# An Evaluation of Proposed Light Rail Transit Impacts on Land Use in Nanning, China

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# ABSTRACT

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This thesis examines how urban land-uses could support a planned Light Rail Transit (LRT) line in Nanning, China. Current and planned land-use is examined at two different scales: small-scale (overall network) and large-scale (four typical stations). The aim is to identify land-use characteristics around twenty proposed stations and their potential impact on the LRT line through analysis of land use intensity, land-use mixing and building densities. The study found that in general the current and planned future conditions are characterized by dense and mixed use development with extensive pedestrian infrastructure: all factors which are supportive of the Transit-Oriented Development (TOD) ideal. Even though future land use change is generally consistent with TOD goals, less dense development around outer stations might not be supportive for rapid transit. In addition, much of the built environment planned to surround future stations could be described as "transit-adjacent" rather than "transit-oriented". Recommendations for how the planned LRT line, as well as other planned rapid transit lines in Nanning City, could be best integrated with land use are proposed, based on experience worldwide as well as analysis of the Nanning case.

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# CHAPTER 1: INTRODUCTION

## 1.1 China's Urbanisation and Urban Transportation Challenges

China's urban areas have been undergoing rapid expansion and economic transition since the inauguration of the nation's 'open-door' economic policy in 1978 (Gu and Shen, 2003) [1]. Land use changes have been driven by economic reforms including the establishment of land and housing markets. Shifts in manufacturing industries and in housing policies [2] have resulted in spatial changes which include rural-urban migration, rapid suburbanization, industrial decentralization (in many cases to suburban industrial parks), redevelopment of old city cores, and the formation of new Central Business Districts (Gaubatz, 1999). A Chinese-style "sprawl" has emerged around cities classified as "large" (500,000 and more people) and "medium" (200,000-500,000 people). Movement from compact and mono-centric cities to poly-centric cities where growth is locate far from the traditional centre is currently a major planning issue in China (Zhang, 2000; Ma, 2003; Deng and Huang, 2004; Ma and Wu, 2005; Yang, 2007).

During China's recent economic boom and urbanization processes, intercity highways, inner city ring roads, and construction of large areas for automobile parking have been pursued as a means of increasing mobility for a population which is increasingly living and working in locations such as Central Business Districts (CBD), industrial parks, and residential estates (Ma and Wu, 2005). Growth in traffic congestion, air pollution and energy consumption have accompanied these increases in private motor vehicle use (Qu, 2006).

In response, many city governments are planning rapid transit infrastructure as a means of increasing mobility and accessibility with less negative impacts such as air pollution and traffic congestion than cars, motorcycles, or buses on city streets. While China's first "metro" (heavy rail, high frequency) line began service in Beijing in 1969 during the planned economy period, most of China's rapid transit infrastructure has been built since the mid-1990s, and particularly since 2002 (Table 1).

Table 1: Initial Rapid Transit Lines in China

| Rapid Transit Line | Technology | Initial Operations | Length (km) | Stations |
|---|---|---|---|---|
| Beijing Metro Line 1 | Metro | 1969 | 30 | 25 |
| Shanghai Metro Line 1 (Phase 1) | Metro | 1995 | 16 | 13 |
| Guangzhou Metro Line 1 | Metro | 1997 | 18 | 16 |
| Beijing LRT Line 13# | LRT | 2002 | 41 | 16 |
| Dalian LRT | LRT | 2003 | 49 | 12 |
| Shenzhen Metro Line 1 | Metro | 2004 | 17 | 15 |
| Tianjin Jinbing LRT Line | LRT | 2004 | 45 | 19 |
| Wuhan LRT Line 1 (Phase 1) | LRT | 2004 | 10 | 10 |
| Nanjing | Metro | 2005 | 17 | 13 |
| Chongqing LRT Line 1 | Monorail | 2005 | 14 | 13 |
| Beijing South Axis BRT | BRT | 2005 | 16 | 17 |
| Hangzhou Line B1 | BRT | 2006 | 28 | 13 |
| Dalian BRT | BRT | 2008 | 14 | 14 |
| Changzhou BRT | BRT | 2008 | 24 | 15 |

Source: www.ccmetro.com, www.urbanrail.com, www.brtchina.org

Some of these rapid transit systems have been highly successful. For example, 24% of the Shanghai metropolitan area's daily public transit ridership is carried by a 113 km metro network and ridership increased sharply from 370,000 passengers per day in 2000 to 1.63 million in 2005 after the opening of new lines (SUTAB, 2006). Beijing's recently-opened Bus Rapid Transit system (BRT) carries 220,000 passengers per day (Zheng and Xv, 2007). Others have been less successful. One example is LRT Line 1 in Wuhan City which suffers low ridership (around 40,000 persons per day) partly due to the low density land use along the corridor (Ye, 2007).

Many additional rapid transit systems are being planned or constructed under the strict control of the Chinese Central Government, which permits cities to build rapid transit systems (heavy rail and light rail) depending on minimum requirements of municipal finances, GDP, population and peak hour public transit ridership. For instance, to build a heavy rail system (metro), the municipal government's annual income must exceed 10 billion RMB (US$ 1.4 billion), and annual municipal GDP must be over 100 billion RMB (US$ 14.2 billion). At the same time, the total population in the central city must be above three million and existing ridership of the planned rapid transit corridor must reach 30,000 persons per hour (single direction, peak hour). The requirements for Light Rail Transit are 6 billion RMB (US$ 857 million), 60 billion RMB (US$ 8.6 billion), 1.5 million persons and 10,000 persons in each direction during the peak hour (Chinese Central Government Office, 2003).

## 1.2 Interaction between Rapid Transit and Land Use in China

While China's central government has established minimum guidelines of municipal finances, GDP, population, and established ridership, these guidelines have not included the important question of local land uses along rapid transit lines. Ambitious plans for rapid transit infrastructure have not considered how urban land use should be planned to support the proposed infrastructure. Yet, it is well established that the integration of land use conditions which are compatible with rapid transit is crucial to achieving high ridership (Dittmar and Ohland, 2004; Ginn, 1998). Compatible land uses include commercial, residential, government, and light industrial activities located within walkable distances from stations. Under certain conditions, rapid transit serves as a catalyst for complementary development of urban form and the economy (Cervero, 1998; Cervero et al., 2004; Huang, 1996).

In spite of the central government's lack of attention to planning land use around rapid transit stations, China has some of the world's premier examples of high density, mixed use development around transit. One example is Hong Kong, the city which is now a special administrative region where since the 1970s development has been shaped by planning of housing and activities around rapid transit stations. In Shanghai, a MRT system has had a positive impact on land use, with densification occurring along metro routes (Wright and Fjellstrom, 2003).

Overall, the residential population density in China's metropolitan areas is high in comparison with other cities around the world. The average metropolitan density of Beijing, Shanghai, and Guangzhou was 206 persons/ha in 1995, in comparison to averages of 15 persons/ha in the US, 26 persons/ha in Canada, and 55 persons/ha across of a number of Western European metropolitan areas (Kenworthy and Townsend, 2002). A similar figure of 200-250 persons/ha is cited as the recent average density for metropolitan areas across China (Loo and Lam, 2007). Population densities within parts of China's metropolitan areas can reach extremely high levels; Dimitriou and Cook (1998) cite a figure of 517 persons/ha in Shanghai's inner city before the first metro line opened in 1995.

While rapid transit has been successful in the largest and most dense parts of the largest cities, it is now being planned in many medium-size cities such as Nanning. These cities (as well as the less central and less dense parts of the largest cities) will be more difficult to establish rapid transit systems which will carry large numbers of passengers and take significant pressure off their overloaded road systems. Heavy rail has received much attention since it can carry more passengers and has potentially significant influence on land use along the corridor and station areas. While mid-capacity rapid transit modes (both LRT and BRT) on land use, which are viewed as more viable options than heavy rail by many mid-size Chinese cities such as Nanning, have not yet been discussed since most of them they were developed since last decade.

The relationship between planned land uses and rapid transit in a medium-size Chinese city is the subject of this thesis, which examines the specific case of Nanning. The success or failure of LRT line will depend on appropriate plans, policies and regulations to encourage high-level of integration between LRT line and surrounding land use. Experiences from worldwide countries can be examined in order to make recommendations for how rapid transit in Nanning can be a success.

### 1.3 Research Questions

1. In what ways do certain characteristics of built environments such as population densities encourage or discourage the use of rapid transit?
2. What kind of public policies can encourage transit-supportive urban form?
3. Will land use patterns around proposed LRT stations in Nanning support a high level of ridership?
4. Will proposed changes to built environment support the use of Nanning's LRT system?

The first two research questions about integration of land use and rapid transit are addressed through a review of the academic literature and planning documents. The last two questions are addressed through land use inventory and analysis around planned LRT Route 1 stations in Nanning based on current official plans and regulations.

### 1.4 Thesis Outline

Following this chapter which introduces the background to the thesis and the research questions, Chapter 2 summarizes the literature on the integration of land use and transportation infrastructure with a particular focus on the integration of stations areas and rapid transit infrastructure. Chapter 3 describes the methodology used for this research. Chapter 4 focuses on background information about transportation planning and land use planning of Nanning City. Chapter 5 describes an original methodological approach used to analyze primary data on land use surrounding Nanning's proposed initial line and four of its selected station areas in detail. Chapter 6 focuses on findings via while Chapter 7 offers conclusions and future topics for research.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Transportation Infrastructure and Its Effects on Accessibility and Mobility

Two concepts that are central to understanding transportation are accessibility and mobility. Accessibility refers to the number of opportunities, also called 'activity sites', available within a certain distance or travel time. Mobility refers to the ability to move between different activities sites (Hanson and Giuliano, 2004). Accessibility includes the attractiveness of a place as an origin (what opportunities are there to reach other destinations) and as a destination (how easy is it to get there from all other origins) (May, 2004).

Transportation systems (both road and transit) influence land development by increasing accessibility and mobility (Hanson and Giuliano, 2004). Transportation infrastructure provides alternatives to travel between two places (e.g., a new expressway linking between two places, or a rail line connecting the CBD and a residential district), which enable people to travel farther in a given time than they could before. Accessibility is increased by transportation infrastructure because movement becomes less costly in terms of time or money, all other things being equal. Transportation also contributes to the growing spatial separation between activity sites in urban areas because it raises accessibility of places. A transportation network affects not only travel time, travel cost and travel speed, but the accessibility of the entire network. As accessibility increases, the level of spatial interaction increases because travel becomes less costly and effective.

As the distances between activity sites become longer, accessibility has become more and more dependent on mobility, particularly in the private-car era. American cities, for example, have experienced growth in mobility, related to the construction of a national highway system which also links cities, to such an extent that accessibility has become automobile dependent. Between 1975 and 1997, person travel in the US grew by 77%. Western European cities have also seen increased mobility but through wide public transit use which accounts for around 10% to 20% of total travel, while only 3% in the US (Hanson and Giuliano, 2004).

## 2.2 Interaction between Land Use and Transportation Infrastructure

Land-use and transportation are interlinked. Transportation systems determine mobility, or the ease of moving from one place to another. Accessibility is raised when mobility is high and it is easy to reach more activities. Land use change affects accessibility: as more activities or interaction occurs, accessibility In general terms, this is what happens when urban growth occurs and populations and employment increase in a given area. When daily travel occurs along with urban growth, travel patterns, expressed as travel flows on the transportation network, affect the transportation system. In short term, the existing land use helps to shape travel pattern, however, in long term, transportation system shapes land use patterns (Hanson and Giuliano, 2004).

Land use and transportation influence each other, and come to balance after any of these two issues change. The distribution of activities (both jobs and residence) responds to changes in the transportation network because distribution of population and employment, as well as transportation supplement result in transportation performance. In the short term, travel demand changes in response to the increase of transportation facilities and capacity. In the long term, change of activities locations result in further change in travel demand and further change in system performance (Hanson and Giuliano, 2004; May et al., 2004).

Transportation technology has historically evolved with urban form through the Walking-Horsecar Era, Electric Streetcar Era, Recreational Automobile and Freeway Era (Hanson and Giuliano, 2004). Until the early 19th century, most people could walk from home to workplace and cities were compact. Transportation technology in late nineteenth and early twentieth centuries increased mobility, which mean people could move longer distances in a shorter time. Cities grew in both population and area because of transportation innovation and railways in particular (Huang, 1996; Hanson and Giuliano, 2004). Notable examples include US cities such as New York, Chicago and Boston during the first half of the twentieth century (Dunphy et al., 2001). The freeway and rapid transit era began in the post-World War II era. Extensive construction of expressway networks, as well as gas stations and parking have encouraged private car use and suburbanization in the US (Mceldowney et al., 2005). Urban growth largely followed expressway corridors, resulting in dispersed U.S. city form and low-density sprawl in west coast cities such as Los Angeles (Cervero and Landis, 1997; Dunphy et al., 2001).

Decentralization, suburbanization, polycentrism and sprawl are among the main characteristics of post-World War II cities. They happened already in many U.S.A. cities widely (Hanson and Giuliano, 2004). The usual urban form could be described as greatest population density and highest land value in city center and density and land value gradients decline with distance from city center. Comprehensive expressway system and cheap automobile offered opportunity to move away from the center because travel cost and travel time reduces, which caused population decentralization. Not only population, jobs decentralized as transportation costs declines. The construction of freeway system in U.S.A. was a primary force behind large scale suburbanization. More and more people migrate from historic metropolitan to suburban depending on cheap travel from their urban home to downtown workplace. At the same time, Sub-centers grow when transportation provides more convenience to daily travelers. Activities including retailing, business and light industrial become common features near highway intersections away from inner city. Although the downtown Central Business District (CBD) generally remains the location of the greatest density and the highest land value within the region, the central city is surrounding by new growing competing sub-centers spread out along transportation corridors, with much of the employment and population dispersed throughout the metropolitan area (Hanson and Giuliano, 2004).

Facilitated by high-speed transportation infrastructure, especially highways, sprawl is the typical form of most types of late-twentieth-century suburban development (Gillham, 2002; Hanson and Giuliano, 2004; Mceldowney et al., 2005). It is defined as a form of urbanization distinguished by leapfrog patterns of development, commercial strips, low density, separated land uses, automobile dominance and minimum of public open space (Gillham, 2002). But to create a more livable environment, most Canadian and European cities built a relative compact city form with mixed-use, multifunction and dense development. They are much denser, less decentralized and less polycentric than U.S. cities because they pursued a more transit-related development in metropolitan areas earlier than U.S.A. cities, which has prevented car-dependent activities and urban sprawl to some extent (Hanson and Giuliano, 2004; McEldowney et al., 2005).

Decentralization and suburbanization which are encouraged by large-scale migration to China's rapidly growing urban regions are distinctive from forms of sprawl and polycentric urban forms found in North America and Western Europe (Zhang, 2000; Deng and Huang, 2004; Yu and Ng, 2007). Sharp increases in population and employment have driven the expansion of cities such as Beijing, which has grown from 62.5 $km^2$ in 1949 to 391 $km^2$ in 1988, and then to 488 $km^2$ in 1996 (Deng and Huang, 2004). China's growing urban areas have retained high densities and centralized, uni-centred structures (Zhang, 2000; Deng and Huang, 2004; Yu and Ng, 2007). In addition, new urban growth in China includes specially designated "development zones", "industrial zones", and economic zones and migrant villages. These fringe areas are more mixed use than mono-functional sprawl found in North America (Gaubatz, 1999; Gu and Shen, 2003; Deng and Huang, 2004). Moreover, most Chinese cities, especially medium and small ones. are still developed in single-center structure and their central cities are still booming, even though some large cities such as Beijing, Shanghai and Guangzhou are changing from traditional concentric zone cities to today's multi-center cities (Deng and Huang, 2004; Yu and Ng, 2007). To meet the needs of rapid urbanization, more and more transportation facilities (e.g., ring roads, rapid transit systems, expressway systems) were built such as Beijing's ring roads in inner city and Shanghai's metro system (Loo and Li, 2006).

In summary, areas with high accessibility to land provided by transportation attract developers via reducing travel time and travel cost. More developments generate more activities and more travel demands, which affects travel mode choice, travel time and travel cost again. New transportation may be offered to address the change. When new transportation provides, road facility in particular, cities growth has boomed, both dense and less dense, sub-centers in large metropolitan are functional linked.

