

Chapter 14

Mapping Walking Accessibility, Bus Availability, and Car Dependence: A Case Study of Xiamen, China

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Abstract As stated in the existing literature, travel behavior and transportation choice are closely related to urban forms and the built environment. The study presented in this chapter attempts to conduct a citywide evaluation of the walking accessibility to urban facilities and the availability of public transport, as well as relevant potential car dependence. By taking the city of Xiamen, China, as a case study, the current study generates some useful information vis-à-vis both public transport and urban facility providers, by illustrating the city's spatial patterns and identifying problematic areas. The methodology developed in this study might also serve as a reference for future studies.

Keywords Sustainable transportation • Walking accessibility • Bus availability • Car dependence • Xiamen

14.1 Introduction

Newman and Kenworthy's (1989) phrase "car dependence/automobile dependence" has been frequently used in the travel behavior, transport planning, traffic management, and urban policy-making literature. Although no common definition for this term has been agreed upon to date, it might be briefly described as characterizing "a high level of physical need or/and mental demand for car transport."

Car dependence is associated with a range of environmental, economic, and social problems. In general, an increase in car dependence can worsen the

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transportation structure of cities, retard the construction of green transportation systems, intensify oil vulnerability, create a shortage of urban land and infrastructure, aggravate environmental stress, and contribute to greenhouse gas (GHG) emissions. Additionally, it can also result in a loss of street life and community, suburban isolation, access problems for carless people, and health problems among car drivers. Compared to other forms of transportation, car traffic has the highest cost and lowest efficiency and creates the most pollution—including the highest volumes of GHG emissions per passenger. Therefore, it is generally suggested that car transport be ranked the least preferred form in terms of “greening” urban transportation systems (CNU 2000; Huang 2004; Pan, et al. 2008; China Society of Urban Studies 2009). A city cannot be considered “sustainable” if it is car-dependent (Newman and Kenworthy 2000), and researchers use words such as “reducing,” “overcoming,” “combating,” and “abandoning” in their work, to distinctly express their opposition to car dependence (Newman and Kenworthy 1999; Stradling 2002, 2003; Guo 2010). With the growing popularity of the “sustainable development” concept, there has been burgeoning public awareness of the damaging impact of car use on cities. As a result, reductions in car dependence in order to improve transport sustainability now constitute a major goal of transport policy in many cities (Cullinane and Cullinane 2003).

In reviewing a variety of literature, we can say that the factors that determine or influence car dependence are quite numerous, and vary from place to place. However, according to Gorham (2002), car dependence can be categorized thus: (1) *physical/environmental dependence*, which is caused by the built environment, including the urban form, regional structure, the distribution of activities within the structure, and the nature or status of collective transportation modes; (2) *social/psychological dependence*, which is caused by the symbolic meanings or “signs” of cars in society and in a consumption culture and/or the mental desire for the convenience and comfort of car travel; and (3) *circumstantial/technological dependence*, which describes the relationship between the technological capacities of a car (speed, carrying capacity, privacy, etc.) and the particular requirements of an individual life (e.g., a professional musician needs a car to carry a music instrument between home and working place, and his or her instrument itself is large, bulky, and expensive and therefore not suitable for public transit). In China, circumstantial/technological dependence manifests when people need to travel with pets (pets cannot be carried on public transport in China). “The[se] three types of car dependence outlined above interact significantly,” says Gorham, and therefore, “it is probably difficult in practice to identify particular behavior with any one of them” (Gorham 2002, p. 110).

Conventional thinking states that an increase in the number of private cars derives from a growth in wealth. However, owning a car does not necessarily imply frequent car use, let alone car dependence. As shown in the studies of Kenworthy and Laube (1999, 2001), based on data gathered from over 100 cities worldwide between 1960 and 2000, patterns of automobile dependence in cities do not significantly relate to differences in wealth among cities, but they do vary in a clear and systematic way in terms of land-use patterns. The most car-dependent

cities (i.e., low-density cities in the United States and Australia) are less wealthy than some densely settled and more transit-oriented cities in Europe and Asia (e.g., Singapore, Hong Kong, and Tokyo) that have very low automobile dependence. Therefore, “there are stronger factors determining automobile dependence” (Newman and Kenworthy 2000, p.112). According to a multiple regression analysis undertaken by Newman and Kenworthy, very strong correlations can be found between the level of automobile use (indicated by transport energy use) and certain parameters such as the level of public transport provision, public transport speed to traffic speed ratio, total length of roads, and parking provision; however, the strongest correlation is with urban density. Thus, “achieving a more sustainable urban form inevitably involves the development of densities that can enable transport, walking and cycling to be viable options” (Newman and Kenworthy 2000, p. 113). Urban structure does matter in shaping travel behavior and car dependence (Naess 2006). In *Seven Rules for Sustainable Communities*, Condon (2010) also emphasizes how essential it is to create an urban structure and built environment that is conducive to reductions in car dependence and the promotion of sustainability. New Urbanism, as a dominant planning theory in postmodern society, also advocates a “compact urban form,” “mixed land use,” “a pedestrian-friendly built environment,” and “transit-oriented development” as key elements of sustainable urban development (CNU 2000). Therefore, an increase in car use cannot be attributed merely to a growth in wealth. We need to consider the ways in which we build and organize our cities.

