THE IMPACT OF LOCAL DEVELOPMENT DENSITY ON HOUSEHOLD LOCATION AND TRAVEL DISTANCE

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ABSTRACT

This paper is aimed at analysing the impact of development density on demand of household location and travel distance at a neighbourhood level. Land-use transport models have significantly contributed to regional analysis to empirically test the sustainability impacts of spatial and transport policies. However, little research has been made for a micro-scale approach to analysing the impact of neighbourhood design on location and travel. Neighbourhood design could affect local travel distance by changing household location according to local attractiveness. In this paper, empirical analysis is carried out to test the neighbourhood impact of local development to introduce different levels of density. A micro-scale land-use model compatible with a regional model is applied to estimating local household location in an urban core and fringe areas in Cambridge, UK. By comparing the estimated household location with the Census data, it analyses households' preferences to local factors associated with density. Then, urban design options are tested with the model for the impacts on household location and travel distance. This analysis shows the different impacts of development density in urban design between the areas.

Keywords: Urban Design and Transport Planning, Neighbourhood Spatial Analysis, Land-use Transport Model, Development Density, Local Household Location and Travel

INTRODUCTION

The effective integration between land use and transport has been one of key approaches to improving sustainability. In land-use transport planning, high-density development along with public transport improvement is generally promoted for a compact city to reduce travel distances and environmental emissions from transport. Land-use planning based on development control has contributed to controlling urban sprawl. However, it has often caused an imbalance between the supply and demand of development. In the UK, expensive urban rents in some cities are attributed to development control through green belts, which generates dense built-environments in urban areas. The limitation of densification has been recognised and more attention has been paid to the possibility of development within green

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belts (Barker, 2006). This raises a question of whether high-density development is effective for both economic and environmental benefits. Accordingly, spatial planning has become important in its role to allocate developments to achieve the benefits taking account of the demand of urban growth with multi-scale approaches.

Land-use transport models have been applied to empirically testing the policy options of spatial planning at a regional level, considering the interaction between supply and demand of the land-use and transport markets. The SOLUTIONS project (2009) tested the effects of spatial development options in combination with transport policy options in the regions of London, Tyne and Wear and Cambridge, UK, in terms of economic, environmental and social impacts. The analysis using the spatial model examined the effects of spatial development options, such as compaction, dispersal and planned expansion options, by changing the distribution of future development of dwellings and employment floorspace into the urban and suburban areas of each region. Nevertheless, according to the results, it concluded that the spatial development options for next decades have limited impacts on the region. Thus, the ReVISIONS project[2] has been set up to explore the possibility of alternative options to introduce infrastructures with new technologies suitable for different levels of development density on different scales for the benefits.

On the other hand, less empirical analysis has been carried out in terms of a micro-scale approach to analysing the effect of design for a neighbourhood. The relationship between urban design and travel behaviour has increasingly received attention at a neighbourhood level. High-density development has currently been a key interest in urban design as represented by the design concept of New Urbanism (CNU, 2002). The density of development has been recognised as one of the potential determinants of travel patterns by mode in a neighbourhood (Cervero and Kockelman, 1997). The impact of development density on travel distance has been tested more in the US cities where the density of built environments is much lower than European cities (Giuliano and Narayan, 2003). However, the relationship between development density and travel patterns are still inconclusive in empirical studies suggesting that travel patterns are affected not by land-use characteristics of a neighbourhood but by socio-demographic characteristics of residents (Boarnet and Sarmiento, 1998). Therefore, it is useful to analyse the impact of neighbourhood characteristics on household location by household type in order to explore the relationship between neighbourhood characteristics and travel patterns.

In the empirical study of household location, there has been a lack of consideration to both regional and local factors in terms of their impacts on the location choice. The neighbourhood analysis has a limitation in considering the regional context of a neighbourhood. On the other hand, while household location choice has been analysed within land-use modelling, neighbourhood characteristics have rarely been considered in regional studies. Currently, land-use models have been developed as more micro-scale model (Veldhuisen et al., 2000; Waddell, 2002; Strauch et al., 2003; Salvani and Miller 2005). Many of these models have taken an activity-based approach by disaggregating activities' behaviour so as to analyse the

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[2] http://www.regionalvisions.ac.uk/ReVISIONS/Home.aspx

aggregate pattern of complex behaviour. The spatial scale of an analysis unit has also become smaller with an urban-grid cell as urban models increasingly take a cell-automata approach along with an agent-based model (Batty, 1997 and 2005). Nevertheless, the spatial disaggregation is unlikely to sufficiently capture neighbourhood characteristics of a built environment to represent an urban design option. The recent development of GIS can provide such detailed data of neighbourhood characteristics, which enables a micro land-use model to analyse an urban design option at a neighbourhood level.

While land-use transport models have analysed travel accessibility as a key determinant of household location choice at a regional level, local household location may be affected more by neighbourhood characteristics as local attractiveness. Neighbourhood characteristics have been empirically analysed with GIS as for their impacts on house prices so as to explore households' preferences. Empirical studies have tested neighbourhood characteristics associated with development density and often found negative impacts of high density on house prices due to the values of open space and landscape (Orford, 2002; Sander and Polasky, 2009). This approach has been applied to analysing the effect of high-density development for New Urbanist development on house prices (Song and Knaap, 2003). These results imply that an urban design option could change household location through changes in local attractiveness.