### 2.3 Theories about Integration of Land Use and Rapid Transit

Public transit helps to relieve congestion. save energy, reduce pollution, revitalize cities, provide mobility to the disadvantaged and ensure basic mobility option for everyone

(Hanson and Giuliano. 2004). Viable public transit, particularly mass rapid transit, is a critical factor to changing development patterns, redeveloping central cities and creating sustainable cities (Huang, 1996; Hanson and Giuliano, 2004; Mceldowney et al., 2005). It provides the most service at peak travel times in the most congested travel corridors, and carries high-volume trips concentrated in space and time. Without viable public transit, development has little alternative but to adopt an auto-dependent suburban pattern. The influence degrees of rapid transit system on land use is variety, including some cases having strong influence such as Hong Kong, Toronto and Ottawa, as well as some having limited influence such as most U.S.A. cities (Cervero, 1998). The theoretical view is that the construction of rapid transit system should have significant impact on land use by providing accessibility, while empirical evidence shows that the influence is not sufficient (Hanson and Giuliano, 2004). Several US rapid transit systems failed to attract expectation of development and achieve predicted ridership, such as San Francisco's BART and Washington D.C.'s Metro (Cervero and Landis, 1997; Hanson and Giuliano, 2004). Thus, for transit to work most effectively, it is required that land use should be amenable to transit use.

Land use/rapid transit integration appears to influence urban development at two difference scales. At the regional scale, rapid transit systems help to shape urban form and new development areas (Cervero, 1998; Dunphy et al., 2001). At the community scale, transit is a consideration of development around a certain district, station area in particular. Concepts such as TOD, smart growth, compact growth and infill development are developed to encourage compact, mixed-use development around rapid transit stations to struggle with transit-unfriendly, single-use development. Integration of land use and rapid transit infrastructure (high-capacity metro/subway, mid-capacity LRT and BRT) has been important for station areas, which is strongly promoted as Transit Oriented Development (TOD). TOD is widely defined as compact, mixed use development near transit facilities with high-quality walking environments (Cervero et al., 2004) and described as residential, retail, open space and public use arranged in comfortable proximity, making it possible for residents and workers to travel by transit, bicycle and foot (Loukaitou--Sideris and Banerjee, 2000). In essence, TOD promotes compact and mixed land use with centrally located transit stations, aiming to increase rapid transit system ridership (The Urban Land Institute, 2001; Loo and Lam, 2007). Generally speaking, a strategy combining mixed-use centres with high-density, closed spatial integration and friendly-pedestrian environment is seen as successful integration of rapid transit station and land use.

Intensive development around station areas is an important influencing factor supporting operation of rapid transit. Density is the most important land-use predictor of ridership rates based on studies in U.S. cities (Cervero et al., 2004). High-density development can generate more travel demand and encourage usage of public transit (Babalik-Sutcliffe, 2002; Cervero et al., 2004). According to Cervero et al. (2004), a doubling of population density is associated with nearly 60% increase in transit boarding (Cervero et al., 2004). Newman and Kenworthy (2006) found that a minimum of urban density (residents and jobs) as 35-per-hectare will make city centers less automobile-dependent. For decades, most local and provincial governments in Canada have implemented a range of land use policies encouraging clustered development and high density coordinating with rapid transit (Hanson and Giuliano, 2004). Contrarily, many rapid transit lines introduced in last two decades in U.S.A. have attracted relatively little ridership because they do not directly serve any densely populated areas and fail to shape high density development in station areas, but the stations area are of low-density, single use development, even industrial district (Huang, 1996; Dunphy et al., 2001).

Secondly, mixed land use around rapid transit station is strongly encouraged to shape an effective rapid transit system. Mixed–use districts include commercial, residential, official, open space and civic uses within walking distance of rapid transit stations, organized to generate transit ridership throughout the day for different purposes (housing and employment uses) and support transit riders. A mixed use network results in a large number of daily trips which strongly supports the ridership of rapid transit system. Some destinations, like office and residential buildings, produce trips during peak hours. Other, like entertainment complex, restaurants, and retail shops, generate trips mainly during off-peak hours, helping to squeeze efficiencies into the deployment of costly rail services. When mixed-used are aligned along linear corridors, trip origins and destinations are evenly spread out, producing efficient bi-directional flows (Cervero et al., 2004). On the contrary, if the function along rapid transit corridor is homogenous, daily trips could not be generated from home to workplace and could not satisfy the operation of rapid transit systems. Many researchers have found that the level of land use mixing is an important criteria for evaluation of rapid transit and urban land use (Huang, 1996; Dunphy et al., 2001; The Urban Land Institute, 2001). The level of mixed use may contribute to travel demand, particularly through the decentralisation of less specialised employment.

Moreover, convenient spatial connections between rapid transit stations and surrounding environments have received attention. Because walking is the preferred mean of access to rapid transit (The Urban Land Institute, 2001), providing good access from retail, office or apartment buildings to rapid transit stations is important.

These high density, mixed land use and well spatial integration of rapid transit station and land use surrounding station areas, such as land use in Canadian and European cities, result in more successful transit systems which have higher modal split shares than U.S. system supported by low-density, single-use development (Hanson and Giuliano, 2004).

**2.4 Approaches to Encourage Integration of Land Use around Rapid Transit Station**

Not all rapid transit lines have spurred new, compact land development. For instance, without political and design support, San Francisco's Bay Area Rapid Transit (BART) had a modest influence on land use and urban development, and failed to create new growth on the outskirts (Cervero and Landis, 1997), while more compact, mixed-use development occurred along Toronto's initial subway line and Curitiba's BRT (Cervero, 1998). Single-use, low-density suburban sprawl is the hardest place to make transit work effectively. The origins and destinations are dispersed, which makes it difficult to find a good way to make rapid transit, even bus work effectively. For these systems to work more effectively urbanization and transportation should be coordinated regionally and land use and rapid transit also need to work together. Once transit provides a good alternative, development should be made amenable to walking and transit access. To create well integration of land use and rapid transit, several measures are encouraged.

Firstly, encouraging dense development around rapid transit station area has been as a means to a successful rapid transit system in many cities. The high-rise, high-density and compact urban development in Hong Kong entirely attributes to the remarkable rapid transit, which was recognized as one of the most profitable, successful metro in the world (Dimitriou and Cook, 1998; Loo and Lam, 2007). Hong Kong Government's strict control on the dispersal of development avoided the tendency towards low-density sprawl. After several-decade development in a very high density, average residential densities on developed land sums up to 36,335 person/km$^2$ in 1993 (Dimitriou and Cook, 1998), which strongly support the usage of Hong Kong's metro system. Toronto's subway system appears to have significantly shaped and intensified high-density development particularly along the Yonge Street corridor which was opened in 1953 (Knight and Trygg, 1977). By allowing liberal FAR (up to 12:1), awarding density bonus, permitting higher intensity development as well as selling land rights and air rights, high-density development was encouraged in the areas along the metro line and surrounding stations along the Yonge Street subway line (Knight and Trygg, 1977; Huang, 1996). More than 90 percent of all office construction in the city of Toronto between 1952 to 1962 occurred within a five-minute walk of Yonge Street stations (Huang, 1996). In two Canadian cities where Light Rail Transit (LRT) served since 1980s, Calgary and Edmonton, LRT stations are integrated with adjacent land use to encourage high-density development with allowable FAR of up to 4:1 and 3:1 adopted around LRT stations (Huang, 1996; Mckendrick et al., 2006). The success of SkyTrain in Vancouver, where public transportation patronage is fairly high, was to some extent owed to relatively high population density along the corridor (Babalik-Sutcliffe, 2002). High densities adjoining to the BRT transit way in Curitiba, resulted by various zoning bonuses and density bones granted only in zones within walking distance of the transit way, plays roles in running a successful BRT system (Cervero, 1998).

Secondly, mixed land use patterns, especially commercial/residential/official/light industry, have been implemented in many cities to integrate with their rapid transit systems. For instance, mixed land use was proved to play a role in affecting average weekday boarding in Hong Kong (Loo and Lam, 2007). Toronto's Yonge Street subway enjoyed successes in spurring intense apartment and office construction around its stations, which contributes to high ridership (Dunphy et al., 2001). Residential/commercial development was encouraged along with the BRT lines in Curitiba, via special restriction which requires that at least 50 percent of the ground and second floors of all new buildings devoted to retail/commercial, and mixed-use development along BRT corridors could receive bonuses (Cervero, 1998). In many other cities, planners designated most station areas as multi-function centers with both mixed-use commercial and residential zones (Huang, 1996). In U.S.A., shareholders are recommended to pursue mixed use development around stations in some planned LRT projects (Dunphy et al., 2001; The Urban Land Institute, 2001). In Calgary planners designed most stations to be multi-purpose centers with both mixed use commercial and residential zones (Huang, 1996).

Thirdly, urban design guidelines should be prepared to create a transit accessible, pedestrian-friendly environment. Transit-supportive development includes not only distance and density, but also design to make transit an attractive option. To promote connection of land use and BRT, many cities such as Ottawa, Curitiba and many U.S. cities adopted spatial design to integrate station and land development, such as connecting entrances of buildings and stations directly to minimize passenger walking distance, locating bus stops as close as possible to the station entrances to enhance transfer security, reducing transfer distance, preventing front yard parking along rapid transit corridors to reduce distance between stations and buildings, creating pedestrian-friendly design in station areas to promote walking environment (Huang, 1996; Cervero, 1998).

Fourthly, developing an attractive downtown area could strongly support the operation of rapid transit system. An economically vital and healthy CBD or downtown, which is the main center for both employment and retail, can contribute to the success of an urban rapid transit system since it can generate and attract more daily trips between outer residential neighborhoods and downtown commercial, business center (Huang, 1996; Babalik-Sutcliffe, 2002). Boston's dense, concentrated urban core facilitates transit use. Fifty-five percent of daily work trips into the center city are by transit (Dunphy et al., 2001). A significant amount of development in downtown Toronto has been attributed to the introduction of subway system and rapid transit ridership was enhanced by existing development process (Knight and Trygg, 1977).

Furthermore, because industrial land use often fails to encourage, sustain and generate more transit-oriented trips, this type of land use is seen as less positive to rapid transit and discouraged. The Blue Line, connecting downtown Los Angeles to downtown Long Beach, passes through industrial areas which positively influence usage of rapid transit (Loukaitou-Sideris and Banerjee, 2000). Similarly, Cleveland's rapid transit line has less influence because it passes through areas of low-density, industrial development (Huang, 1996).

Moreover, parking policy such as parking limited, reducing parking lots in sensitive areas, usually in high-density downtown area and areas around rapid transit stations, is a helpful means to directly limit car use and induces rapid transit usage (Cervero, 1998; Mceldowney, 2005; Mckendrick et al., 2006). The success of rapid transit system in Hong Kong owes to a strictly limited restriction of parking lot construction and private car use (Dimitriou and Cook, 1998). During the period of construction and operation of the CTrain in Calgary, parking policies such as limited parking in downtown, changing the land use of existing parking lot, vacant land to commercial, residential usage, and high priced parking rates have been adopted (Mckendrick et al., 2006). In Ottawa, since 1983, after the opening of their BRT system, a new restriction of eliminating free parking for federal government employee and reducing downtown parking supplies was implemented in order to encourage the usage of BRT (Cervero, 1998).

Finally, integration of urban transportation planning and land use planning is called for and implemented in many cities where rapid transit systems play successful roles in urban transportation. Planning involves both states at the regional level and specific planning at site level. To struggle with metropolitan decentralization, suburbanization and urban sprawl, many European cities developed integration of land use planning and transportation planning; both at regional and metropolitan scale (Mceldowney, 2005).

Ottawa and Curitiba, where the rapid transit systems are well acknowledged as successes, integrate land use planning and transportation planning before implementing rapid transit (Cervero, 1998).

To sum up, based on worldwide experience in integration of land use and rapid transit, the success of transit primarily rely on a number of important characteristics: dense concentration of activities, mix of uses, and close spatial integration between stations and surrounding.

# CHAPTER 3: METHODOLOGY

## 3.1 Introduction

There is much academic debate surrounding the most effective way to quantitatively measure integration between land use and transportation infrastructure. In fact, approaches vary in terms of purpose of studies and results vary significantly depending on data sources, geographic scales and spatial resolution (Talen, 2003). Land use cover, density and diversity, accessibility and built environment are all elements to measure integration of land use and transportation (Crane, 2000; Geurs and Wee, 2004; Clifton et al., 2008). Some researchers opt to evaluate land use. For example, Loukaitou-Sideris and Banerjee (2000) looked at land use distribution along Los Angeles's Blue Line, and Cervero and Landis (1997) compared land use composition and land use change after introduction of San Francisco's BART. Some studies focus on analysis on employment and population density at metropolitan scale (Cervero and Landis, 1997; Loukaitou-Sideris and Banerjee, 2000). Newman and Kenworthy (2006) measure both residents and jobs per hectare to evaluate land use intensity which could spur less car-usage development. Some researchers evaluate accessibility (travel time, travel distance and travel speed), while some measure built environment characteristics such as road networks, sidewalks and bicycle systems, street intersection density and average block size (Clifton et al., 2008). Land value and housing prices are also evaluated to indicate the link between land use and transportation facilities (Condon, 2004; Gospolini, 2005). Haywood (1999) measured land use change at different distances from new transportation infrastructure: South Yorkshire Supertram in Sheffield U.K. Accessibility measurement is described and applies in a case study of railway stations for the Randstad of the Netherlands (Geurs, et al., 2006).

The density and diversity of development is importance to planners because they are known to influence trip generation, trip distribution and mode choice. More density means a greater concentration of trip origins and destinations, and more diversity mean a lower share of trips by car (Clifton et al., 2008). Density can be defined in several ways: by the number of people per land use unit or by the number of dwelling units per land use unit. Employment and population density are norms of land use density, usually at the metropolitan scale, while dwelling units and FAR are usually used at local scales (Gillham, 2002, Hanson and Giuliano, 2004). In many studies, Geography Information Systems (GIS)are used to conduct data quantitatively.

In this study, land use analysis primarily focuses on the local scale. Land use density and diversity will not be measured by population and employment density because it is very difficult to get employment data in Nanning City due to lack of statistics on this issue, and population data of the city is not accurate because of a large number of 'floating population' in Nanning. Depending on existing data, land use density will be reflected by two norms, Building Coverage and FAR on land plots. Denser buildings on a plot usually mean more population and more employment. Land use diversity can be reflected through comparison of land use patterns and mixed degree before and after introduction of LRT. The integration of LRT with land use surrounding station areas will be evaluated using calculation of total length and area of sidewalks. Denser public pedestrian infrastructure can contribute to higher local accessibility surrounding rapid transit stations although this measurement does not take the qualitative characteristics which influence environmental quality for pedestrians.

Another measure which could have been used is parking policy such as parking limited, reducing parking lots in sensitive areas, usually in high-density downtown area and areas around rapid transit stations. It is a helpful measure to directly limit car use and induce rapid transit usage, and an important characteristic of TOD. Due to lack of available parking data and difficulty to calculate and account parking lots, parking provision will not be examined and analysis in this research.

### 3.2 Nanning City

Nanning is the capital of Guangxi Province which has 49 million inhabitants (Figure 1). Nanning is a "region" comprising six districts and six counties which together house 6.4 million people (Figure 2). The districts making up a metropolitan area which includes rural fringe are officially home to 1.6 million in an area of 166 km² (2003). Given the high population density in the rural districts and the industrialization of the countryside, it is impossible to distinguish an area and population comparable to the Statistics Canada definition of a "census metropolitan area" which uses a minimum population for the urban core of 100,000 and adjacent municipalities which have a high degree of integration with the urban core measured in terms of commuting flows.