For this reason, urban planning and design is widely recognized as essential to a city’s coping with car dependence. In reshaping cities’ built environments, planning tools can be used to influence the amount of travel carried out via various modes of conveyance, and the proportions thereof. The “right design” will encourage walking and discourage car use. A citywide evaluation of car dependence and of related walking accessibility and bus availability is necessary. A city-specific analysis of the spatial pattern of car dependence would be even more helpful for local planners and decision-makers in acquiring information on where the problematic areas are and what corresponding solutions there may be. This considered, by taking the city of Xiamen as a case study, with the aid of ArcGIS software and based on an examination of the walking accessibility to urban facilities and the availability of public transport, the current study attempts to evaluate and map potential car dependence. The study results will be useful in identifying the most appropriate locations for new urban facilities, as well as public transport services.

This chapter is organized into six sections. Following this introduction, the background of the research is presented in Sect. 14.2, in order to provide the reader with a “bigger picture” of the issues at play. Section 14.3 discusses the appropriate level of detail needed to measure overall walking accessibility from a given city block to all types of urban facilities. The study starts with the measurement of walking accessibility, because motor traffic demand would be low wherever walking accessibility is good. Then, public transportation availability is measured in Sect. 14.4, because the greater the availability is of public transit lines in a block, the better that area is connected to other areas of the city. In Sect. 14.5, in view of

the fact that car dependence is somehow inversely proportional to walking accessibility and the availability of public transport, the potential car dependence across the city of Xiamen is measured and mapped, in the hope of providing useful information for local planners and decision-makers. Finally, the chapter concludes in Sect. 14.6 with a summary.

14.2 Research Background

Since China's undertaking of reforms and general "opening up," Chinese cities have been experiencing rapid growth and remarkable restructuring. As a result, both the macro- and microlandscape of Chinese cities have been changing markedly. While the overall urban form is becoming larger and increasingly fragmented, the spatial patterns of people's daily lives have also changed. People's work and nonwork lives are becoming more and more separated each day, with the commercialization of housing (e.g., many commercial houses are built in newly developed suburban areas) and the disappearance of "work-unit compounds" (i.e., welfare housing or factory dormitories nearby the work place). As a result, more and more people in China's cities face long, frustrating commutes on a daily basis. Meanwhile, urban facilities (such as shops, hospitals, schools, and public transport) have also become completely or partially "commercialized," resulting in service dropouts whenever or wherever the residential density is not sufficiently high to make such service provision profitable, which in turn makes it more difficult to introduce a transit-oriented development (TOD) model. With the inducements created by car advertisements and increases in people's incomes, more and more people are choosing to buy a private car when they can just barely afford to do so. As a result, there has been a surging "car boom" in China.

In 2009, China overtook the United States to become the world's largest market for personal vehicles, with sales of 13 million cars and light trucks in that year. It is still too early to get "the annual sale in 2012". In fact, China has become the world's number one automaker and seller since 2009, with two-digit rates of annual increase in sales figures. Road networks in megacities like Beijing and Shanghai (as well as in many second-tier cities such as Xi'an, Dalian, and Xiamen) have doubled or tripled over the past decade to adapt to the growing popularity of automobiles, but they continue to suffer from ever-worsening congestion and parking problems. As more cars appear on the city streets of China, more and more pedestrians and cyclists are being crowded out. It is reported that between 1995 and 2005, bicycle ownership dropped by 35% in China. In the meantime, the development of public transport has been far from satisfactory. As a result, urban transportation in Chinese cities is tending to be increasingly car-dependent.

Increasing car dependence may be particularly alarming for a city like Xiamen. The city of Xiamen, on the southeast coast of China (117° 53' E–118° 27' E; 24° 25' N–24° 55' N), is one of the earliest four special economic zones in China and a major city on the west bank of the Taiwan Strait. It has a total population of 3.53

million, about half (52.7%) of which lives on Xiamen Island, i.e., the earliest developed area of the city stretching over a 131-km² area. The city enjoys a fine reputation of being “a garden city at sea,” and it is a winner of the UN Habitat Award, on account of its beautiful natural scenery and living environment. It has also been designated as one of China’s ten low-carbon pilot cities since 2010, and it has set for itself the ambitious target of becoming a Chinese role model for low-carbon cities. However, one of the biggest challenges in reaching this goal has been the rapid increase in motor-vehicle use (especially private cars).

