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Envisioning Beijing 2020 through sketches of urban scenarios☆

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Abstract

To provide the decision-makers in Beijing, China, with an assessment of alternative development futures, we introduce scenario planning to process of drafting Beijing's 2020 Plan. The sketches of scenarios for Beijing are fruitful in several ways. First, the development of scenarios can meet the Beijing Municipal Commission of Urban Planning (BMCUP)'s needs to explore different urban development options. Second, scenario planning can accommodate uncertainty in economic and population growth caused in part by China's rapid social and economic transformation. Third, in the course of creating evaluation framework to assess scenarios, scenario planning informs decision-makers about choices regarding predicted outcomes. We demonstrate that in a city that is experiencing unforeseen growth in the era of transformations, the decision-making process can be informed by evaluating the performance of alternative development scenarios.
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Keywords: Scenario planning; Evaluation of plans; MAUA; Beijing

Background

Many Chinese cities have experienced unprecedented growth during the recent era of transformation from a planned economy to a market economy. To adapt to this rapid transformation of both social and physical environment, Chinese urban planners are seeking to inject innovative planning methodologies to previous Chinese comprehensive planning processes which have been criticized as being too static, too focused on physical and land use planning, and too single-dimensional without considering other social goals (Huang, 2004). As a result, many of the comprehensive plans of Chinese cities have not been able to keep up with rapid urban developments in recent decades.

Beijing, the capital city of China, offers one such example. The city experienced double-digit growth rate in its gross domestic product (GDP) over the last decade. By 2003, the rapid population and employment growth exceeded the forecasts that underlie Beijing's previous, 1992–2010, Comprehensive Plan (hereafter "the 1993

☆This paper summarizes major findings of a large research project funded by the Lincoln Institute of Land Policy and the Beijing Municipal Commission of Urban Planning (BMCUP). For more details of the project, a 250-page technical report, drafted in both English and Chinese, would be available upon request from the authors (Knaap, Ding, and Song, 2005).

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Plan'' since it was adopted in 1993) which cause that plan to fail in guiding urban development patterns in an effective manner. Consequently, the Beijing Municipal Commission of Urban Planning (BMCUP) began to prepare a revision to the 1993 Plan. The revision was sought to create new guidelines for accommodating the city's inevitable urbanization process, to reduce the land use and infrastructure inefficiencies that have accumulated over the past 20 years, and to address the social, economic, and physical development challenges the city has been facing. In 2003, the BMCUP developed its Beijing Urban Spatial Development Strategy Study'' (hereafter ''the Study'') in which a synopsis over Beijing's urban goals and visions has been presented. The city became conscious of the need to develop a planning process that can accommodate rapid growth without loosing the sight of comprehensive societal goals. The Study stated that it is essential to balance environmental protection and economic development and to protect cultural, historic, environmental, open space, and other special areas. The Study also initiated a set of questions regarding Beijing's urban scale, density, and spatial expansion pattern. Given the level of uncertainty associated with rapidly changing urban growth situations, the BMCUP endeavoured to explore a full range of alternatives of urban growth patterns and growth policies to prepare for possible growth scenarios.

In this context, we were invited by the BMCUP to provide technical assistances during drafting the revision to the 1993 Plan in summer 2004. Representing an effort to address the questions raised in the Study, we applied scenario planning to probe new planning strategies in Beijing's planning process. The purpose of this article is to report the procedures we used to create and evaluate scenarios and the major findings that emerged from this process. The paper is divided into the following sections. In the next two sections we include reviews of Beijing's planning system and on the use of scenarios in planning, respectively. In the fourth section, we present the procedures we followed to construct urban growth scenarios for Beijing's 2020. The fifth section contains a discussion of techniques we adopted to evaluate those alternative scenarios. A summary of the key issues for policy implication and for future research are put forward in the concluding section.

Urban planning in Beijing, China

Located in North China, Beijing consists of 16 districts and two counties (see Fig. 1), with a total land area of 16,808 km^2 and a total registered population of almost 15 million in 2002 (Beijing Statistical Bureau, 2003). The spatial structure of Beijing reflects its imperial traditions rooted in serving as the national capital or the political centre for much of the time since the 10th century A.D. Before 1949, Beijing was focused on the time-honoured ceremonial axis and centre. Beijing, in the 1949–1978 era, strengthened its traditional urban form by constructing ring roads and aligning major street networks and monumental architecture along the cardinal directions. Planning in this period placed new developments around large, walled work-units, based on the assumption that job and housing balance can be upheld within the work-unit compounds and that various basic functions of daily life can be provided within the work-unit community (Ding & Song, 2005). After 1979, urban development in Beijing shaped the city into a set of spatially and functionally specialized districts (Chen, 1991; Gaubatz, 1995; Huang, 2004; Quan, 1991): the historic city core supported by extensive preservation efforts; the central built-up area, which hosts much of the rapid developments since the 1980s; the low-density greenbelt zone, which surrounds the urbanized area; the inner suburban development area, which serves as a bedroom community with a lack of mixed uses, employment opportunities, and public transportation services; and the outer suburban area with 14 satellite towns that retain strong ties with the central urban core area[1] (Fig. 1).

Since 1979, two comprehensive plans were prepared by professional planning bureaus for Beijing: one in 1982 and the other in 1993. Despite the concerted efforts to adopt analytical frameworks ranging from central-place theory to social-area analysis (Gaubatz, 1995), urban planning in the period was mainly geared to physical and land use planning. This focus of physical planning process is likely to be expanded with three major developments.

First, economic change and development are occurring so fast that uncertainties with respect to major variables, such as economic and population growth, have increased. For example, obtaining accurate population estimates, indispensable in the planning process, has become more challenging as the national

[1]For a more detailed overview on historic and current urban development patterns in Beijing, see Gaubatz (1995).