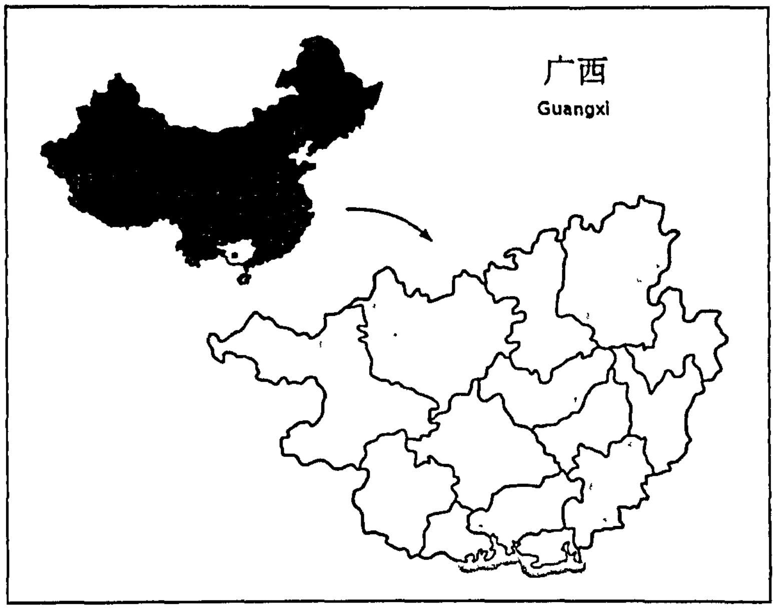


Figure 1 Location of Guangxi Province

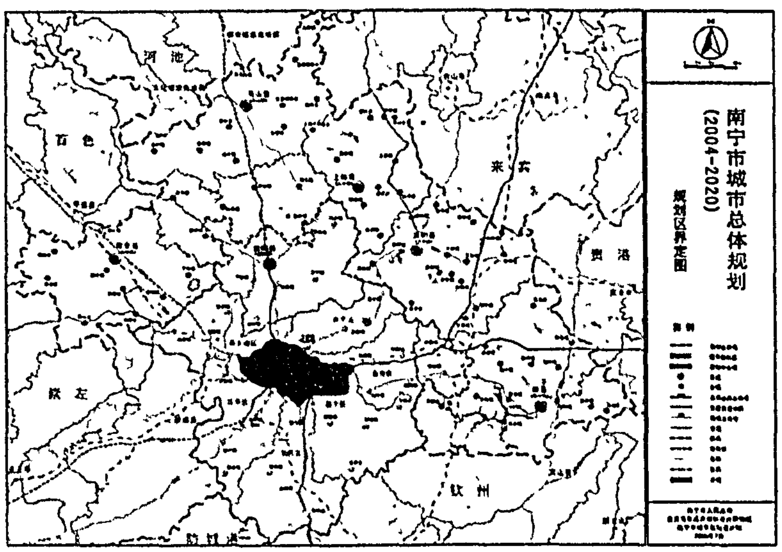


Figure 2 Nanning Region

The difficulties in distinguishing rural from urban in densely populated Asia have led to a number of attempts to create new definition of urban regions. For the purposes of this thesis, "Nanning City" is used to refer to a metropolitan area of 1.6 million inhabitants, and "old city core" is used to refer to the built-up, densely populated centre of the area.

In 2003, the Gross Domestic Product (GDP) of Nanning Region was 50.2 billion RMB (US$6.3 billion), averaging 7,862 RMB (US$982) per person. The economy of Nanning City is based on commerce, tourism, and light manufacturing (TUPRI, 2005). By 2020, Nanning Region's total metropolitan population is forecast to reach 7.9 million and there will be 2.9 million residents living in Nanning City (which by then will have expanded to 298 $km^2$). Yongjiang River flows through the middle of Nanning City, and future development will occur along the river in the old city core and two new sub-centres (Xixiang Tang and Yongning), linked up by the planned LRT Route 1 (Figure 3). In 2004, Nanning City was chosen as the permanent site for Association of South East Asian Nations (ASEAN) International Expo, which has spurred the government to accelerate the process of enhancement of infrastructures, including the introduction of rapid transit infrastructure, and commercial and official facilities.

To evaluate land use factors and know what is going on at present and what it likely be in the future around proposed LRT stations in Nanning, land use data from Nanning Urban Planning Geography Information System and official planning documents provided by the Urban Planning and Administration Bureau of Nanning City will be conducted. Land use data will be separated into two difference scales: small-scale (overall network) and large-scale (typical stations). The former aims to disclose land use classification around the whole proposed 20 LRT stations of LRT Route 1 (Phase I) and their impact on the overall LRT network, which could give us a comprehensive understanding of the land use status along the whole planned LRT route. The latter is to analysis physical environment changes before and after LRT Route 1 in Nanning, analyzing four typical planned LRT stations through analysis on land use intensity, land use mixed degree and physical built environment (Figure 3).

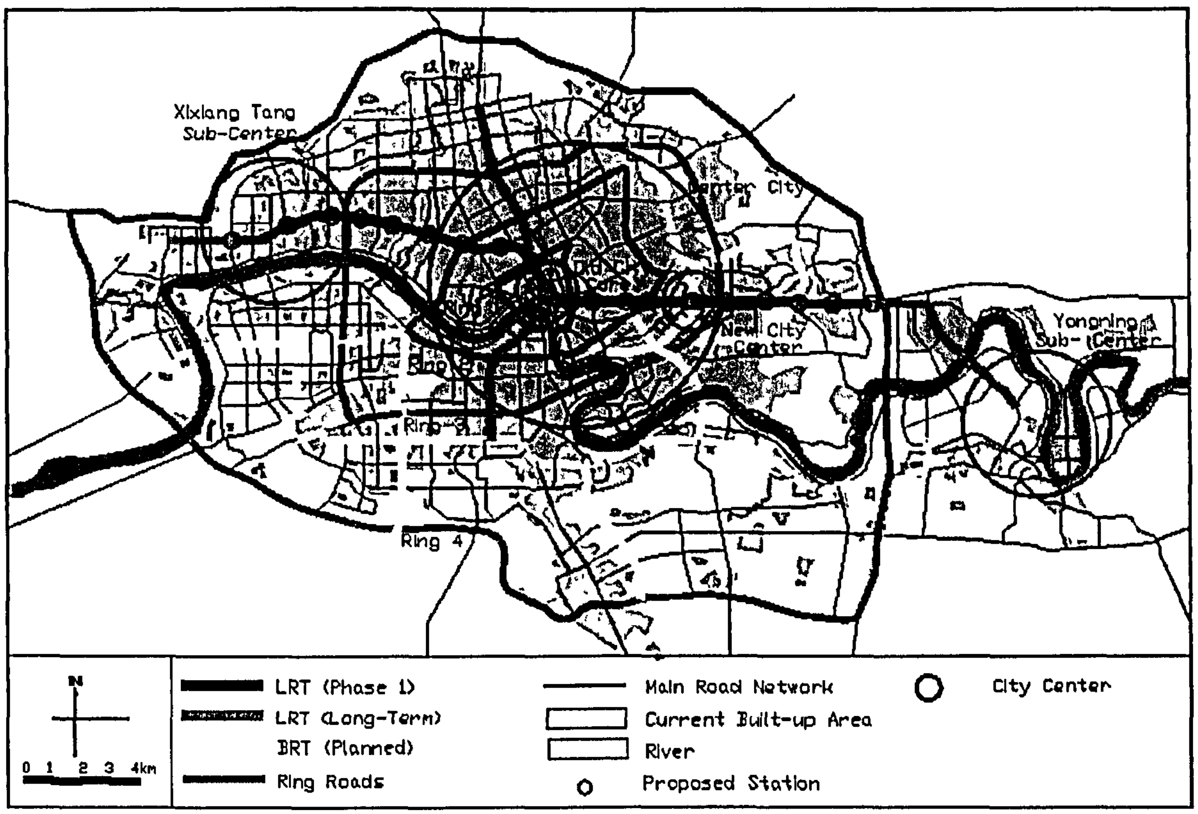


Figure 3 Existing and Proposed Transportation System in Nanning City

The above-mentioned aspects are all evaluated in two different periods: existing status in 2004 (the year when the last Master Planning was prepared in Nanning), and plan status after introduction of LRT based on current official plans and regulations.

### 3.3 Research Area

Data is collected for a 400m radius area which is recommended in the Master Plan of Nanning City (2004-2020) for the implementation of land use controls. A 400m radius is also commonly used around the world to capture most pedestrian trips to and from an urban rapid transit station. In small-scale analysis, to describe the general characteristics and land use pattern of overall network, research area concerns about the land use within 400m radius of total 20 proposed LRT stations. To measure the physical conditions, four stations are selected for analysis as samples of proposed 20 LRT stations (also within 400m) based on their geographical location in relation to the main city center and their age: developed old city core, new city center and under-construction city edge.

### 3.4 Data Collection and Measurement Methods

In order to estimate the change before and after the introduction of LRT Route 1 (Phase I), two kinds of data, land use data and spatial data, would be collected in two different periods (existing status in 2004 and plan status after introduction of LRT). Methods including land use classification, building coverage and FAR calculation, land use mixed degree measurement and spatial connection assessment are used in two different scales, overall land use of LRT network and physical condition of four typical stations. Land use data concerning building coverage and FAR calculation including building distribution and building areas, land use patterns and public sidewalk system can be collected from 1:500 or 1:1000 digital maps from Nanning Urban Planning GIS.

Analysis on overall land use of total 20 proposed stations is conducted based on small-scale Master Plan of Nanning City (2004-2020), whose benchmark year is 2004 and planning target-year is 2020, which could be regarded as existing status and future planning after LRT. Existing (in 2004) and planned land use (in 2020) of Master Plan of Nanning City (2004-2020) are basic data used here to classify land use within 20 planned LRT stations.

There are two basic data sources for evaluation of four typical stations. Firstly, to measure the existing conditions before LRT, large scale digital maps (1:500 or 1:1000) were used. The maps contain detailed information such as landform (lake, river, mountain) and physiognomy (building boundary, storey, function and owner, road boundary, width, square, tree, farmland, forest and site), revised during 2003-2004 by Nanning Urban Planning Administration Information Center, could accurately reflect existing status (in 2004) in detail.

Moreover, to describe future land use and physical conditions, for the reason that LRT Route 1 is under planning recently and land use around station area in the next five years are not on site, the researcher will estimate construction in research area based on three types of official planning and regulation. Firstly, researcher uses the large scale (1:500 or 1:1000) site layout of individual plots finished by developers, landlords and permitted by urban planning administrative bureau within research area. Secondly, under the condition that lack of detail site layout, a small-scale official planning (named regulatory plan), conducted by urban planning institute and permitted by Nanning government, will be seen as planning in the future. Lastly, the rest area where above planning uncovered will be measured basing on large-scale Master Planning of Nanning City (2004-2020) and Nanning Urban Planning and Administration Technical Regulation.

# CHAPTER 4: URBAN PLANNING AND RAPID TRANSIT IN NANNING

## 4.1 Nanning's Transportation and Rapid Transit Planning

Similar to other Chinese cities, Nanning is experiencing decentralization, suburbanization, industrial relocation, and motorization. Between 1994 and 2003 the built-up area of Nanning City grew from 81.4 km² to 124.7 km² (Figure 4). The total number of motor vehicles grew from 266,482 in 1999 to 411,684 in 2003, an increase of 54% (TUPRI, 2005). Motorcycles accounted more than 31% of total daily trips in 2001 (Figure 5). Heavy motorcycle use is associated with serious environmental problems (air pollution, greenhouse gas emissions and noise pollution) and low levels of traffic safety (SCUTPI, 2002).

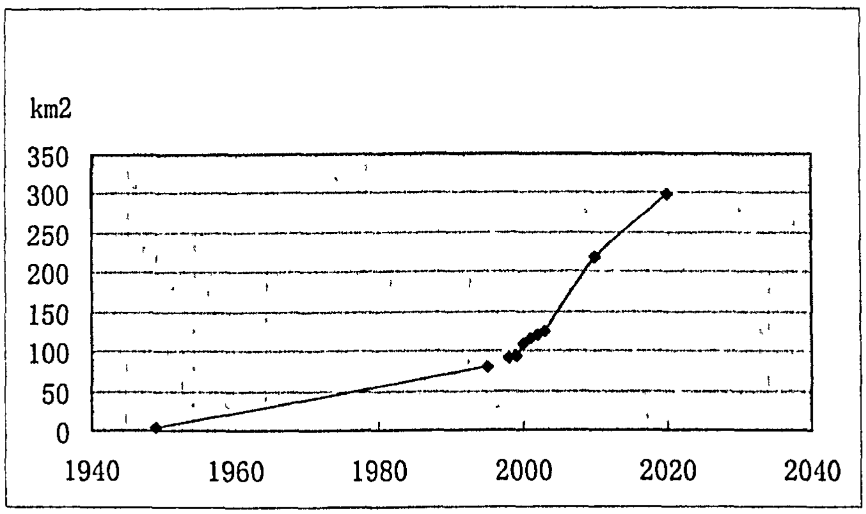


**Figure 4 Built-up Area of Nanning City**

Source: Special Subject of Population, Collection of Basic Data of Master Planning of Nanning City (2004-2020), Master Planning of Nanning City (2004-2020)

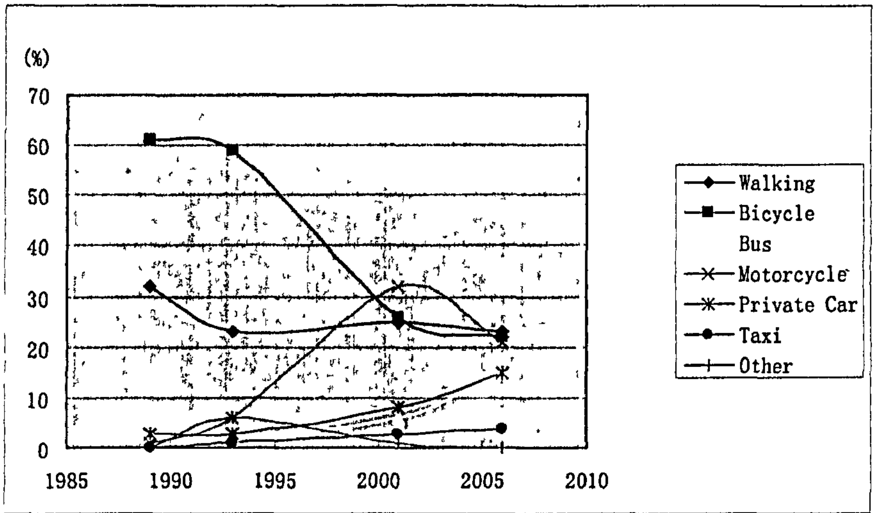


**Figure 5 Daily Modal Split (Weekday) for Nanning City**
Source: Shanghai Comprehensive Urban Transportation Planning Institute, 2006; Tsinghua Urban Planning and Research Institute, 2005; Shanghai Comprehensive Urban Transportation Planning Institute, 2002

To mitigate worsening traffic congestion and deteriorating environmental conditions, Nanning's government implemented several transportation policies such as investment in road infrastructure and banning of motorcycle ownership permits in the central city beginning in 2002 (SCUTPI, 2002). Road-based transportation infrastructure has been expanded to meet the demands of a growing number of cars. Four ring roads and several radial main roads were finished in last two decades (Figure 3). By the end of 2003, there were 81,657 km of completed road (13.58 million $km^2$) in Nanning (TUPRI, 2005). New road infrastructure has been partly responsible for increasing traffic congestion as more people are shifting from motorcycles to more space-consuming private cars. The policies were not successful.

Nanning's government is now considering giving public transit priority in order to achieve better results. Nanning City currently lacks rapid transit and the only public transit mode is regular bus. According to official planning, by 2020, Nanning's transit share should rise from 15.3% in 2006 to 23-25% of total daily trips with around 30% of that percentage accounted for by a rapid transit system (SCUTPI, 2005; CTPNC, 2002). In order to meet this ambitious goal, a rapid transit network of between 60 and 70 km should be built before 2020 (SCUTPI, 2005). To enhance public transit service and attract existing and potential private car-users, medium-capacity LRT and BRT rapid transit systems have been recommended. A comprehensive rapid transit system consisting of two LRT lines and eight BRT lines have been in the planning stages since 2001 (TUPRI, 2005) (Figure 3). A cross-shaped LRT network, Route 1 (30 stations, 40km) and Route 2 (16 stations, 20km) is planned to act as the trunk rapid transit infrastructure (Figure 3) (NRTB, 2007).

The total current public transit ridership in the old city core area was 147,284 persons per day (double directions) in 2006. To address urban transportation problem and achieve official transit goal the first phase of LRT Route 1 will be built from 2008 to 2012 by Nanning's government, with a predicted ridership of 266,000 persons per weekday (SCUTPI, 2005; NRTP, 2007).

### 4.2 Nanning's Land Use Planning

The first phase of LRT Route 1 will run 23 km (15 km underground and 8 elevated) and have 20 stations with a total cost of 8.87 billion RMB (US $1.22 billion). Figure 4 indicates the location of the planned LRT stations distributed at an average interval of 1.2km along the 23.5km. MPNC (2004-2020) identifies five city planning areas which the planned LRT line will serve (Figure 6):

1. Xiangsihu Area: western sub-center, focusing on tertiary education facilities, high-technology industry and high-rent residential buildings. It is partly a rural area and will be built in short-term. Five LRT stations (Xixiang Tang, Minzu University, Nongke Yuan, Chencun Station and Zoo) are planned for Xiangsihu area.