This paper is aimed at analysing the impact of urban design options on demand of household location in a neighbourhood area and assessing travel distance of local shopping trips attributed to the location within the neighbourhood. Among types of local trips, shopping trips are selected for analysis because they are likely to generate the longest distances in central places. A key research question is whether high-density development would always be the best option to reduce local travel distance, considering the impact on household location. The impact of development density on household location may vary depending on household type. While high-density development is suitable for small-size households without cars, large-size households with cars may prefer low-density development with larger houses and gardens. This different impact on location by household type could affect household travel distance at a neighbourhood level. Travel distance of a larger-size household may be longer because of more persons to travel in a household. Although high-density development could reduce travel distance by locating more households closer to a key destination in a neighbourhood, it might fail to attract large-size households. Accordingly, there could be the potential of low-density development to reduce local travel distance by locating large-size households closer in a neighbourhood.

In this paper, empirical analysis is carried out to examine the impact of development density on local household location and travel distance for shopping within a neighbourhood area, considering different preferences by household type in terms of household size, socio-economic status and car ownership. This paper illustrates the neighbourhood impact of development density, focusing on dwelling types, site coverage and garden availability as key local factors. This analysis employs a neighbourhood-scale micro land-use model compatible with a regional-scale strategic model, in which location choice of an individual household for each dwelling in a neighbourhood is modelled with both local and regional factors. The model is applied to two different types of development areas, an urban core area and an urban fringe area in Cambridge, UK, and calibrated with the Census neighbourhood data to identify the preference of households for the local factors. Then, different urban design options based on development density are tested with the model for the impacts on local household location and travel distance within a neighbourhood area in order to address the differences of the impacts between design options and between different areas.

MICRO LAND-USE MODEL FOR HOUSEHOLD LOCATION

The Aim of the Model

A land-use transport model is a well-established integration model between a land-use model and a transport model. With an econometric approach, a land-use model estimates the future distribution of activities within a region, such as households and employment. It considers the interaction between their demand for location and the supply of it, such as dwellings and non-domestic floorspace, under different economic and policy scenarios. In a land-use model, trips for work, shopping and other business are generated by the spatial linkages between activities. A transport model is applied to estimating costs of these trips and transport accessibility. The integration model uses transport accessibility as a key factor affecting location demand for the interaction between land-use and transport markets. This model has often been focused on regional accessibility, while local attractiveness is fixed.

This study pays more attention to modelling residual local attractiveness by introducing local factors to the location-choice process of a land-use model. The impact of local factors on location choice is analysed with a micro land-use model to estimate household location at a neighbourhood level in a consistent way with a strategic land-use model at a regional level. The SOLUTIONS project has developed the micro land-use model (Caruso, 2005) to be consistent with the equilibrium-based strategic model, MEPLAN (Echenique et al., 1990). The MEPLAN strategic model estimates the numbers of households by type and employment by sector depending on their living and production costs, including rents, in each ward-level strategic zone. These costs are estimated by the model through the balance between demand and supply, using the inputs of regional socio-demographic information, spatial development patterns and transport costs. It considers the interaction of location choices between households and employment, following the Lowry (1964) approach. As a complementary model to the strategic model, the micro model is aimed at estimating residual attractiveness associated with the local factors of neighbourhood characteristics within a strategic zone, which cannot be explained by the strategic model.

In this study, the micro land-use model is applied to testing an urban design option for the impact on household location in real neighbourhood areas. The micro model estimates household location choice within the strategic zone at a dwelling-property level with the bid-rent approach (Alonso, 1964). In this model, both regional and local factors are taken into account by using the outputs of the strategic model and the data of neighbourhood characteristics associated with density as the inputs to the micro model. Residual attractiveness can be estimated by the micro model based on the impact of local factors on household location, which is applicable to the strategic model as part of factors affecting location choice at regional scale. Although it is extremely difficult to accurately estimate household location on the micro scale because of so many factors affecting location choice, the focus of this study is more on the impact of selected local factors on household location than the accuracy of estimation of location.

The Theory of the Model

The micro land-use model applies the consistent theory of a behavioural model in the strategic model. Households are assumed to obtain utility by consuming housing *H* and other composite good *Z* and minimise their expenditure of living cost *Y*, which consists of dwelling rent *R*, expenditure *G* for daily goods, such as financial, retail, education and other services, and composite good expenditure *Z*, in the constraint of utility budget *U*. *R* and *G* are endogenously estimated by the strategic model through the interaction between supply and demand in the land and labour markets. Based on the assumption, the strategic model estimates *Y*, determining the levels of household consumption for *H* and Z depending on the parameter γ of housing consumption.

