theme (Ewing et al. 2001; Zhang 2004; Susilo and Maat 2007). Those studies observed that various aspects of built environment have impacts on travel patterns, albeit in some cases only limited effects could be found. Compared with the effects of urban form on transport, the reverse impact from transport to land use is relatively less well known (Wegener and Furst 2009). Research in this domain is mainly concentrated in the influence of two transport means: automobile (highway) and transit on local and regional accessibility, redistribution of employment and population, economic consequences, etc. (Boarnet and Chalermpong 2001; Cervero and Landis 1997; Nelson and Sanchez 1997). They observed both highway and transit operation have been a necessary but not sufficient condition for the scale of suburban growth, low development density, dispersed employment and population and urban sprawl (Handy 2003). The land use-transport connection developments are also related to some social consequences (Preston and Rajé 2007). The famous 'spatial mismatch hypothesis' is the case in point, which addresses the problem that the social vulnerable groups, especially the urban poor, get economically and socially excluded in the urban form developed based on fast transport mode, especially, private car (Kain 1992; Gobillon, et al. 2007).

To date, there is quite limited research focusing on the dynamic relationship between land use and transport *over times*. Susilo and Maat (2007) examined the influence of the built environment on commuting parameters at three points in time: 1995, 2000 and 2005 in the Netherlands, and found that the contribution of built environment in commute distance and commute mode choice models has increased. Through a comparison of commuting duration in 1977 and 1996 in Quebec city, Vandersmissen, et al. (2003) found that due to decentralization and the scatteration development, accessibilities measuring the degree of mutual co-location of jobs and housing have decreasing effects on commuting time. With respect to the research in China, to the best of our knowledge, there is no literature examining the dynamic linkage between land use and travel. The limited research draws on analysis at single point of time. For example, Pan et al. (2009) examine the impacts of urban form on travel behaviour in four neighbourhoods of Shanghai and find that people of pedestrian/cyclist-friendly neighbourhoods travel shorter distances than those of other types of neighbourhoods. Wang et al. (2011) reported that residents of the newly developed built environments, such as commodity housing community and social welfare housing community tend to travel longer distance and time with more private cars than people living in traditional *danwei* community in Beijing.

Our review of the literature has revealed that few studies have focused on the dynamic relationship between socio-demographics, built environment and travel behaviour *over times*, especially in China. In the current paper, we have the following hypothesis: due to the expansion of the metropolitan area, the increase in car ownership and huge investment in public transport, especially in transit system, it is expected daily travel distance will be enlarged accompanied by the increase in the use of private cars and the ridership of public transport while travel time remains steady according to 'time budget hypothesis' in Nanjing metropolitan area, just as what have taken place in western counties; the 'classic' socio-demographics are expected to be less influential in determining travel behaviour owing to the more individualized society; as a result of the constructions of new metro lines as well as more diversified group composition in built environment in terms of density and mixed land use compared three years ago, the built environment is expected to get even weight in influencing travel behaviour.

3. Research design

3.1 Data and case study area

Our case study area is Nanjing metropolitan area. It is the capital of Jiangsu Province, and the second largest commercial centre in East China. As a former national capital, the city has a prominent place in Chinese history and culture (Cotterell 2008). Our data on travel behaviour in Nanjing results from the Nanjing Residents Travel Survey (NRTS; in Chinese: Nanjingshi jumin chuxing chouyang diaocha). It is conducted on all Tuesdays, Wednesdays and Thursdays in June every year. Our sample contains 2991 cases in 2008 and 1990 cases in 2011. The big difference in sample size is because that in 2008, Nanjing Transport Planning Committee made so called 'Comprehensive Transport Planning', and thus more samples are conducted. The reason why we choose 2008 as the start point is because since that year, the suburbs of Nanjing city have been included in the survey.