2. Mingxiu Area: complex city area which includes a number of different types of functions. Three LRT stations (Xinxv Jiang, Guangxi University and Heng Yangxi) are planned for the Mingxiu Area.

3. Old City Core: the historical commercial center of the region. The MPNC (2004-2020) identifies this high residential density, old city center as the location of regional commercial and transportation hub functions. Four LRT stations (Rail, Chaoyang Square, Xinmin Lu and Museum) are planned for the old city core.

4. Nanhu Area: new city center of Nanning City. Defined as a comprehensive district including official center servicing both provincial and municipal governments, regional business centre and high-quality residential group, Nanhu Area, which has been under construction since 1993, will be ameliorated in the near future for strengthening the administrative and commercial function. Three LRT stations (Macun, Nanhu and Wuxiang Square) are planned for Nanhu Area.

5. Fengling Area: new city area which has been under construction since 2000 and which will soon be home to various facilities including ASEAN Business Center, ASEAN Liaison Department Zone, international exhibition center, transportation hub and residential buildings. The rest of stations (Exhibition Center, ASEAN, Fengling, Lang Dong and Sanwu) serve the Fengling Area.

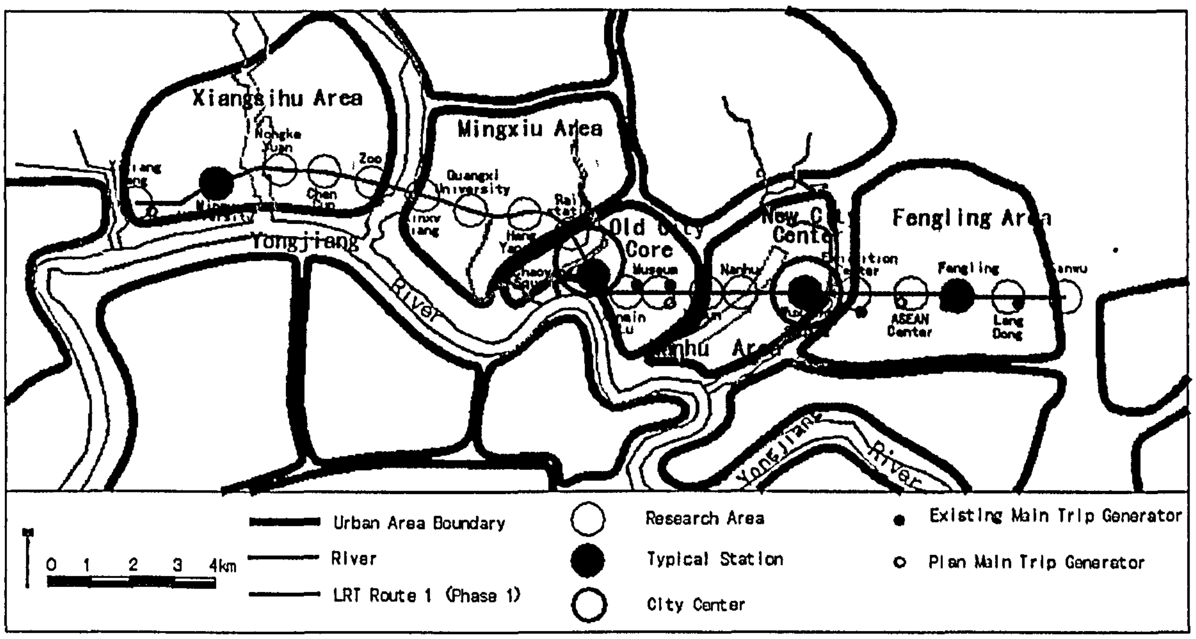

Figure 6 Research Areas and City Planning Area

Transportation and land use planning are integrated weakly at a high level (master planning and special planning), but not at all in terms of detailed planning and implementation at the local level. Two government agencies, Land Use Bureau and Urban Planning Bureau are concerned with land use planning. The Land Use Bureau is located under the national Minister of Land Use and Resources, and oversees land use planning (land use supplement, land use value, rent and toll) of all metropolitan areas. The Urban Planning Bureau is located under the national Minister of Construction and is responsible for land use function, distribution and construction intensity of the whole metropolitan area and the center city in particular.

At the level of master planning, both land use and transportation infrastructure are planned together, and high intensity land use is encouraged along main infrastructure, including rapid transit system. However, a lack of coordination between plans process by the two government bureaus leads to outcomes which often differ from those recommended in the plans. For instance, a proposed large scale sub-city center on existing farmland may miscarry because of strict prohibition of shift from farmland in building usage by master land use planning.

Moreover, at the local level planning, high intensity development is not encouraged particularly to support rapid transit use, and there is lack of special regulation and planning to spur higher intensity, denser development along the corridor (LRT stations have not been proposed in this stage). For instance, recent developments in the proposed station areas are being built without consideration of the planned LRT stations. Transportation infrastructure, especially rapid transit, is seen by the government as a solution to Nanning's current transportation problems, but not as a catalyst for new land development.

Compared with China's mega-cities, Nanning has a medium population density which has been declining over time and which is predicted to stabilize at a level of about 100 persons/ha (Figure 7), which would still be much higher than that of most North American and European metropolitan areas.

Figures 7 and 8 indicate that Nanning's declining density is the result of higher growth in the urbanized land area relative to population growth. Gross population density dropped by 28% from 150 persons/ha in 1995 to 117 persons/ha in 2003. This is almost half the 1949 level of 204 persons/ha. Expansion of lower-density suburbs on Nanning's outskirts is encouraged by policies and a general planning principle of moving the current residential population from the compact city core out to new developing areas (TUPRI, 1999; TUPRI, 2004). Population density in the core city is predicted to drop sharply (from 200 persons/ha in 2000 to 158 persons/ha by 2020) as commercial, service industry functions replace residential and secondary industries in the old city core. Population densities in suburbs are predicted to increase gradually, but will remain at low levels.

commercial/residential, official/residential, and commercial/official, have emerged over the last two decades in new city areas. These newer forms of land use mixing occur not only horizontally on one plot of land, but also vertically, with commercial uses on ground floors with residential on upper floors.

Large streets and squares have shaped Nanning's form. Existing and planned streets are wide, the main road network in particular, almost with a width of no less than 40m. The main roads where LRT Route 1 is planned (in elevated and underground alignments) all have widths of 40-100 m. These large-scale main roads create large city blocks averaging 600-700m on each side. Until recently, these large blocks were each occupied by a small number of "work units" (*danwei*) where people lived and worked together. Different work units and residential districts are separated by roads and walls, and few alleys go through these areas, resulting in difficulty for transit system to support this type of urban design.

Finally, there is lack of direct connection between buildings and streets. Entrances of buildings are separated from their surrounding environments by walls, greenbelts on the ground level (Figure 9). Underground space is particularly isolated without any linkage between buildings, underground commercial spaces and underground pass facilities. Even traveling at the same underground level between two nearby buildings, people have to arrive to the ground level at first, then cross the boundaries (parking, street, and greenbelt) before entering another building and going down to the underground.

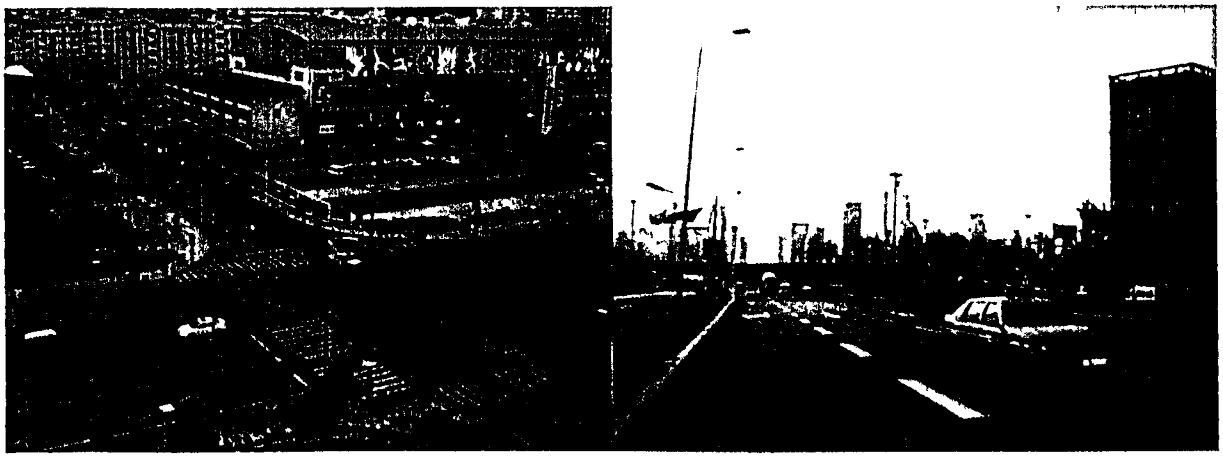

Figure 9 Separated Built Environments in Nanning (Chen, Ming)

# CHAPTER 5: DESCRIPTIVE ANALYSIS OF LAND USES

## 5.1 General Land Use around All 20 Planned Stations

Land use classification in 400m radii of all 20 planned LRT stations was conducted in order to identify the existing (2004) and planned (2020) land use patterns in research area. Figure 10 describes the general land use characteristics and Table 2 shows comparison of land use patterns in all 20 research areas. Relying on above analysis, the existing and planned land use could be summarized as follows:

1. A mix of activities will occur along the planned LRT Route 1. Educational institutions dominate in the west; commercial uses dominate in the old city core and eastern stations, while residential uses are widely distributed. Government administrative uses occur widely, and particularly in the new city center. In general, this pattern would appear to favor the use of LRT in this corridor.

2. The central city core will become a stronger and more attractive location of commercial and administrative uses. Their central position will be enhanced in the future through the introduction of new commercial facilities, redevelopment of existing low intensity land in old city core, and construction of large-scale official/commercial facilities in new city center, which potentially results in increase of employment and usage of planned LRT system.

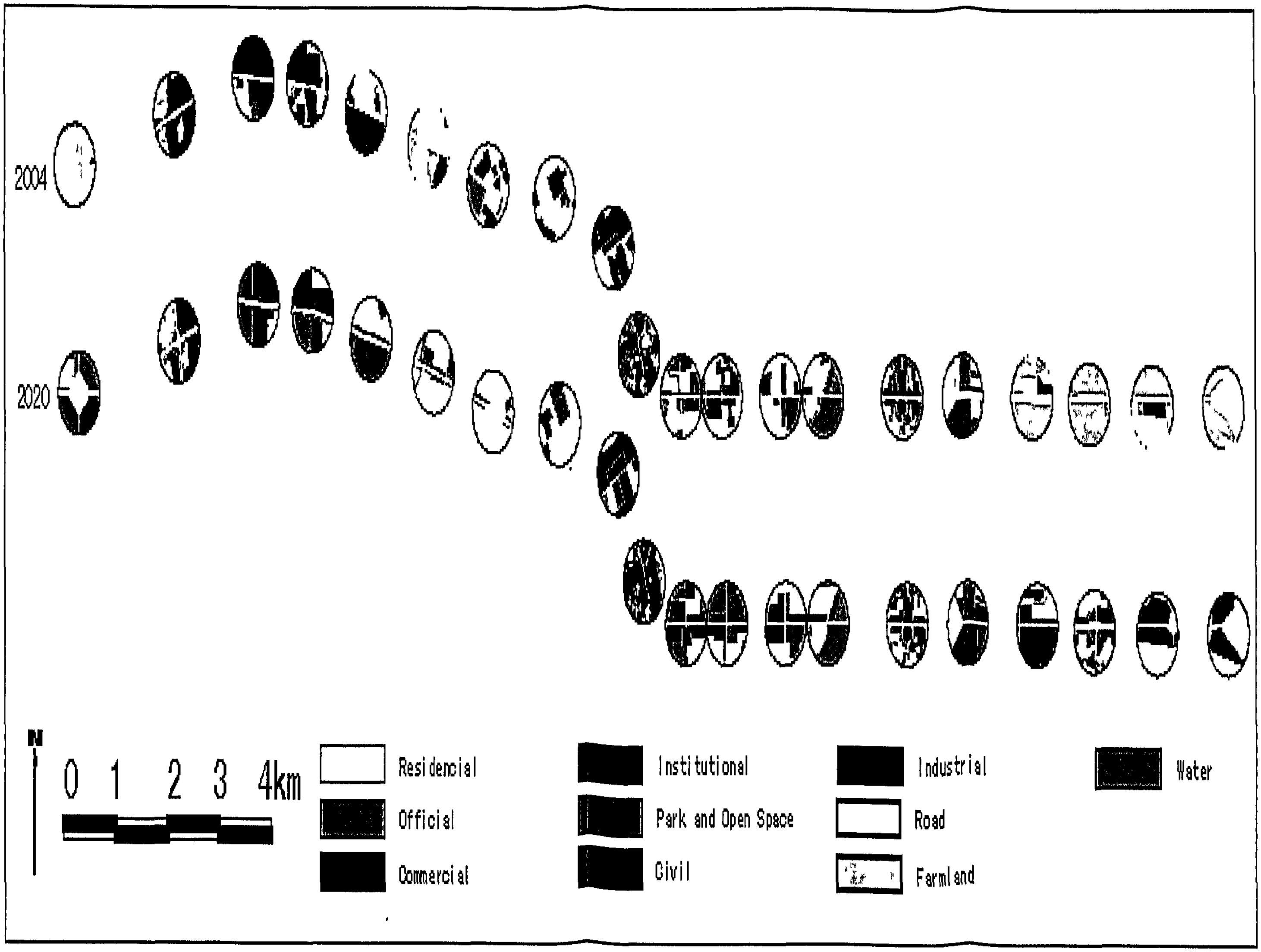


Figure 10 Land Use Classification of all 20 Planned LRT Stations

Table 2 Description of Existing and Plan Land Use of 20 Planned Stations

| Station | Land Use Classification in 2004 (%) | | | | | | | Change of Land Use (2004-2020) (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R | C | O | Inst. | Ind. | R&O | A | R | C | O | Inst. | Ind. | R&O | A |
| Xixiang Tang | 2 | 0 | 0 | 0 | 1 | 0 | 97 | +10 | +1 | +2 | +2 | -1 | +54 | -92 |
| Minzu U. | 1 | 2 | 0 | 60 | 1 | 12 | 17 | +14 | -2 | +1 | -19 | 0 | +22 | -17 |
| Nongke Yuan | 0 | 6 | 0 | 67 | 0 | 12 | 15 | +7 | +12 | 0 | -41 | 0 | +36 | -14 |
| Chen Cun | 21 | 0 | 0 | 38 | 10 | 11 | 19 | -8 | 0 | +23 | -9 | -10 | +12 | -8 |
| Zoo | 30 | 0 | 0 | 0 | 10 | 56 | 4 | +5 | +2 | 0 | 0 | -10 | +3 | 0 |
| Xinxv Jiang | 58 | 7 | 0 | 0 | 1 | 13 | 20 | -4 | -7 | 0 | +8 | -1 | +24 | -20 |
| Guangxi U. | 33 | 4 | 16 | 8 | 19 | 20 | 0 | +30 | -4 | -16 | -4 | -19 | +11 | +2 |
| Heng Yangxi | 61 | 3 | 6 | 5 | 7 | 18 | 0 | -8 | +1 | +6 | +6 | -7 | 0 | +2 |
| Rail Station | 20 | 14 | 3 | 0 | 8 | 27 | 30 | -4 | +12 | 0 | 0 | 0 | -2 | -6 |
| Chaoqyang Sq. | 13 | 43 | 6 | 2 | 34 | 1 | 0 | -3 | +7 | -3 | -1 | +1 | -1 | 0 |
| Xinmin Lu | 39 | 6 | 16 | 7 | 0 | 32 | 0 | -18 | +15 | -1 | +1 | 0 | +3 | 0 |
| Museum | 37 | 8 | 10 | 15 | 0 | 28 | 1 | -17 | +9 | +27 | -12 | 0 | -6 | -1 |
| Macun | 46 | 1 | 16 | 13 | 0 | 24 | 0 | -17 | +4 | +10 | +2 | 0 | +1 | 0 |
| Nanhu | 34 | 1 | 15 | 0 | 0 | 50 | 0 | -7 | +7 | -3 | +1 | 0 | +2 | 0 |
| Wuxiang Sq. | 19 | 3 | 18 | 0 | 0 | 60 | 0 | +3 | +5 | +4 | 0 | 0 | -12 | 0 |
| Exhibition Ctr. | 19 | 13 | 15 | 10 | 0 | 52 | 0 | -14 | +9 | +8 | -1 | 0 | -2 | 0 |
| ASEAN Ctr. | 14 | 6 | 0 | 0 | 0 | 17 | 63 | +2 | +38 | 0 | 0 | 0 | +21 | -61 |
| Fengling | 4 | 0 | 2 | 2 | 0 | 12 | 79 | +23 | +9 | +15 | 0 | 0 | +32 | -79 |
| Lang Dong | 32 | 0 | 0 | 0 | 0 | 20 | 49 | -1 | +10 | 0 | 0 | 0 | +34 | -43 |
| Sanwu | 2 | 0 | 0 | 0 | 0 | 58 | 40 | +10 | 0 | 0 | 0 | 0 | +30 | -40 |

Note: R: Residential; C: Commercial; O: Official; Inst.: Institutional: Ind.: Industrial; R&O: Road and Open Space; A: All Other

3. Existing undeveloped farmland, forest and mountain areas near outer stations is planned for new urban land uses. For example, the future location of Tixiang Tang Station which is currently surrounded by 97% farmland is predicted to be replaced by residential, commercial and other land uses.