According to the latest data released by the Department of Traffic Police, the number of motor vehicles in Xiamen reached 827,150 at the end of February 2012, of which 438,400 are private cars (53.01%). In each of the three most recent months, an average of 6,628 new motor vehicles has been added to the streets of Xiamen. The number of newly registered motor vehicles in January 2012 alone was 9,324—over 70% of which are private cars. According to the figures of the sixth national population census, the resident population in Xiamen is 3.53 million, and they form up to 1.24 million households. This means that car ownership in the city has reached a ratio of 35.36 per 100 households in Xiamen (i.e., one car per 2.83 households, or 12.42 cars per 100 people). Although these numbers appear modest compared to the US ratio of 94 cars per 100 people, the rate at which automobile use is expanding in Xiamen is alarming. Traffic jams have become so serious that the average vehicle speed has fallen to less than 20 km/h at peak commuter times, over half of all intersections are saturated, and there is a serious shortage of public parking lots. Casualties and economic loss stemming from traffic accidents also continue to grow, not to mention a series of other negative consequences, such as environmental pollution, oil shortages, GHG emissions, the extrusion of public space, access problems for carless people, a worsening of personal mobility, and an erosion of quality of life. These effects not only challenge the city’s efforts to become a role model for low-carbon cities, but it is also seriously damaging its image as an “ecological garden city” and its attractiveness for investors and individuals of talent.

The damage of car-oriented transportation has aroused public concern and complaints. Pressures have also been placed on local authorities at all levels since China announced at the Copenhagen Conference its goal of a 40–45% reduction in carbon emissions by 2020, based on 2005 levels. Besides developing new vehicles driven by alternative “clean energy” fuel sources—like those described in China’s National Climate Change Program (NDRCC 2007)—more and more policy analysts have come to see the manipulation of the urban form as a tool by which carbon emissions could be cut, by affording reductions in travel demand and car dependence. To undertake such manipulations, citywide analysis and region-specific guidance is much needed by local decision-makers, as they need to know where the problematic areas are (i.e., those with the highest car dependence) and what the corresponding solutions may be.

14.3 Walking Accessibility to Urban Facilities in Xiamen

14.3.1 Relationship Between Walking Accessibility to Urban Facilities and Motor Traffic Demand

It has become common knowledge that the energy consumption and environmental impact per passenger of different transportation modes are in the following ascending order: walking → bicycle → rails and subway → bus → taxi → carpool → single-occupancy car. Thus, to develop an environmentally friendly and low-carbon transport system, a major principle is to promote nonmotorized transport, especially walking.

There is a growing acknowledgement that travel demand and travel-mode choice (motorized vs. nonmotorized, transit vs. car) in urban areas are affected by the urban spatial structure and land-use characteristics. A number of studies have addressed this issue. The general wisdom is that enforced dependence on automobiles and long-distance travel will be mitigated by the establishment of compact cities (as indicated by urban density) with well-distributed urban facilities and job opportunities. Car dependence can be largely reduced through critical design that creates a diversity of urban amenities within a 10–30-min walking area (Newman and Kenworthy 2006). Thus, overcoming car dependence, to a large extent, becomes a question of whether people can access the facilities of a city without the use of a car. Walking accessibility to urban facilities—which refer to the services and activity possibilities that the residents and visitors of a city may use and visit—then becomes an important indicator. In general, motor traffic demand will be low if the walking accessibility to urban facilities is high; as walking is a comfortable mode of transport in accessing needed services, motor transport would be less of a necessity, in such a scenario. The converse is also true: motor traffic demand will be high if walking accessibility is poor.

14.3.2 Measuring Walking Accessibility to Urban Facilities

Accessibility is a measure of the ease of reaching places (Grengs 2001). Measuring the walking accessibility of a certain place to urban services and facilities is one of the key steps in evaluating potential car dependence. Moreover, in planning terms, measuring accessibility to local services and facilities also allows improvements to be made more precisely, to either transport or the ways in which services are provided.

A rich body of literature addresses the methodology of measuring accessibility, and a variety of accessibility measures have been developed. Most published measures of spatial accessibility to urban facilities tends to be one of four types: (1) provider-to-population ratios, (2) travel impedance to nearest provider, (3) average travel impedance to a set of providers, or (4) gravitational models of provider influence (Winter 1992). By taking “path distance” as the indicator of “travel impedance”—and by taking Cooper et al.’s (2009) relevant work as its

main reference—the measurement of “walking accessibility” developed in this research combines the second and third aforementioned types.

Measuring the walking accessibility of a city requires a view of a grid of areas at an appropriate level of detail; this grid serves as the basis of all calculations. This research divides the case city into hundreds of “blocks,” each of which is a grid defined by the city’s second-class roads, and it excludes areas of water, wetland, farmland, forest land, and protected ecological areas.

Suppose that there are in total n blocks in the city, that m types of urban facilities are considered, and that d_{ij} stands for the average shortest path distance from the center of block i to the nearest three facilities of type j . (The nearest three facilities of a certain type are the most frequently visited ones for the people living in a certain block.) Evidence from Reneland’s report (2000) suggests that there is a relationship between path distance and crow-fly distance. More specifically, as a common rule in the field of transportation planning, the former is roughly 20–30% greater than the latter (Reneland 2000). The specific number is 31% greater in the case of Xiamen, according to a test sample of that city’s road map. This means that the value of d_{ij} can be calculated as being 1.31 times the average crow-fly distance from the geographic centroid of block i to the nearest three facilities of type j .