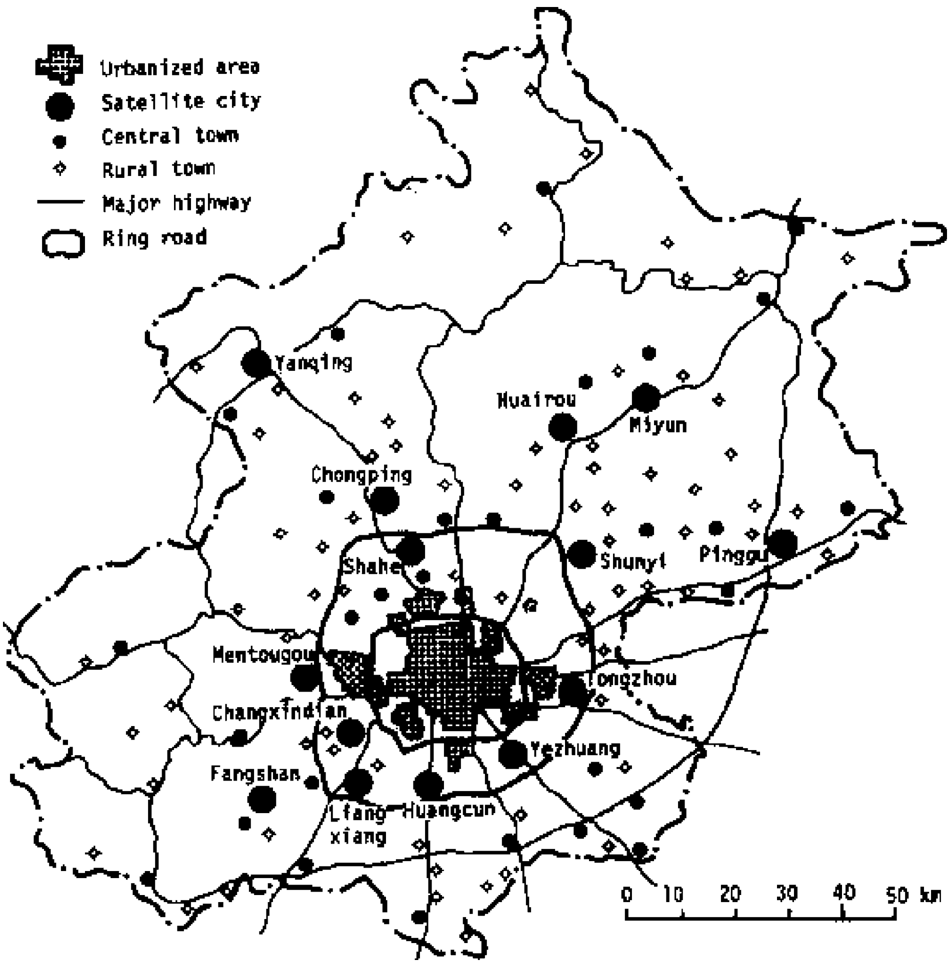

Fig. 1. The spatial structure of Beijing (Source: Fan, 1993).

population policy[2] changes and the urbanization process continues. Without certainty, it is difficult to predict the pace at which the city is growing. While the current Chinese comprehensive planning process has been criticized as being too static (Huang, 2004), it is essential that urban authorities and planners are aware of this drawback. The evolution of a new urban planning approach, in this respect, is to understand the implications of uncertainty, to characterize alternative visions, and to prepare for various situations. Constructing development scenarios provides a useful means for carrying out this task.

Second, planning practices in many Chinese cities have their emphasis on shaping physical forms of cities. In spite of planners' determined efforts in utilizing physical and land use planning to guide developments, planning in many Chinese cities has been less responsive to the increasing strength of market forces. Increasing number of politicians and planners has gradually realized the futility of such a planning practice. For example, Beijing's 1993 Plan called for polycentric spatial pattern, transforming the city into a multi-nuclei format through the establishment of self-sufficient satellite towns in the outer suburban area. Conversely, several factors, such as the continuing attractiveness of urban core and the paucity of various services provided in satellite towns, contributed to the initial failure of this plan. In other words, the planned polycentric pattern neglected the impact of market forces and cultural preferences. Spatial development pattern of urbanization in Beijing remains monocentric (Huang, 2004). Another example of the deficiency of over-relying on physical planning can be illustrated by the gap between the planned and actual distribution of job and housing in

[2]Ding and Song (2005) provided more discussion on China's HuKou regesitry system which is one of the population control policies.

Chinese cities and its resulted negative impacts on transportation. Planning efforts, since the 1950s, have emphasized job-housing balance at the neighbourhood level, a concept inherited from the old danwei work unit system (Ding & Song, 2005). However, this land use pattern no longer functions. As the city continues to expand and increasingly fewer people report to a local work unit, more and more city residents live and work in different parts of the city. These expanded journeys-to-work, along with the constraints by the urban form with the inherited land use and grid pattern in the city core and the lack of consideration of integrating land use and transportation systems, are causing deteriorated urban transport conditions (Huang, 2004; Sit, 1996). An advancement of the urban planning approach in this respect is crucial for a functioning urban system that endures in the era when economic activities are occurring at an unprecedented rate.

Third, there is an increasing need for a planning system, which can integrate a broad set of goals. Undoubtedly, there are multiple issues that Beijing's plan attempts to address. Among many issues, Deng and Huang (2004) document Beijing's excessive urban expansion (or urban sprawl) and its causes. Sit (1996) lists the elements that have interlocked to produce Beijing's current congested transportation situations. Hao, He, Wu, Fu, and He (2000) provide some evidence on how Beijing is facing the environmental threat resulting from the air pollution from vehicle emissions. Other issues include regional equity (Lu & Wang, 2002), inner city renewal (Leaf, 1995) and general well-being of the citizens. The set of imminent goals that have been considered by the urban authority in Beijing are: *efficient land consumption,* to preserve the nation's limited agriculture land resources; a *cost-effective transportation system,* to increase the integration of the transportation and land uses; and *improved air quality,* to safeguard the general health of the public (Huang, 2004). Inevitably, there are conflicts between planning goals, between stakeholders, and between planning and development interests. An enhancement of the urban planning approach in this respect involves the evaluation of alternative development scenarios based on the employment of multiple indicators corresponding with the set of goals.

The use of scenarios in urban planning

Development of scenarios as a means of representing possible future alternatives has been in the planner's toolkit for several decades. Van der Heijden (1996, p. 29) states that "scenarios are a set of reasonably plausible, but structurally different futures", thus, as a set, scenarios should "represent our current understanding of the rage of uncertainty" and should be used to represent "our best knowledge of the situation and outlook, and thereby lead to better strategies" (Van der Heijden, 1996, p. 105).

Xiang and Clarke (2003) provided a list of examples where scenarios were included in the regional land use planning process. Recent examples of places that include alternative urban future studies include: the City of Vasteras, Sweden (Khakee, 1991), the greater San Francisco Bay region, California (Landis et al., 1993), New York (Yaro & Hiss, 1996), and the Santa Barbara region, California (UCIME, 2001). According to Majone (1984), Khakee (1991), Avin and Dembner (2000), and Xiang and Clarke (2003), the use of scenarios in land use planning has gained growing popularity because: (1) planners can selectively envision a set of hypothetical development contingencies with each set either matching with a combination of goals and priorities, or resulting in part from the decisions and actions of various actors; (2) planners can use scenarios to delimit the uncertainties; (3) planners can incorporate explicit assumptions to construct different set of alternatives; (4) planners can employ scenarios to synthesize fragmented, dispersed and sometimes vague knowledge; (5) planners can utilize scenarios strategically to search for vehicles to achieve goals and to inform the decision makers; and (6) planners can employ a set of scenarios representing different futures to encourage a lively discussion and to engage citizens who may have difficulty comprehending community planning in the abstract. In summary, use of scenarios not only contribute to modeling and planning of alternative developments, but also ultimately improves the quality of decision-making.