In the micro model, the estimated output *Y* and *G* of the strategic model are kept same as the regional input to the micro model and, thus, the micro-level dwelling rent of each property is estimated considering the local inputs of neighbourhood characteristics *A*. The micro model assumes that households would maximise their utility *U*, incorporating the impacts of local factors *A*, in the constraint of the expenditure budget *Y*. This is the different interpretation of behaviour from the strategic model based on the same theory. The gap between the utility budget of the strategic model and the estimated utility of the micro model represents residual attractiveness for households associated with the local factors.

$$\text{Max} \quad U = Z^{1-\gamma} H^{\gamma} \prod_k A_k^{\alpha_k}$$
$$\text{s.t.} \quad Y = G + R(A_i) \cdot H + Z$$

The micro-level rent has a variation depending on the local factors compared with the average rent of a strategic zone. This study estimates the bid rent by each household according to their utility. Assuming that each household type has the same utility level, the micro model takes the utility budget U_s of the strategic model as the initial value of utility including local attractiveness. The bid rent is estimated in such a way that the better local factors are compensated by the rent premium. The parameter α for the impact of local factors on the rent needs to be calibrated, where the input of local factors are standardised to values between 1 and 2. The socio-economic information of expenditure level also affects the bid rent, which differentiate the rent by household type. Based on these inputs, the bid rent can be obtained for each household type by solving the utility maximisation problem, as below.

$$R(A_i) = (Y - G)^{1/\gamma} U_s^{-1/\gamma} \prod_k A_k^{\alpha_k/\gamma} \gamma (1-\gamma)^{(1-\gamma)/\gamma}$$

This micro model uses the bid rent to estimate household location by allocating the total number of households by type into each dwelling in a neighbourhood area. For the bid-rent approach of household allocation, it employs a simple way by making following assumptions. The first key assumption is that a dwelling would be allocated to each household in a household-type group being the highest bidder. While the behavioural model estimates the rate of sharing a dwelling with the housing consumption *H*, it is not used by the micro model in estimating household location. As another key assumption, each household would choose a dwelling with the highest bid rent because of their demand for better local factors. In order to represent the complex behaviour of disaggregate location choice, a stochastic process has often been employed in the activity-based models to estimate household location with the probability of location among the choice set of dwellings for each household. However, the choice set is not considered in this study because it requires detailed information of dwellings. In this way, this micro model employs a simple process of allocating households into dwellings with the bid-rent approach.

The micro model can adjust the rent after the initial estimation by considering the interaction between the supply and demand of the housing market and making it consistent with the regional data. This adjustment of rent can estimate the utility change as the residual attractiveness associated with local factors. In analysing household location with the bid-rent approach, this study is focused more on the relative level of bid rents among household types than the absolute values of rents. Therefore, the detail of adjustment of rents is not discussed in this paper.

The Application of the Model

This study applies the micro land-use model to two stages of analysis. The first is to analyse the impact of local factors on household location by type. It compares the estimated output of household location by type with the aggregate data in each Census neighbourhood area. The parameters for local factors are calibrated in such as way that the model estimation is best fit for the Census data. The purpose of analysis is not to develop a model to accurately estimate household location with possible local factors, but to analyse the impact of factors associated with development density on household location.

This result is used for the second analysis to test urban design options in terms of the impacts on local household location and travel distance for shopping within a neighbourhood area. The options are designed by changing the location, numbers and areas of dwellings by type, non-domestic buildings and open space for new development. Although the new development of dwellings expects more households to move into the neighbourhood area, this needs to be analysed with the interaction between neighbourhood analysis and regional analysis. Such an interaction between the micro and strategic models has not been established yet in this study. Thus, this study tests urban design options, assuming that the number of households and the composition of household type would not be changed by development. Although this assumption may not be realistic, it is useful to illustrate whether new development could sufficiently be attractive compared to existing development and could reduce local travel distances for shopping from changes in household location. Accordingly, this analysis is carried out to test the potential of new developments.

THE CASE STUDY AREAS AND DATA COLLECTION

The Case Study Area

For the case study areas, this study selected two development sites in Cambridge, UK. The city of Cambridge is a centre of Cambridgeshire County and is surrounded by a green belt. The sub region of Cambridge is formed as a mono-centric pattern of development around the city. As a university town, the economy of the city is supported by university-related industries and has experienced rapid growth in knowledge-based industries since the development of large business and research parks started in 1970s. Nevertheless, the strong development control of a green belt has resulted in expensive urban rents in the city of Cambridge and many households living in suburban areas beyond the green belt due to the affordability of urban dwellings.

The growth of suburban areas has increased households' travel distances and the number of travel by car because public transport network is not well-established around Cambridge. This causes a serious issue of traffic congestion in the city and, therefore, more development to reduce travel distance may be effective. The Cambridge Futures study (1999 and 2003) recommended more development of dwellings closer to the city, particularly at the edge of the city along public transport corridors, by relaxing the development control of a green belt, which was favoured in the public consultation.