Those urban facilities that apparently generate or attract travel within a city are investigated:

- *Type 1*: Shopping centers (supermarkets, department stores, shopping malls) with business space exceeding 5,000 m² each
- *Type 2*: Kindergartens and primary schools
- *Type 3*: Secondary schools
- *Type 4*: Hospitals/medical centers ranked as class I or class II
- *Type 5*: Major public culture, entertainment, and sports centers

A formula for “the *overall* walking accessibility from a given block (e.g., the block i) to *all types* of facilities” (marked as A_i) is designed as follows:

$$A_i = \sum_{j=1}^m W_j a_{ij}$$

where W_j ($0 < W_j < 1$) is the weighting coefficient of a certain type j facility ($j = 1, 2, \dots, m$; in the case study, $m = 5$), which will be set according to the results of a questionnaire survey about the frequencies that people visit a variety of urban facilities. The index a_{ij} stands for “the *individual* walking accessibility from block i to the type j facility.” The value of a_{ij} relates to the value of d_{ij} as well as general opinions about what distance constitutes a “travel impedance.” According to investigations conducted in our field survey in Xiamen, “within five minutes” is generally considered a “comfortable distance for walking”; most people are willing to walk if the walking time is less than 10 min, and they are more likely to use motorized transport (public or private) if the time exceeds 15 min. Therefore, a walking time of 15 min can be considered a watershed value that separates “good”

Table 14.1 Correspondence among path distance, walking time, evaluation value of walking accessibility, and status of walking accessibility

Path distance (d_{ij}) (m)	0–300	301–600	601–900	901–1,200	1,201–1,500	>1,500
Walking time (min)	<5	5–10	10–15	15–20	20–25	>25
Evaluation value of walking accessibility (a_{ij})	100	80	60	40	20	0
Status of walking accessibility	Comfortable	Easy	Fine	Tolerable	Barely accessible	Difficult to do so
Overall walking accessibility (A_i)	>90	71–90	51–70	31–50	11–30	0–10
Evaluation level	Very good	Good	Fine	Tolerable	Poor	Bad

walking accessibility from “bad.” Table 14.1 shows the correspondence between path distance, walking time, the evaluation score of walking accessibility, and the status of walking accessibility.

Finally, “the overall walking accessibility to urban facilities from block i ”—namely, A_i —can be obtained by carrying out the aforementioned processes. A_i ranges from 0 to 100, and the greater its value is, the better the overall walking accessibility from a given block i to urban facilities—and, hence, the lower the potential demand for motorized transport there will be. Conversely, the smaller A_i is, the poorer the overall walking accessibility is, and the higher the potential demand for motorized transport there will be.

All these calculation processes can be facilitated through GIS software. The results thereof can be visualized as a kind of “walking-accessibility map” where the values of A_i can be shown in different colors after being classified into five levels.

14.3.3 Data and Results

Using the aforementioned methodology, this project carries out an empirical case study of Xiamen, China.

First of all, the “Master Plan of Xiamen City (2010–2020): The Overall View Map” is taken as the study’s base map, after subjecting it to vectorization processing in ArcGIS. According to the road grid—combined with land-use classifications and terrain maps—the entire city’s construction land is divided into 560 “blocks,” each of which is a grid defined by secondary-class roads and excludes the areas of water, wetland, farmland, forest land, and ecology protection zones. Then, using the relevant analysis tools in ArcGIS, the “centroids” of those 560 blocks are extracted as the centers of the blocks.

Various data on urban facilities are obtained from the Xiamen Municipal Bureau of Commerce, Bureau of Education, Bureau of Health, Bureau of City Planning,

and the like. In total, there are 78 shopping centers, 696 primary schools and kindergartens, 82 secondary schools, 20 hospitals, and 25 public cultural/sports centers. These data are processed in ArcGIS to create a research database, and the facility locations are marked on the base map.

Then, using ArcGIS analysis tools, the average crow-fly distances from each block's centroid to the nearest three facilities of each type are measured. As mentioned, according to a sample analysis based on the road map of Xiamen, the path distance d_{ij} is 1.31 times the crow-fly distance. Furthermore, the value of d_{ij} can be converted to a_{ij} , according to the score assignment standards shown in Table 14.1.

Then, through expert inquiry and discussion among the members of the research team, using the analytic hierarchy process, the weight coefficient W_j of each type of urban facility is established: $W_1 = 0.4174$ (shopping centers), $W_2 = 0.2634$ (kindergartens and primary schools), $W_3 = 0.1605$ (secondary schools), $W_4 = 0.0975$ (hospitals), and $W_5 = 0.0612$ (cultural/sports centers).

Finally, the overall walking accessibility to urban facilities in block i —namely, A_i —can be obtained according to its calculation formula. A_i ranges from 0 to 100. The greater the value of A_i is, the better the overall walking accessibility is from a given block i to urban facilities—and, hence, the lower the potential demand will be for motorized transport. In accordance with the standards shown in the last two rows of Table 14.1, the final results of A_i are assessed as being at one of six levels: very good, good, fine, tolerable, poor, and bad. Using ArcGIS grading tools, the results can be visualized as Fig. 14.1, below. This figure directly reflects the spatial pattern of the overall walking accessibility to urban facilities and indirectly reflects the spatial pattern of the potential demand for vehicle transport.