4. Existing manufacturing and heavy industry, generally regarded as incompatible with Transit-Oriented Development, are planned to be replaced by residential activity. The

most obvious change is at the proposed Guangxi University Station, where existing industrial land use will be completely replaced by residential uses.

5. Placement of main trip generators near planned stations may strongly encourage future operation of LRT Route 1 (Figure 5). The planned LRT Route 1 links a cluster of high-trip-volume, high-frequency-use trip generators such as long-distance coach services, a railway station, commercial center, office center, exhibition center and ASEAN business center, all of which will potentially support rapid transit.

6. Mixing of activities and land uses is less intense at the outer, suburban stations than inner city stations (between Railway Station and Exhibition Center Station) where there is and will continue to be a mix of commercial, government administration, and residential activities. The westernmost stations Xixiang Tang Station and Chencun Stations will maintain mainly single-function institutional or residential areas. Residential land use occupies a large proportion of total land use between Zoo Station and Heng Yangxi Station. Eastern stations, ASEAN Center Station and Fengling Station focus on relevant facilities serving ASEAN. As for two easternmost stations, Lang Dong and Sanwu Station, transportation and urban landscape land use indicate a mainly single use function.

7. Roads and open space occupy a large portion of land area surrounding the proposed

station overall. Along with new construction of new roads network, a large part of existing undeveloped land will be maintained as road and open space (e.g., interchange, reservoir and city parks). Around six stations, the proportion occupying land around stations is more than 50%.

## 5.2 Typical Station Selection

The selected stations are (Figure 6):

1. Minzu University Station (Figure 11): located to the west of central Nanning. Tertiary education facilities occupy most land in low density. A large part of open space, large-scale road network and existing farmland are presented as the main characteristics.

Figure 11Tertiary Education Facilities near Minzu University Station

2. Chaoyang Square Station (Figure 12): located in developed old city core. It is the historical, traditional and regional commercial hub in Nanning with high-density

development. Interweaving of new, large-scale redeveloping projects and old, small-scale heritage buildings, will grow there.

Figure 12 Old City Core (Chen, Ming)

3. Wuxiang Square Station (Figure 13): located in new city center. It is so-called new CBD in the east of Nanning city, consisting of nearly entirely high-rise buildings and skyscrapers finished in recent years. Official, commercial and governmental center are centralized around a new open space, Wuxiang Square.

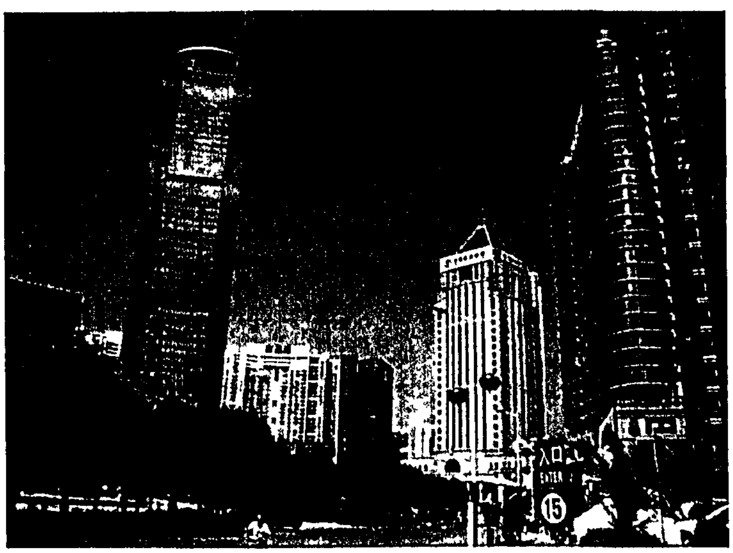

Figure 13 New City Center (Chen, Ming)

4. Fengling Station (Figure 14): located in the east of Nanning City. The main function of this mountain area is residential and official. A few high-rise, mixed-use buildings are emerged along the wide main road, besides that, a large number of high price, low density residential buildings are finished or under construction recently.

Figure 14 Farmland and Forest near Fengling Station (Chen, Ming)

## 5.3 Description of Land Use around Four Stations

### 5.3.1 Minzu University Station

Minzu University Station is west of central Nanning and is surrounded by educational, institutional and residential land uses. A 70m wide main road, Xixiang Tang Avenue, divides the area. Minzu University is located north of the road and two other institutions, Machine College and Foreign Language High School, occupy the area south of the road (Figure 15). Minzu University, Machine College and Foreign Language High School occupy 39% of total research area. A small quantity of residential land use, about 6%, mainly serves existing institutions as support facilities. A smaller number of mixed land use contributes to 5% of the total land use. Farmland occupies around 37% of total land use. Because Xixiang Tang Avenue is currently the only road in the area, the level of road coverage is very low at 12%.

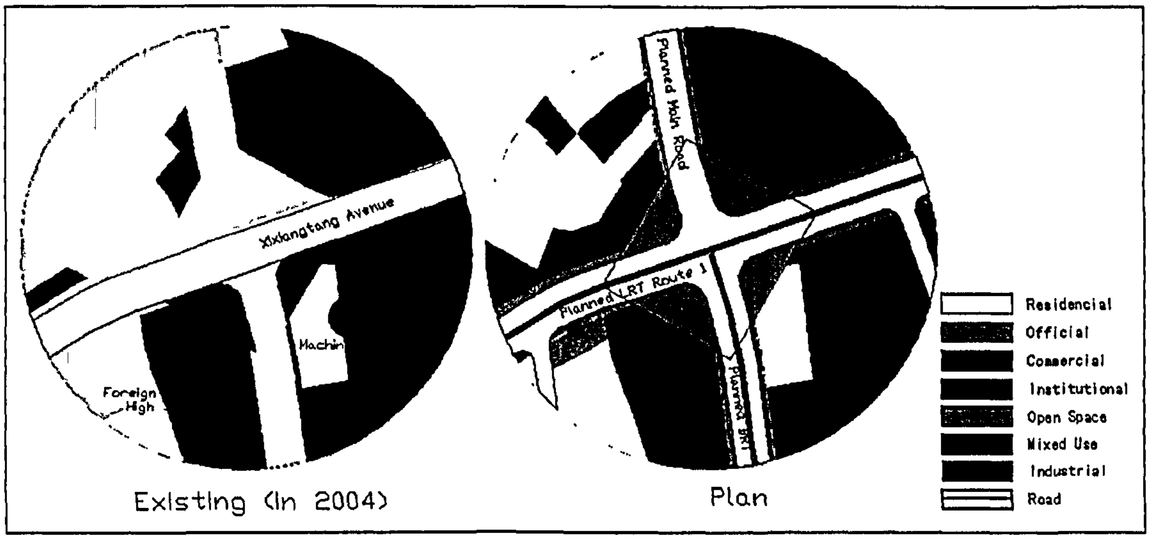


Figure 15 Land Use Distribution of Minzu University Station

The LRT is planned to be elevated in this section, and the elevated station platform will be located in the middle of a main road and interchange. In addition, a Bus Rapid Transit line is planned to reach the LRT station from the south in the future. Figure 15 indicates that education is planned to continue as the main activity around Minzu University Station. The share of land use classified as "institutional" is planned to be 38% of the total station area land use which is similar to the present situation. A notable change is shift of farmland into residential buildings with planned road network which rises of residential component of the area to 17%. A new road network and a huge multi-level interchange in addition to green belts on both sides of two main roads will increase the proportion of road and open space to 34%. As a result, the current land use mixed will change to include high-density commercial/residential mixed buildings, which will occupy 9% of land in the research area (Figure 16).

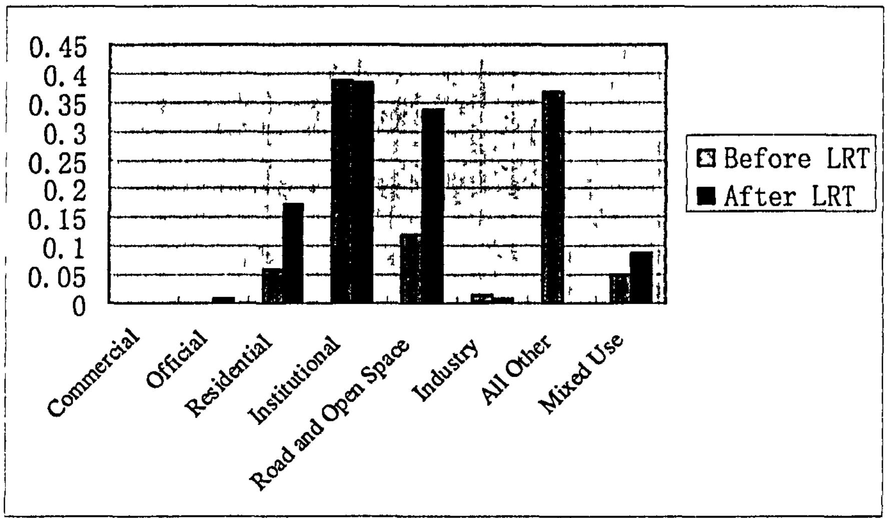


Figure 16 Land Use Classification of Minzu University Station

The current built form is characterized by small, irregularly located structures of one to two storeys. Building coverage of most LUUs within the three educational institutions is less than 30%, while some of LUUs receive a score of zero because there are no buildings but rather large green space, farmland, and vacant lands. The average building coverage of Minzu University Station was only 8% in 2004.

The planned increase in floor space is modest because a large portion of the area (33%) will be occupied by roads and open space, and the institutional buildings will continue to cover less than 30% of the area around the station. Thus, even though new residential land use will raise plot coverage, the planned average building coverage is only 13%

within Minzu University Station area (Figure 17 and 18).

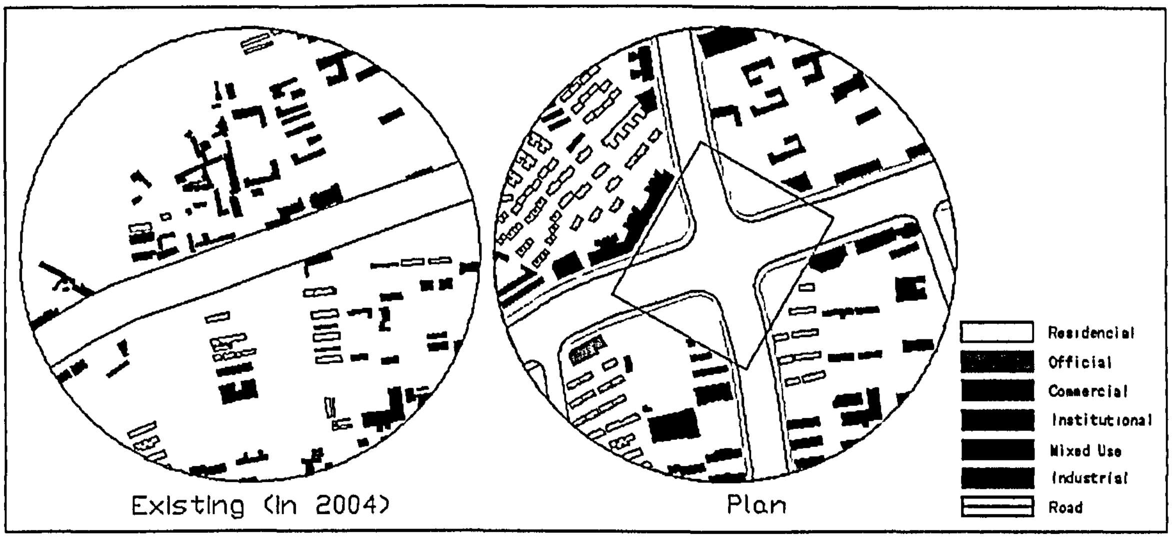


Figure 17 Building Location of Minzu University Station

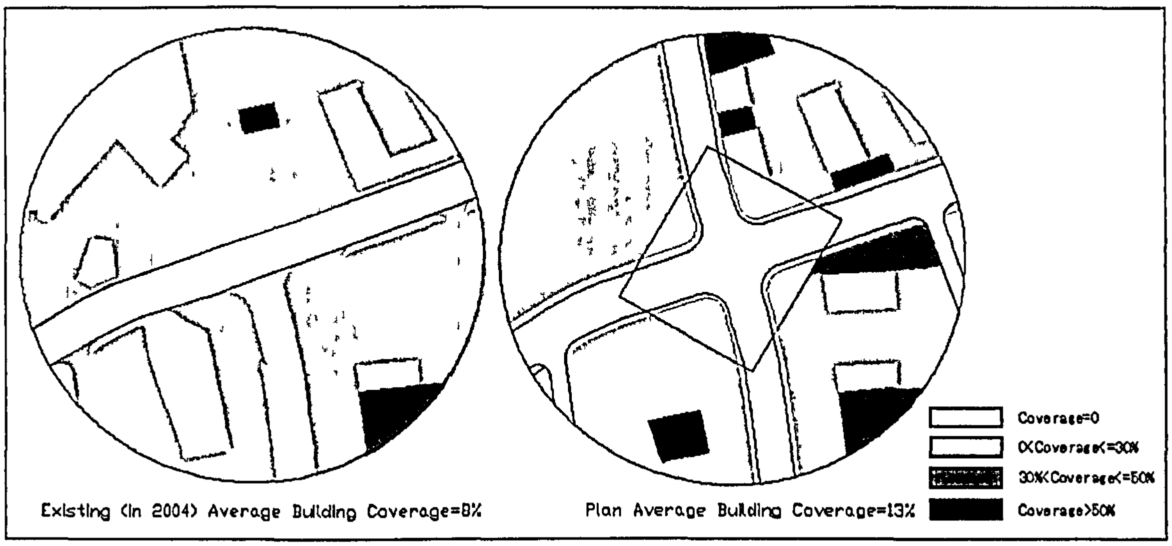


Figure 18 Building Coverage of Minzu University Station

FAR on a plot level is very low, particularly on existing institutional lands (Figure 19). Also, FAR of other land use does not present higher land use intensity because of low-rise, dispersed residential and 1-2 story temporary buildings. Existing farmland contributes zero to average FAR in research area. Thus, the existing average FAR in 2004 is only 0.13.

