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Planning support in estimating green housing opportunities for different socioeconomic groups in Nanjing, China

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Abstract. The sustainable city concept is often criticized for being unaffordable for the majority. To cater for various socioeconomic groups, it is essential that planners consider both affordability and sustainability. We provide planners with a methodology for estimating green housing potential for various socioeconomic groups in Nanjing, China, with reference to their green housing preferences and budgets. Results indicate that under the current situation the lower-middle class can barely afford a green apartment. If the metro network is extended, the green housing opportunities for the lower-middle class will increase in the central districts if they trade housing size for location. If heavy industries are relocated, green housing opportunities for the upper-middle class will increase in the central districts, but the lower-middle and middle classes will be pushed to the suburbs. Results also show that development of greenfields will provide more options for each socioeconomic group than redevelopment of brownfields.

Keywords: Planning support methodology, housing affordability, sustainability, green housing opportunity, socioeconomic groups

1 Introduction

In the transition to a market-driven postindustrial urban economy, China's planners are facing three urgent challenges to building sustainable cities. First, with the rapid urbanization of China, approximately half the new buildings constructed worldwide this century were built in China, and the energy consumption of buildings made up roughly one fifth of China's total energy consumption (Fernández, 2007; Zhao and Lou, 2013). In sustainable planning (here loosely defined as the application of the three sustainability concepts—people, planet, and profit—to spatial planning), 'green buildings' are those which contribute to reducing emissions and energy consumption. Currently, green building focuses on improving energy efficiency, reducing water consumption, using durable and nontoxic materials, and saving life-cycle costs, yet a standard definition of green building is still lacking (Ali and Al Nsairat, 2009; Perzan, 2006; Zachariah et al, 2002). In line with the existing research, we define green buildings as environment-friendly, resource-efficient, energy-saving, health-improving, and comfortable buildings. They should provide residents with good quality of both indoor life and outdoor environment since residents buy a green building for a bundle of housing attributes not just the green technique (Hu et al, 2014a).

Second, the increasing use of cars in China has resulted in severe traffic congestion and air pollution. To improve transportation and air quality, planners need to incorporate public transport networks in their sustainable planning strategies.

Third, heavy industries located in the central urban districts occupy large areas and heavily pollute the air, thus hindering the process of postindustrial transition. To achieve a sustainable city it is essential to relocate these heavy industries to the outskirts of the central urban districts. However, in implementing these sustainable planning measures it is important to consider affordability, so that sustainable planning corresponds to the local market.

With the expansion of the market reform, the urban housing market in China has become more differentiated (Zhang, 1999). Different socioeconomic groups can afford homes only in certain segments of the housing market. Green apartment buildings are built mainly in urban areas with good accessibility to jobs and services and a high neighbourhood quality. The high price of green apartments is a sign of luxury for the upper-middle class (Cai et al, 2013). While some studies have considered affordable sustainable housing or affordable low-energy housing they have primarily stressed the use of affordable materials and techniques in green buildings (Mousavi et al, 2013; Noguchi, 2011). The affordability of green apartments goes beyond the attributes of green buildings, however. Consumers' purchase of green housing is driven by their purchasing power and their demand for a bundle of housing attributes, with green attributes in their homes and in the wider living environment, including accessibility to jobs and services and neighbourhood quality (Kibert and Grosskopf, 2007; Kientzel and Kok, 2011; Leaman and Bordass, 2007; Schweber, 2013).

To date, neighbourhood quality in China is unevenly distributed across urban areas. Market reform is generally seen as a means to restructure urban land use. Old neighbourhoods and work-unit compounds in the central urban districts are being replaced by office buildings and large-scale housing properties (Li and Song, 2009; Xue et al, 2013); urban factories are being either closed down or forced to move out to the suburbs (Zhou and Ma, 2000). Consequently, the quality of life in the central urban districts is improving at the expense of the suburban districts, resulting in increasing differentiation in house prices between these areas (Hald, 2009; Wang, 2003). Good-quality housing and a good living environment which are affordable for the different socioeconomic groups are unevenly distributed between the various urban areas (Li, 2012).

The environmental component is fundamental to sustainability, yet environmental changes have impacts on society and the economy. Planners need to understand the interaction between these three components. Successful sustainable planning should be affordable not just for a few but for all citizens (Soper, 2004). To expand the group of citizens who can enjoy the fruits of sustainable planning, it is essential that affordability and environmental issues are considered simultaneously. In this article we propose a planning support methodology to estimate green housing opportunities for various socioeconomic groups in Nanjing, China, according to their green housing preferences and their budgets. This methodology employs hedonic price modelling to estimate market supply and conjoint modelling to estimate market demand. As China undergoes a transition from an industrial to a postindustrial society, the construction of metrolines and the redevelopment of brownfield sites in the central urban districts will save energy and resources and improve the quality of urban life. Improving quality of life will also affect house prices and therefore the affordability of housing. This article simulates green housing opportunities in Nanjing for three different urban development scenarios: the current situation, after extension of the public transport network, and after the relocation of heavy industries.

The next section briefly describes the theoretical background of this research, after which a framework of the proposed planning support methodology is presented. The application of the planning support methodology is then described, and an analysis of the results is given for each of the various socioeconomic groups in Nanjing. Finally, we state our conclusions and recommendations for future research.

2 Theoretical background

Although the concept of sustainable planning is related to the integral development of society, the economy, and the environment, the issue of affordability in the built environment is not often raised (McIntosh and Guthrie, 2010; Mousavi et al, 2013). In fact, the sustainable city is often criticized for being inaccessible or unaffordable for the majority. The improvements in the quality of urban life made by sustainable planning, such as easier pedestrian access and pleasant open spaces, can lead to a significant market premium making it affordable only for the minority rich (Dale and Newman, 2009). In such a case, sustainable planning results in greater social inequity (Luke, 2005).

Though social justice is an explicit component of sustainability, most sustainable developments have not shown equal concern for social equity (McNally et al, 2010; Mohamed and Darus, 2011). Sustainability often prioritizes environmental or ecological issues and neglects the social dimension (Kruize, 2007; Zhang and Fung, 2013). For instance, Dale and Newman (2009) found evidence in the Canadian cities of Toronto, Victoria, and Vancouver that environmental improvements make a neighbourhood more attractive but drive up real-estate prices, resulting in the displacement of existing lower-income and lower-middle-income residents. It is, therefore, critical to consider who wins and who loses as a consequence of sustainability measures in the built environment.

The relationship between affordability and sustainability in the built environment is complicated. On the one hand, sustainable housing features such as solar panels and ventilation can be seen as a large expense for investors. On the other hand, sustainable housing can result in affordability for the end-users: more energy-efficient dwellings lead to lower energy bills, and proximity to public transport means less money spent on fuel (Friedman, 2013; MacKillop, 2013). Besides, sustainable housing development is not only a technocratic undertaking but part of a socioecological process (Portney, 2002). The socioeconomic background of consumers will affect their demands for living quality (Jenks, 2000). For instance, Mousavi et al (2013) found in Malaysia that although green housing was provided with multiple green features, the middle-income group was only willing to pay for a solar water heater. Evidence from New Zealand shows that only higher income buyers tend to pay extra for environmental features in their houses, but location and house price still appear to be the most important determining factors for house purchase (Eves and Kippes, 2010). Sustainable planning should take into account the green needs of various socioeconomic groups (Curran and Hamilton, 2012).

For successful sustainable planning, it is crucial to understand the consumer market and the trade-offs homebuyers make between green and other attributes, such as neighbourhood quality and accessibility to jobs and services. Some research has found that green dwelling attributes (eg, energy conservation) that directly reduce residents' utility bills provide economic incentives which increase consumers' willingness to pay (Yau, 2012). Attributes of the living environment for which people are willing to pay extra are accessibility to jobs, cleanliness and security, distance from landfills, and higher air quality. These attributes are valued more than sports facilities and cultural services (Hite, 2009; Torres et al, 2013). In mainland China it has been found that people are willing to pay more for neighbourhood safety and improved accessibility (Wang and Li, 2004; 2006).

