



Urban Accessibility Planning Support Systems

With a case study in Wuhan, China

Background and Context

Accessibility is a fundamental measure of the benefits of urban life. In essence, it measures the end benefit of the integrated transportation and land use system: how many destinations (generally jobs but also shops, schools, entertainment, and recreation facilities) can be accessed in a given time using a given mode of transport. Increasing accessibility – bringing people, opportunities and goods within easy reach of each other – has always been the fundamental role of cities.

In the past, policy makers often analyzed the transport system using metrics that focused on mobility – the ease of movement in a city. The most prominent of these metrics is congestion, often expressed as the ratio of road speeds between congested and uncongested conditions. A recent Brookings Institution report on accessibility aptly summarizes the shortcomings of this metric in analyzing the performance of the urban transport-land use system. Consider a comparison between Manhattan (the heart of New York City) and Manhattan, Kansas, a small town. The New York metro area has some of the worst congestion in the country – travel speeds in Manhattan, Kansas are at least 37% faster than comparable speeds in the New York metro area at peak hour. However, because of the incredibly high density of jobs in Manhattan – a commuter there could reach 1.3 million jobs in a half hour commute, compared to 64,000 for an equivalent drive in Manhattan, Kansas (Levinson and Istrate, 2011).

Clearly, using mobility metrics that focus on travel speeds alone tends to exclude a crucial component of urban system dynamics – the interactions between the land use functions and the transport systems in a city. Accessibility metrics offer an improved way to analyze these interactions, allowing for integrated analysis of the land use-transport system. In concrete terms, accessibility analysis can help understand the implications of a new road, a new transit system, or the relo-

cation of a large employer from the downtown area to a city's suburban fringes, all using the same tool and measured with the same metrics. Several policy scenarios along these lines of particular pertinence for the pilot city of Wuhan were analyzed as part of this study.

Accessibility metrics that consider both the ease of movement on the transport system and the corresponding number of destinations reached are not entirely new (refer to Box 1). What has changed in recent years is that increasingly powerful spatial analysis tools (GIS) have become more prevalent and common place – allowing for a more practical and fine grained analysis of these issues. The spread of GIS has also allowed for greater use of high quality visualizations that can be more readily used and understood by planners, policy makers, and the general public. The rapid development of these tools is a benefit for all those interested in understanding the complex interactions that take place in cities.



Aerial view of bridge over the Yangtze river in Wuhan
source: The China Perspective.com

This project is the latest in a series of research efforts that the Bank has supported in recent years that focus

on measuring accessibility in Chinese cities, of which 2 are highlighted in Box 1. First, the World Bank supported analytical work that compares pedestrian access to jobs and commercial opportunities in the central business districts of Beijing, London and New York. This comparison is simple but powerful, and has been used to illustrate the importance of integrating urban design with public transport systems to planners and decision-makers in several Chinese cities.

Another piece of analytical work supported by the World Bank assessed the quality of pedestrian access to the Jinan Bus Rapid Transit system.

This document is a brief summary of the latest work completed in this series. The document provides a description of a pilot project in Wuhan, China to demonstrate the value of accessibility metrics in the urban planning decision making process, including a description of the tools used and policy lessons generated. The primary purpose of the exercise was to demonstrate the practical applications of these tools for use in understanding transport/land use dynamics in World Bank client cities.

These tools allow for a deeper understanding of the connections between urban residents and employment opportunities by different modes of transport or, looking in the opposite direction; between business locations and their potential clients. This can help highlight, for example, a spatial mismatch between low income residents and jobs within reach by public transport within a reasonable time threshold. Given the crucial role that access to economic opportunity plays in economic development and improving the lives of

the poor, these tools can help highlight critical investment or policy reform needs in client cities.