One might argue that the time period is too short to have sufficient changes for comparing. However, urban China is experiencing fast transitions in economic, spatial and social aspects nowadays and the speed for Nanjing, one of the pioneering cities in the east part of China, is even notable. Table 1 shows some of the basic socio-demographic, the built environment and public transport supply information in Nanjing in 2008 and 2010. Because the statistical data for 2011 is not yet released, here we use the data of 2010 by which we can see that huge changes are already observed. As indicated by Table 1, the pace of built-up area increase is much faster than that of population, which results in a large reduction in population density. Household car ownership increases at a speed of more than 2% every year which could be the consequence of the rapid rise of income. With regard to public transport, both bus and transit supply increase considerably in only two years. It is needed to note that in 2008 there is only one metro line while in 2011, there are two more. The built environment changes can also be found in figure 1.

Insert Table 1 here

Insert Figure 1 here

3.2 methods

In investigating the changes of daily travel behaviour, what are the appropriate characteristics? Daily travel behaviour can be measured in terms of travel frequency, distance and time spent travelling, and mode choice. Travel frequency captures the total number of activities conducted, but provides limited information because of the small variations between individuals (Giuliano and Narayan 2003) and is thus excluded in our analysis. Existing literature shows that mode choices vary substantially with travel purposes (Zhang, 2004). In our analysis, we split mode choice into two sets: mode choice for commuting and for shopping-leisure trips (including shopping trips, social visits, sports, culture, recreation, waling or cycling around). The daily travel distance can fairly measure the 'everyday competence' or the ability to accomplish maintenance activities and to participate in social and economic activities of a person (Mercado and Paez 2009) and total daily travel time represents an indicator for the ability of people to move through the city for pursuing their daily life. In sum, in this paper we will focus on four travel characteristics: mode choice for commuting, mode choice for shopping-leisure, daily travel distance and time.

The general model for travel behaviour is:

$$Y=f(X, B, \mu)$$

Where, Y=daily travel behaviour; X= attributes of the individual; B= attributes of the built environment; μ = unobserved factors. The X variables capture the main socio-demographic characteristics related to travel. In this paper, we include gender, age, education level, household car ownership, household composition and household income in the regression models. The built environment variables including in the paper are population density, access to transit measured as distance to the nearest metro station and land-use mix (add note here, for methods of the calculation of land-use mix).

The present research intends to examine the changing impacts of socio-demographics and the built environment on travel behaviour between year of 2008 and 2011. To do so, the two sets of observations are pooled into one set. Here, the 2991 observations for 2008 are added to the 1990 observations for 2001, producing a pooled sample of 4981. Dummy variables are then

used to test both independent and first-order interaction effects (Giuliano and Narayan, 2003; Vandersmissen, et al.; 2003) as shown in the following equation:

$$Y=f(X, B, \mu, XR, BR, R)$$

Where, R= yearly dummy, which equals 0 for 2008 observations and 1 for 2011 observations, are used to test the difference between the intercepts. XR and BR are the interaction variables of the original independent variables multiplying by the yearly dummy variable R, which are used to test the difference between the regression coefficients of each variable.

4. Descriptive analysis

Insert Table 2 and Table 3 here

In this section, we show the changes in mode choice, daily travel distance and time by some cross-tables. The discussion here serves as a background of multivariate analysis.

As demonstrated in Table 2, big changes in mode choice have occurred in only three years time. The use of public transport and car both increase by 4 percent at the expense of decline of cycling. These changes are duo to, firstly, the great increases in public transport supplies in both bus and metro systems and fast motorization, as shown in Table 1. Secondly, the fast urban expansion and suburbanisation has enlarged the average trip distance which stimulate use of fast transport modes.