Planners need to understand the trade-offs that people make and to focus on those sustainability issues which are important to prospective residents. However, insights into green housing preferences and the trade-offs that the various socioeconomic groups are willing to make are difficult to explicate. We propose a planning support methodology to address such issues.

3 The planning support methodology

Sustainable planning interventions will improve environmental sustainability. For instance, constructing green buildings will reduce energy consumption, while extending a metronetwork and relocating heavy industries will improve the air quality of the urban environment. Improvements to the environment have impacts on house prices. To make sustainable planning successful, planners need to understand these impacts. Our proposal helps planners to understand how environmental improvements impact on green housing opportunities for different socioeconomic groups. Our proposed planning support methodology was developed to consider market demands (preferences of socioeconomic groups and willingness to pay) along with market supply (eg, house prices, location) to predict green housing opportunities for the various socioeconomic groups. To do this, it uses conjoint modelling to analyse market demands and hedonic price modelling to simulate market supply (figure 1). Planners first need to identify the preferences of various socioeconomic groups for green housing and housing affordability, and then provide a fair distribution of green housing opportunities for these different groups.

To calculate the market supply, we chose hedonic price modelling to estimate property value by integrating housing-market information with land-use and transportation data. Hedonic price modelling is considered the best way to analyze the relationship between house prices and a set of heterogeneous attributes (Goodman, 1978; Li, 2012). These attributes fall into three broad categories: dwelling attributes, accessibility to jobs and services, and neighbourhood quality. To build a hedonic price model, we first collected individual housing-transaction data, detailed urban land-use data, and transport-network data, including both public transport and the road network. On the basis of the urban land-use data, we measured the size and location of residential amenities such as jobs, shops, and parks. On the basis of the transport networks, we conducted detailed calculations of accessibility to these amenities. Following data collection, we built a database for the hedonic price model. The database included categories for house prices, dwelling attributes, accessibility, and neighbourhood quality. We then simulated house prices after the implementation of two specific sustainable planning interventions: the extension of the public transport network and the relocation of heavy industry from central to peripheral locations.

To calculate market demand, we chose conjoint modelling to analyse consumers' willingness to pay for green housing. This is because the green market in China is only just

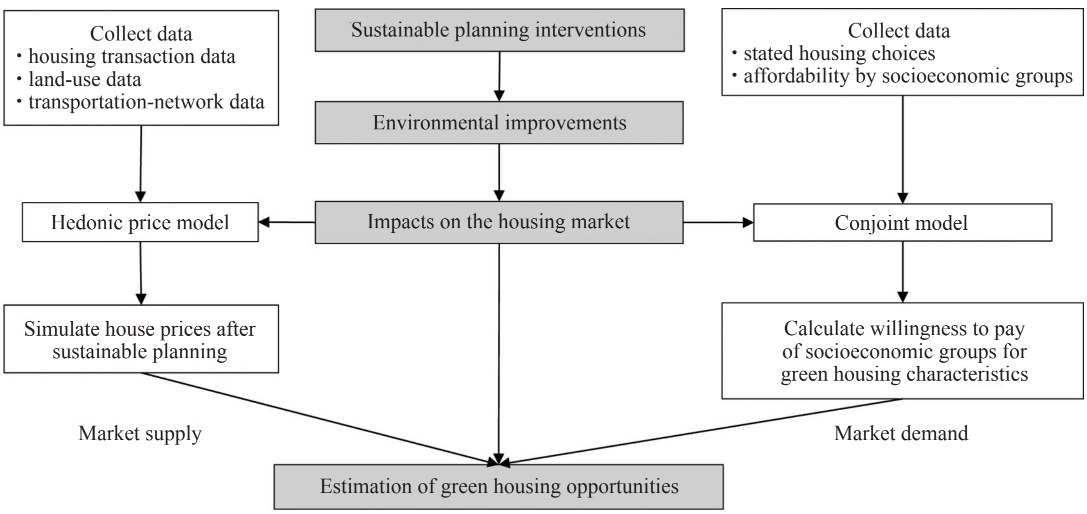


Figure 1. Framework of the planning support methodology.

emerging, and no reliable market information is available yet. The stated-preference method can be used to create a hypothetical market in which willingness to pay can be considered directly as a housing attribute (Howie et al, 2010; Wang and Li, 2006). According to the literature, influential housing attributes can be divided into five categories: house price, physical quality of the neighbourhood, social quality of the neighbourhood, accessibility, and dwelling attributes (Howie et al, 2010; Visser et al, 2008). The conjoint model assumes that homebuyers make trade-offs between these housing characteristics, choosing the housing bundles with the most benefits. To build a conjoint model, we collected details of homebuyers' stated housing preferences and information about their budget. The conjoint model was then used to estimate willingness to pay for green housing attributes relative to other housing attributes, and to distinguish between different segments of the market.

With the data on house prices (market supply) and willingness to pay (market demand), we estimated the suitability of each parcel of residential land for building green apartments for various socioeconomic groups. We termed this 'estimation of green housing opportunities'. Since the estimation reflects consumers' preferences and considers both affordability and sustainability, it helps to reconcile ecological, social, and economic perspectives. Planners can use the estimation results as a reference for sustainable planning.

4 Case study

4.1 Study area and socioeconomic groups

We used the city of Nanjing on the Yangtze River Delta as our case study area (figure 2). The sustainable problems faced by Nanjing, such as huge energy and resource consumption and severe air pollution, can be found in many other big Chinese cities, for instance, Tianjin, Shenyang, Chongqing, Xi'an, Wuhan, and Lanzhou. All these cities have a population greater than 1 million and many heavy industrial sites in urban areas. The provision of green housing for various socioeconomic groups in these cities is urgent. The two planning interventions to improve environmental quality are also feasible in these cities. Given that each city has its local housing market, planners can use our methodology to build valuation models and parameters for their own usage.

In 2010 the total area of Nanjing municipality was 6587 km^2, the urban space was 4733 km^2, and the population was over 8 million (Statistical Bureau of Nanjing, 2011). Since 2000 the Nanjing government has attempted to change the image of the city by transforming it from an industrial to a postindustrial city. Land in the central districts is mainly allocated for commercial, governmental, and residential functions. The southern districts of Nanjing are primarily residential, commercial, and light industrial areas, with some concentrations of heavy industries. The districts in the north are mainly residential and heavy industrial sites, with several areas of concentrated commercial activity. These three areas are different, not only in land use but also in other respects. Since jobs and metrolines are concentrated in the city centre, apartments there have much better accessibility to jobs and public transport compared with the newly developed surrounding districts. The southern districts have better accessibility than the northern districts which have no metroline, and three bridges and one tunnel connect the northern and the southern parts of the city. Air quality also varies within the city, with heavier air pollution in the northern districts. These differences affect house prices: the average house price in the central districts is higher than in the surrounding districts, and houses in the southern districts are generally more expensive than those in the northern districts.