The tools also allow for more in depth analysis of issues crucial to long term environmental sustainability that now forms a central element of the global (and World Bank) agenda. In particular, these tools can assess how, where, and when public transport systems provide a service that is competitive with automobiles. To help promote the use of these lower emitting transport modes, accessibility tools allow the analysis of scenarios of both transport and land use change (for example, new zoning regulations or a new express bus service) that can address this spatial mismatch in a level of detail previously unavailable.

For the rapidly growing cities of the developing world (including but not limited to China, where this work was piloted), using accessibility measures to understand the role that land use and transport dynamics can have on the economic, social and environmental life of the city will be a powerful new tool. This study also goes one step further, using accessibility metrics in combination with a dynamic model of land use and transport that allows for the analysis of how current trends, policies, and plans will influence accessibility in future years. Given growing populations, incomes, and motorization levels, the urgency of the global sustainability agenda, and the irreversible nature of urban development, understanding the accessibility implications of current trends may be more crucial than it has ever been. The new class of tools presented in this paper help provide the means of understanding and addressing these issues.

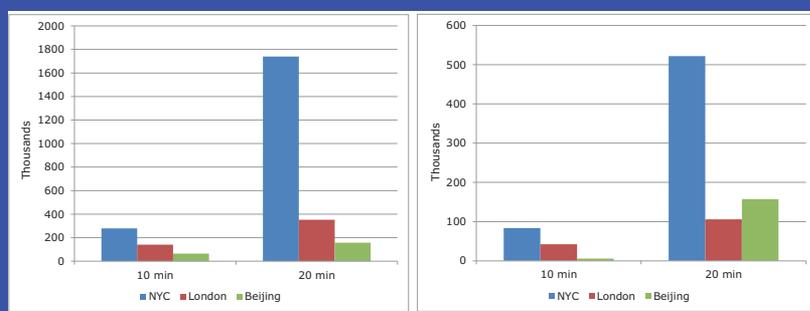
Box 1: Previous World Bank work on Accessibility in Chinese Cities

Pedestrian Accessibility: Comparing Commercial Districts in Beijing, London, and New York City

While planners agree that transit-oriented urban design is essential to attract those who have a choice in using public transport, it is not always easy to illustrate the concept of pedestrian accessibility to city leaders. Research by Torres et al. (2010), which was developed to illustrate this concept, shows the importance of coordinating urban design with public transport by looking at a basic accessibility indicator: the number of jobs and square feet of commercial floor-space accessible within a 10 or 20-minute walking radius of a major public transit station in the city's central commercial or central business district. Data was gathered in three metropolitan areas: Beijing, London, and New York (see figures).

The study demonstrated that a city with design characteristics like midtown Manhattan provides a much more accessible urban environment than a city with the design characteristics of Beijing, which has fewer and wider roads, large superblocks, and widely spaced buildings set back from the road. The study highlighted the need to consider the following aspects when designing an urban area plan for high accessibility:

- (a) high density land use with high-rises built close together
- (b) a dense grid network with sufficient secondary roads and small city blocks and
- (c) a pedestrian-friendly environment



Left: Number of Jobs Accessed within 10 or 20 Minutes of Walking. Right: Commercial Areas Accessed within 10 and 20 Minutes of Walking (in 1,000 square meters). source: Torres-Montoya et al. 2010.

Box 2 - Accessibility indicators and applications

In a highly dynamic globalized economy, adequate access to spatially and temporally dispersed resources (consumers, jobs, suppliers) are vital conditions for firms and households in order to thrive or even just to survive (Castells, 1996). Accessibility is the potential for interaction between these resources and is influenced by the qualities of the transport system (reflecting the travel time or costs of reaching a destination) on the one hand and by the qualities of the land-use system (reflecting the qualities of potential destinations), on the other hand (Handy and Niemeier, 1997). Accessibility can therefore be used as an indicator of the integration between land-use and transport. To date, simplified infrastructure focused mobility indicators have generally been used in most analyses, as they are easy to understand, measure, and communicate. Examples of such infrastructure-based indicators are the level of congestion, travel time, or travel cost, all of which have strong methodological disadvantages (Geurs and Van Wee, 2004) as compared to the accessibility metrics presented in this paper.