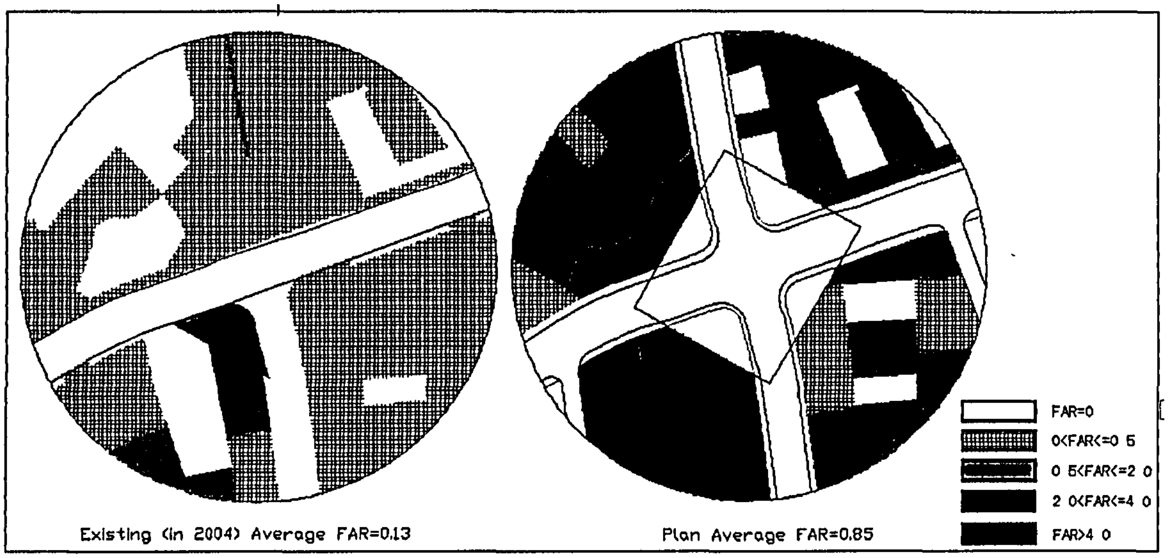

Figure 19 FAR of Minzu University Station

FAR is planned to rise as a result of the addition of large-scale, high-rise building (Figure 19). The highest FAR (4.0) in the future will be next to the planned interchange and along Xixiang Tang Avenue. Middle intensity land use partly occupies plots along two main roads as a result of large-scale educational facilities in Foreign Language High School, part of Minzu University and Machine College, as well as several mixed use high-rise buildings along planned main road. A significant increase in road, vacant, green space and sport yard prevents an increase of FAR in the whole research area. Through quantitative calculation, the planned average FAR of Minzu University Station is 0.85.

Due to lack of mixed building, the existing average mixed score of Minzu University Station area is 0.05 (Figure 20). New mixed land use, mostly commercial/residential mixed in northeast part along Xixiang Tang Avenue, and commercial/institutional mixed, will appear along the south of Xixiang Tang Avenue. On account of single use function of Minzu University, Machine College and Foreign Language High School, in addition to new road system and interchange, the future mixed score rises only to 0.15.

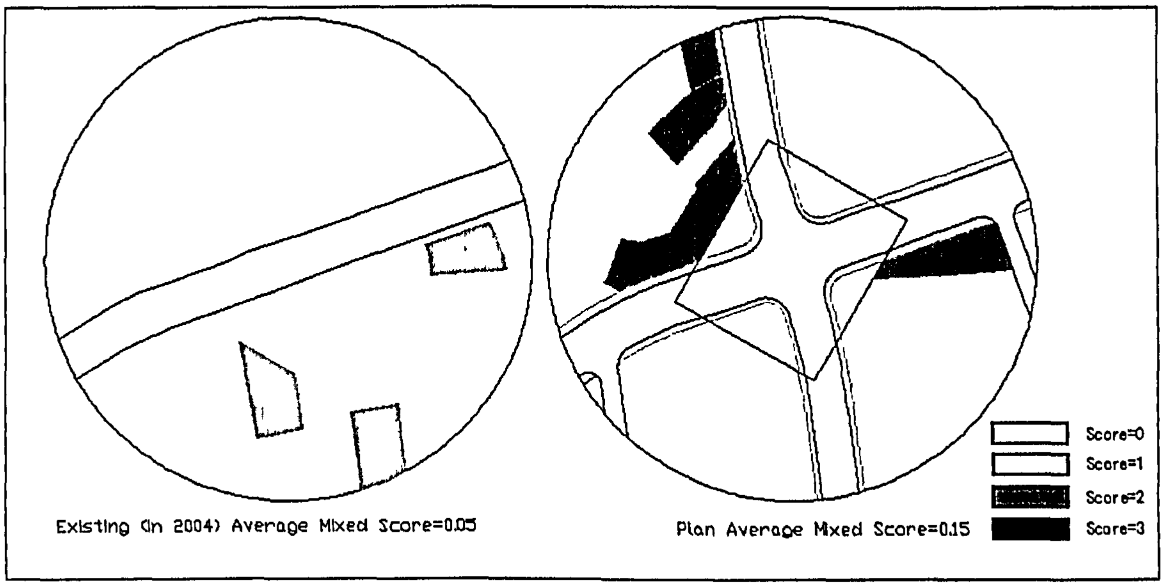


Figure 20 Mixed Score of Minzu University Station

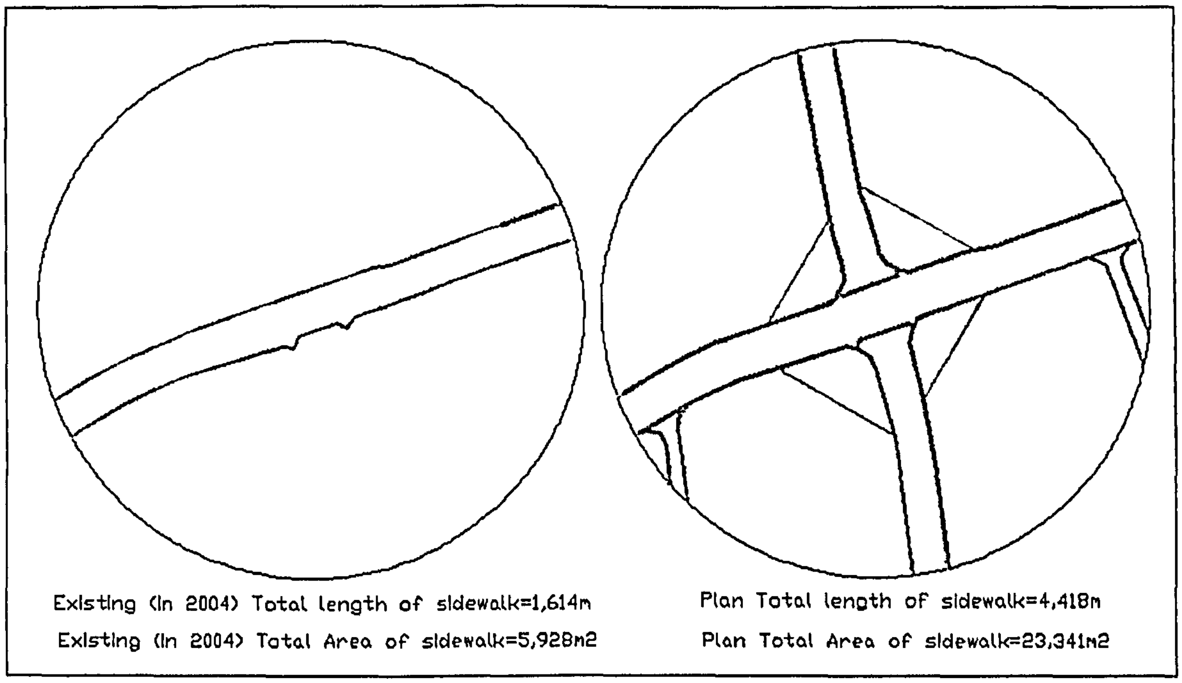


Figure 21 Sidewalk system of Minzu University Station

There is currently lack of public sidewalks in the area, which only has a 3.5m-wide sidewalk, partly 6.0m, on both sides of Xixiang Tang Avenue (Figure 21). The walkways in the area are currently limited to compounds which are blocked by walls and gates from the surrounding public pedestrian infrastructure. Without calculating the above special non-public system, the existing total length of sidewalk is only 1,614m, and total area is 5,928m².

The sidewalk system will be expanded as the new road network expands (Figure 21), while the existing non-public pedestrian collection systems in institutional units will remain and a similar system will be developed in a new residential district (northwest). The total length of sidewalk will rise to 4,418m and total sidewalk area is 23,341m².

### 5.3.2 Chaoyang Square Station

As a traditional, regional commercial center, the old city core is planned to be served by underground Chaoyang Square Station. The station platform will be constructed in the middle of 40m wide Chaoyang Road. The existing main road network (Minzu Avenue, Chaoyang Road and Xinhua Street etc.), pedestrian-only streets, Xingning Road and Minsheng Road as well as Chaoyang Square, the only large-scale open space in old city core, contribute to a relative high portion of road and open space, 33% of the total land. Land use in Chaoyang Square Station influence area is mainly commercial, residential and mixed use (Figure 22). Commercial development accounts for 20% of the total land and is prevalent in the northwest large-scale old commercial buildings such as Baihuodalou Commercial Center. southeast-part new large-scale commercial centers (Wanda and Gende) and south-western small-scale traditional commercial facilities. A special style commercial facility named 'Top-residential and Floor-commercial', mixed with small-scale retail on the ground floor and residential on the second to fourth storeys is presented in historical, traditional district (Figure 23). Distribution of single use official land and single use residential land represents only 1% and 6% of entire area respectively (Figure 24). High population-density residential land use disperses in the whole station area, primarily in low-rise or multi-rise styles (Figure 25). The amount of institutional land use is only 1%, composing of health care, police station, fire stations and primary school. A vehicle serving shop, the only current industrial land use, occupies 1% of total land use. Currently, mixed use could be deemed as dominate land use within research area as it accounts for 36% of the total land (Figure 24). Mixed land use can also be classified into different categories including large-scale, vertical commercial/official/residential mixed along Chaoyang Road, small-scale 'Top-residential and Floor-commercial' mixed along traditional commercial pedestrian-only streets as well as horizontal commercial/residential distributing mainly in historical, traditional district, and official/residential mixed located in the northwest.

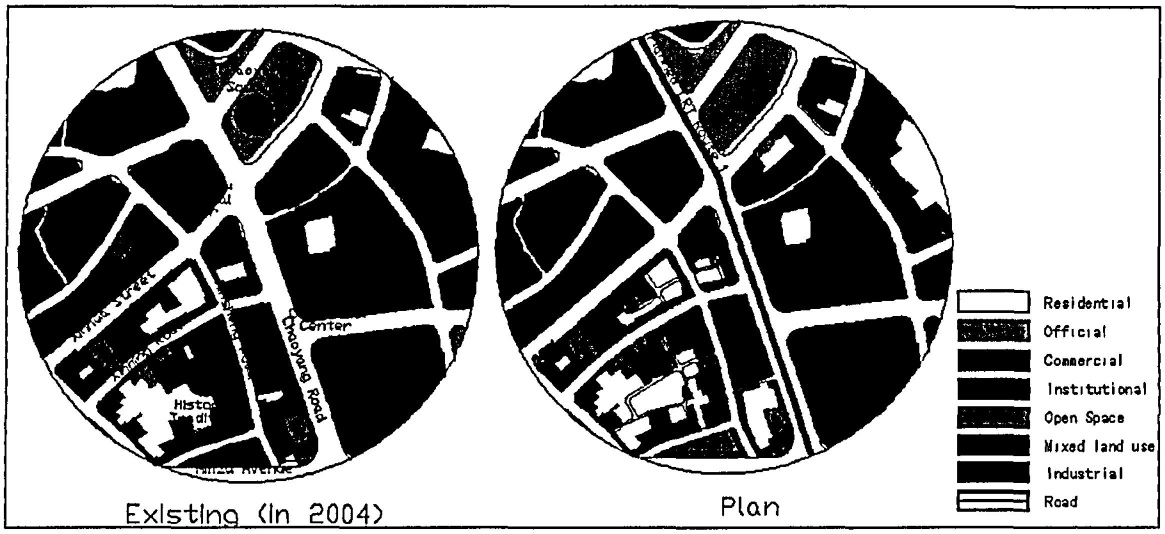


Figure 22 Land Use Distribution of Chaoyang Square Station

Figure 23 Traditional 'Top-residential and Floor-commercial' Building (Chen, Ming)

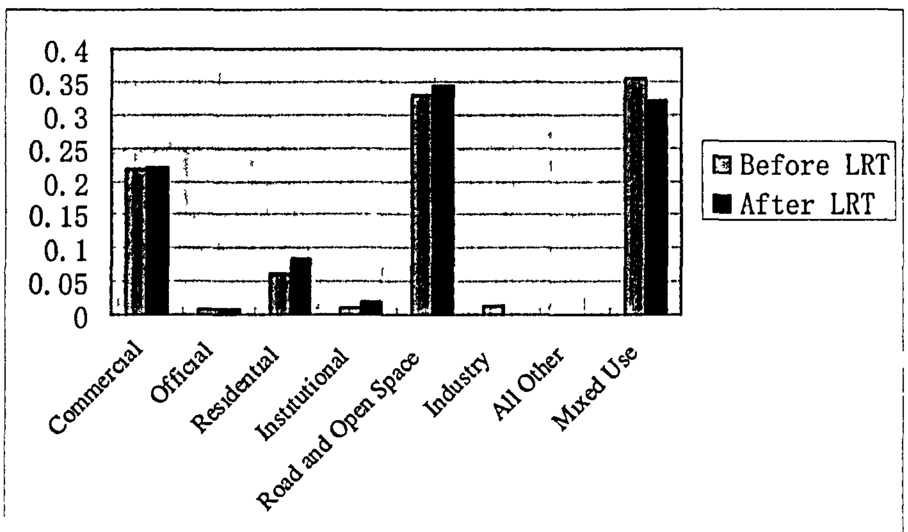


Figure 24 Land Use Classification of Chaoyang Square Station

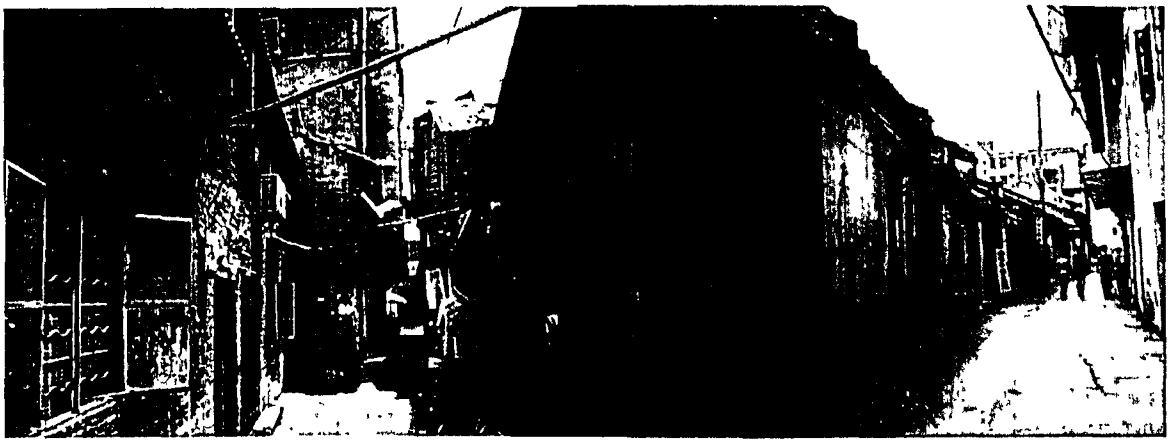

Figure 25 Vernacular Residential Architecture in historical district (Chen, Ming)

The current land use pattern emphasizing on commercial, official and residential uses will not change significantly after appearance of LRT and block structure will remain in place, and the mix of commercial/official/residential activities will remain largely unchanged (Figure 22 and 24). Some historical low-rise housing will be replaced with large-scale buildings that will occupy 3% more land. Industrial land will be removed from the city core. Road and open space will increase by 1%, via enhancing alley system, providing several small-scale green yards (inner neighbourhood) in historical district by demolishing some simple-structure buildings and illegal buildings. Due to the above-noted reconstruction and redevelopment of existing land use in city core, future mixed land use drops from 36% to 32%.

Dense building location and various building forms, mixed by large-scale, modern commercial buildings, dense small-scale residential building and compact mid-scale buildings, are characteristics in this area (Figure 26). In the southeast, plots with building coverage over 50% modern large-scale commercial, mixed-use complexes, including

89,000m² Wanda Commercial Center and 60,000m² Gende Commercial Center, collect on the east of Chaoyang Road. Dark grey (30%-50% building coverage), reflects hotel, existing residential and industrial buildings of 'danwei', a special Chinese work unit. An existing fire station in the south of Chaoyang Square remains. A high-density circumstance in the northwest consists of several large-scale commercial, commercial/residential and commercial/official buildings, including 89,000m² Baihuodalou Commercial Center (Figure 22). A small amount of less dense coverage, 30%-50%, such as official/residential development exists west of Chaoyang Road. The south-western historical, traditional district is home to all kinds of traditional architectures in this area, including a great deal of small-scale traditional 'Top-residential and Floor-commercial' buildings. Almost all land units have high building coverage of more then 50%, even up to 80%-90%, and many lack necessary maintenance, including illegal buildings. According to calculation, the average building coverage at present is up to 41%, the highest of all four station areas.