Since the price of green apartments is high, developers only target the upper-middle-class market at present and locate green apartment buildings only in the newly developed areas near the city centre and in the southern districts. There is no heavy industry nearby. Amenities such as a metrostop, supermarket, park, hospital, and kindergarten are within

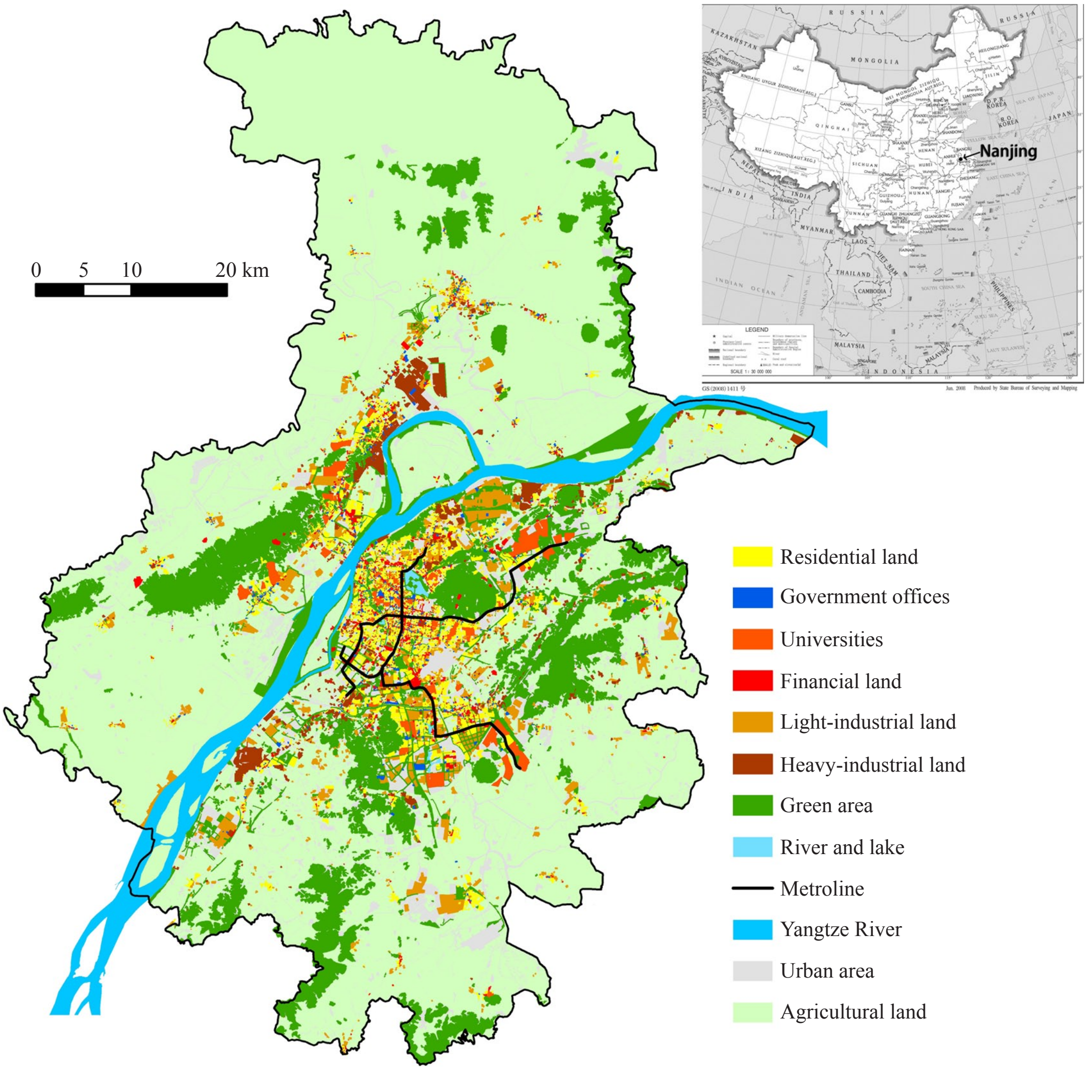


Figure 2. [In colour online.] Location and land-use map of the study area.

walking distance. A geothermal heat pump was installed in these green buildings, to reduce running costs for energy, as well as carbon emissions. The use of thermal insulation glass and the elimination of thermal bridging serve the same goals. A high-tech ventilation system was built to freshen and humidify indoor air and to regulate temperature.

The segmentation of the housing market influences the housing choices of the different socioeconomic groups. For this study, we considered three socioeconomic groups who could more or less afford to buy a commercial apartment: the lower-middle class, the middle class, and the upper-middle class. The lower-middle class consists mainly of young people just starting their careers and mostly new to Nanjing. They have a good educational background, and are either singles or couples with no children. They have a relatively low budget of less than ¥1 million, which allows them to buy an apartment of around 100 m^2 in the northern districts or a much smaller one in the southern districts. The middle class is a larger group, consisting of people aged 30 years and above who have lived in the city for a relatively long period of time. They have received tertiary education (university degrees) and have established their careers. Many of them have a school-aged child. Their budget allows them to purchase an apartment in either the southern or northern districts. They are also able to buy an apartment in the central districts if they trade dwelling size for location. The upper-middle class consists mainly of those aged 30 years and older. Their educational level is higher than that of the other two classes and many have a well-established career. A high proportion of couples within this group have school-aged children. Their budget allows them to choose an apartment in any of the three market segments, which gives the upper-middle class the most flexibility where housing is concerned.

4.2 Modelling and estimation of green house prices

The green house prices consist of two parts: the conventional house price and the house price for green dwelling attributes, including energy and water costs, construction materials, thermal insulation, sound insulation, and ventilation (see Hu et al, 2014b). These green dwelling attributes are the key variables found in the green preference research discussed in the literature (eg, Chau et al, 2010; McKinley, 2009; White and Gatersleben, 2011; Yau, 2012).

To estimate conventional house prices in Nanjing, we integrated geographical theories and detailed spatial measurements into a hedonic price model (see Hu et al, forthcoming). The estimated parameters in the hedonic price model can be found in appendix A. Results in appendix A are based on real housing transactions.

To consider the impact of additional metrolines, we assumed that the public transport network in Nanjing would be intensified. Since this would improve the accessibility of the whole public transport network, we needed to rebuild the transport-network data and recalculate all accessibility variables which related to public transport accessibility. After this we estimated the average house price of each residential block using the parameters in appendix A (a residential block is the smallest land parcel in the land-use map; it is divided by branch roads or paths).

For the impact of relocating heavy industry from central to peripheral areas, we assumed that all heavy industrial land in Nanjing would be redeveloped as residential areas. As a consequence, the negative and positive effects of heavy industry on house prices would disappear. We set the variables related to heavy industries to zero, and then estimated the average house price of each residential block using the remaining parameters in our hedonic price model.

We used the conjoint model to estimate each socioeconomic group's willingness to pay for green dwelling attributes in a hypothetical green market. Since the green housing market in Nanjing is still new we could not use hedonic price modelling to estimate prices of green apartments in each residential area (see Hu et al, 2014b). Considering the significant variables in appendix A and the influential housing factors in an existing conjoint model study, we included thirteen variables from five categories in our conjoint model: house price, physical quality of the neighbourhood, social quality of the neighbourhood, accessibility to metrolines and jobs, and dwelling attributes (Howie et al, 2010; Visser et al, 2008). The utility of significant housing attributes can be seen in appendix B. On the basis of these utilities, we estimated the willingness to pay for three significant green dwelling attributes: reduced energy and water costs, construction materials, and thermal insulation. Following this we estimated the green house prices in relation to the estimated conventional house price (from the hedonic model) and the willingness to pay for green dwelling attributes (from the conjoint model). The formula is:

$$\mathrm{P\_Ghouse} = \mathrm{P\_house} + \mathrm{P\_G} ,$$

where $\mathrm{P\_Ghouse}$ is the average price of a green apartment in one residential block (yuan/m^2), $\mathrm{P\_house}$ is the average price of a conventional apartment in one residential block (yuan/m^2), and $\mathrm{P\_G}$ is the willingness to pay for green dwelling attributes. In each submarket, $\mathrm{P\_G}$ is the sum of each socioeconomic group's willingness to pay for all significant and positive green dwelling attributes.