The development sites selected as the study areas are Mill Lane site in the city centre of Cambridge and North West Cambridge site in the urban-fringe area of the city. Both of the sites are the university development sites to provide dwellings, shops and university facilities. While the development of multi-use buildings is expected as mixed-use development in Mill Lane, North West Cambridge has a development plan to allocate a different use to each land-plot as a larger-scale development. To design the master plans, a number of design options have been examined through public consultations. The Mill Lane development is planned to develop an existing built area located close to the market as a core shopping area of the city centre. Despite the popularity of walking and cycling in the city, more than a half of households living in the city centre own cars (2001 Census[3]). This may reflect the lack of public transport services in and around the city. The North West Cambridge development is a development plan for brownfields and green areas on the route of a new guided bus. As one of new developments of public transport, a guided bus system has been developed to link urban areas inside the city and suburban areas outside it. Taking advantage of a large development area at the urban fringe, North West Cambridge plans to introduce a new

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[3] http://www.ons.gov.uk/census/index.html

shopping area for local residents. In this way, both development sites have potential to reduce local travel distance by developing dwellings closer to key destinations, such as shops and offices, in the neighbourhood areas.

The Data Collection

The input data of the micro land-use model needs to be collected for the analyses of the neighbourhood impact of local factors on household location and the neighbourhood impact of urban design options on the location and travel distance for shopping. These analyses require the following data.

1. Regional data for household expenditure and the parameters of a behavioural model by household type
2. Neighbourhood data for the number of households and dwellings
3. Local data for dwelling types and density of the study areas
4. Local data for dwelling types and density of urban design options
5. Transport data for the number of trips generated by each household and street networks in the study areas

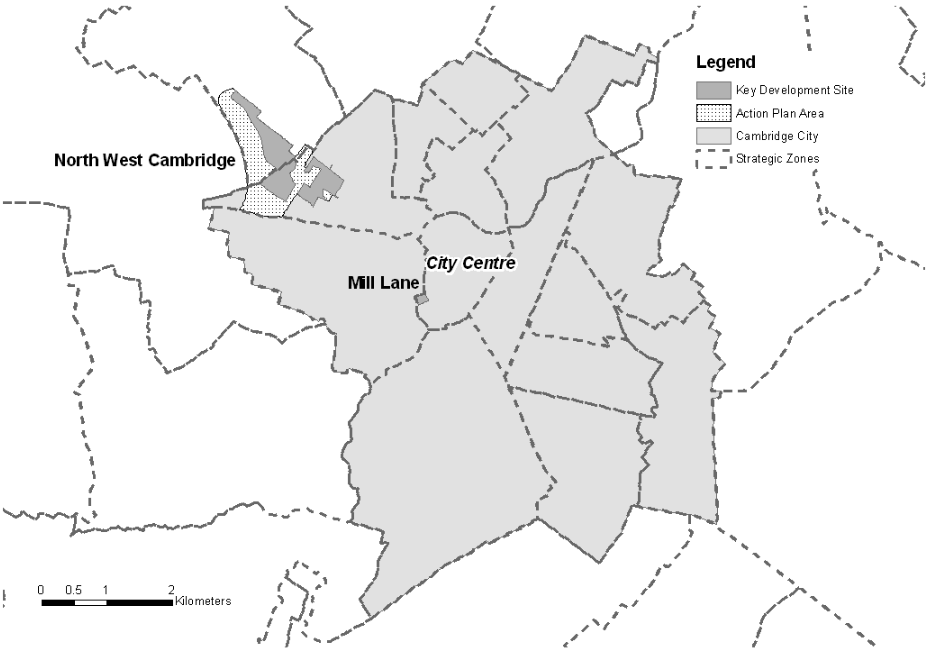

Figure 1: Development Sites in Mill Lane and North West Cambridge

Regional data is necessary for a regional input to the micro land-use model to take account of the regional contexts of the study area. The output of the strategic land-use model is used to take the data of total household expenditure, expenditure for daily consumption and the model parameters as the regional data. The strategic model was developed for the sub-region of Cambridge in the Cambridge Futures study. This study uses the strategic output for 2001 to be consistent with the year of the Census data, which was the starting year to forecast the impact of future development in the Cambridge Futures study. While the development site of Mill Lane is covered by one zone of the strategic model, the North West Cambridge site is located within two strategic zones (Figure 1). Thus, the more suburban strategic zone is used to take the regional data for North West Cambridge to be distinguished from the urban core area.

Table 1: The Numbers of Households and Dwellings by Type in the Neighbourhood Areas[4]

		Mill Lane		North West Cambridge	
		abs	%	abs	%
Households		1,842	100%	891	100%
Household Size	More than 1 Adult	930	50%	633	71%
	1 Adult	912	50%	258	29%
Socio-economic Type	SEG1	824	45%	476	53%
	SEG2	130	7%	68	8%
	SEG3	142	8%	52	6%
	SEG4	38	2%	10	1%
	Unemployed	17	1%	0	0%
	Inactive	691	38%	285	32%
Car Ownership	More than 1 Car	180	10%	316	35%
	1 Car	828	45%	457	51%
	No Car	834	45%	118	13%
Dwellings		1,909	100%	906	100%
Dwelling Type	Detached	43	2%	414	46%
	Semi-detached	64	3%	312	34%
	Terraced	956	50%	10	1%
	Flat	846	44%	170	19%