The overall building density in Chaoyang Square Station area is planned to be reduced through the replacement of dense housing stock and adjoining industrial buildings with large-scale commercial, residential or mixed-use high-rise buildings, as well as for new small open space (Figure 26 and 27). Thus, the future average building coverage of exisitng research area drops to 36%.

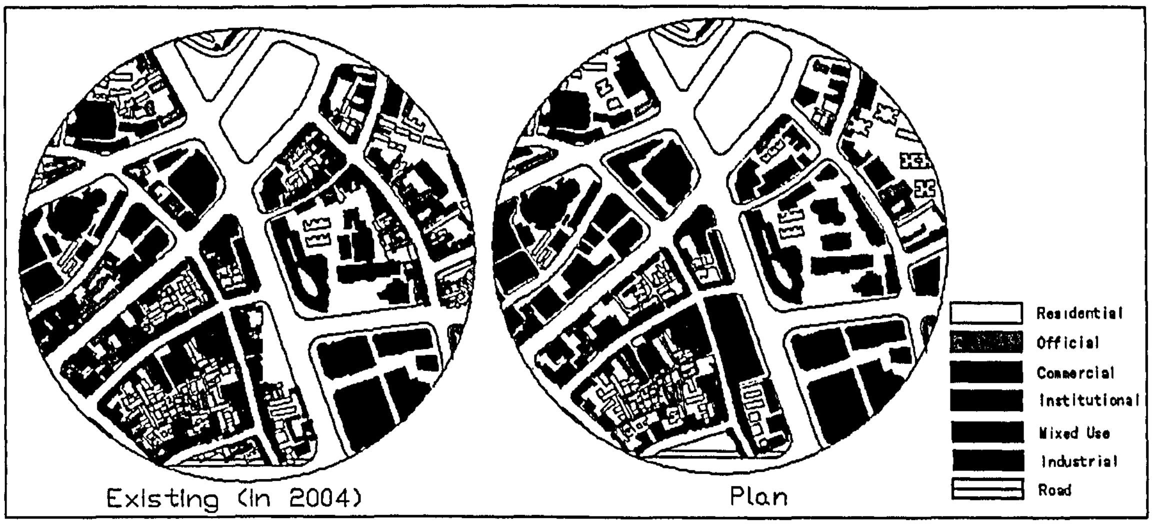


Figure 26 Building Location of Chaoyang Square Station

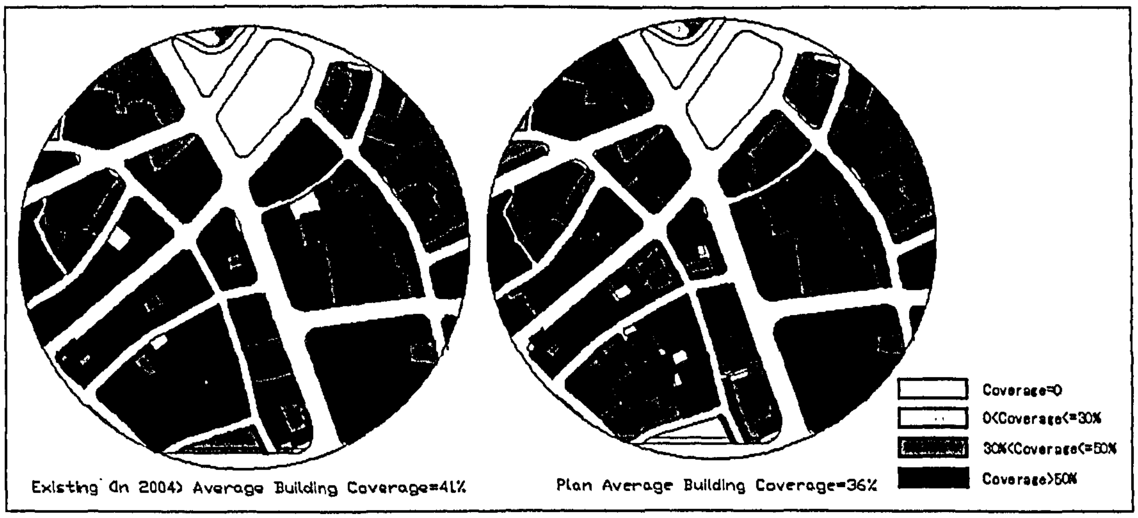


Figure 27 Building Coverage of Chaoyang Square Station

Existing high FAR plots within the Chaoyang Station area combine to give a high total FAR of 2.13. The contributions to the high total FAR include several large-scale commercial/residential complex, closely-space low-rise historic housing (Figure 28). The high-level FAR (>4.0) plots emerge primarily in northwest part and along main roads because of several existing large-scale commercial/residential complexes. FAR of 2.0-4.0 covers large part of LUUs in southeast, characterized by 2-4 floors traditional folk houses, LUUs locating at inner part of traditional district contributes low FAR (less than 2.0). Differing from expectation, some high building density plots do not contribute to an high FAR, chiefly because of low height of buildings. For instance, the FAR of large-scale Wanda Commercial Center is only 2.63 due to they are all 3-5 floors multi-storey buildings. The same relatively low FAR (usually 2.0-4.0, even less than 2.0) occurs in historical, traditional district because of introduction of dense, low-rise buildings. The average FAR of Chaoyang Square Station area is 2.13.

Future FAR of Chaoyang Square Station area will increase slightly because of land use redevelopment, old building demolishment and modern, large-scale reconstruction. Large-scale city reconstruction projects in the southeast part, which has a high FAR more than 4.0, contributes to the increase of future FAR (Figure 28), while FAR in historical, traditional district will slightly drop. In terms of Conservative Planning of Historical and Traditional District in Nanning City, the FARs of plots covered by existing dense buildings, particularly traditional buildings, folk buildings and heritages will drop to less than 2.0 through demolishing some simple-structure, temporary buildings and illegal buildings and creating green space and public alleys. Plots along traditional commercial streets, Xingning Road and Mingsheng Road, will maintain former building density and intensity by strict control on building style and volume. By means of quantitative calculation, the average FAR of the whole research area will slightly rise to 2.6 in the future.

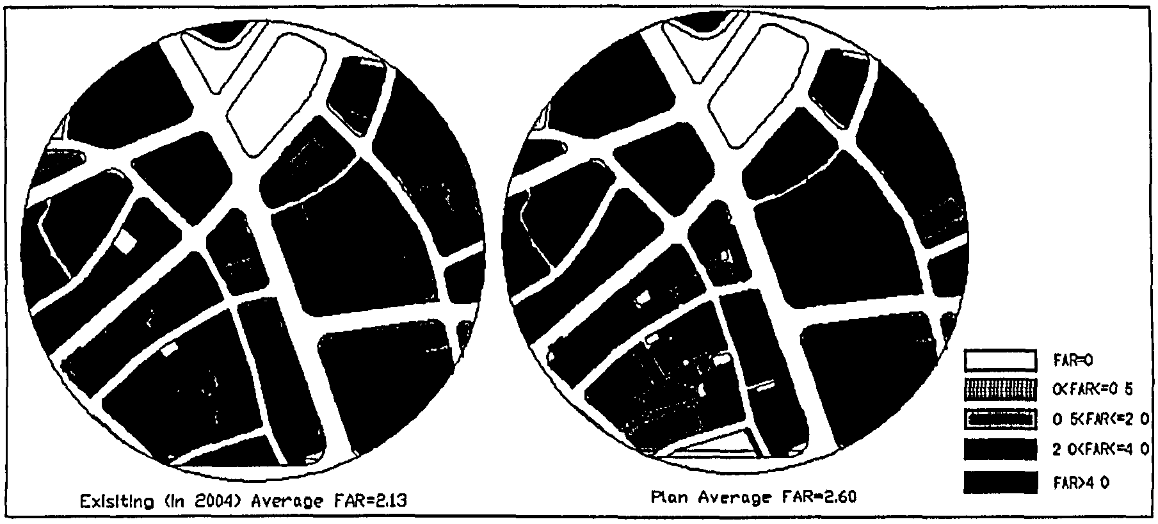


Figure 28 FAR of Chaoyang Square Station

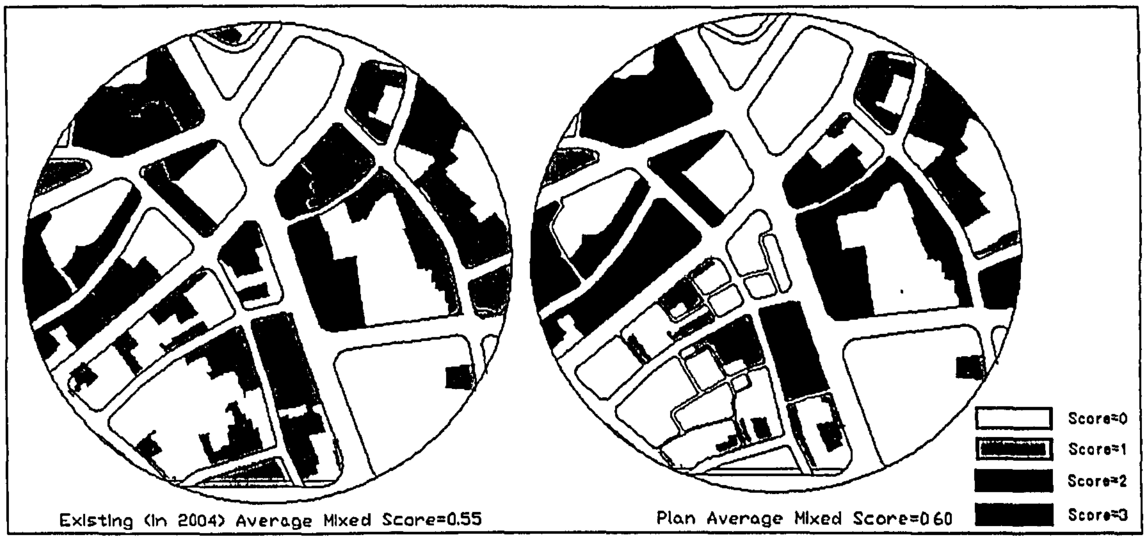


Figure 29 Mixed Score of Chaoyang Square Station

Current mixed land use distributes widely within the whole research area and includes commercial/residential, commercial/official and commercial/official/residential development (Figure 29). High-level mixed (show in black) area composed of commercial at podium and offices, hotels and restaurants on tower are centralized along Chaoyang Road. Mid-level mixed (dark grey), presented mostly by commercial podium (wholesale and retail) and residential or official on top, locates in northwest part of station area. The rest mixed land use appears primarily along existing roads as a low-level mixed (light grey), consisting of 'Top-residential and Floor-commercial' transitional style buildings. Single use (white), including road and open space, large-scale wholesale facility, commercial center, hotel and single use residential in historical traditional district occupied around 64% of the total land. Based on the calculation, current average mixed score of Chaoyang Square Station is 0.55.

Planned mixed intensity will rise slightly (Figure 29). Two contrary redevelopment projects contribute to the change. On one hand, promotion of mixed level emerges due to replacement of existing small-scale 'Top-residential and Floor-commercial' by large-scale mixed complexes, mostly podium commercial and tower residential in northwest and southeast part of study area along Chaongyang Road. On the other hand, renovation in historical, traditional district by demolishing existing mixed use building alters the existing mixed-used district to a relative pure function. Here the focus will be on residential development in particular and will be found south of Xinhua Street and north of Minzu Avenue. Influenced by the above conflicting elements, future mixed score of Chaoyang Square Station will go slightly up to 0.6.

The sidewalk system of Chaoyang Square Station is the best one of the total four stations due to integration of the existing road network, (Figure 30). Composing of main road, local road and alley, the public road network provides dedicated sidewalk (black line in

Figure 30) whose width is range from 2m to 10m on double sides of all roads offering direct link between public roads and almost all large-scale buildings. Since 2000, motor vehicles and bicycles have been prohibited to access Xingning Road and Minsheng Road, which were reserved as pedestrian-only streets. Via calculation, existing total length of sidewalk is 9,684m and total area of sidewalk is 49,891m².

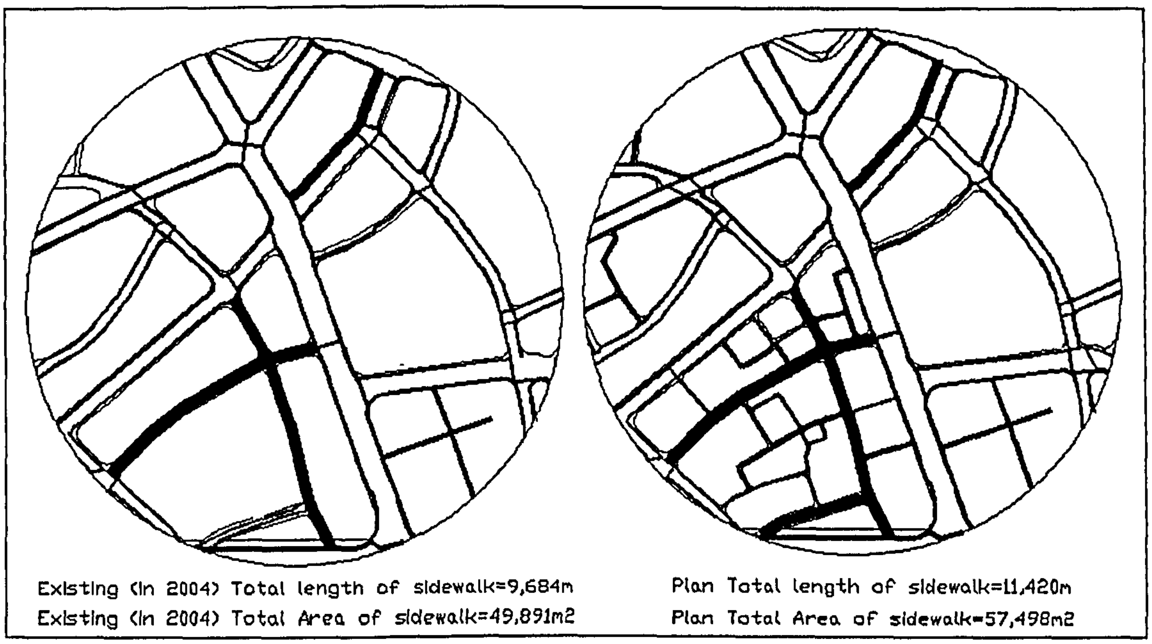


Figure 30 Sidewalk System of Chaoyang Square Station

Promotion of existing sidewalk system and increase in pedestrian-only street and alley network could improve the entire sidewalk system in the future (Figure 30). However, pedestrian accessibility would be enhanced by demolishing some old buildings to create 2-7 meter public alley system in historical, traditional district. Relying on official planning, non-motorized district cycling by Chaoyang Road, Xinhua Street, Minzu Avenue and the southwest edge of research area is under plan in which several streets and alleys will enter the non-motorized family where motor is prohibited. Thus, future total length of sidewalk is 11,420m and total area of sidewalk is 57,498m².

### 5.3.3 Wuxiang Square Station

Mixed land use, road and open space dominate a large part of existing land while other uses are less dominant within Wuxiang Square Area (Figure 31 and 32). A large number of mixed land use (22%) combining of financial, commercial, official and residential mixed high-rise buildings are clustered along 100m-wide Minzu Avenue and 6ha public Wuxiang Square, creating a district of skyscrapers (Figure 33); most of them are headquarters of financial institutions built in the late 10 years. High-density, public road system, Wuxiang Square, and existing vacant (currently under construction or under planning) contribute to high proportion (61%) of road and open space. Pure commercial land use is almost zero and official land use is seven percent because of several financial institutions and province-level governmental agencies along Minzu Avenue. Pure residential land use covers 10% land of the research area and is mainly composed by multi-storey buildings located in south along 40m-wide Jinhu Road. Institutional and industrial land uses are zero in study area.

The central-located Wuxiang Square Station is planned right under Wuxiang Square, the new heartland of new city center (Figure 31). Future land use strengthens the function as new city center via a continuous increase of commercial, official and financial facilities (Figure 32). Pure commercial is still infrequent in the future, but official land use increases by 2%. Residential rises from existing 10% to future 13%, driven by high-rise residential buildings. Institutional and industrial land uses are still refused from center area. Vacant land will change into developed and the percentage of road and open space will drop to 49%. Most of new buildings adopt mixed form, commercial/residential mixed in particular. As consequence, mixed land use will account for 29% of total land use (Figure 32).