As Fig. 14.1 shows, no area in the city achieves the level of “very good”; only the old downtown area on Xiamen Island and a small number of blocks in the Haicang and Tong’an districts are “good” or “fine.” Most of the remaining areas are “poor” or even “bad,” which means it is not convenient to live there, or one is otherwise unlikely to access urban facilities by walking there, and that such areas may exact a high potential demand for motorized transport. Fig. 14.1 also indicates that almost all types of urban facilities are mainly located on Xiamen Island—i.e., the earliest developed area of the city—leading to an obvious imbalance between areas inside and outside Xiamen Island.

14.4 Availability of Public Transport in Xiamen

14.4.1 *Connection Between Availability of Public Transport and Car Dependence*

As stated, a major principle in developing a sustainable “green” transport system is to promote nonmotorized transport (especially walking). By adding urban facilities to areas where pedestrian accessibility is poor (i.e., bringing facilities closer to

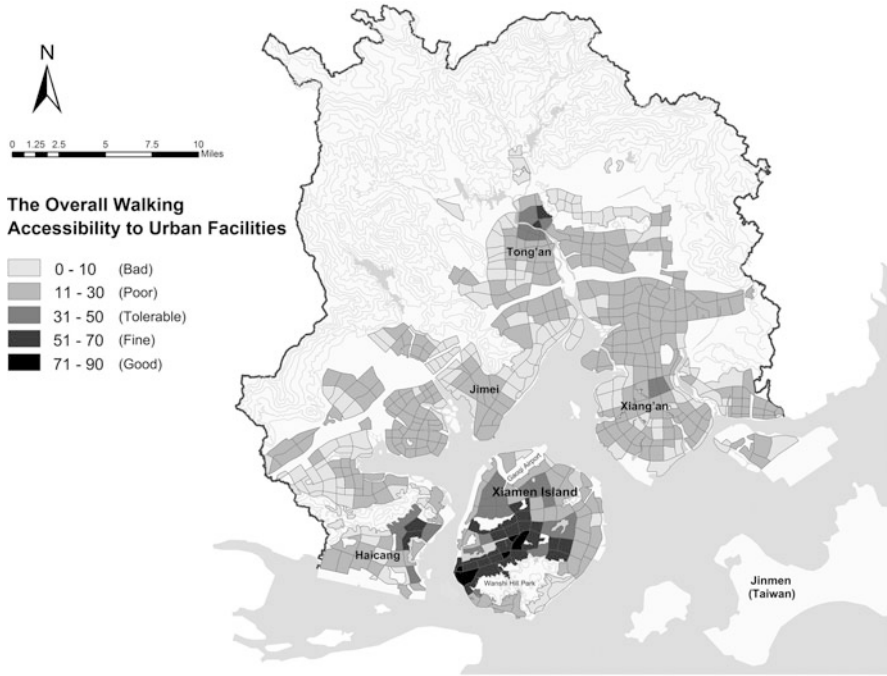


Fig. 14.1 Spatial pattern of overall walking accessibility to urban facilities in Xiamen

people), potential demand for motorized transport could be reduced to some extent. Besides, doing so could also reduce the probability of a need for long-distance travel involving a single destination. However, it is unrealistic to distribute urban facilities to every corner of the city. Besides, high-order services that demand a “threshold radius” that exceeds the walking scale cannot survive if they are too close to each other. Moreover, as the city expands and its structure becomes looser and more fragmented, the distances among residences, work sites, and service facilities will gradually increase, normally far beyond what is walkable. Such changes make the need for motorized transport inevitable, and a “second choice” of mode of transport will be necessary. Comparatively efficient, fair, energy-saving, and low carbon-emitting modes of public transport, rather than private cars, should then be encouraged. Besides encouraging nonmotorized transport (e.g., walking, biking), the promotion of public transport is another main solution to the problem of car dependence.

However, whether or not public transport can become a dominant choice for local residents—and how competitive it can be, compared to private cars—depends heavily on its availability. “Availability” is a concept that connotes “possibility of obtaining it,” “ease of access to it,” and “utility of using it.” The concept is often used to examine whether medical facilities or other resources are fairly allocated,

convenient to access, and efficiently used (Winter 1992; Hearn et al. 1998). The greater the availability of public transport is, the less likely individuals will use private cars.

14.4.2 Measuring the Availability of Public Transport

Concerning public transport, the research introduces the concept “availability,” to express the possibility and convenience of using public transport, as well as the utility of doing so. The availability of public transport in a certain area is certainly proportional to the number of public transit stations, but it is more determined by the number of transit lines that relate to those stations. The greater the number of public transit lines, the better an area is connected to other areas of the city (i.e., the higher the utility of using public transport will be), and thus the more likely local habitants are to use public transport. In view of this, the current study measures the availability of public transport in a certain block, which is based on the total number of those public transit lines that set up at least one station within the block. Grading tools in ArcGIS are then used to rank the results through a general comparison of all blocks.