4.3 Estimation of green housing opportunities on existing residential land

We built a score table to estimate the green housing opportunities for each socioeconomic group based on appendix B (table 1). Considering that the two sustainable planning interventions will mainly improve air quality and accessibility by public transport, we selected indicators such as submarket preference, house price, school quality, environmental pollution, accessibility to metrostops, and accessibility to jobs. The submarket preferences of each socioeconomic group were derived for our score table from the constants in appendix B. Scores for house prices represent housing affordability for each socioeconomic group in each of the three submarkets. Scores for school quality indicate whether an apartment is located in a district with a good school. To set the score for environmental pollution we used distance from heavy industries. Heavy industries were found to be a source of employment opportunities, but also a source of air and noise pollution at close distances. The positive effect of heavy industries as a source of jobs was seen at further distances. We found that the threshold for this positive effect in Nanjing was a commuting time on public transport of 20–40 minutes from heavy industries, while the positive effects disappeared when commuting time exceeded 40 minutes. To set the score for accessibility to jobs we used accessibility potential

Table 1. Score of housing attributes by socioeconomic class.

Central districts				Southern districts				Northern districts			
attribute	L[a]	M[a]	U[a]	attribute	L[a]	M[a]	U[a]	attribute	L[a]	M[a]	U[a]
Submarket preference	0	0	1		1	2	2		2	1	0
House price (yuan/m^2)											
20 000–25 000	2	2	2	10 000–15 000	2	2	2	6000–8000	2	2	0
25 000–30 000	1	1	1	15 000–20 000	1	1	1	8000–10 000	1	1	0
>30 000	0	0	0	20 000–25 000	0	0	0	10 000–15 000	0	0	0
School quality											
Very good	2	2	2	very good	2	2	2	very good	2	2	0
Good	2	1	0	good	1	1	1	good	2	2	0
Average	2	0	0	average	0	0	0	average	2	2	0
Environmental pollution											
>40 min to heavy industry	2	2	2	>40 min to heavy industry	2	2	2	>40 min to heavy industry	2	2	0
20–40 min to heavy industry	2	2	1	20–40 min to heavy industry	0	0	1	20–40 min to heavy industry	1	0	0
<20 min to heavy industry	2	2	0	<20 min to heavy industry	0	0	0	<20 minutes to heavy industry	0	0	0
Accessibility to metrostop											
<1 km	0	2	2	<1 km	2	2	2	3–4 km	2	2	0
1–2 km	1	2	2	1–2 km	2	1	2	4–5 km	1	2	0
2–3 km	2	2	2	2–3 km	2	0	2	>5 km	0	2	0
Accessibility to job (by public transport)											
Good	2	1	0	good	2	2	2	good	2	2	0
Relatively good	2	1	2	relatively good	2	2	1	relatively good	1	1	0
Poor	2	0	0	poor	2	2	0	poor	0	0	0

[a]L, M, U represent lower-middle, middle, upper-middle class, respectively.

to centres of higher education, large governmental institutions, and financial and business services. 'Good' indicates that the aggregated accessibility potential score was above 75%, 'relatively good' indicates that it was between 50% and 75%, and 'poor' indicates a score of below 50%.

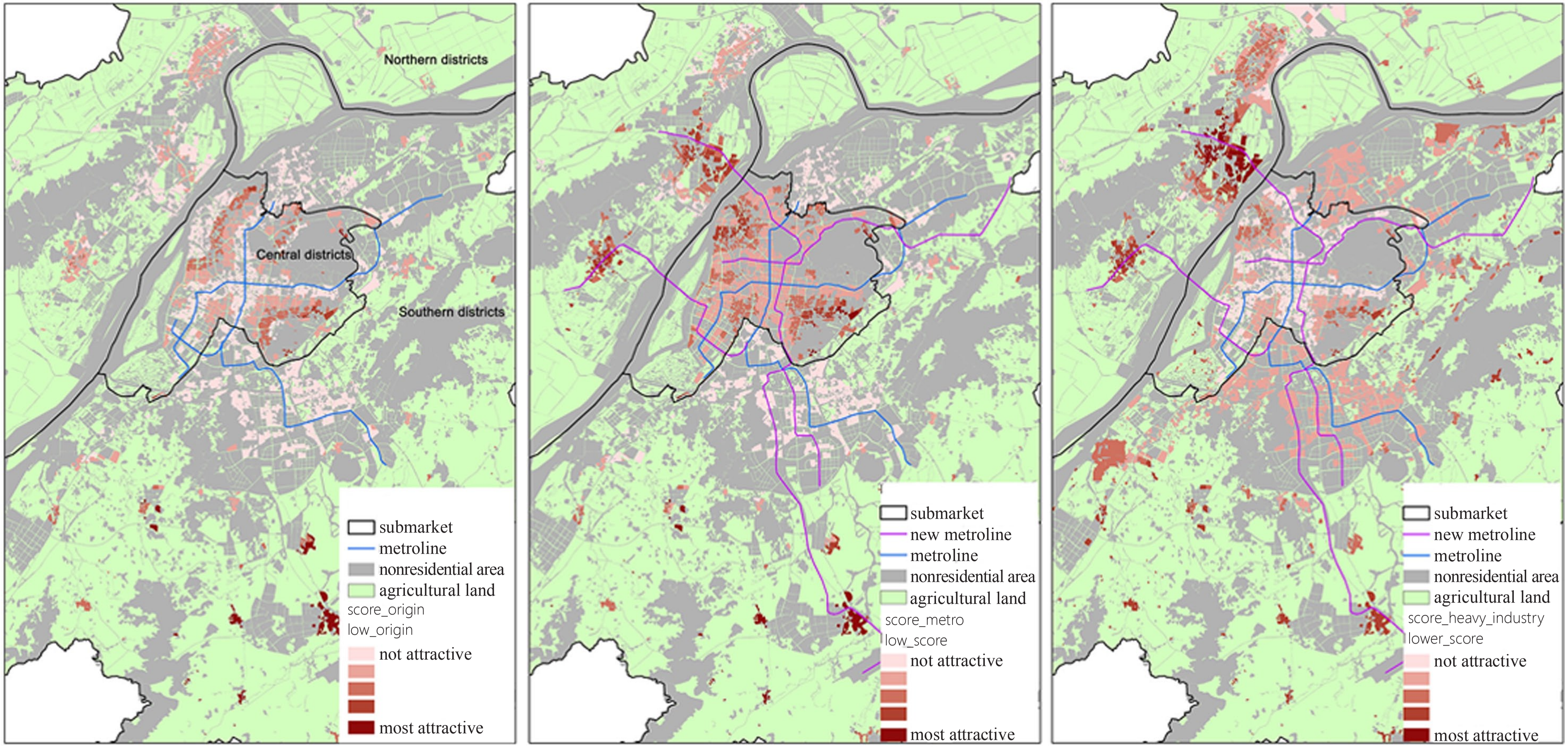
The constants in appendix B imply that the lower-middle class does not wish or is not able to choose an apartment in the central districts; the middle class is willing to pay for an apartment in the southern districts, with the northern districts as its second choice; the upper-middle class prefers the southern districts over the central districts and is not at all interested in living in the northern districts. Accordingly, for the lower-middle class we gave a score of 0 for the central districts, 1 for the southern districts, and 2 for the northern districts. For the middle class we assigned these districts scores of 0, 2, and 1, respectively, and for the upper-middle class 1, 2, and 0, respectively.

In appendix B the utility of various attributes indicates the importance of the attributes in home-purchase decisions. If the utility of the attribute is significant, it implies that homebuyers place importance on that attribute when buying an apartment. We measured the utility of each significant attribute with scores of 0 to 2. A score of 0 means that the utility is negative, 1 means positive or close to 0, and 2 means that the utility is the most positive. If the utility of the attribute is insignificant, it implies that homebuyers do not take that attribute into account when buying an apartment. In other words, if the other attributes meet their requirements, homebuyers will buy the apartment regardless of the quality of such an attribute. In this case, we gave the attribute a score of 2. Since the upper-middle class does not even consider living in the northern districts, we set all the scores of the northern districts at 0 for the upper-middle class. In the end, we aggregated the scores of all the attributes for each residential block. The aggregated score indicates the attractiveness value of a green apartment in each residential block for each of the three socioeconomic groups.