There is little specific guidance on scenario-building in planning field (Avin & Dembner, 2000). Xiang and Clarke (2003) proposed three criteria of good scenarios. First, a good scenario creates *surprising and plausible* futures by incorporating future uncertainty, the likelihood of alternative outcomes, comprehensiveness of issues, and diversity of stakeholders in their values and goals. Second, good scenarios use *vivid information* in their compositions and present information in a vivid way. In other words, effective scenarios are connected with important issues so that they can inspire the stakeholders, the general public, policy makers, planners, and other interested groups. Finally, the design of scenarios—specifically, the number of themes or dimensions, the size, and the timeframe of a scenario set—should be carefully chosen so that the scenarios can interact with the users effectively. In addition, Shearer (2005) argues that since scenarios are founded on assumptions of possible change, the perceptions about the future scenarios should be *explicitly* addressed before an investigation is undertaken to avoid methodological biases in the creation of the scenarios and misunderstanding of the results. Important perceptions about scenario analyses include issues such as: why a study is undertaken, how change occurs, and what it expected to change or not change over the time horizon of the study. Unless the assumptions are explicitly addressed as part of scenario construction, the representation of the future may be ill defined.

Concomitant with the creation of the scenarios, evaluation criteria can be established (Avin & Dembner, 2000) so that an evaluation of alternative scenarios can be performed to reveal future opportunities and directions. As a response to the evaluation challenges in considering multiple goals and objectives scenario planning, multi-attribute utility analysis (MAUA) has been considered as the most effective method for evaluating different scenarios or policy options for several reasons (Edwards, 1977; Roth & Bobko, 1997; Von Winterfeld & Edwards, 1986). First, MAUA enables scenario builders to incorporate policy makers' inputs. Second, it allows for the inclusion of many different and often conflicting and incomparable objectives into the decision-making process. Finally, it provides a framework for decision makers to come to agreement about their priorities. To perform the MAUA, stakeholders are asked to assign weights to the quantitative indicators according to their opinions on which attributes are most important. Although the process of assigning weights might involve arbitrary decisions, discussion and agreement on the weighting by a group of stakeholders provides assurance that sufficient checks and balances existed in the process to eliminate any outlier opinions. In effect, factor weighting conducted by a group of high-level officials is not arbitrary but represents consensus building on the jurisdiction's priority goals and objectives. In addition, performance indicators need to be adopted to provide a range of measures to assess the achievement of each scenario. The literature suggests an empirical method by which expert opinions should be considered in the selection of indicators and the weighting and scoring of these indicators (Hemphill, Berry, & McGreal, 2004). Coombes and Wong (1994) illustrate a four-step procedure in determining the selection of indicators: (1) clarify the basic concept to be represented in the analysis, (2) provide a rationale for the identification of the indicators that are closely related to the current issues which policy-makers are to address, (3) identify indicators based on data availability, implementation and interpretability, and (4) select a weighting scheme to combine the individual indicators into an index according to their relative importance.

Constructing scenarios for Beijing

We introduce the use of scenario planning to the drafting of Beijing's 2020 Plan. We describe our three steps in scenario building below.

Step 1. *Review of current planning system*. The first step in scenario planning is to obtain an understanding of the general context in which urban development has occurred to date, such as prior planning efforts and broad political and economic characteristics. We have presented this part of our review in Urban planning in Beijing, China.

Step 2. *Analysis of existing urban development patterns*. The second step is to conduct an analysis of existing urban development patterns such as population and economic growth, demographic characteristics, existing land use and transportation patterns, and the development capacity of each jurisdiction. This analysis is important since it reveals the range of possible urban development futures that could occur.

Given the data available, we carry out Geographic Information System (GIS) analyses for each jiedao, the lowest administrative unit for which socioeconomic data is collected for Chinese cities, in the study area (Fig. 2). We present the measures of existing urban development patterns and describe the patterns below:

(1) *Current population density*: Population density is calculated by dividing total jiedao population by total jiedao land area. Fig. 3a illustrates the population density for each jiedao. It shows that population density declines as distance from the urban core increases and that urban development follows major highway corridors. These patterns are similar to many urban areas in developed countries.

Fig. 2. Beijing city boundary and our study area.

Table 1
Frequency distribution of levels of job and housing balance

	Population density	Employment density	Count
Module 1	30,000–40,000 (High)	> 13,000 (High)	4
Module 2	15,000–30,000 (Medium)	5000–13,000 (Medium)	5
Module 3	< 15,000 (Low)	< 5000 (Low)	11
Module 4	15,000–30,000 (Medium)	> 13,000 (High)	21
Module 5	< 15,000 (Low)	> 13,000 (High)	3
Module 6	30,000–40,000 (High)	5000–13,000 (Medium)	5
Module 7	15,000–30,000 (Medium)	< 5000 (Low)	24
Module 8	30,000–40,000 (High)	< 5000 (Low)	0
Module 9	< 15,000(Low)	5000–13,000(Medium)	0

(2) *Current employment density*: Employment density is obtained by dividing total employment by total industrial, commercial, and office space in each jiedao. We show that employment density tends to be less dispersed than population density and is highest toward the city centre (Fig. 3b).

(3) *Analysis of distribution of population and employment*: Using the above computed employment and population densities, we further study frequency distributions of those densities for each jiedao. We perform cluster analysis in order to group jiedaos into different categories based on their population and employment densities. In other words, rather than assigning jiedaos to different density groups (high, medium, and low) based on a priori classifications, we cluster the jiedaos statistically. We adopt the hierarchical agglomerative clustering method[3] and identify nine distinct development types (Table 1). We find that 24 jiedaos have

[3]The essence of cluster analysis is to allocate individual observations to groups so that observations in a cluster can be more similar to one another than to the properties in other clusters. There are two general forms of cluster analysis: hierarchical clustering and K means clustering. Further, There are two types of hierarchical clustering: agglomerative and divisive. In agglomerative clustering, each object is initially placed in its own group. The two ''closest'' groups are combined into a single group. This procedure of grouping the two most similar clusters at each stage continues until all observations are in a single cluster. In divisive clustering, all objects are initially placed into a single group. The two objects that are in the same group but are ''farthest'' away are used as seed points for two groups. All objects in this group are placed into the new group that has the closest seed. This procedure continues until a threshold distance is reached. K means clustering analysis is different from hierarchical clustering in that the number of clusters, K, needs to be determined at the onset. The goal is to divide the objects into K clusters such that some metric relative to the centroids of the clusters is minimized.