Compared with 2008, travel distance shows a sharp increase of 0.8 km per person per day. Checked for specific travel purposes, it shows the increase mainly stems from commuting trips. This might be caused by urban expansion and residence suburbanisation. As shown in Table 1, Nanjing metropolitan area has been extended with 32 km² in only two years, which leads to increase of travel distance. The statistics show that in 2010, the population of the central part of the metropolitan area decreased about 5 000 person while in the suburbs, the population increased with 30 000 person (NSB 2006-2011). Economic reconfiguration, fast motorisation and expansion of infrastructure are the main reasons for this spatial redistribution (Feng and Zhou 2005). Nanjing is still at an early stage of suburbanization so far, only residences of the urban population moved out to the suburbs while employment is still concentrated in the central city. This causes substantial increase in commuting distance from 3.8 km to 5.6 km (Table 3).

Unlike with mode choice and travel distance, total daily travel time shows negligible change in the last three years. This seems to be in line with the so called 'travel time budget' hypothesis (Zahavi and Ryan 1980). Table 3 shows that the stable total travel time is actually a react of a large increase in commuting time and a decrease in travel time for shopping and other travel purposes.

Turning to specific transport modes, all transport modes show increase in travel time. The exception is public transport which could be the consequence of the operation of two new metro lines in Nanjing which greatly improved the speed of the public transport system. Our dataset shows that trip time of public transport decreased from 51.7 to 43.9. The time for commuting by car increased the most, which might be caused by the increasing car ownership

and usage. Less time is spend on shopping, leisure and other purposes by car which might be a reflection of the chaining of these trips.

In sum, in only three year time, large differences are already shown in mode choice and travel distance. In the next section, we will employ regression analyses to reveal what are the reasons for those changes. We have conducted regression models for mode choice and travel distance and time. However, in the travel time model, quite few variables have significant changes, moreover, the information of those significant result could be sufficiently covered by the models of travel distance and mode choice. Also for the reason of limited space, here we only demonstrate models for mode choices and travel distance.

5. Multivariate analysis

5.1 Mode choice for commuting trips

Insert Table 4 here

As indicated in Table 4, the dummy variables of the year of 2011 for both walking, public transport and car are positive and significant, meaning that the possibilities that people choose these transport modes for their work trips increase compared with cycling when independent variables are zero. This is in line with the descriptive result that cycling decreases the most among the four modes. The dummy variables here capture the many differences between the two points in time that are not explicitly controlled for in the model. For example, the road environment is becoming more and more crowded and unsafe for cycling, owing to more cars flooding into the roads which are mixed used by both bicycles and cars (Li et al. 2010). This change will make people hesitate to cycle. In this section we only focus on significant parameter for changes.

There is only one variable having significant change in the column of walking. The effect of distance to the nearest station on choosing walking relative to cycling decreases significantly. In 2008, as there is only one metro line, stations are located at the employment and shopping centres where all kinds of facilities distribute compactly. Consequently, the nearer to the metro stations, the high propensity to walk. But in 2011, more metro lines and more stations were constructed. Some new stations are no longer located at employment and shopping centres. For instance, some of them were located in residential areas which might be far away from employment centres. People living there therefore have to commute by other means rather than walk. For this reason, the impact of access to metro station diminishes.

With respect to public transport, women are less likely to take public transport for commuting than men, but in 2011 the gap was significantly narrowed. This might be interpreted by the diminishing gender difference in commuting distance. Our dataset show that the gap decreases from 0.6 km in 2008 to 0.3 km in 2011. The diminishing gender differences actually is the result of more provision of daily care facilities for children and elderly (Goh 2009), more higher educated women and the emancipation of the society (Leund 2003), which all relieve women from heavy household task and allow them to have the same jobs as men. For the households with cars, the propensity of using public transport for commuting increases significantly. In Nanjing most households have only one car which means other members except the one who use car have to commuting by public transport. The impacts of

household composition do not change so much with only couples having significant increases in the usage of public transport. Since the big increases in public transport supply have encouraged all people to commute with public transport, especially for couples who confront less time pressure and easily make coordination with family members, however, public transport is less attractive to core families, due to the inconvenience to combine other trips such as sending child to school with commuting. Only one measure of built environment has significant changes: population density shows decreasing negative impacts on the choice of public transport. The reason is that recent public transport provisions are located in the suburban communities where the density is not so high, which makes density not so efficient indicator for public transport use as before.