There are three important reasons why planners should move away from merely focusing on infrastructure-based indicators (Straatemeijer, 2008):

- From the perspective of households and firms, the transport system itself is not important — its importance is that it provides them with access to spatially and temporally dispersed opportunities.
- Accessibility defined in this way gives planners the opportunity to assess the effects changes in transport and land-use system have on the potential for interaction, and can be used as a policy design tool (Groenendijk et al., 2003).
- For politicians, citizens and firms it may be easier to discuss the quality of access to education services and markets than it is to discuss the inefficiencies of the transport system.

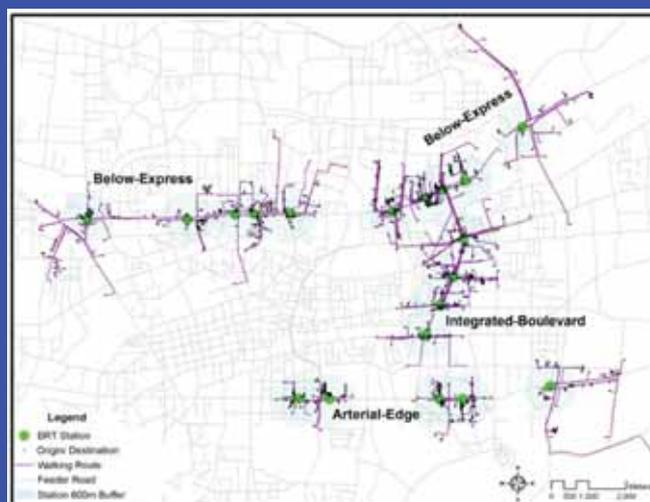
A whole range of improved accessibility measures have been proposed in scientific literature. However, more complex indicators also require more analytical skills from users (Handy and Clifton, 2001) and they place high demands on available data. Activity-based measures provide an important class of measures as they analyze the accessibility of

locations, typically on a macro-level such as Traffic Analysis Zones (TAZ). Typical measures are the cumulative opportunities (or contour) measures that, for example, measure the number of jobs within 30 minutes by car from the origin location, and the potential measure (or gravity measure) that discounts these opportunities over time (or distance) using a distance-decay function. This is done to count an opportunity closer by as more important than at a distant location. More complex location-based measures explicitly incorporate capacity restrictions of supplied activity characteristics to include competition effects (Geurs and Ritsema van Eck, 2003). This type of measure was analyzed for the work in Wuhan following on other recent applications such as in Tel Aviv, for assessing the difference between potential accessibility by car and public transport in (Benenson et al., 2010), in Boston, Los Angeles and Tokyo to compare potential accessibility to jobs versus different urban form (Kawabata and Shen, 2006), and in Finland to study the relation between potential accessibility by road and railway to population change (Kotavaara et al., 2011).

Walk the Line: Station Context, Corridor Type and Bus Rapid Transit Walk Access in Jinan, China

Based on pedestrian interviews and a field investigation, the study found that people walk further to Jinan BRT stations when the walking environment has certain “quality” features, such as a median transit way station, or when the corridor is shaded, active and interesting, or when wayfinding is straightforward. In addition, mapping the walking paths revealed that a small network of paths accounted for a large portion of access trips (see map).

Through an unarticulated consensus, pedestrians seem to agree on a particular set of route choices due to a combination of quality, comfort, and safety. This suggests that, as with other modes, identifying and improving the quality of a relatively small pedestrian network can bring significant benefits by actively encouraging pedestrians to use the network.



Map of Pedestrian Access to the Jinan BRT System
source: Jiang et al. 2010.