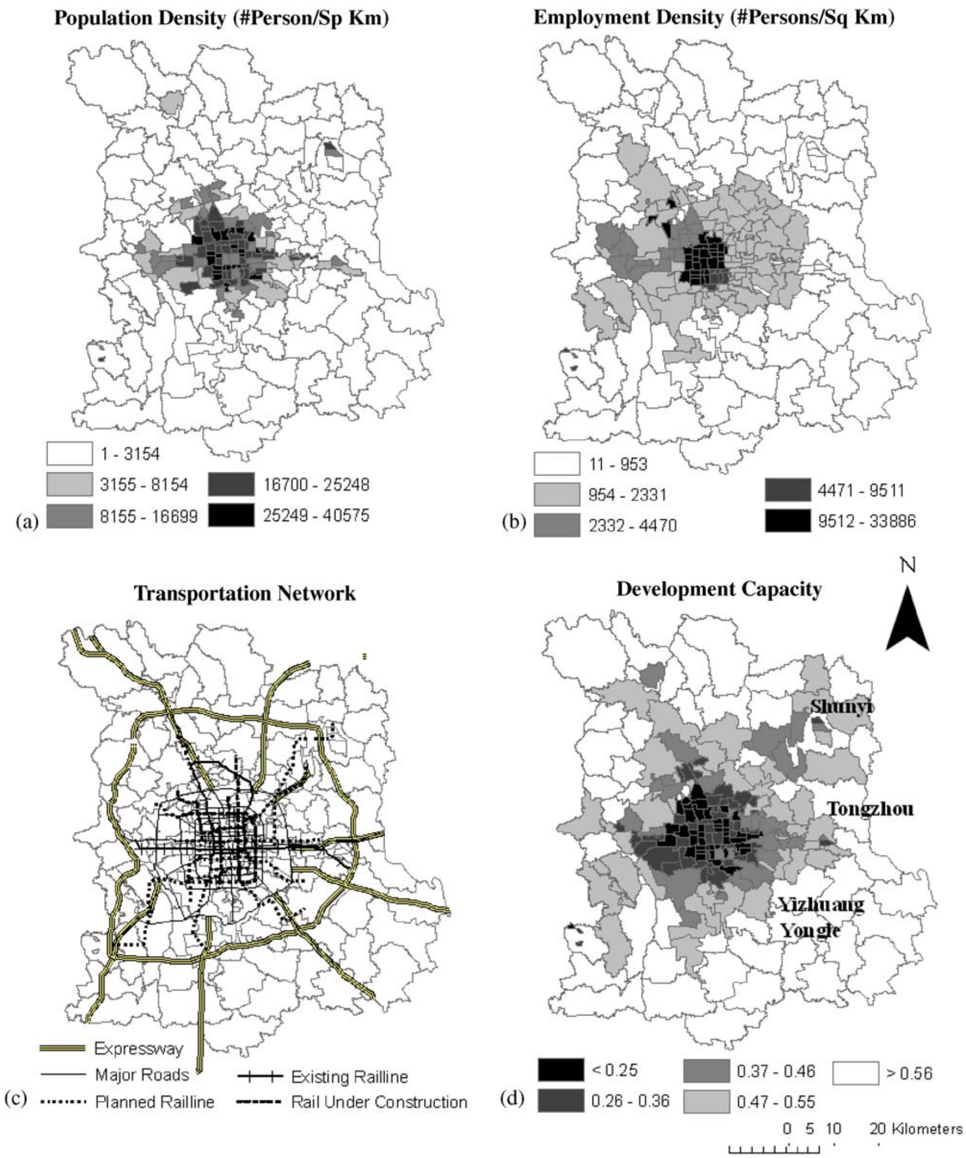

Fig. 3. Existing conditions: population and employment density, transportation network, and development capacity.

medium population density with low employment density (less than 5000 employments per km^2) and 21 jiedaos have medium population density (15,000–30,000 people per km^2) and high employment density (greater than 13,000 employees per km^2). Only 4 out of 73 jiedaos fall into the high population (30,000–40,000 people per km^2) and high employment density category. Eleven out of the 73 fall into the low-density population (less than 15,000 people per km^2) and low employment category and these jiedaos are located on the outskirts of the study area.

The grouping of jiedaos into density categories can serve for two purposes. The modules created from the cluster analysis inform us about existing development patterns. More importantly, the modules can be used as prototypes or "building blocks" that replicate properly the distribution pattern in reality when we allocate future population and employment in drafting of scenarios at the later stage.

(4) *Transportation networks*: Beijing has invested heavily in transportation infrastructure such as roads, expressways, and rails (Fig. 3c); it is thus sensible to guide growth to make most efficient use of the transportation investments. For this reason, we study the distribution of transportation infrastructure through

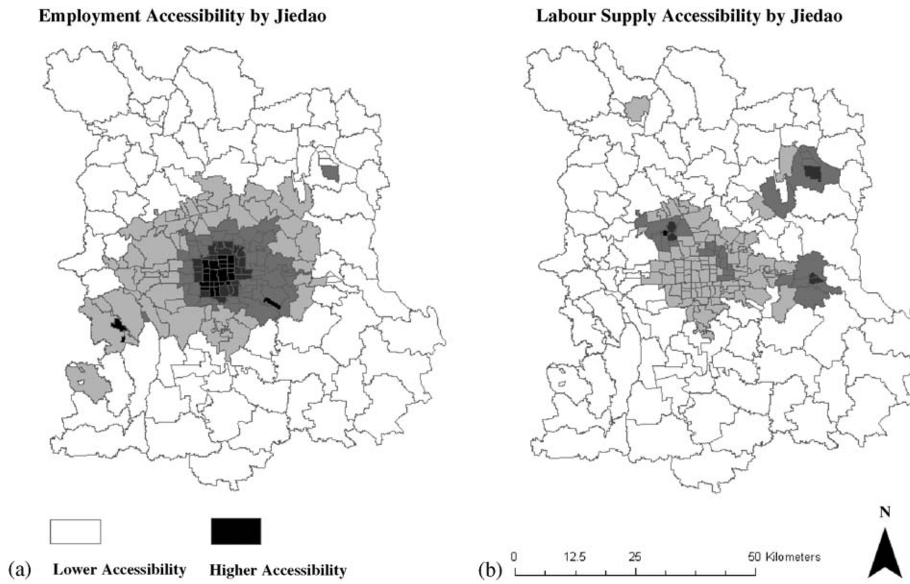

Fig. 4. Existing conditions: employment and labour supply accessibility.

measures such as road, highway, and rail densities, which are calculated by dividing linear length of each type of infrastructure in each jiedao by the area of the jiedao. We show that central city zones have received greater investment in road and rail constructions than remote districts. We also calculate two measures of highway investments per capita by dividing total length of highways by total jiedao population or total number of employees per jiedao, respectively. We find that highway investment per person or per employee is lower in central city zones than in the urban and suburban fringe zones.[4]

(5) *Development capacity*: Development capacity analysis, an essential tool for land use planning, determines the environmental, topographic, and existing land use opportunities for and constraints to future development. Given that several crucial data sets, such as historically preserved land, restricted land uses, natural topographical features, are unavailable to us, we perform a crude capacity analysis using our limited datasets by calculating the percentage of available land for development in the jiedao. We find that most developments have occurred along major transportation corridors, and thus development capacity is less in these corridors and in the central city area than in the outer areas (Fig. 3d).