Gender differences also significantly diminish in choosing private car for commuting in 2011. Again, the decreasing gap of commuting distance between men and women might account for this change. The gap between people of more than 50 years and young people in using private car is significantly widened due to the lower rate of car and licence ownership of the employed elderly. With respect to the effect of income, people of low income are less likely to commute by car than they were three years ago relative to high income which is a consequence of relatively low car ownership amongst low income category. Couple is the only household type showing significant increasing in choosing private car in household types. The gap between core families and couples is narrowed, which might be a consequence of the complex travel patterns and tight time budgets of families. As for the built environment, in contrary to the changes in public transport, population density is even more influential in choosing private cars for commuting. The emergence of lower density communities in the fringe of the city in which people mainly use car for commuting to cover the long distance might account for the effect (Zhou and Logan 2008). People who live far away from the metro stations are more likely to use cars for commuting than they were three years ago. This could be the case that the places far away from metro stations are actually the places far away from employment centres. Consequently, when public transport is not an option, people will rather likely commute by cars.

5.2 Mode choice for shopping-leisure trips

Insert Table 5 here

Similar to the model for commuting trips, the dummy variables of 2011 for walking, public transport and car are significantly positive. The same reason could be found. The other significant change appearing in the column of walking is from people of more than 50 years old. Compared to three years ago, people of this category are more inclined to choose to walk instead of cycling. This is not surprising, given that the elderly should be more sensitive to the 'cycling-unfriendly' road environment changes mentioned above (Mercado and Paez 2009).

With regard to public transport, people of more than 50 years old again show increasing propensity to use public transport instead of cycling compared with three years ago. The improved public transport service could have changed their perception of using public transport, and consequently more use of public transport are observed. A short distance to the nearest metro station has a strong positive impact on the use of public transport, and in 2011 the impact is enhanced. The reason might be that more shopping and leisure centres are linked by metro lines compared with three years ago, which induces more people to use it for shopping and leisure trips.

More significant changes appear in car use. Females are more likely to use car for shopping and leisure than three year ago, which partly is the result of a dramatic increase of driving license from 13% to 21% among women. The difference in car use for shopping and leisure trips between people of more than 50 years old and the young people is enlarged in 2011. In the three years, more rural resorts are emerging in the fringe of the metropolitan area to provide opportunities for the urban residence to experience farm life (Gao et al. 2009). Compared with the elderly, young people are more likely to drive car there for recreational activities.

The importance of household income is more pronounced in 2011 on car use. The difference between people of high income and middle income is decreased while the gap between people with high income and low income was deepened. For the middle income people, the relatively lower cost for owning and using private car compared with their income increase, encourage them to own and use more of cars (Ng et al. 2010). But for the low income people, especially for the urban poor, things go the other way around. Due to the increasing inflation, the increase of transport cost is actually relative higher than their income increase. Compared with three years ago, extended families are more likely to use car for shopping and leisure activities relative to cycling. This makes sense since: extended families have more financial resources to afford the ownership and use of car than core families. Cars are more suitable for complex travel patterns in extended families than other modes.

Compared with the commuting trip model, the impact of the built environment is less changed in affecting car use. The only significant change is the enhancement of the positive impacts of distance to the nearest metro station, suggesting that people living far away from metro station are even more likely to choose car for shopping and leisure trips. The reason could be same as that in commuting trip model. Generally, the results here indicate that when public transport is not an option, people will choose the car if they live far away from city centres.