We then used the 'natural breaks method' to classify the aggregated scores of all the residential blocks into five categories. This method identifies break points by picking the class breaks which group similar values the best and which maximize the differences between the classes. In the maps in figures that follow, the lighter colours indicate lower attractiveness and the darker colours indicate higher attractiveness.

4.3.1 *Lower-middle class*

Figure 3 shows the attractiveness of green housing for the lower-middle class in three urban development scenarios. The nonresidential areas in the maps include built-up areas, water bodies, mountainous areas, green parks, and open spaces. In the current situation [figure 3(a)], very few areas are attractive to the lower-middle class wishing to buy a green apartment, except in the southern fringe of the southern suburban districts. In the central districts, accessibility to metrostops is important (see table 1). However, the lower-middle class prefers to live in an apartment at a certain distance from the metrostops (2–3 km), probably because of the high cost of sites close to these stops. As a consequence, the green housing opportunities in the central urban districts for this class gradually increase with an increase in distance from metrostops. In the southern suburban districts, sites both close to and further away from metrostops are not attractive due to the close vicinity of heavy industries; the lower-middle class does not accept any pollution in the southern districts. In the northern suburban districts, house prices are relatively affordable. However, there are just a few areas that are considered to be attractive for green housing, primarily due to the presence of heavy industry in the northern districts and the poor accessibility to the city centre (just three bridges and one tunnel connect the north with the centre and the south). In the northern districts, environmental pollution and accessibility to jobs by public transport are the main concerns of the lower-middle class.



(a) (b) (c)

Figure 3. [In colour online.] The attractiveness of green housing to the lower-middle class in three urban-development scenarios: (a) current situation; (b) after constructing new metrolines; (c) after relocating heavy industries.

With the construction of new metrolines, the area of attractive places for the lower-middle class in the central and northern suburban districts increases greatly [see table 2 and figure 3(b)]. Although new metrolines exert a property price premium, they also improve the accessibility of these areas. In the central districts, the lower-middle class is apparently willing to trade accessibility improvements for a smaller size of green apartment. The attractiveness of small, green apartments gradually increases with an increase in distance from metrostops (which translates into a decrease in house prices). In the northern districts sites close to metrostops show the greatest attractiveness. Although a price premium is produced by the new metrolines in the northern districts, they are still more affordable than the central districts. In the southern suburban districts, the construction of new metrolines does not create an increase in attractiveness. This is probably because the distance to metrostops is not the prime concern of the lower-middle class in that area, in contrast to concerns about schools and air quality.

Following the relocation of heavy industry [figure 3(c)], the number of attractive places increases in the northern and southern suburban districts but decreases in the central urban districts (we included the brownfield sites in this estimation). Replacing heavy industry with residential areas exerts a house price premium because of an improvement in air quality. At the same time, however, it can also reduce house prices as a result of reduced job opportunities if heavy industry is only replaced by residential development without the creation of alternative jobs. The central urban districts are not attractive under such circumstances. The northern districts become more attractive due to affordable house prices, improved air quality, and relatively good accessibility to metrostops. Even areas further from metrolines in the north show increased attractiveness, largely due to the removal of the heavy industries which are the source of air pollution.

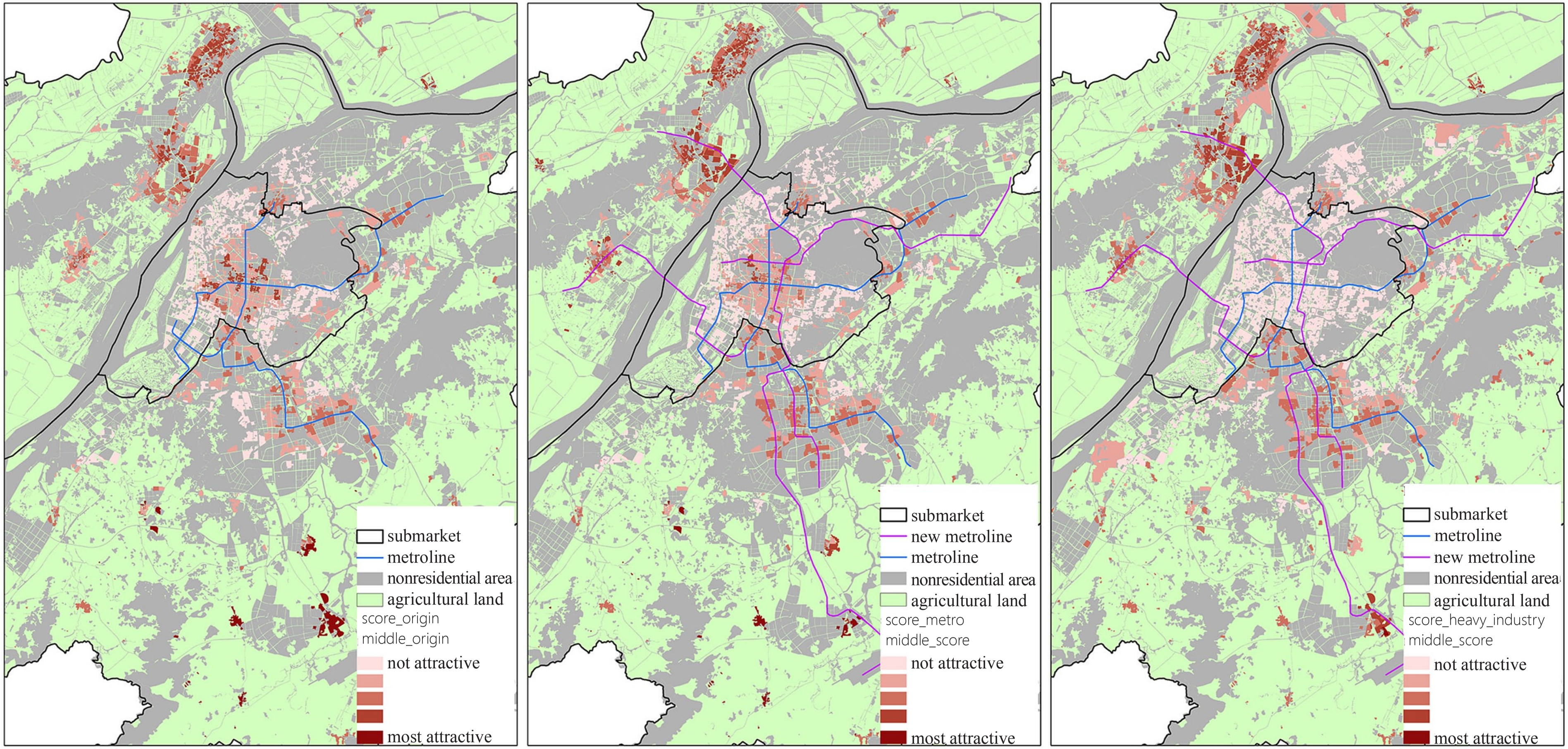
4.3.2 *Middle class*

Figure 4 shows the attractiveness of green housing to the middle class in three urban development scenarios. In the present situation [figure 4(a)], the middle class, due to their higher budgets, has more opportunity than the lower-middle class to buy a green apartment. In the central districts the middle class is sensitive about school quality, accessibility to metrostops, and, to a lesser extent, accessibility to jobs by public transport (see table 1). In the southern districts those in the middle class focus on good school quality and accessibility to metrostops at a short distance; accessibility to jobs also becomes more important. In the northern districts, although air quality and accessibility to jobs are not attractive, house prices are more affordable to the middle class, making the northern districts relatively attractive.

Table 2. Estimated area of attractive lands for green apartment construction (km^2).