Accessibility tools and applications in Wuhan

The interaction between land use and transport is highly complex and dynamic. Everything that happens to land use has transport implications and vice versa. Urban development generates travel, and travel generates the need for new facilities, which in turn affects accessibility and may attract further development. These interconnections are particularly vivid in China where rapid urbanization and urban restructuring have dramatically transformed urban areas in recent years at the same time as urban infrastructure is being completely reshaped. Both will clearly have profound effects on accessibility to jobs and other activities for residents of China's emerging urban regions (Wang et al, 2011), who continuously adapt their behaviour to perceived opportunities.

Because these processes are inherently spatial and dynamic, Geographical Information Systems (GIS)-based technologies provide an ideal tool to model and understand their impacts. GIS are databases that are capable of storing, analyzing and visualizing spatial data such as roads, transport networks, and locations, sizes, and uses of urban structures. As an example, GIS allows for the effects of (alternative) policy options on the quality of the socio-economic and physical environment to be simulated. With this information at hand, awareness building, learning, and discussion, prior to decision-making and investment can be stimulated and facilitated. In this study the widely available GIS tool ArcGIS Desktop v10 was used to model and visualize accessibility, while Metronamica (refer to Box 3) was used for the dynamic modeling of land use - transport dynamics (see Figure 1).

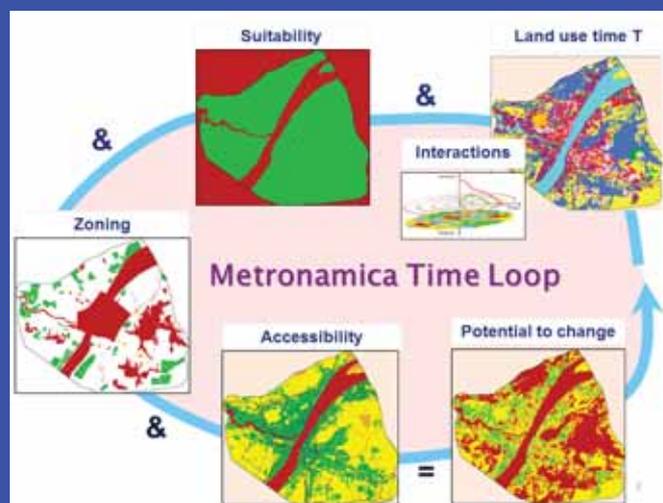
To show the capability of ArcGIS in accessibility modeling two types of accessibility measures have been implemented and visualized. These accessibility metrics were developed using the modeling processes depicted in Figure 1. The "contour" measure maps the area that can be reached in different time bands of travel (30, 60, 90 minutes) around one or more fixed locations. Travel times are calculated in a multi-modal network model, based on estimated travel speeds and attributes such as average waiting times at bus stops. The number of jobs or people within one contour can be calculated using job and population locations. The "potential" measure is an extension to the contour measure that discounts jobs that are further away potential of a location. Finally, using 3D visualization the potential accessibility can be visually combined with the number of people living in a certain area. The next sections highlight some results of the application of these tools in Wuhan.

Box 3 - What is Metronamica?

Metronamica is a generic forecasting tool for planners and decision makers to simulate and assess the integrated effects of planning measures on urban and regional development. As an integrated spatial decision support system, Metronamica models socio-economic and physical planning aspects. It incorporates a mature land use change model, implemented in a Cellular Automata environment, that helps to make these aspects spatially explicit. The software interactively simulates the impact of a variety of external influences (e.g. macro-economic changes, population growth, etc.) and policy measures (e.g. land use zoning, conservation policies, densification policies, etc.) on the regional development of a city, region, country or even continent. With the integrated scenario support what-if analyses can be performed that help evaluate alternative plans or communicate the future problems that need to be addressed today. Since the models of social, economic, physical and environmental processes mutually affect each other, Metronamica presents a possibility for truly integrated analysis of real-world problems and solutions.

In this study Wuhan's urban core city is represented as a mosaic of 75,429 cells each representing 1 hectare. Together the cells represent the changing land use pattern of the study area.