The 2001 Census data for neighbourhood areas is used to estimate the numbers of households and dwellings in neighbourhoods of the study areas (Table 1) for the analysis of the impact of local factors on household location. While the micro land-use model estimates household location by type for each dwelling, the outputs are aggregated for the number of households by type in each neighbourhood area to be compared with actual data. The Census neighbourhood area, called Census Output Area, is the most micro-scale area for UK's Census output and is on a smaller scale than a strategic zone. The Census neighbourhood data is prepared for a number of areas covering each of the development sites and its surrounding areas. For Mill Lane, all 15 neighbourhood areas within the strategic

[4] The table shows the absolute values (abs) of households and dwellings and their composition (%) by type in the 2001 Census data. The household types are classified to 30 types depending on household size, socio-economic type and car ownership. The socio-economic type is classified as SEG1 (professional and managerial jobs), SEG2 (other non-manual jobs), SEG3 (skilled manual jobs) and SEG4 (unskilled manual jobs).

zone of the city centre are selected for the area of analysis. 7 neighbourhood areas are picked for the study area of North West Cambridge among the areas in the strategic zones.

The local data of dwelling location and density within a neighbourhood area is collected with the GIS map, OS Master Map[5] (2009), as the local input to the micro land-use model to represent the local characteristics of a built environment. Although the GIS data for 2001 is not available for this analysis, the data for 2005 from GLUD[6] (2005) based on the OS map data is used as alternative information. In terms of the dwelling-type data, the size and type of buildings are measured based on their footprints and shapes. The location of buildings for dwellings is identified by the tax data of dwellings published by the government's tax office[7] (2009). Each dwelling is classified into detached houses, semi-detached houses, terraced houses and flats, according to the morphological patterns of building footprints and the number of activities in a building (Crooks and Smith, 2008). These dwelling data is adjusted, if necessary, to be consistent with the Census data for the number of dwellings by type.

The local density data is collected for buildings and domestic garden. The footprint area of buildings is measured for the surrounding area of each dwelling within the straight distance of 100m. The site coverage is calculated as the proportion of a building-footprint area to a 100m-radius buffer area. Domestic garden can also be identified on the GIS map as the garden attached to each dwelling. The area of garden is divided by the sum of a dwelling footprint area and a garden area to calculate garden availability.

Figure 2: Urban Design Options of the Development Sites

5 http://www.ordnancesurvey.co.uk/oswebsite/products/osmastermap/
6 http://www.communities.gov.uk/publications/planningandbuilding/generalisedlanduse
7 http://www.voa.gov.uk/

To test urban design options with the micro model, the options are designed with the GIS data for the location, numbers and areas of dwellings by type, non-domestic buildings and open space, including domestic gardens, in each study area (Figure 2 and Table 2). The option design is made for an option to promote higher-density development and another one to promote lower-density development in each development area, based on the existing options for the development sites[8]. The high-density and low-density options do not represent the overall density for the whole development area because the total number of dwellings for new development is kept same between the two options in each area in order to examine the neighbourhood impact of local urban design. The option design is rather focused on the different design of plot-level development densities within the development area. The low-density option is designed to introduce more plots with lower density development than the high-density option.

Table 2: Local Inputs of the Urban Design Options

	Mill Lane		North West Cambridge	
	High density	Low Density	High density	Low Density
Total Dwellings (count)	218	218	500	500
Detached (count)	-	-	-	105
Semi-detached (count)	-	-	-	128
Terraced (count)	13	35	-	142
Flat (count)	205	183	500	125
Average Dwelling Size (m2)	33	35	32	63
Average Garden Availability (share)	0.12	0.18	0.40	0.87

The design concepts for density are differently applied to an urban core area and an urban fringe area due to the different levels of land availability. In an urban core area which has limited land for new development, the low-density option designs more plots with low-density development by introducing more open space and more terraced houses than the high-density option, although it increases densities on the plots for remaining developments to provide the same number of dwellings between the options. Accordingly, the Mill Lane development has a high-density option to change only activities without changing existing dense buildings and a low-density option to introduce open space by demolishing some of existing buildings and developing new ones. On the other hand, an urban fringe area has sufficient available land for development to control density, so that the options can be designed by simply changing the plot sizes of development. In the North West Cambridge development, a high-density option is designed to provide dwellings in a smaller plot-area than a low-density option, where more flats and less garden area are allocated.

[8] The existing design options are shown in the following reports.
Old Press/ Mill Lane Site: Area Development Framework, 2nd Stakeholder Workshop, 24 July 2008 Final Report (http://www.cambridge.gov.uk/ccm/content/policy-and-projects/old-press-mill-lane-supplementary-planning-document.en)
North West Cambridge; Third Stakeholder Workshop and Public Exhibition 1&2 March 2005 (http://www-building.arct.cam.ac.uk/northwestc/masterplanning.html)

Transport data is also required to calculate travel distance of local households' trips for shopping within a neighbourhood area. In this study, the focus is on the distance of travel from each dwelling to a key supermarket within the study area. This study only analyses the internal travel within the neighbourhood area, so that external travel associated with the outside areas is not considered. Travel distance by transport mode is not analysed either, so that this study simply measures distances from each dwelling to a supermarket, although the reduction of travel distance by car is of interest in planning to reduce environmental emission. This study assumes that travel distance by car can be reduced by reducing total travel distance. It does not carry out analyses on modal choice for local travel and travel distance by walk to generate positive benefits.