	Present situation	Constructing new metrolines	Replacing heavy industry
Lower-middle class	9.60	20.84	32.54
Middle class	18.32	21.93	15.99
Upper-middle class	7.30	9.10	38.24

Following the construction of new metrolines [figure 4(b)], the total number of attractive areas does not increase significantly in the central and northern districts since the improvement of accessibility to metrostops in these areas is not a top priority among the middle class (see figure 4) who are, however, sensitive to accessibility to metrostops in the northern and southern districts, where the commuting distance makes use of the metrosystem practical.



(a) (b) (c)

Figure 4. [In colour online.] The attractiveness of green housing to the middle class in three urban-development scenarios: (a) current situation; (b) after constructing new metrolines; (c) after relocating heavy industries.

After the relocation of heavy industry [figure 4(a)], attractive sites for green apartments decrease, in general, in the central districts, probably due to reduced job opportunities. In the northern and southern suburban districts, the number of attractive sites for the middle class increases because of the improved air quality (see table 2).

4.3.3 *Upper-middle class*

Figure 5 shows the attractiveness of green housing for the upper-middle class in three urban development scenarios. In the current situation [figure 5(a)], there are a few places in the central areas that are attractive to those in the upper-middle class wishing to buy a green apartment. In these districts the upper-middle class is more sensitive about air quality than the other two groups. Since there is some air pollution in most central districts, the attractiveness of these districts is quite low. Moreover, the upper-middle class is not sensitive about distance to metrostops in the central districts, probably because they can either walk to activities or use a car. The southern districts are preferable due to the relatively lower house prices and lower density compared with the central districts. The northern districts are not at all attractive to the upper-middle class.

After the construction of new metrolines [figure 5(b)], the number of attractive places does not increase significantly. Although the upper-middle class can afford the price premium exerted by the construction of new metrolines, it is not sensitive to the improvement of accessibility to metrostops. In the central and southern districts a few areas along the extended metrolines show an improved attractiveness, probably due to better accessibility to jobs.

With the relocation of heavy industry [figure 5(c)], the number of attractive places increases dramatically (see table 2). In the central urban districts those places with very good accessibility and good school quality show the greatest attractiveness. In the southern districts the removal of heavy industry reduces air pollution, which would otherwise be a deterrent. As a consequence, the southern districts' attractiveness improves exponentially.

4.4 Estimation of green housing opportunities in the surrounding agricultural areas

Figures 3, 4, and 5 show that the extension of the metronetwork impacts the attractiveness of green apartments within the transport corridors, and also potentially impacts locations further away from the metronetwork because of improvements in the overall quality of the transport network (Smith and Gihring, 2006). In this scenario, not only will the existing residential areas be influenced, but also the agricultural land surrounding the metronetwork and the residential land. For that reason, we analysed the potential effect of green housing opportunities on the surrounding agricultural land following the extension of the metronetwork and the relocation of heavy industry.

We chose to consider agricultural land within 5 km of the new metrolines. We also added a new variable in table 1, reflecting the noise levels generated by aeroplanes landing and taking off at Nanjing Lukou airport, which is located in a southern district. On the basis of the information for this airport, 70 dB is considered the threshold value influencing residents' day and night living activities. We gave a score of 2 to areas outside the 50 dB contour, 1 to areas within the 50–70 dB contour, and 0 to areas within the 70 dB contour.

In constructing green buildings and green neighbourhoods, planners can choose between redeveloping brownfield sites or developing greenfield sites (agricultural land). Comparing figures 3, 4, and 5 with figure 6, we see that after implementing the two sustainable planning interventions, the number of attractive areas for green apartments on greenfield sites dramatically outscores those on brownfield sites. While the attractive brownfield sites are concentrated mainly in the northern districts for the lower-middle and middle class and southern districts for the upper-middle class, greenfield sites provide much more attractive location options for all socioeconomic groups. The eastern agricultural land in the southern

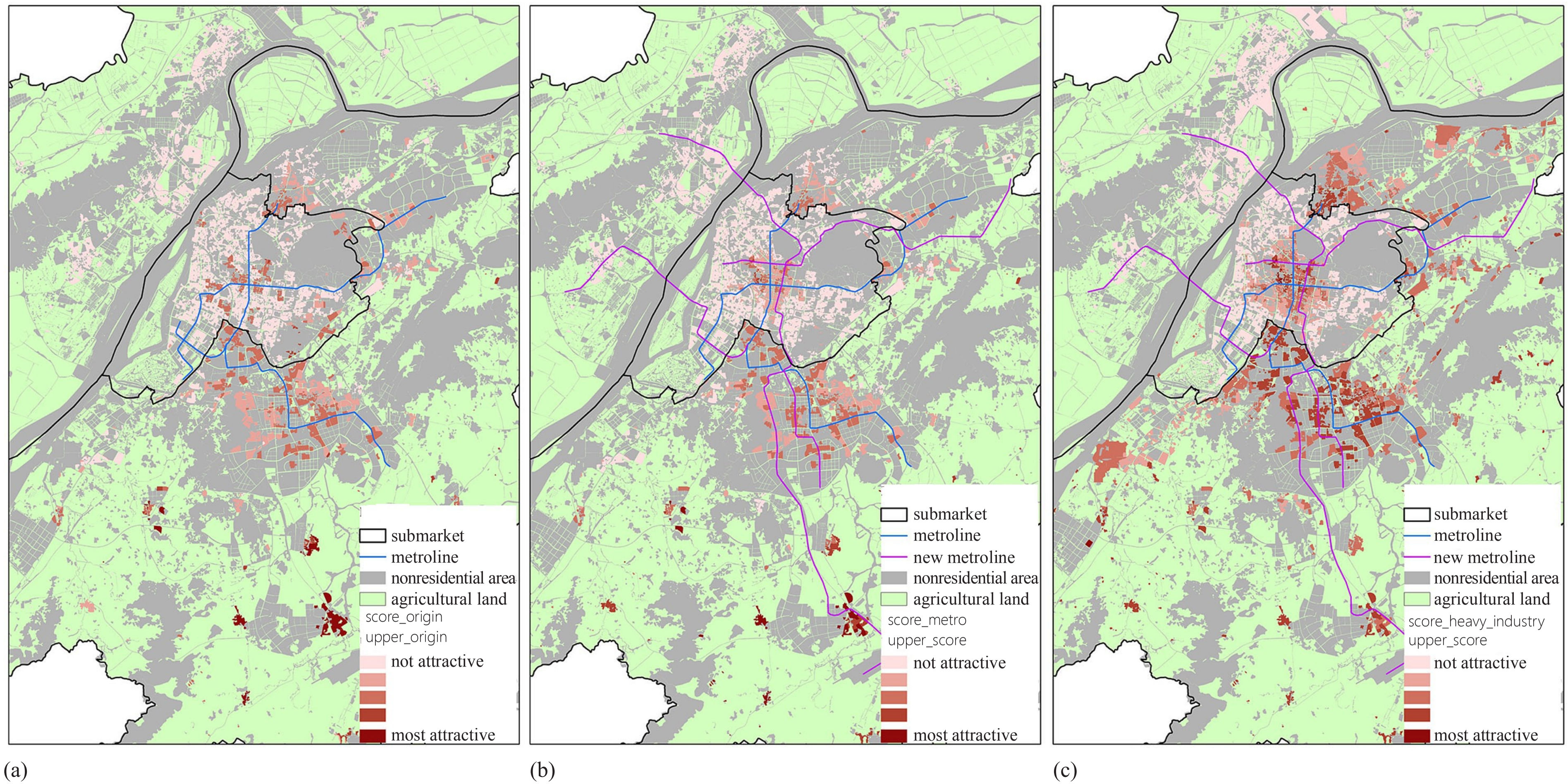


Figure 5. [In colour online.] The attractiveness of green housing to the upper-middle class in three urban-development scenarios: (a) current situation; (b) after constructing new metrolines; (c) after relocating heavy industries.