Information: <http://www.metronamica.nl/>



Land use allocation mechanism in Metronamica



Scenario 6: Transport networks and simulated land use 2020

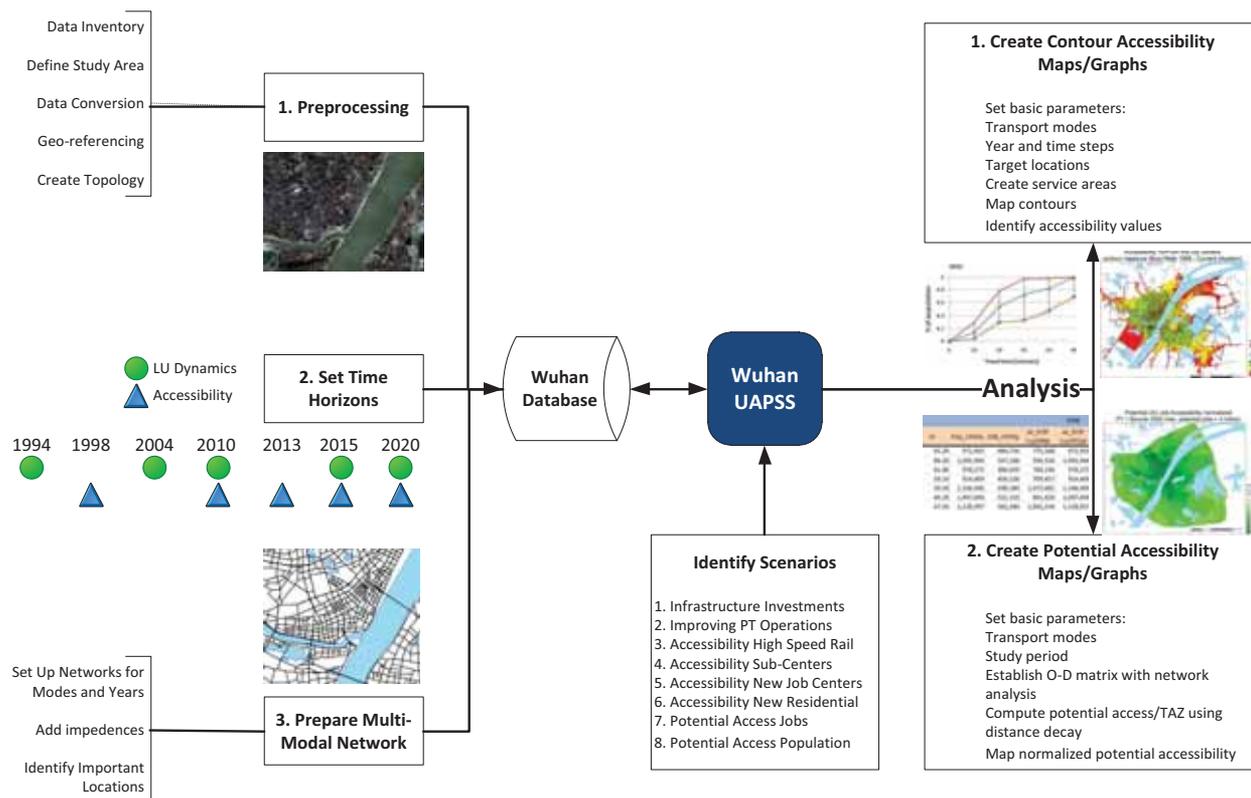


Figure 1: Geospatial modeling process for land-use accessibility scenarios based on land use dynamics

Land use change due to infrastructure investment in Wuhan

Several land use change scenarios have been developed and analyzed to show possible future land use developments and the impact of different policy alternatives on urban development. The scenarios built from the common base of a Business-As-Usual (BAU) scenario that assumes a continuation of historic land use dynamics combined with current land use and transport policies. The alternative scenarios vary in terms of: spatial planning (zoning); trends in urban development such as compact development versus urban sprawl; and differing programs of infrastructure investment. Using Metronamica, simulations for the period 2010 – 2020 were carried out. Figure 2 shows a comparison of simulation results in the year 2020 of urban development between the business-as-usual (BAU) scenario and a 'metro focus' scenario where the Wuhan metro construction plan has been fully implemented, urban development is assumed to be strongly attracted to public transport, and new road construction has ceased after 2010 (LU 7). The purple color indicates urban development that only occurs in the latter scenario, demonstrating a significant shift toward the metro stations.