The data of the number of trips per month is taken from the strategic land-use model. The number of trips is assumed to be different by household type and be fixed for this analysis, in which more trips are produced in larger size and high car-ownership households. Moreover, the OS data of a street network in the study area[9] is used to measure trip distance based on the street network between each dwelling and the nearest supermarket (Figure 3). Mill Lane has two major supermarkets in the nearby shopping area. North West Cambridge is assumed to have a new supermarket in the development area.

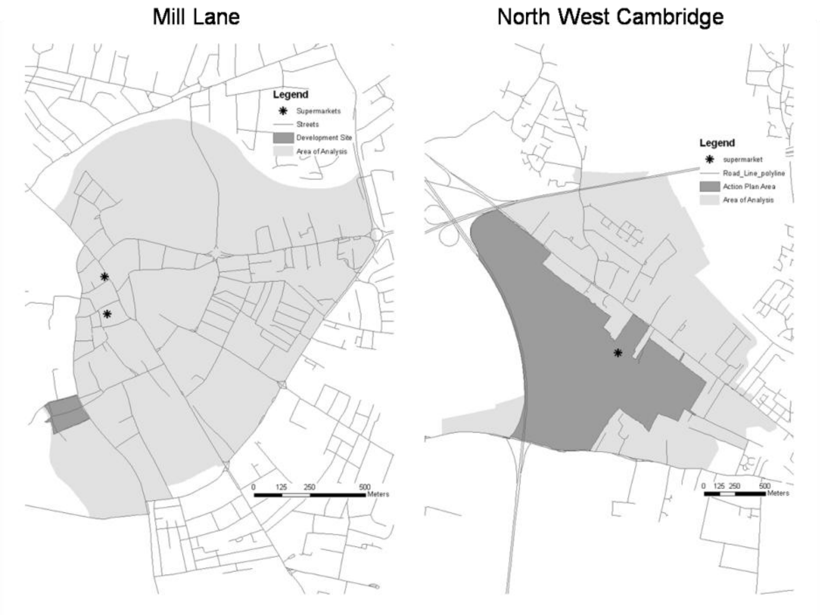

Figure 3: Street Networks in the Study Areas

THE ANALYSIS OF DWELLING TYPE AND DENSITY AFFECTING HOUSEHOLD LOCATION

The impact of dwelling type and density on household location is analysed with the micro land-use model. Using the data of 2001, the model is run with a set of parameters for the impacts of local factors on household location in each study area. The parameters are set for each household type to identify the different preference for local factors by household type.

[9] http://www.ordnancesurvey.co.uk/oswebsite/products/osmastermap/layers/itn/

This analysis calibrates the parameters by testing a number of sets of parameters so as to increase the fit of the model outputs to the Census data by each neighbourhood area. In the calibration, the initial values of parameters are taken from the previous SOLUTIONS study, which calibrated them with hedonic analysis based on the rent premium attributed to local factors, although it did not calibrate the differentiated parameters by household type.

This study manipulates the parameters by household type in terms of household size, socio-economic type and car ownership. Due to the nature of a bid rent approach, it is difficult to identify the preference of households as low bidders. Therefore, this analysis excludes the parameters of household types which do not affect the model fit from the result. The model is repeatedly run by gradually adding local factors in order to identify the impact of dwelling type and density. The first run is made with the local factor of dwelling size for each dwelling using the parameter of housing consumption by household type taken from the strategic model. The factors of dwelling type are added to the next runs because dwelling type has a significant impact on house prices. After identifying the parameters for dwelling type, it is followed by the runs adding the factors of density to calibrate their parameters.

Table 3: The Calibrated Parameters of Local Factors for Mill Lane[10]

Mill Lane	Dwelling Size	Dwelling Type				Density	
		Detached	Semi-detached	Terraced	Flat	Site Coverage	Garden Availability
More than 1 Adult	0.165	0.009	0.002	-	-0.025	-0.003	0.027
1 Adult	0.165	-	-	-	-	-	0.011
SEG1	0.270	0.033	0.009	-	-0.042	-0.007	0.051
SEG2	0.220	-	-	-	-0.028	-0.003	0.031
SEG3	0.150	-	-	-	-0.013	-0.001	0.014
SEG4	0.100	-	-	-	-0.006	-	0.006
Unemployed	0.100	-	-	-	-	-	0.006
Inactive	0.150	-	-	-	-	-	0.014
More than 1 Car	0.165	0.028	0.007	-	-0.037	-0.009	0.040
1 Car	0.165	-	-	-	-0.018	-	0.021
No Car	0.165	-	-	-	-	-	0.010
R2	0.325				0.359		0.502

The results of this analysis (Table 3 and Table 4) show that dwelling type affects household location with the positive impacts of detached and semi-detached houses and the negative impacts of flats and the impacts are different by household type. In both Mill Lane and North West Cambridge, the introduction of dwelling-type factors improves the model fit. North West Cambridge shows the more significant impact of dwelling type than Mill Lane. This may reflect the smaller variation of dwelling type in the urban-core area, which is dominated by flats and terraced houses, and the stronger preference for detached and semi-detached houses in the urban-fringe area.