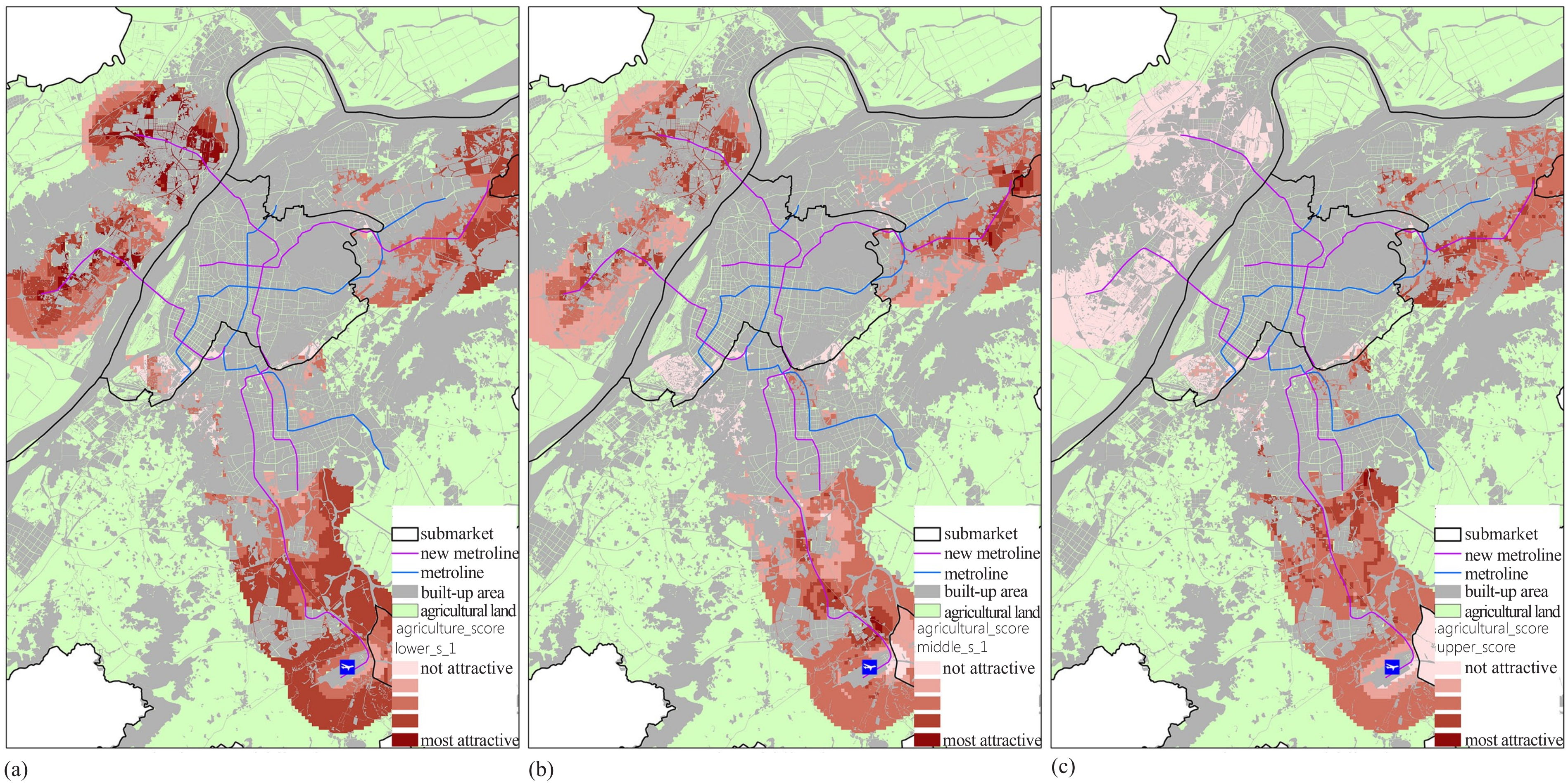


Figure 6. [In colour online.] The attractiveness of green housing located on the surrounding agricultural land for (a) the lower-middle class; (b) the middle class; and (c) the upper-middle class.

suburban districts is the most attractive to all three groups. These areas are close to not only the metrolines but also university campuses. The agricultural land in the south of the southern districts also shows a clear potential for the development of green buildings despite being comparatively far from the city centre. Agricultural land in the northern suburban districts is attractive to both the lower-middle and middle classes. With the new metrolines crossing the Yangtze River, the commuting time to the city centre from these areas is substantially reduced. In addition, the relocation of heavy industry helps to improve the air quality in these areas, making them much more attractive. However, the upper-middle class is not willing to live at the greenfield sites of the northern districts. Even after improvements in accessibility and environmental quality, the northern districts still lack attractiveness to the upper-middle class. If only the land-development cost and the revenues from the land lease are considered, the development of greenfield sites for green apartments would appear to be much more profitable than the redevelopment of brownfield sites. Planners need to be aware of this issue, especially in connection with sustainable planning.

5 Conclusions and discussion

Planning strives for a fair distribution of amenities and disamenities as well as of the advantages and disadvantages for the various groups in society. To successfully promote sustainable planning, sustainability and affordability need to be considered simultaneously. In this paper we have considered housing affordability and the green housing preferences of different socioeconomic groups in Nanjing, and proposed a planning support methodology to estimate green housing opportunities for these different groups. Since providing green housing consists of more than just constructing green dwellings, we have taken into account the wider living environment surrounding green buildings, such as accessibility to jobs and metrostops, and neighbourhood quality.

The proposed planning support methodology analyzes green housing opportunities from two perspectives: market supply and market demand. It uses conjoint modelling to analyze market demands (the willingness of various groups to pay for green housing attributes relative to other attributes in various segments of the market) and uses hedonic price modelling to simulate market supply (green apartment prices). With the simulated willingness to pay and affordability, this methodology estimates the attractiveness of land for green construction in three scenarios: the current situation, following improvement of the public transport network, and after relocation of heavy industry to peripheral locations. This planning methodology aims to support planners to explicitly take housing affordability into account in sustainable planning.

Our results show that, in general, green apartment buildings are attractive when they are located in good neighbourhoods which offer good accessibility to jobs, metrostops, and clean air. However, the green housing opportunities of various groups are constrained by housing affordability and homebuyers' green housing preferences. In the current situation in Nanjing, the lower-middle class can hardly afford to buy green apartments anywhere in the city due to high house prices in relatively good locations. The middle class has more opportunities to buy green apartments in the various submarkets since those in the middle class have relatively higher budgets. The upper-middle class considers only a few areas in the southern suburban and central districts attractive for buying a green apartment. The extension of the metronetwork will increase the attractiveness of the northern districts and could potentially increase green housing opportunities in the central urban districts for the lower-middle class if housing size is traded for accessibility to the metronetwork. However, this planning intervention has limited effects for the middle and upper-middle class since they do not value accessibility to metrostops as highly as the lower-middle class. In contrast, the relocation of heavy industry will dramatically increase the green housing opportunities for the upper-middle class, but will force the lower-middle and middle classes out of the city centre because of decreased job opportunities. Moreover, after the sustainable planning interventions, the greenfield sites within a few kilometres of the metrolines are more attractive for green housing than brownfield sites for all three socioeconomic groups. From a market perspective, the redevelopment of greenfield sites into green residential areas might be more beneficial than the redevelopment of brownfield sites.