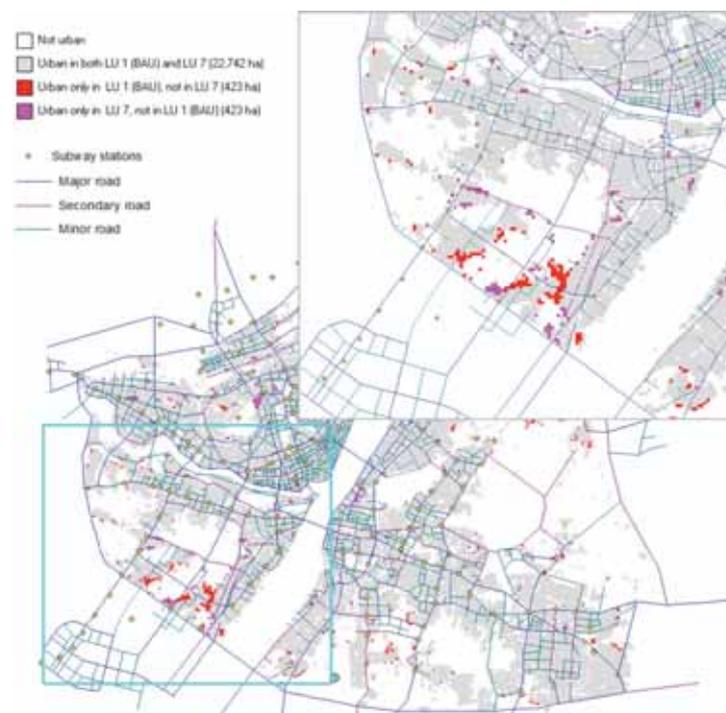


Figure 2: Comparison of simulation results in the year 2020 of urban development between the business-as-usual (BAU) scenario and a 'metro focus' scenario

Influence of land use change on contour-based accessibility

The simple contour-based accessibility measure calculates travel time contours in Wuhan for a given year. In Figure 3 the contour measure for bus-based public transport with walking access and egress is depicted for 2020. Travel times are calculated in relation to the nearest of the three city centres in Wuhan.

To assess the influence of different land use patterns, this type of contour maps can be overlaid with the land use maps derived from the Metronamica simulations. By doing so, compact development can be compared to the urban sprawl and business-as-usual scenarios, as is shown in Figure 4, depicting the percentage of people living in a certain travel time contour to the nearest of three city centers. A positive accessibility effect can be determined for the compact development scenario.



Figure 3: Contour measures for bus with walking access in 2020.

Mapping the difference in potential job accessibility between two modes

The potential accessibility measure explicitly combines opportunities with the difficulty of travel. Job opportunities are discounted with distance; a distant job is valued less than one close by. The differences in this accessibility measure across modes can be substantial. To demonstrate this, a comparative accessibility measure comparing car and public transport accessibility in the year 2020 is depicted below. Areas in dark green represent areas where public transport provides better job access than a car, light green areas are where cars provide marginally better access, and the orange areas are where public transport is far less competitive than automobiles.

It is obvious that there are significant areas of Wuhan where public transport is a less competitive option for accessing urban opportunities than the car. Clearly, as incomes continue to rise in Wuhan and automobiles become affordable for a greater share of the population, those with choice in these areas will begin to choose cars over public transport. Figure 5 highlights important zones of the city where this differential between automobile and public transport accessibility is likely to become a significant problem. If used as part of a systematic approach to urban transport planning, this accessibility measure could help highlight areas with critical investment needs in the area of public transport. The percentage of population living in areas where public transport is far from competitive (ratio $\geq 1/5$) is slightly more than 11% but growing rapidly as the next section demonstrates.