5.3 Daily travel distance

Insert Table 6 here

Table 6 shows the regression result for total daily travel distance. The last two columns indicate the changes of confidents of independent variables, which actually are our main focus. The Yr 2011 dummy has a significant positive coefficient as expected and of reasonable magnitude. Like the dummy variables in the regression models of mode choices, it also captures the many differences between the two years not explicitly controlled for in the model, for example, social changes in values (more intention to have out-home activities due to the tendency toward recreation and consumerist society (Chao and Myers 1998; Stockman 2000)), expansion of the metropolitan area (longer trip distance), relative low transport cost compared with income increase in general (financial support for longer travel), and transport supply differences (more bus lines available), etc, which contribute to the longer distance in 2011.

With regard to socio-demographic attributes, people of more than 50 years old travel significant longer than they were three years ago. Due to the social changes mention above, people tend to have more out-home activities than before, and the elderly confront less time constrains which ensure them travel more (Mercado and Paez 2009). Household car ownership shows no significant impact on distance travelled in 2008 but significant positive

influence in 2011. This might be related to the change in value of use of car from status symbol to instrumental purposes (Li et al. 2010). Similar to model for shopping-leisure trips, the two categories of household income changes in different directions. The same reason could be expected. With respect to household structure, couples travel significant longer distance than they were three years ago relative to core families. This could be an effect of social changes mentioned above that couples who live together are more inclined to make more out-of-home activities, while for the adult member of core families, the presence of a child largely offsets the effect.

All of the three measures of the built environment have expected impacts on total travel distance. The significant coefficient of the interaction term of population density indicates that it has larger impacts compared with three years ago. Two possible reasons might be given. First of all, population density can be considered, to some extent, a surrogate of distance to city centre (Levinson and Kumar 1997). Due to the concentration of jobs in city centre and residential suburbanization, commuting distances have increased. Secondly, during the three years, more lower density and relatively mono-functional communities are developed in the suburbs (Zhou and Logan 2008). Compared with high density communities, these low density areas are more diversified in that high density places are more similar with each other in levels of accessibility, transit availability, etc. (Giuliano and Narayan 2003). The more diversified group compositions increase the importance of population density. People living near to metro stations seem to be inclined to travel larger distance. Those two new metro lines in Nanjing have created network effects that have greatly promoted the accessibility of more places and induce people travel longer distance.

6. Conclusion and discussion

The present study set out to explore the changes of mode choice, travel distance and time in Nanjing metropolitan area. As expected, impressive changes have occurred in only three years. The ridership of public transport and use of private cars increased sharply at the expense of cycling. Meanwhile, daily travel distance also enlarged considerably. Through analysis, it is found that those changes can be partly explained by two interrelated causes. On the one hand, economic development results in individual affluence, fast motorization and expansions of infrastructure, which provide more opportunities to use the fast transport modes. Motorization and investments of infrastructure, on the other hand, fuel expansions and suburbanization of the metropolitan area, which increases the average travel distance and in turn facilitates the need to use fast transport modes. The results here lend some supports to the hypothesis of Muller (1995) which assumed that urban form and the dominant transport systems are dynamically linked as mentioned above, It is worth noting that the significant yearly dummy variables in the regression models for travel distance and mode choice indicate that the changes in travel behaviour are also partly the result of other period-specific factors that not directly incorporated in the models. For instance, the lower transport cost relative to the income increase provides more financial resources for ownership and use of private car and longer travel.

Our analyses support the hypothesis that the classic socio-demographics of individuals show attenuated impacts on travel behaviour. The economic growth and spatial transformations have provided people more opportunities in terms of more financial resources, more

specialized destinations, and more transport mode choices, etc. which make it possible that majority of the population to choose from various options in their consumer, specifically travel, behaviour and lead to more individualized and contextual behaviour. Many researchers have claimed that some of the objective socio-demographics such as gender, age and education, will lose weight in determining travel behaviour and make way for the subjective elements including personal attitudes, values and preference and wishes (Scheiner 2010). The current empirical study supports the hypothesis. In our model, the travel differences caused by 'classic' socio-demographic such as gender, education and age are diminishing. Our results here suggest that to make precise projections of travel behaviour of metropolitan residents in the future as the base for policy making, it is not insufficient to count only on the conventional factors, other lifestyle-oriented variables including personal attitudes and preferences, etc. are also needed.