[10] This table shows the parameters averaged by household type. The correlation between the data of household location and the estimated outputs is shown at the bottom of a table in the analysis for each type of local factors.

Table 4: The Calibrated Parameters of Local Factors for North West Cambridge

North West Cambridge	Dwelling Size	Dwelling Type				Density	
		Detached	Semi-detached	Terraced	Flat	Site Coverage	Garden Availability
More than 1 Adult	0.165	0.046	0.016	-	-0.025	-	-
1 Adult	0.165	-	-	-	-	-	-
SEG1	0.270	0.100	0.024	-	-0.042	-	-
SEG2	0.220	0.066	0.016	-	-0.028	-	-
SEG3	0.150	-	0.007	-	-0.013	-	-
SEG4	0.100	-	0.003	-	-0.006	-	-
Unemployed	0.100	-	-	-	-	-	-
Inactive	0.150	-	0.007	-	-	-	-
More than 1 Car	0.165	0.046	0.018	-	-0.037	-	-
1 Car	0.165	0.023	0.009	-	-0.018	-	-
No Car	0.165	0.023	0.006	-	-	-	-
R2	0.474				0.642		-

In terms of the difference of parameters by household type, while detached and semi-detached houses are preferred by large size, high socio-economic and high car-ownership households, small size and no car-ownership households do not have any negative preference for flats in both areas. In North West Cambridge, lower socio-economic and lower car-ownership, including no car-ownership, households show their preferences for detached and semi-detached houses. Although these results depend on availability of dwellings in the area, they provide the evidence that high-density development to provide more flats only attracts the limited types of households.

While household location is also affected by the density factors with the negative impact of site coverage and the positive impact of garden availability in Mill Lane, the impacts are not shown in North West Cambridge. By introducing the density factors in addition to the dwelling-type factors, the analysis of Mill Lane improves the model fit better than the analysis only with the dwelling-type factors. This suggests that open space is important in the urban core area where the areas of open space are likely to be small compared with developed areas due to a dense built-environment. On the other hand, the urban fringe area with low-density development has plenty of open space, so that every dwelling can enjoy the sufficient level of open space. This may be the reason why the impact of density factors is not significant in the analysis of North West Cambridge.

The analysis result of Mill Lane shows the difference of parameters for the density factors by household type. All types of households have the negative preference for site coverage, in which the more negative preference is shown in large size, higher socio-economic and higher car-ownership households. There are the positive impacts of garden availability on the location of the similar types of households. Moreover, although the availability of public green space was tested, it did not show any impact on household location at all. These results suggest the positive impact of low-density development on household location which can be affected by the type of open space.

THE ESTIMATION OF HOUSEHOLD LOCATION AND TRAVEL DISTANCE BY URBAN DESIGN OPTION

The micro land-use model with the calibrated parameters is applied to testing the impact of urban design options on household location and travel distance for shopping within a neighbourhood area. The data of dwelling type and density based on the design options is the new input to the micro model. The regional data, including the total number of households, is kept same as the 2001 Census data under the assumption that no new household would move into the study area. Although new development can bring new households from the other areas in the city or the region, the different impact by local urban design option on the region has not been captured by the existing strategic land-use model. In order to analyse the regional impact of urban design, it is necessary to identify the impact on the neighbourhood area as the initial impact. The neighbourhood impact can be passed onto the regional model, so that the interaction between the regional and local impacts can be analysed in the end. The simple assumption that more dwellings would bring more households despite local design options is not adequate to test the hypothesis that high-density development would not attract all types of households. Accordingly, this study is focused on the initial impact of urban design on the location of existing households in the neighbourhood area.

This analysis runs the micro land-use model for each urban design option to output household location by type for each dwelling. The output of household location is used to calculate total local travel distance for shopping produced by each household based on the location as internal travel distance within a neighbourhood area. Travel distance for the nearest supermarket from each dwelling is calculated by multiplying trip distance between the origin and destination by the number of trips generated by each household. The output of travel distance is the sum of travel distance for all households. As a result, the difference of travel distance by urban design option is attributed to the difference of household location within the neighbourhood area.

The results of household location show the differences of the impacts of urban design options depending on the options and on the study areas (Table 5). In Mill Lane, the high-density option attracts more households, particularly small size and no car-ownership households, than the low-density option. The development provides more flats, which leads to an increase in those types of households. Nevertheless, large size and higher socio-economic households are less attracted by the lower-density option due to the insufficient space of dwellings and gardens. This result suggests the negative impact of lower-density development in a dense built-environment like the urban core area. On the other hand, North West Cambridge has much more households in the low-density option than in the high-density option. More provision of detached and semi-detached houses attracts large size, high socio-economic and higher car-ownership households. The development of more flats can only increase lower socio-economic and no car-ownership households by small numbers. This implies the limitation of high-density development to attract more households in the urban fringe area with a low-density built environment.