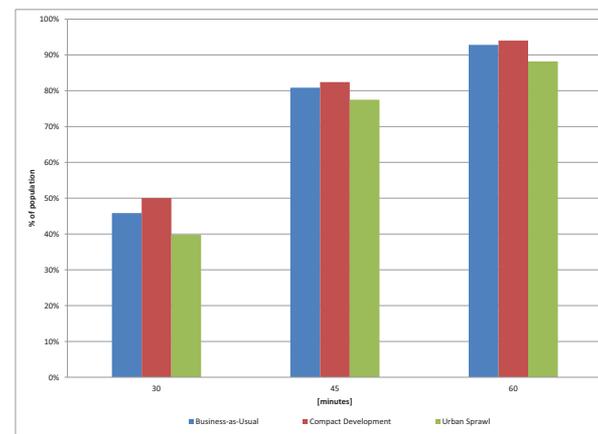


Figure 4: Impact of urban development scenarios on percentage of population within cumulative travel time contours for public transport with walking access in 2020.

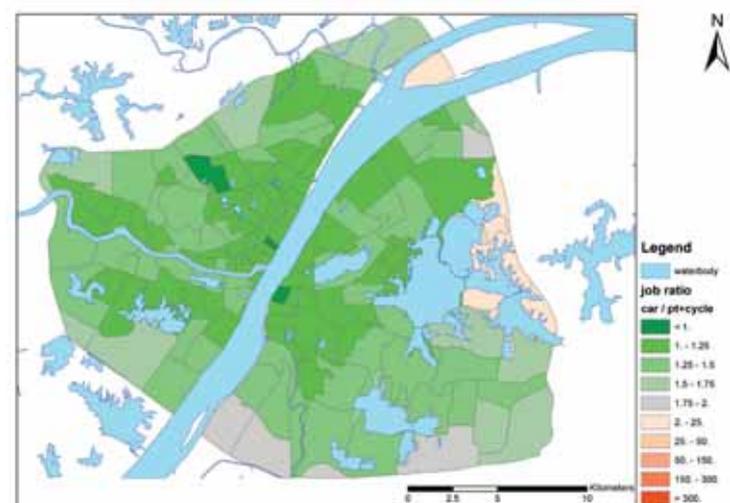


Figure 5: Difference map (job-based potential accessibility ratio) for Wuhan in 2020, comparing car based accessibility and public transport based accessibility.

Is population growth happening in areas with easy access to jobs by public transport?

The next question that begs to be asked is: how many residents are affected by poor public transport accessibility, and how is the trend changing over time? In Figure 6, the color of each zone represents the degree to which the zone provides easy access to jobs by public transport, while the height of each zone represents the absolute population growth of each zone from 2010-2020.

High accessibility to jobs by public transport can be created by both the presence of local jobs (within the same zone) or rapid access by public transport in adjacent zones. Those areas with relatively dark coloration in the above figure represent the best of Wuhan in terms of easy access to jobs without a car. From the point of view of the competitiveness of the public transport system (and ultimately the overall urban transport energy consumption and sustainability of the city as a whole), population growth should be focused in these areas to the degree possible.

However, the above figure shows that significant growth is actually occurring in other areas. High peaks with light colors represent these areas where population is growing significantly, but accessibility by public transport is poor.

This 3D visualization helps provide a quick snapshot of urban growth for the next decade in Wuhan. This visualization technique can easily incorporate different assumptions about both transport network and population growth over time (as was done in this study) to help policy makers compare different projected scenarios of both infrastructure and urban development. In addition, with more refined data, the same visualizations could be used to highlight areas where, for example, low income populations are particularly concentrated, analyzing their access to potential employment opportunities using different transport modes.