In contrast to the increasing influence of socio-demographics on travel behaviour, the built environment are even pronounced in determining travel behaviour in 2011, also as expected. This could be the result of more diversified group compositions in urban configurations of 2011. For instance, communities in 2008 show more similarities with each other in built environment in terms of high population density. While in 2011, more low density commutes are developed and consequently, more diversified communities is emerging. Since land use, which is considered as effective means to achieve desirable transport objectives is premised on that residents' travel behaviour can be influenced by the regulation of land use patterns, our results here have implications for transport policy. The increasing impacts of the built environment on travel behaviour enhanced the premise and therefore provide theoretical base for planning initiatives.

However, the picture of urban China also shows some dissimilar to western countries. Due to the urban form of Nanjing transforming toward development with spread-out opportunities, the number of economic and social opportunities in the same radius decreases and causes social inequalities for social vulnerable groups, especially the urban poor, in that less economic and social opportunities can be accessed within the same distance compared 3 years ago. Unlike western countries, which developed at a much lower speed and have time to relieve the tension of the mobility inequality between different social groups, the massive changes taken places in a very short time in urban China make them confront even severe situation. More attentions should be paid to promotion of the mobility of special social groups and the reduction of the transport-related social exclusion in the future to guide the development towards socially sustainable direction.

Another negative consequence of the current developments is the transformation of land use-transport system of Nanjing metropolitan area towards a direction away from environment sustainability. Fast motorization, more use of private cars and longer travel distance all contribute to the increasing emission of CO₂ and noise and energy consumptions. Statistics show that China has already become the world's single largest emitter of greenhouse gases (International Energy Agency 2010), while the country is still in the early stages of motorization, with just 32 vehicles per thousand persons in 2007, compared to 595 per thousand persons in Japan and 820 in the United States (World Bank 2010). How to guide the Chinese cities to develop in a sustainable way will become the biggest challenge for the policy-makers in urban China.

As mentioned in the literature review, Muller has identified four eras of land use pattern in line with dominated transport modes for the US urban development history: the 'Walking-Horsecar Era', the 'electric Streetcar Era', the 'Recreational Automobile Era', and the 'Freeway Era'. The theory is also suitable for the urban development of some European countries. However, when applied into Chinese cities, the four-stage model needs modifications. Due to the fast and massive urbanization, industrialization and motorization coming at the same instant, we might see that urban China seems to be compressing these four eras into a single hybrid. It is possible that the urban form of Chinese cities will be much more fragment in land use configuration than their western counterparts: some parts of the cities is 'walking-cycling' city, some parts 'transit city' and other parts automobile city shaped by the dominated transport modes-walking (cycling), transit and automobile-respectively.

The fast and massive changes in economic, social and spatial dimensions have made China a quite unique and complex case and pose great challenge for the policy-makers. Thanks for the strong capability of controlling land and other resources (Pan et al. 2009), the government can quickly and effectively respond to those changes and resolve the problems, to some extent, through land use planning and other policy instruments. However, as there is always lag between planning and the reality as well as uncertainty of planning outcomes, there still are big risks that the Chinese cities go in an unintended and unsustainable direction.

The research has some obvious limitations. For instance, we only have a three year period, which might be too short for the social changes, especially the changes in people's world view and perception, though economic changes are considerable. It should be more valuable to investigate the dynamic connections between socio-demographics, built environment and travel behaviour in a long term. Another shortcoming is that we only include the conventional 'object' socio-demographics in our models with no subject lifestyle-oriented variables, such as personal values and preferences. Since the society is transforming toward more individualized settings, those variables are expected to explain more of people's behaviour. Therefore, in the future, more research that incorporates those effects is needed. Despite these limitations, however, the results provide a pioneer research for systematic comparative analysis on travel behaviour and its determinants over times.

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