(6) *Employment accessibility*: We calculate employment accessibility,[5] a measure of the balance between employment and population within a certain jurisdiction or area, because it indicates the degree of labour market efficiency. The information on employment accessibility is useful since it facilitates the allocation of future housing—notionally, putting housing in areas with greater employment opportunities would prevent excessive commuting between housing and employment centres. The index counts both locations of employment and locations of households. Thus, it considers not only the supply side but also the demand side of employment. Results of the distribution of employment accessibility indicate that employment accessibility is high in central city areas (Fig. 4a).

[4]For economics of exposition, we do not present the figures of this set of measures. They are available from the authors upon request.

[5]The employment accessibility index is calculated as follows:

$$AE_i = \sum_{j=1}^{n} \frac{E_j (d_{ij} A_{ij})^{-\beta}}{\sum_{k=1}^{m} d_{kj}^{-\beta} P_j},$$

where AE_i is the employment opportunity accessibility of jiedao i; n, m the number of jiedaos in the study area; E_j the number of employment opportunities in jiedao j; d_{ij} the distance between jiedao i and jiedao j; β distance decay parameter; P_j the population of jiedao j; and A_{ij} the accessibility enhancement parameter (if there is rail connection between jiedao i and jiedao j).

(7) *Labour supply accessibility*: Similarly, we calculate the labour supply accessibility index, which measures a jiedao's relative locational advantages for job seekers. The results show that labour accessibility is high in the central Shunyi and TongZhou districts (Fig. 4b).[6]

Preferably, a composite index of suitability for development can be further constructed by weighing and combining the above measures and this index would then be used to classify various development zones such as urban developed area, urban transition area, conservation zones, and other zones (Berke, Godschalk, Kaiser, & Rodriguez, 2006). Due to time limitations, we are not able to carry out the suitability analysis. Nevertheless, this set of measures of existing conditions informs us on the areas that are suitable for future development.

Step 3. *Drafting scenarios*. We synthesize our analyses of prior planning efforts and existing conditions and establish the framework necessary for the third step—the creation of alternative development scenarios. It is not realistic to study more comprehensive aspects of the urban built environment given our limited time so we attempt to address the following key problems. First, we seek to incorporate uncertainties in future population and employment growth. We decide to incorporate two sets of growth rate scenarios: slow growth and fast growth.[7] The creation of two different sets of scenarios allows decision makers to select growth patterns that best serve priorities in both low- and high-growth situations. Second, we incorporate our understandings of the existing conditions regarding population and employment density, transportation networks, employment and labour supply accessibility, and development capacity so that the scenarios generated are realistic. Third, we consider land use and transportation integration.[8] Finally, we strive to assimilate political preferences and differences in assumptions regarding parameters such as the distribution of population, employment, and transportation networks in alternative developments. We develop the scenarios using GIS applications.

In constructing the set of scenarios, previous analysis of existing conditions helps us determine the location of the growth centres and the amount of population and employment contained in each of the growth centres. For example, the information regarding the development capacity informs us where to locate the population centres; the information on employment and labour supply accessibility guides us where to plan for employment centres; and the information on development modules offers us a convenient way to target population and employment density levels for the growth centres and to sum the allocation of population and employment to reach our target fast or slow growth rates.

For each set of growth forecasts, we prepare three scenarios for the year 2020. Each scenario contains a set of images of its end-state. Because of the sketchy nature of our task in constructing the alternatives, the scenarios are exercised in an intuitive and qualitative outline.[9] The scenarios are nonetheless useful for examining the implications of various urban development alternatives. We summarize the scenarios below.

Scenario 1: *Compact growth*. Scenario 1 is a ''compact city'' type of scenario in which all new development is contained, either at increased densities, or at new growth centres along transit corridors, within the existing urban area of Beijing. Fig. 5[10] presents a conceptual illustration of the proposed urban development pattern in 2020. The compact growth scenario adopts the following primary growth management policies: (1) Direct growth toward major transit centres. Actions taken for implementation include allocating the majority of the growth to existing major employment centres in the city core, and TongZhou, YiZhuang, Haidian, and Shijingshan districts where a great deal of urban infrastructure investments, such as heavy rail, schools and hospitals, are already in place. Measures are also taken to assign the majority of the population growth-to-growth centres along the main transit corridors; (2) Balance population and employment along transportation

[6]For economics of exposition, we do not present more information on this measure here. They are available from the authors upon request.

[7]The fast and slow growth scenarios provide capacity for the population to increase to 21, or 16 million people and for the employment opportunities to increase to 8, or 6 million in the core area within the study area in year 2020, respectively. Details on our procedures of forecasting population and employment growth are available from the authors upon request.

[8]For all the scenarios, we adopt the 2020 transportation plan as it is given from the Transportation Centre. The scenarios do not vary in transporation systems.

[9]The descriptions of the main aspects of our scenarios may give an impression that the rationals for constructing scenarios were superficial. This is, however, not the case since the description of the scenarios and their associated performance in various parameters together with the analysis of existing conditions leading up to the scenarios cover over 250 pages in our complete technical report.

[10]For economics of presentation, we only present the results of the fast growth scenarios in Figs. 5–7 and Table 2.

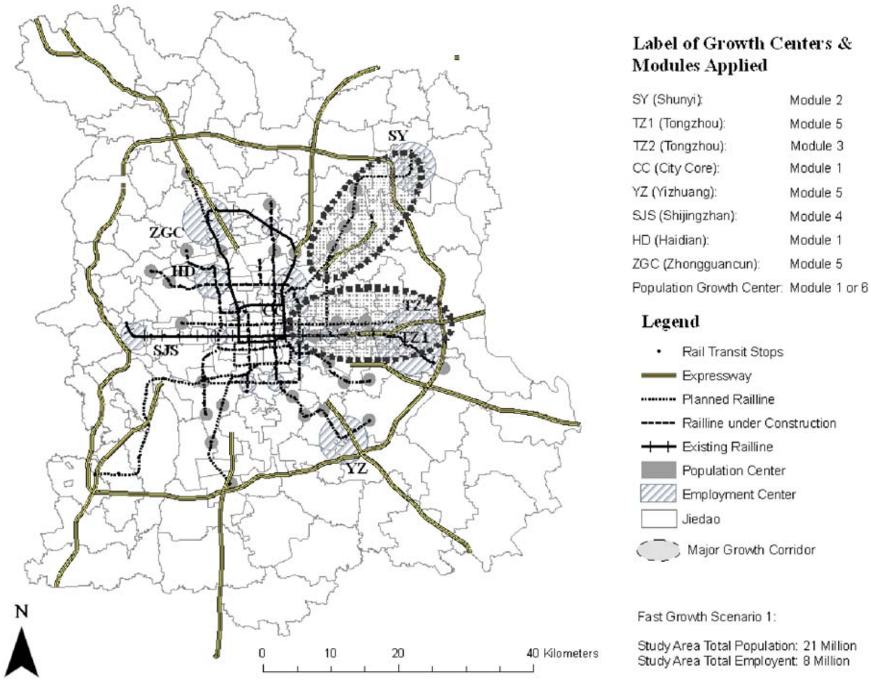

Fig. 5. Schematic map of fast growth scenario 1—Compact growth.