This methodology will help planners to devise sustainable plans based on a better understanding of green demand and supply in the market. This understanding is derived from a simulation of the willingness of different socioeconomic groups to pay for green apartments in the various submarkets in Nanjing. More generally, this planning support methodology facilitates sustainable planning through reconciling three perspectives: improving the energy performance of dwellings and the living quality of the wider environment to promote ecological sustainability; ensuring green housing opportunities for various socioeconomic groups to promote social sustainability; and considering the willingness of homebuyers to pay for green buildings in specific submarkets, which can be stimulated by the introduction of special subsidies as well as the provision of long-term housing loans to green homebuyers. This will increase green housing affordability and also enable these groups to have a higher quality of life. In addition, governments can introduce measures to reduce the cost of green construction by providing subsidies for healthy construction materials that are good for the environment and people's health, such as solar panels. This will help, indirectly, to increase the affordability of green apartments.

This methodology, like any other, has its limitations. It processes a simulation of the housing market before and after the implementation of some planning interventions without verifying the effects of such interventions in a real-world situation. We carried out more than 1000 surveys with residents and lots of interviews with planners, developers, and residents. Since these planning interventions are just beginning, and the fieldwork was based on a hypothetical market, it would be helpful to verify the effects of such planning interventions using a follow-up survey. Generalization of the results reported here is restricted because the simulation and results are influenced by specific local policies and urban development constraints. For instance, we did not include information about the destinations of the relocated heavy industries and, thus, did not take into account the potential negative impacts on these areas. Despite these limitations, however, this planning support methodology can be applied to other cities; it will simply require certain adaptations to the input values in the modelling process in order to identify sites for green apartments which are both affordable and attractive to various socioeconomic groups.

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Appendix A

Table A1. Coefficients of the variables in the hedonic price model.

Variable	Description	Mean	Standard deviation	*B*
LN_PRICE	Logarithm of house price per square meter (Yuan/m^2)	9.36	0.44	
Dwelling attributes (H)				
AGE	Age of an apartment building	7	6.93	−0.013
BATHROOMS	Number of bathrooms	1.31	0.57	0.069
Accessibility (A)				
URBAN	Dummy: 1 if urban	0.65	0.48	0.364
SSUBURBAN	Dummy: 1 if in southern suburb	0.13	0.34	0.088
LN_BTJOBEDU	Job accessibility potential in higher education (log)	−0.97	0.43	0.135
LN_BTJOBGOV	Job accessibility potential in large governmental institutions (log)	−1.23	0.43	0.100
LN_BTJOBF&B	Job accessibility potential in the financial and business services (log)	0.34	0.71	0.047
BTJOBHIND<20	Accessibility count of heavy industrial jobs within 20 min	3434	2969	−0.004
BTJOBHIND20-40	Accessibility count of heavy industrial jobs within 20–40 min	21 328	12 086	0.001
LN_DEXPRESS	Log distance to nearest access of city expressway (km)	0.76	1.08	−0.029
LN_DMETRO	Log distance to nearest metrostop (km)	0.62	1.21	−0.009
LN_BTSQUARE	Log time cost by public transport to the nearest square (min)	2.88	0.62	−0.051
LN_BTPARK	Log time cost by public transport to the nearest large park (min)	2.79	0.45	−0.032
LN_BTTRAINS	Log time cost by public transport to the railway station (min)	3.60	0.57	−0.019
Neighbourhood quality (N)				
NSCHOOLDIS	Dummy: 1 when apartment is in a high-quality school district;	0.06	0.24	0.105
NHERITAGE	Dummy: 1 when in a neighbourhood with historical heritage;	0.09	0.29	0.055
NRILAKE	Dummy: 1 when there is an urban river or lake within 500 m	0.07	0.26	0.056
NPARK	Dummy: 1 in a neighbourhood with a park	0.11	0.32	0.023

Appendix B

Table B1. Utility of housing attributes for three social groups.

Central districts				Southern districts				Northern districts			
attribute utility	L[a]	M[a]	U[a]	attribute utility	L[a]	M[a]	U[a]	attribute utility	L[a]	M[a]	U[a]
Constant	−2.664*	−1.403*	−0.412*		−1.055*	0.153*	−0.189*		−0.009	−0.769*	−6.511
House price (yuan/m²)											
20 000–25000	0.401*	0.599*	0.627*	10 000–15 000	0.772*	0.936*	0.256*	6000–8000	0.870*	0.277*	0.080
25 000–30000	0.168*	−0.131*	0.089*	15 000–20 000	0.065*	0.161*	0.154*	8000–10 000	0.164*	0.117*	0.101
>30 000	−0.569*	−0.468*	−0.716*	20 000–25 000	−0.836*	−1.097*	−0.410*	10 000–15 000	−1.034*	−0.394*	−0.181
School quality											
Very good	0.172	0.145*	0.254*	very good	0.151*	0.068*	0.190*	very good	−0.833	0.073	0.529
Good	0.137	0.039*	−0.020*	good	0.012*	0.060*	0.010*	good	1.805	−0.019	−3.649
Average	−0.309	−0.185*	−0.233*	average	−0.162*	−0.128*	−0.200*	average	−0.972	−0.054	3.120
Environmental pollution: travel time to heavy industry											
>40 min	0.225	0.158	0.688*	>40 min	0.213*	0.341*	0.647*	>40 min	0.299*	0.349*	3.788
20–40 min	−0.071	−0.065	0.017*	20–40 min	−0.083*	−0.100*	0.049*	20–40 min	0.073*	0.014*	3.340
<20 min	−0.154	−0.093	−0.704*	<20 min	−0.130*	−0.241*	−0.695*	<20 min	−0.373*	−0.364*	−7.128
Accessibility to metrostop											
<1 km	−0.256*	0.048	0.102	<1 km	0.002	0.119*	0.071	3–4 km	0.064*	0.113	3.606
1–2 km	0.018*	−0.121	−0.058	1–2 km	0.061	−0.006*	−0.001	4–5 km	0.056*	−0.061	−3.481
2–3 km	0.238*	0.074	−0.043	2–3 km	−0.063	−0.113*	−0.070	>5 km	−0.120*	−0.051	−0.125
Accessibility to job (by public transport)											
Good	0.094	0.105*	−0.093*	good	0.101	0.042	0.136*	good	0.158*	0.140*	−0.167
Relatively good	−0.203	0.108*	0.168*	relatively good	0.018	−0.042	−0.007*	relatively good	0.131*	0.038*	3.262
Poor	0.109	−0.213*	−0.075*	poor	−0.120	0.000	−0.129*	poor	−0.289*	−0.178*	−3.096

Table B1 (continued).

Central districts				Southern districts				Northern districts			
attribute utility	L[a]	M[a]	U[a]	attribute utility	L[a]	M[a]	U[a]	attribute utility	L[a]	M[a]	U[a]
Energy and water costs											
Low	−0.017	−0.144	0.135*	low	−0.039	−0.050	0.030	average	0.018	−0.044	0.254
Average	−0.108	0.126	−0.018*	average	−0.031	0.011	0.020	above average	−0.046	−0.020	0.085
High	0.125	0.017	−0.117*	high	0.070	0.039	−0.050	high	0.028	0.064	−0.339
Construction materials											
Healthy	−0.015	0.018	0.109*	healthy	−0.014	0.091*	0.081*	somewhat healthy	0.017	−0.058	0.306
Somewhat healthy	0.260	0.043	0.002*	somewhat healthy	0.074	−0.019*	0.044*	somewhat harmful	0.023	0.024	−3.518
Harmful	−0.244	−0.062	−0.110*	harmful	−0.060	−0.071*	−0.125*	harmful	−0.040	0.034	3.212
Thermal insulation											
Good	−0.140	−0.048	0.014	good	0.069	−0.004	0.016	average	0.012	0.170*	0.084
Average	0.291	0.025	0.066	average	−0.069	0.039	0.003	below average	−0.049	0.029*	3.467
Poor	−0.151	0.022	−0.080	poor	−0.000	−0.035	−0.019	poor	0.037	−0.199*	−3.551

* indicates that attributes are significant at 0.05 level.

[a] L, M, U represent lower-middle, middle, upper-middle class, respectively.