Conclusions

The primary purpose of the study was to test out a variety of new techniques and tools to understand urban development and its dynamic relationship to transport in a rapidly growing Chinese city. Given this focus and limited spatial extent of this study, which concentrated only on the area within Wuhan's 2nd Ring Road, lessons for the city's development policies are, at this stage, only indicative.

Despite this proviso, what this work has shown is that technical, quantitative analysis for planning matters.

Integrated approaches to urban modelling can provide useful insights into the complex interactions between land development (land use, population and job distribution), transport infrastructure and urban policies that

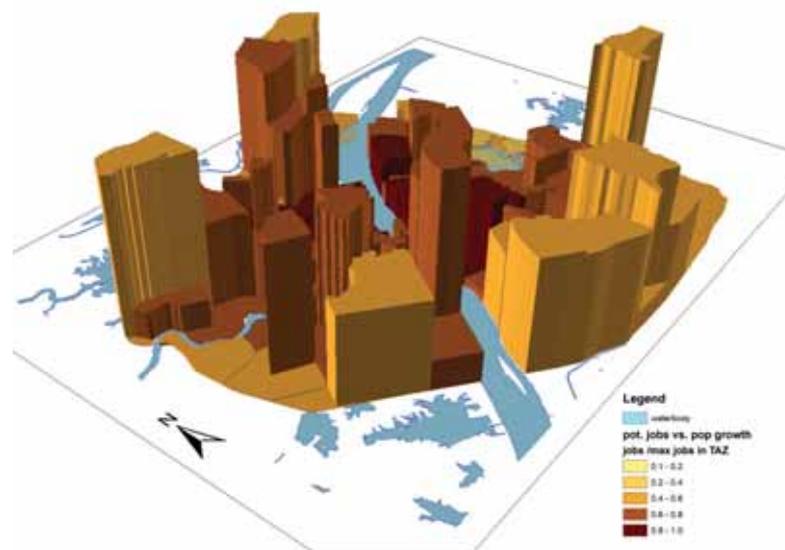


Figure 6: Expected population growth versus public transport based potential job accessibility in 2020.

determine to a large extent the successful achievement of social and economic goals of a given city over a given period of time.

The enormous amount of (re)development that is occurring in cities in China as well as many other developing countries today calls for careful analysis. Today's decisions on urban development and urban infrastructure investment tie up enormous amounts of capital and exert a profound 'lock in' effect on the city and its residents for years to come. These decisions affect the lives of current and future citizens of the city in profound ways, and should be made based on solid quantitative analyses of their distributive and environmental effects. The methods and tools used in this study can be used to provide such support and insights for the local development policy making and implementation.

Urban simulation of land use change in integration with spatial temporal analysis of accessibility provides useful insights into the complex interaction between land development and transport. Historic land and transport dynamics combined with current planning policies can be used to form integral pictures of possible futures for an urban area and to evaluate their relative value on the basis of a set of criteria. A total of seven land use scenarios and eight transport scenarios have been evaluated in the various simulations, including combinations of land use and transport scenarios.

Data availability, data accuracy and data resolution were points of concern and are likely to be limiting factors on future applications as well. To fully integrate the land use dynamics and transport accessibility models, socio-economic, population, and job data should be available at the same resolution for both models. In Wuhan, job and population data was only available at the relatively coarse Traffic Analysis Zone (TAZ) level, of which Wuhan has approximately 150 for the entire modeled area. To realize this greater level of detail, other data sources could be incorporated, including building floor area data from the city's 3D geo-database.

The results of this pilot project demonstrate that these modeling techniques and planning tools can provide valuable insight to decision makers on key issues they confront, not only in Wuhan, but also other cities within or outside China. With greater and more refined data, the policy implications derived could be made yet more robust and more detailed, providing greater utility to practitioners on the ground.

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This summary note is a companion to the two main documents completed for this project – a final report and a more detailed technical report on the modeling techniques. Copies of this note and other documentation are available through ITC and the World Bank teams.

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