corridors at the sub-regional level. To correct for the deficiencies associated with promoting job and housing balance at the neighbourhood level, a sub-regional job-housing balance is sought to avoid incurring additional social and economic costs, such as extended commute times, decreased employee productivity, and severe traffic congestion. The scenario also incorporates Transit-oriented development (TOD) and the development of a Bus Rapid Transit (BRT) system, strategies that have not been considered within the Beijing context, as approaches to improving job-housing balance through the integration of land use and transportation; (3) Increase population and employment density between the second and fourth rings to contain growth to contain the growth within the existing urban area. Development is prohibited on greenfield sites or elsewhere in the rural hinterland.

Scenario 2: *Eastward-directed expansion*. This scenario incorporates many of the policies being pursued at present by the BMCUP: the creation of two-axis—the north–south and east-west axes that run through the centre of Beijing—to preserve the cultural and social identity of Beijing, the creation of two-belt—the west conservation belt and the east development belt—to seek the balance between the environment and development, and the development of ‘‘polycentres’’ in the eastern development corridor. More specifically, the scenario adopts the following policies: (1) Direct the greater part of the growth to three existing satellite towns, namely Shunyi, TongZhou and YiZhuang, along the eastern edge of Beijing and some part of the growth in the corridor to the city of Tianjin which is southeast to Beijing; (2) Restrict development in the environmentally sensitive upland areas west and north of the central city; (3) Strengthen the redevelopment in the central city core area; (4) Balance population and employment along the major highway corridor at the east side of Beijing. The general allocation of future development is illustrated in Fig. 6.

Scenario 3*: Outward expansion*. A final scenario, resembling the ‘‘*Tandabing*’’ (Chinese expression of ‘‘making a pancake’’) development style, is introduced to allow for an outward expansion of growth in a continuous form from the current high-density zones and in all directions from the central city. The greater part of the growth is accommodated within the limited expansion area, where residential development is combined with some industrial developments. Several larger formal industrial sites in the expansion area are redeveloped with mixed uses. Balancing of population and employment along major expressways and transit corridors is also sought. The build out pattern by 2020 is illustrated in Fig. 7.

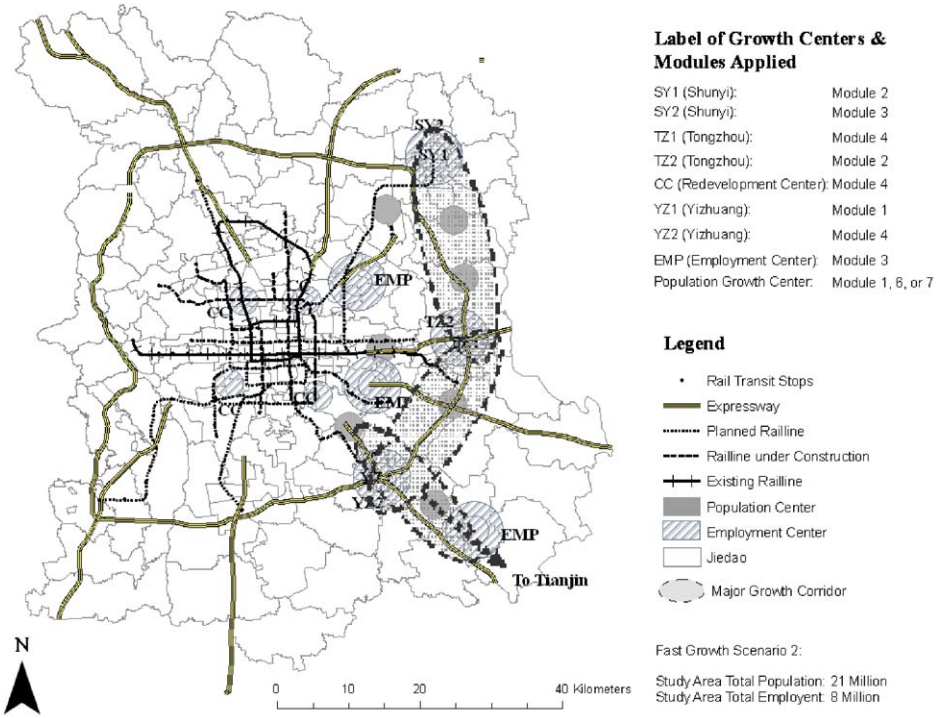

Fig. 6. Schematic map of fast growth scenario 2—Eastward-directed expansion.

The set of scenarios, as we presented here, are generated with the inputs from the politicians and planners in Beijing. Therefore these scenarios are plausible but also with surprises, which stimulate planners, politicians and other interested users to think in new ways of seeing the present as well as of visioning the future.

Evaluating scenarios

As each scenario attempts to address different facets of urban development, which are implications of the additional goals or objectives that each scenario is to achieve, it is useful to evaluate the scenarios to investigate the consequences of alternative scenarios and to inform the decision makers about the performance of each scenario in attaining different objectives. The evaluation is a process unto itself, which can be challenging and time consuming. We begin the process by identifying evaluation criteria and framework and evaluation technique. We then describe the results from the assessment.

Step 1. *Identification of evaluation criteria and framework*. Based on our analysis of existing concerns and our dialogue with planners and politician in Beijing, we identify the following set of goals that have been considered as important by the BMCUP: efficient land consumption, cost-effective land and transportation system, and improved air quality. It is then necessary to seek for indicators that can be used to evaluate effectiveness of scenarios in achieving the above goals. A list of indicators is identified based the following key performance principles, which in their totality, are instructive in evaluating the scenarios: Higher population and employment densities represent a viable measure to alleviate the excessive land consumption. Connection between new development areas and existing built-up areas through transportation corridor promotes land market efficiency. Regional job-housing balance, achieved through TOD, residential development along major transport corridors, and the general integration of transportation and land use can facilitate efficient commuting, decrease traffic congestion, and thus reduce vehicle emission-related air pollutants.[11] To quantify this set of key principles, we choose seven indicators in the following categories: population density, employment density, transit service to housing and to employment, home-based vehicle miles travelled,

[11]For justification of these key principles in the context of Beijing, please refer to the complete technical report.