14.4.3 Data and Results

Considering that a rail transit system is not yet available in Xiamen and that the Bus Rapid Transport (BRT) is operational in only a small area of the city thus far, the current study focuses only on the city’s well-developed mode of conventional public transport: its bus system.

First, according to data collected from the Xiamen Public Transportation Group, Inc., Tuba (www.mapbar.com), and Mabc (code.mapabc.com), there are 208 bus lines, and along with all the bus stops within the city, they are processed into the base map; data items include stop names, stop sites (with latitude and longitude), line numbers, and line paths, among other things.

Then, using the ArcGIS tools for “area + buffer,” each of the 560 blocks and their “border streets” are integrated as units. As a result of this process, when we extract a block from the map, we extract not only the internal area of the block but also the streets that surround it and act as boundaries.

Then, using the relevant analysis tools in ArcGIS, all the bus stops are extracted from each block (including its boundary streets), and the total number of bus lines relating to those stops are counted.

In the results garnered in the last step, the minimum value is 0 (i.e., there is no bus stop in that block), and the maximum value is 76 (i.e., there are 76 bus lines

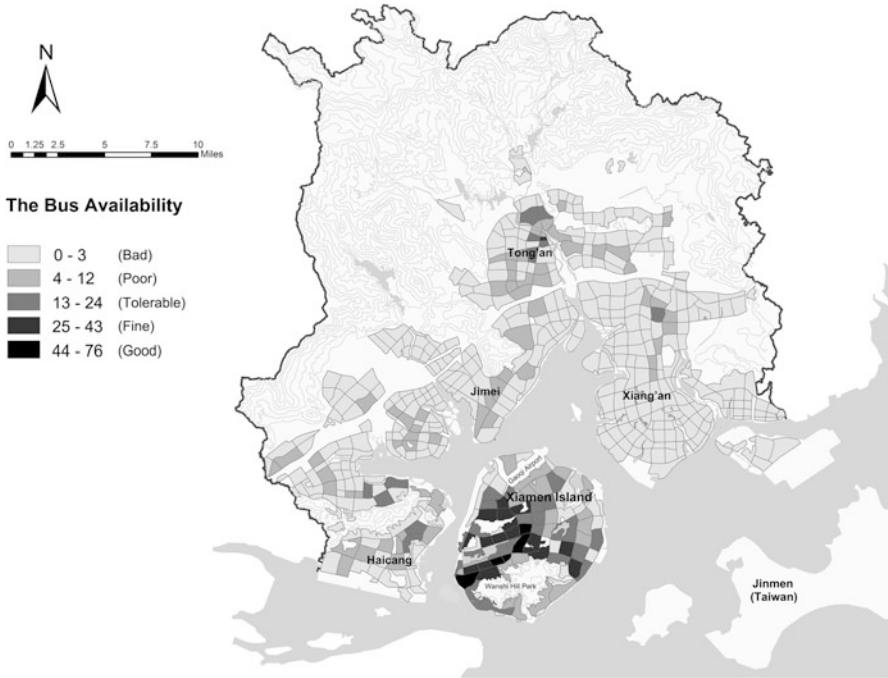


Fig. 14.2 Spatial pattern of bus availability in Xiamen

with stops in that block). By using the classification tool in ArcGIS and the “natural breaks” grading option, all 560 blocks are divided into five levels and differentiated in terms of mapping color. The final result is shown in the Fig. 14.2. Blocks with higher values (i.e., in darker colors) are those with relatively good bus availability, while those with lower values (i.e., in fainter colors) have relatively poor bus availability. Thus, the figure generally reflects the spatial pattern of the availability of public transport across Xiamen.

As shown in Fig. 14.2, the spatial pattern of bus availability in Xiamen closely resembles that of walking accessibility to urban facilities: only the old downtown area on Xiamen Island and a few blocks in the Tong’an district are at the “good” or “fine” level; most areas are only at the “poor” or “bad” level. There is also a significant gap in terms of the availability of public transport between Xiamen Island (i.e., the earliest developed area) and the outer districts on the mainland (i.e., the newly developed areas). This indicates a noticeable lag and insufficiency with regard to the construction of a public transport system in those new districts outside of Xiamen Island; this suggests the ongoing transition of Xiamen from an “island city” to a “bay city,” in which the development of those outer districts is part of the “key strategy” of the plan.