Table 5: The Number of Households by Design Option in the Development Sites

	Mill Lane		North West Cambridge	
	High Density	Low Density	High Density	Low Density
Total	213	160	98	233
More than 1 Adult	11	10	-	105
1 Adult	202	150	98	128
SEG1	26	22	-	191
SEG2	-	3	-	7
SEG3	2	17	15	-
SEG4	1	5	-	-
Unemployed	-	-	-	-
Inactive	184	113	83	35
More than 1 Car	0	0	0	0
1 Car	4	19	38	205
No Car	209	141	60	28

Table 6: Local Travel Distance for Shopping by Design Option in the Study Areas[11]

	Mill Lane			North West Cambridge		
	Trips per Household	Total Distance (km)		Trips per Household	Total Distance (km)	
		High Density	Low Density		High Density	Low Density
All	2.78	3,932	3,965	3.01	3,033	2,745
More than 1 Adult	3.15	2,315	2,305	3.23	2,482	2,100
1 Adult	2.40	1,617	1,660	2.47	551	645
SEG1	2.77	1,818	1,827	3.04	1,724	1,266
SEG2	2.82	305	307	3.11	264	239
SEG3	2.92	311	321	3.12	167	203
SEG4	3.12	94	92	3.51	46	45
Unemployed	3.30	25	50	-	-	-
Inactive	2.71	1,380	1,369	2.90	832	993
More than 1 Car	3.23	461	461	3.29	1,209	1,192
1 Car	2.91	1,931	1,914	2.96	1,604	1,196
No Car	2.55	1,540	1,591	2.47	220	357

The difference of household location leads to the difference of local travel distance produced by households within the study area (Table 6). In Mill Lane, the high-density development reduces 1% of travel distance compared with the low-density development. The shorter travel distance is shown in small size, low socio-economic and no car-ownership households due to their location change closer to the shopping area through more provision of flats. To

[11] The table shows monthly trips and travel distances of local travel within the neighbourhood area. The top row "All" shows the average number of trips per household and total distance for each study area.

the contrary, the development of North West Cambridge has shorter travel distance by 9% in the low-density development. The significant reduction of distance takes place in large size, high socio-economic and higher car-ownership households, who produce more trips than other household types. While the difference of the level of impacts between Mill Lane and North West Cambridge is attributed to the scale of development, it is often the case that an urban core area has a smaller-scale development due to a limited available area for development. These results suggest that the low-density development could be more effective for reducing local travel distance in the urban fringe areas if the impact on household location is considered.

CONCLUSION

This paper has analysed the impacts of urban design options for a neighbourhood area in order to test the hypothesis that high-density development would not always be the best option to reduce local travel distance through household location change. The empirical analysis has been carried out by applying a micro land-use model consistent with a regional-level strategic land-use transport model to the urban core area and the urban fringe area in Cambridge. In the analysis of the impact of dwelling type and density on household location, the local factors associated with high-density development negatively affect household location. Particularly, large size, high socio-economic and high car-ownership households are rather attracted by the factors of low-density development.

The impacts of local factors on household location lead to the different impact of urban design options on local household location and travel distance within the neighbourhood area. High-density development can be attractive in the urban core area because low-density development is hardly introduced to the existing dense built-environment. Nevertheless, the urban-fringe development can attract more households with low-density development thanks to the attractiveness of local factors. It enables more large size and high car-ownership households to be located closer to their travel destinations. These households generate the higher number of trips, so that low-density development can decrease local travel distance than high-density development by reducing the trip distance of households to travel more. Accordingly, this analysis suggests that low-density development could be more effective to reduce local travel distance in the urban-fringe area.

This study has provided useful evidence for the multi-scale effect of development by density. The neighbourhood impact of urban design obtained from the result of this analysis indicates the potential regional impact as a change in the attractiveness of a neighbourhood area for location and travel compared with the other areas in the region. Urban design options have been tested for the neighbourhood impact, which does not consider the interaction between the neighbourhood and regional impacts. The neighbourhood impact of urban design options could be passed onto the regional model, which could attract more households to be located into the neighbourhood area from outside in the region. Accordingly, the positive impacts of urban design options on local travel distance within a neighbourhood area could be more significant by attracting more households into the area. This might also reduce travel distance of longer trips at a regional level by enhancing the attractiveness of local travel. Thus, the interaction is important for assessing urban design options in terms of household location and travel distance at both a neighbourhood level and a regional level.

The result of this study has important implications for regional spatial policies in combination with neighbourhood design in land-use transport planning. In current planning policies, high-density development is generally encouraged in urban areas for a compact city. However, while an urban core area has limited areas for new development, low-density development could be more effective in an urban fringe area. Therefore, more development in urban fringe areas, such as green belts, can be supported as an effective spatial planning policy at a regional level. On the other hand, careful design is needed for development in such green areas at a neighbourhood level. In urban fringe areas, development needs to be designed both for the sufficient level of green space and for the desirable level of travel distance. Furthermore, there are the opportunities of open-space design to introduce de-centralised system of infrastructures to provide energy and water to a neighbourhood settlement in a self-sufficient way. In this way, low-density development could have potential to improve economic and environmental benefits. This study is expected to contribute to the assessment of spatial planning and transport planning policies on multiple scales.

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