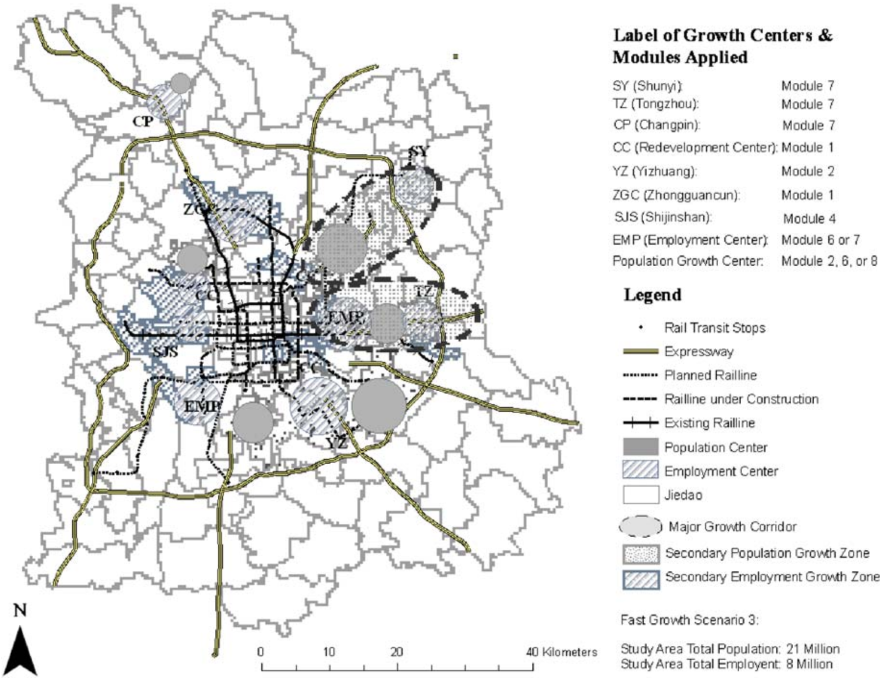

Fig. 7. Schematic map of fast growth scenario 3—Outward expansion.

non-home-based vehicle miles travelled, and greenhouse gas emissions. The formulas for computing these indicators are provided in the Appendix A.

Step 2. *Identification of evaluation technique*. After we finalize the set of goals and their associated indicators, we then decide how to standardize the measurement results and to weigh one measurement against another. For example, it is possible that a scenario is desirable to policy makers in terms of its environmental performance, but at the same time is undesirable in terms of housing density or transportation efficiency. We employ MAUA since it allows for maximum consideration of a wide variety of criteria. In Beijing, it is essential that policy makers examine as many dimensions of development as possible to predict the impact of their planning objectives and policies, and it is important the planners be given the tools necessary to conduct that sort of analysis. MAUA and its incorporation of multiple criteria represent one such analytical tool.

The use of the MAUA and the calculation of multiple indicators require intensive data from a wide variety of sources and over a significant time period. Beijing's lack of data certainly imposes some limitations to the project as it confines the indicators we can choose in evaluating alternatives. The limitation heightens the importance of improving data collection and maintenance in the near future.

Step 3. *Application of MAUA to the scenarios*. Finally, we calculate each indicator, employ Delphi and multi criteria analysis to establish weights to each indicator based on its relative importance, and rank each scenario. This process was aided by the use of INDEX[12] which is an interactive GIS-based planning support system that measures existing conditions, evaluates alternative plans, and supports implementation of adopted plans (CPF, 1999). It is noteworthy that various frameworks are available for modelling urban land use, transportation, and air-quality interrelationships. A sequence of modelling exercises of performances in land use, transportation, emissions, and air quality can be employed for more advanced simulations of land developments and assessment of the associated transportation and environmental impacts. INDEX provides a less sophisticated platform for modelling urban land use, transportation, and air-quality connections and thus demands much less data inputs. Mainly developed as a tool for sketch planning and thus employing a less rigid theoretical framework (Johnson, 2001), INDEX serves our purpose well for its explicit incorporation of a wide range of policy considerations in the decision-making process.

[12]A review of the INDEX software package is available from the authors upon request.

Table 2
Evaluation of fast growth scenarios

Selected indicators	SC I	SC II	SC III	Unit
Population density	16.34	14.63	15.58	p/ha
Employment density	6.22	5.26	5.98	emp/ha
Transit adjacent to housing	35.5	31.5	36.3	%
Transit adjacent to employment	37.7	37.2	38.1	%
Home-based vehicle miles travelled	8	11.5	7.5	mi/day/capita
Non-home-based vehicle miles travelled	4	5.5	3.8	mi/day/capita
Greenhouse gas emissions	4365	4894	4493	lbs/capita/year
Ranking (if efficient land consumption, or less vehicle-related air pollutants is given higher weights)	1	3	2	

Table 2 is a matrix detailing the indicators for each scenario. Performance of several measurements is consistent with the goals that the scenario attempts to achieve. For example, population and employment density are highest in scenario I, the scenario developed specifically to achieve higher densities. Similarly, greenhouse gas emissions, home-based vehicle miles travelled, and non home-based vehicle miles travelled are lowest in scenario I. This could be the case because jobs and housing are found at higher densities and are balanced and thus people do not have to travel very far to get to their residences or jobs. Meanwhile, scenario III has the highest percentage of transit adjacent to housing and to employment. This is consistent with the dominant characteristic of scenario III—that of spreading out growth in pancake-style to all directions from the central city. It is likely that the growth expanded in all directions will be close to transit.[13] The last row of Table 2 displays the ranking of the scenarios. Scenario I ranks first when either the goal of efficient land consumption, or the goal of improved air quality is considered to be policy priorities.

Concluding remarks

As was noted at the outset, Beijing has experienced extraordinary changes over the last decade in the era of transformation from a planned economy to a market economy. To adapt to the transformation, urban authorities in Beijing have recognized deficiencies in current planning systems and have endeavoured to explore a full range of alternatives or urban growth management policies to keep up with rapid urban developments in recent decades. Representing an effort to probe new strategies in the planning process, we apply scenario planning to the urban planning process in Beijing. We summarize in this paper the procedures we use to construct and evaluate three urban growth scenarios for Beijing in 2020.

We show that the use of scenario planning to the drafting of Beijing's 2020 Plan offers several advantages at the early stage of revising the 1993 Plan. First, the development of scenarios can meet the BMCUP's needs to explore different urban development options. Second, scenario planning can accommodate the economic and population growth uncertainty associated with China's emerging market forces. Different scenarios can be produced to reflect different predicted growth rates and patterns. By doing so, the decision-making process can be more resilient to unexpected changes. Third, through the creation of evaluation frameworks based on growth priorities, scenario planning provides policy makers with an objective method of assessing scenarios. Thus, rather than compelling policy makers to select a plan for implementation based on how the development pattern looks, or is assumed to perform, scenario planning simulates predicted outcomes and provides policy makers with quantitative analysis that is useful in informing decision-makers.