14.5 Mapping Car Dependence

14.5.1 Relationship Among Walking Accessibility to Urban Facilities, Availability of Public Transport, and Car Dependence

As stated at the beginning of the chapter, there are three categories of car dependence: physical/environmental dependence, social/psychological dependence, and circumstantial/technological dependence. As Gorham (2002) points out, it is probably difficult in practice to identify behavior endemic to any one of these categories, because they interact significantly. Therefore, it is not easy to measure car dependence, and it is even more difficult to overcome car dependence in practice, especially when social and psychological dependence are at play (Begg 1998; Cullinane and Cullinane 2003; Mackett 2009). Nonetheless, there are still widely recognized interrelations between car dependence and the built environment (i.e., urban form, regional structure, the distribution of activities within those structures, and the nature or status of collective transportation modes). Walking accessibility to urban facilities and the availability of public transport are essential components of a city's built environment. Although there is some debate as to how significantly the urban built environment impacts car dependence (Simmonds and Coombe 2000; Handy and Clifton 2001), it is still safe to say that the level of car dependence is somehow inversely proportional to walking accessibility and the availability of public transport. The better (worse) accessibility and availability are, the lower (higher) car dependence would be: this is why public transport development is still widely regarded as a meaningful and helpful way of optimizing the urban form and built environment and improving public transport, with the endpoint of mitigating car dependence. Despite there being some other factors that urban planning could scarcely affect—e.g., social values, the presence of an automobile culture, personal habits, and psychological needs—the levels of both walking accessibility to urban facilities and the availability of public transport can still reflect the potential extent of car dependence. The analysis of its spatial pattern can provide useful information for urban planning and relevant policy-making.

14.5.2 Evaluation of Potential Car Dependence

The previous sections evaluated the walking accessibility to urban facilities and the bus availability within the 560 blocks of Xiamen; the results of those evaluations were differentiated into five levels: good, fine, tolerable, poor, and bad. Considering that car dependence relates to both walking accessibility to urban facilities and bus availability—and that the level of walking accessibility of a block may different

from its level of bus availability—the scoring method detailed below is designed to quantify potential car dependence in each block.

1. Using “five-point scaling,” we quantify the five evaluation levels of “good,” “fine,” “tolerable,” “poor,” and “bad” into the evaluation scores 5, 4, 3, 2, and 1, respectively.
2. We let “the evaluation score of potential car dependence = the evaluation score of overall walking accessibility to urban facilities + the evaluation score of bus availability.” Thus, the minimum evaluation score of potential car dependence is 2 (i.e., both walking accessibility and bus availability are “bad”), while the maximum is 10 (i.e., both walking accessibility and bus availability are “good”).
3. We then divide the possible scores of potential car dependence (2–10) into five levels: highest dependence, high dependence, average dependence, low dependence, and lowest dependence. Details are found in Table 14.2.

14.5.3 Data and Results

Applying the aforementioned method, by executing layer accumulation analysis in ArcGIS, all the evaluation scores of potential car dependence in Xiamen’s 560 blocks are calculated. Then, according to the five-level division standards listed in Table 14.2, scores are converted to corresponding levels. Finally, a map of potential car dependence is generated (Fig. 14.3), on which different levels are displayed in different colors.

As shown in Fig. 14.3, there are distinct spatial disparities in terms of potential car dependence across Xiamen. Because the best (worst) areas in terms of walking accessibility are very often also the best (worst) areas in terms of bus availability, the spatial pattern of potential car dependence in Xiamen is similar to the patterns of these two factors. The old central area of the city on Xiamen Island is comparatively in the best situation, where the potential car dependence is generally at the level of “low dependence” or “lowest dependence.” However, the vast and newly developed areas—including the north and east fringes of Xiamen Island, as well as those outside areas such as Haicang, Jimei, Tong’an, and Xiang’an—are left behind as disadvantaged areas in terms of urban services and public transport. Hence, they have the worst scenario, where the potential car dependence is generally at the level of “high dependence” or “highest dependence.” Therefore, there is still an obvious disparity between “on-island” and “off-island” in terms of potential car dependence. Similar to Turcotte’s (2001) findings in Canada, areas new and far from the city center and featuring low-density neighborhoods have the highest levels of potential car dependence, suggesting that such areas are problematic and need to be improved. These areas should be deemed a priority for future investment, in terms of both urban facilities and public transport services. Otherwise, an undesirable, highly car-dependent transportation structure could result, in addition to inconvenient living environments. The evaluation and mapping of potential car

Table 14.2 Evaluation scores and ranking levels of “potential car dependence” in Xiamen

Evaluation score of “potential car dependence”	2	3-4	5-6	7-8	9-10
Possible combination of “overall walking accessibility” and “bus availability”	Bad + Bad	Bad + Poor	Bad + Good Poor + Fine Poor + Tolerable	Poor + Good Tolerable + Good Tolerable + Fine	Fine + Good Good + Good
Ranking level of “potential car dependence”	Highest dependence	High dependence	Average dependence	Low dependence	Lowest dependence