It is notable that our task is not to provide sophisticated modelling of future land uses. Within 1 month, we had to simulate and evaluate a set of future development patterns that are distinguishable in the type and

[13]We can also include indicators such as street segment length and transit service coverage. We did not do so here as a result of time constraints and challenges associated with data availability. Inclusion of these indicators can detect the potential impact of transportation policy on urban development.

density of land uses and the integration between land use and transportation, and provide policy makers with a full range of possible futures given the constraints and opportunities of existing conditions and population and employment forecasts. Our aim is to offer policy makers an assessment of different development scenarios through a sketch-planning process within a very limited time frame. Due to time limitations and a lack of more comprehensive demographic, economic, and land use data, the scenarios do not examine all the important uncertainties and they do not cover the full breadth of possibilities of the future. Nevertheless, our approach for generating scenarios is structured with reasoned judgements in describing alternative futures and the scenarios generated account for the context of Beijing's concerns and opportunities and therefore represent the plausible futures of Beijing. The scenario construction, the listing of indicators, together with the accompanying methodology on weighting multiple objectives, represents a significant advance in Beijing's comprehensive planning process.

The purpose of the paper is not to identify or to advocate which scenario should be adopted as the growth vision for Beijing's 2020, the evaluation of the scenarios nonetheless generates interesting implications. We find that high population and employment densities and low values for home-based and non-home-based vehicle miles travelled and greenhouse gas emissions are associated with the scenario designed to produce the most compact development. We also find that the scenario designed to produce growth spread out in all directions in a pancake-style generates the highest percentage of transit adjacent to housing and to employment. Some recommendations can be inferred from the scenario planning application to the City of Beijing. First, land use planning efforts should be promoting high density and contiguous urban development at the existing urban area as opposed to the creation of new satellite towns at the far fringe. Second, a sub-regional job-housing balance along transportation corridor should be sought in order to encourage efficient commuting, to improve employee productivity, and to alleviate severe traffic congestion that the city is currently suffering. Third, plans to integrate transportation infrastructure investment should accompany the efforts to create new land use patterns. We show that scenario planning provides a valuable tool in urban growth policy analysis for Beijing and the application, as demonstrated by the comparison across scenarios, illustrates where and how alternative urban development strategies occur, what impacts these alternative futures have, and in which aspects of our urban environment.

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Appendix A. Indicators and indicator calculation

INDEX, the interactive GIS-based planning support system, provides the formulae[13] of following indicators.

Population density

Population density for each unit of analysis is calculated, a reflection of the spatial distribution of residents in the study area. The value is calculated as the following:

$$\frac{\sum R_p}{\sum A_p},$$

where R_p is the number of residents in polygon p and A_p is the area of polygon p.

Employment density

This indicator is the number of employees per area unit of land designated for employment uses, a reflection of the spatial distribution of employment in the study area. It is defined as the following:

$$\frac{\sum E_p}{\sum A_p},$$

where E_p is the number of employees for polygon p and A_p is the area of polygon p.

Transit adjacency to housing

This indicator is the percent of residents dwelling within a user-defined linear distance of a transit route. The value is calculated as the following:

$$\frac{\sum R_{\mathrm{w}a}}{\sum R_a},$$

where $R_{\mathrm{w}a}$ is the number of residents for area a within a user-defined maximum walkable distance of a transit route and R_a is the number of residents for area a.

Transit adjacency to employment

This indicator is the percent of employees within a user-defined linear distance of transit route. It is calculated as the following:

$$\frac{\sum E_{\mathrm{w}a}}{\sum E_a},$$

where E_{wa} is the number of employees for area a within a walkable distance of a transit route and E_{a} is the number of employees for area a.

Home-based vehicle miles (Kilometer) traveled (VMTHB)

This indicator evaluates the average daily home-based vehicle miles traveled per capita. Its value is calculated as the following:

$$M_{\mathrm{b}}[1 + A1 + A2 + A3 + A4],$$

where

$$A1 = \left(\frac{D_{1\mathrm{c}} - D_{1\mathrm{b}}}{D1b} E_1\right),$$

$$A2 = \left(\frac{D_{2\mathrm{c}} - D_{2\mathrm{b}}}{D_{2\mathrm{b}}} E_2\right),$$

$$A3 = \left(\frac{D_{3\mathrm{c}} - D_{3\mathrm{b}}}{D_{3\mathrm{b}}} E_3\right),$$

$$A4 = \left(\frac{D_{4\mathrm{c}} - D_{4\mathrm{b}}}{D_{4\mathrm{b}}} E_4\right).$$

M_{b} is home-based vehicle miles traveled (or vehicle kilometer traveled) for the current study area, $D_{1\mathrm{b}}$ is the density score for the current study area, $D_{1\mathrm{c}}$ is the density score for the scenario in study, E_1 the density elasticity for vehicle miles traveled, $D_{2\mathrm{b}}$ the diversity score for the current study area, $D_{2\mathrm{c}}$ the diversity score for the scenario in study, E_2 the diversity elasticity for vehicle miles traveled, $D_{3\mathrm{b}}$ the design score for the current study area, $D_{3\mathrm{c}}$ the design score for the scenario in study, E_3 the design elasticity for vehicle miles traveled, $D_{4\mathrm{b}}$

the destinations (accessibility) score for the current study area, D_{4c} the destinations (accessibility) score for the scenario in study and E_4 the destinations elasticity for vehicle miles traveled.

Non-home based vehicle miles (Kilometer) traveled (VMTNHB)

This indicator is the average daily non-home-based vehicle miles travelled per capita. It is calculated by:

$$M_b[1 + A1 + A2 + A3 + A4],$$

where

$$A1 = \left(\frac{D_{1c} - D_{1b}}{D_{1b}} E_1\right),$$
$$A2 = \left(\frac{D_{2c} - D_{2b}}{D_{2b}} E_2\right),$$
$$A3 = \left(\frac{D_{3c} - D_{3b}}{D_{3b}} E_3\right),$$
$$A4 = \left(\frac{D_{4c} - D_{4b}}{D_{4b}} E_4\right).$$

M_b is the non-home-based vehicle miles travelled (or vehicle kilometer travelled) for the current study area, D_{1b} the density score for the current study area, D_{1c} the density score for the scenario in study, E_1 the density elasticity for vehicle miles traveled, D_{2b} the diversity score for the current study area, D_{2c} the diversity score for the scenario in study, E_2 the diversity elasticity for vehicle miles traveled, D_{3b} the design score for the current study area, D_{3c} the design score for the scenario in study, E_3 the design elasticity for vehicle miles traveled, D_{4b} the destinations (accessibility) score for the current study area, D_{4c} the destinations (accessibility) score for the scenario in study, E_4 the destinations elasticity for vehicle miles traveled.

Greenhouse gas emission

This indicator reflects CO_2 emitted from light vehicles in pounds per capita per year. It is calculated as

$$\sum(C_{vmt}M)365,$$

where C_{vmt} is the CO_2 per vehicle mile travelled coefficient, M the vehicle miles traveled per capita per day.

Note that the coefficients are based on the research done by California Air Resource Board in 1997.

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