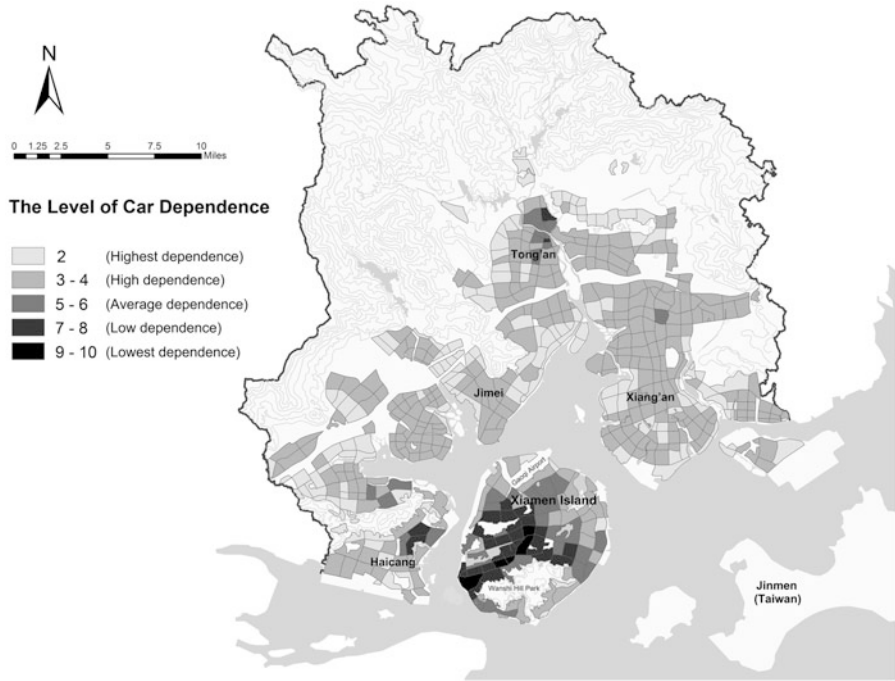


Fig. 14.3 Spatial pattern of potential car dependence in Xiamen

dependence, together with that of walking accessibility and bus availability, can therefore provide very useful information for planners and decision-makers vis-à-vis the ongoing development of areas outside Xiamen Island, as well as the structural optimization of Xiamen Island.

14.6 Summary

Like many other Chinese cities, the case study city of Xiamen has been experiencing a marked spatial transformation in recent decades. Since the strategy of transforming from an “island city” to a “bay city” was initiated several years ago, under the guidance of the “Overall Planning of Xiamen City (2004–2020),” the so-called battlefield of urban development is moving to a much broader space outside Xiamen Island. The spatial pattern of transportation will inevitably present a divergent distribution by taking Xiamen Island as the center. It is foreseeable that travel demand and traffic mileage will thus increase dramatically. The cross-sea, unidirectional traffic flow to and from the island is estimated to amount to 500,000 person-times a day. How to guide and control this unprecedented transformation

and enable the city to lay a foundation for future sustainable development—rather than something quite untenable, unsustainable, and undesirable—is now a crucial issue and stern challenge that local decision-makers, researchers, and planners face.

The results of the current study indicate that the construction of urban facilities and public transportation systems has not kept pace with the development of those new areas, leaving them in an obvious state of hysteresis. This leads to the result where the vast and newly developed areas outside Xiamen Island generally suffer from “bad” or “poor” conditions in terms of both walking accessibility to urban facilities and availability of public transport, as shown in the previous sections. The empirical study undertaken in the current study has highlighted that the worst areas of walking accessibility to urban facilities are very often also those with the worst bus availability; these areas are the ones most susceptible to car dependence. More and more people in those areas of Xiamen need to buy a car, despite the fact that they can barely afford one. Such circumstances make these individuals not only “mortgage slaves,” but also “slaves to cars.” For many cities, an explosive increase in the number of cars is becoming an intractable challenge—and because of the rigidity of their spatial structures and road networks, as well as the mental refractory of car dependence, once a car-dependent transportation system is formed, it is very difficult to change it, due to so-called path dependency and the “locked-in effect.” Therefore, it is critical for decision-makers and planners to put sustainable transportation at the tops of their agendas, in order to avoid the trap of car dependence.

By taking the city of Xiamen as a case study, the current study has also generated some useful information for both public transport and urban facility providers, by identifying problem areas and thus allowing them to join forces to promote improvements therein. The methodology developed in this research might also serve as a practical reference for future studies.

Problems in an individual city can also highlight important features associated with wider dynamics. The “car boom” and car-oriented development is now a common challenge that Chinese cities face. Fortunately, Chinese cities still have a chance to escape the trap of car dependence and innovate new ways to live sustainably, but only if they so choose. After all, since most people in China do not yet own cars and have not yet begun to drive, their travel habits and preferences can still be shaped in an environmentally sustainable way (Qian 2010). All in all, cities need to consider more than just road networks and vehicles when attempting to solve transportation problems: it is more fundamentally necessary to examine the urban form and built environment that push people to drive single-passenger cars.

Acknowledgement The research is supported by the National Natural Science Foundation of China (Project Item: No. 41071101), the Research Fellowship Scheme (2011–2012) at Peking University-Lincoln Institute of Land Policy (Project Item: No. FS-20110901), and the Research Start-up Fund for Introduced Talents at Xiamen University.

The author thanks three graduate students, Huang Jiuju, Li Yongling, and Yan Xin, in the Department of Urban Planning, Xiamen University, for their assistance in collecting and processing data.

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