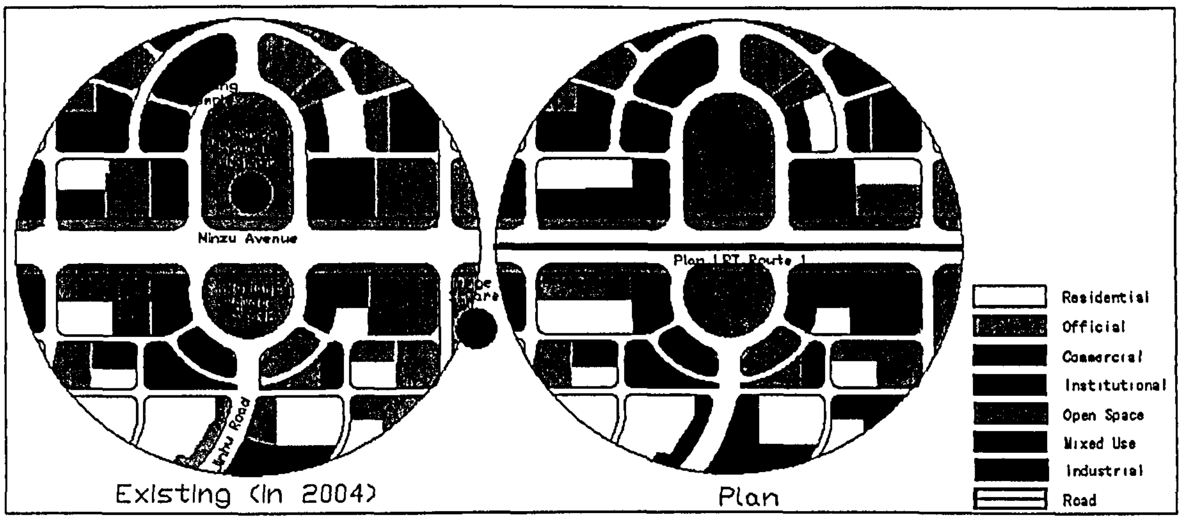


Figure 31 Land Use Distribution of Wuxiang Square Station

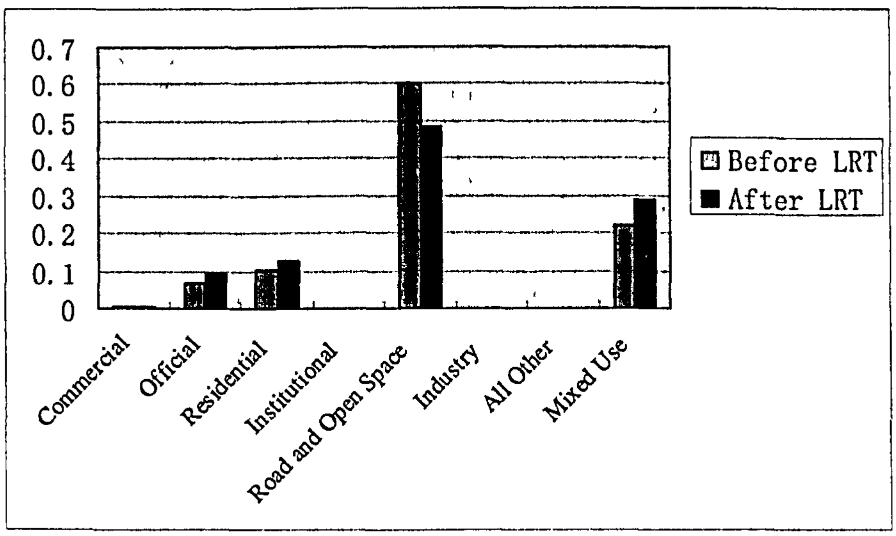


Figure 32 Land Use Classification of Wuxiang Square Station

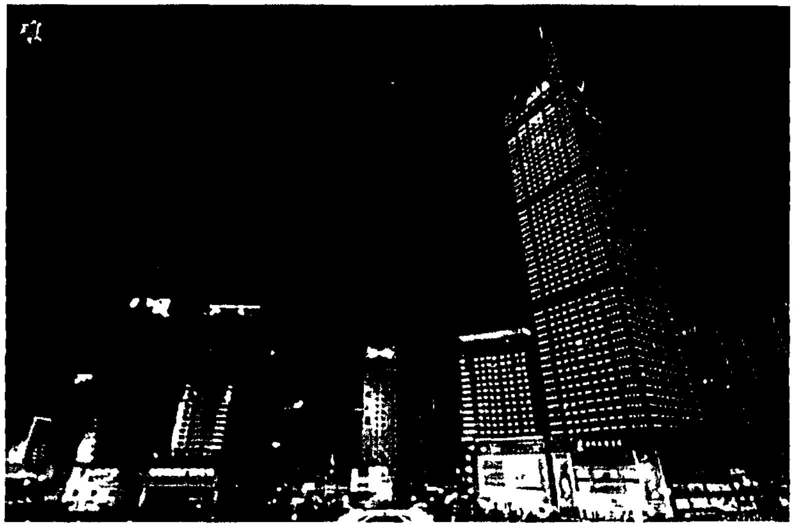

Figure 33 Diwang Complex (right) and Skyscrapers around Wuxiang Square (Lin, Yong)

Differing from mixed form in old city core, existing building distribution in new city center is composed of almost all large-scale, mixed use skyscrapers and high-rise buildings enveloping Wuxiang Square. Existing building coverage is moderate. The eastern part of research area along Minzu Avenue contribute to relative high coverage, mostly between 30%-50% and partly higher than 50% (Figure 34 and 35). Pure official buildings and buildings whose main function is official (partly mixed with other function) show low building coverage of less than 30%, and there are several zero-coverage plots which are dedicated surface parking for official buildings. Some multi-storey residential buildings and mixed building in the south and part of the north part present coverage of 30%-50%, or less than 30%. The existing average building coverage within Wuxiang Square station is 14%, a relative low level compared to other stations under evaluation.

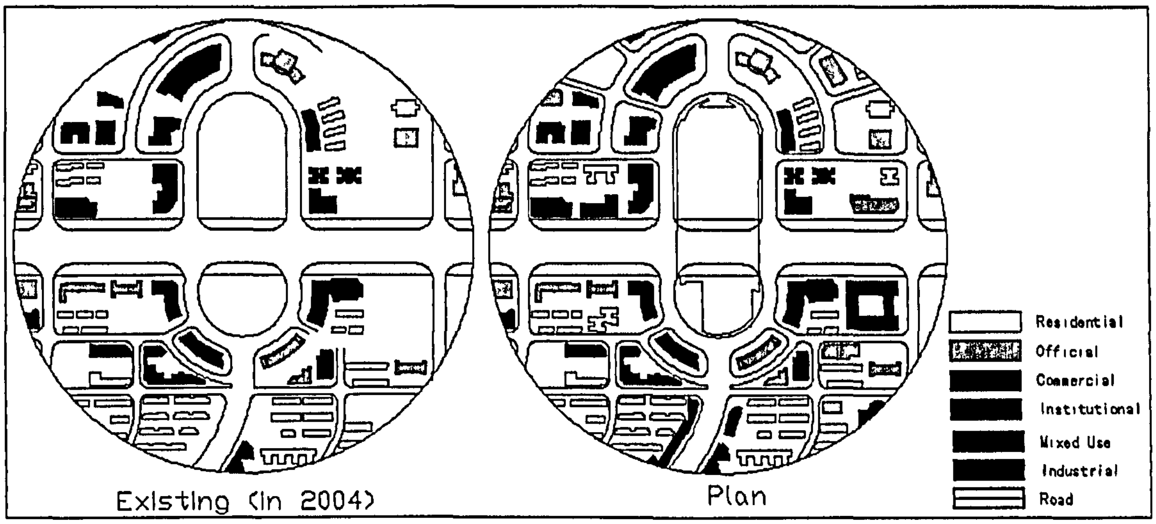


Figure 34 Building Location of Wuxiang Square Station

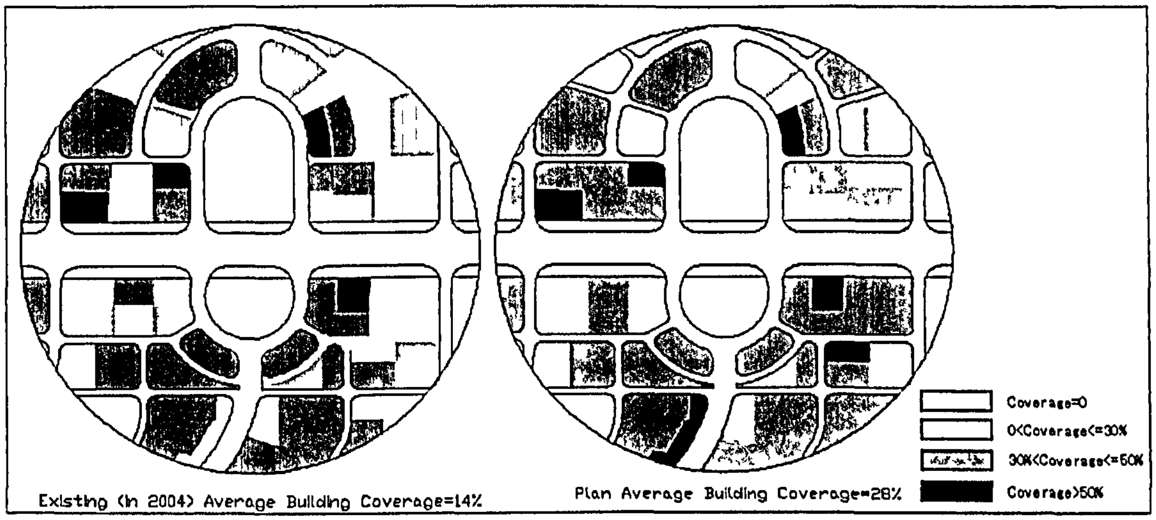


Figure 35 Building Coverage of Wuxiang Square Station

Relying on planning, new large-scale, mixed use buildings will appear along main roads, as well as Wuxiang Square (Figure 34 and 35). For instance, a 123,000m², large-scale, commercial/residential mixed complex will be finished on southeast portion of Minzu Avenue in the near future, and a northwest plot will be occupied by two 100-meter high-rise, commercial/residential buildings with building coverage of 30%-50%. Besides the above-mentioned new buildings, the introduction of a 40,000 m² underground commercial center under Wuxiang Square will directly connect the Right Of Way of planned LRT. It is not, however, calculated into average building coverage because of the main function of open space on ground level. There are still some vacant reserved as surface parking lot serving large-scale commercial an official facilities. Via calculation, future average building coverage of Wuxiang Square is 28%.

High-intensity development appears within Wuxiang Square Station (Figure 36). Land use units adjacent to Wuxiang Square present highest FAR, mostly higher than 4.0. FAR of 58-storey Diwang Complex contributes the highest individual FAR (up to 18) in all research areas (Figure 33). Several plots along Minzu Avenue have FAR of more than 4.0. Mid-intensity developments, FAR between 2.0 to 4.0, are mostly multi-storey residential buildings and high-rise buildings in southeast and northwest. A few low level FAR (0.5-2.0) appear in the southwest, comprised of pure multi-storey residential or official buildings. FAR less than 0.5 emerges only on two plots at the north edge, where the setbacks of large-scale, high-intensity commercial/residential complexes reduce the score. Thus, the current average FAR of Wuxiang Square Station area is 1.88.

The above-maintained high-intensity development will be strengthened in the future (Figure 36). A majority of new developments adopt FAR higher than 4.0, resulting in future high intensity development around Wuxiang Square, and along Minzu Avenue. Thus, future average FAR is 2.88, the highest out of the four selected stations.

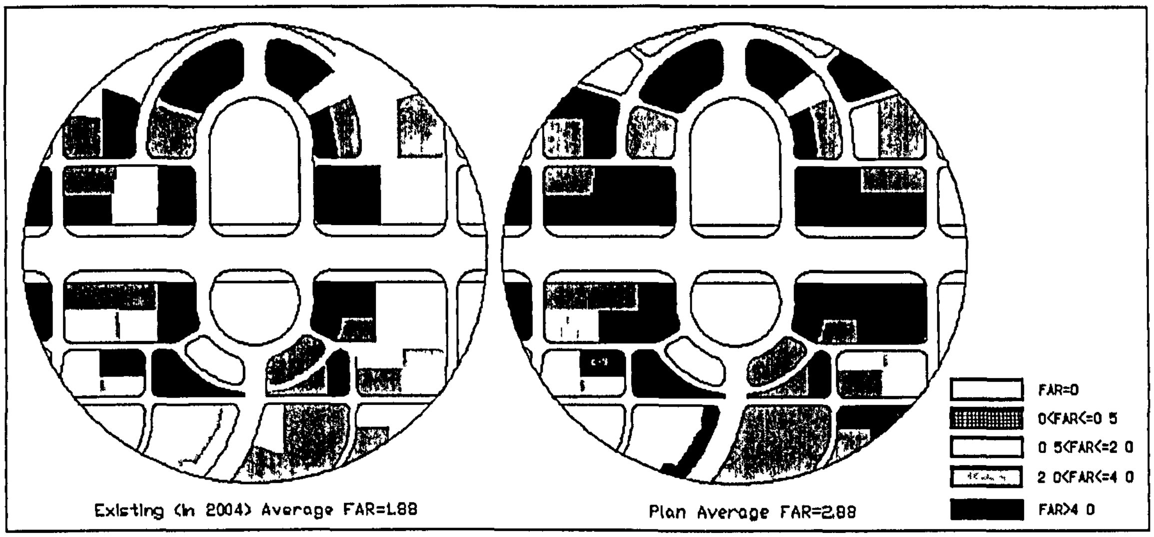


Figure 36 FAR of Wuxiang Square Station

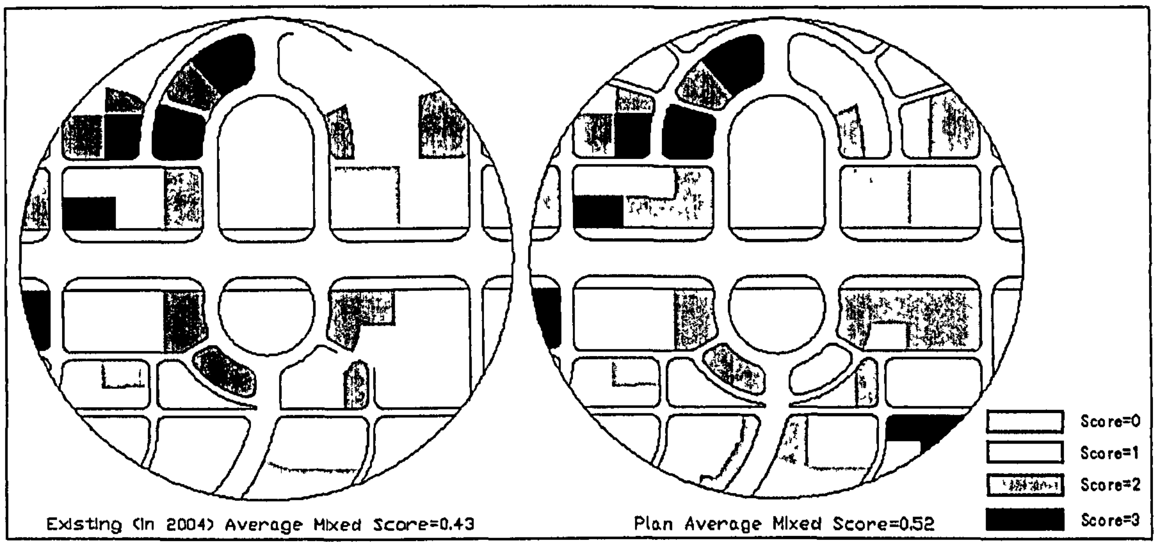


Figure 37 Mixed Score of Wuxiang Square Station

Existing development in Wuxiang Square Station area presents not only relative high intensity, but also a relative high mixed degree (Figure 37). As the new commercial, official and financial center of Nanning City, Wuxiang Square includes a large number of official/commercial, commercial/residential complexes, shaping a various mixed forms. Firstly, existing multi-function high-rise buildings receive highest mixed score in eastern part. Moreover, mid-degree mixed buildings consisting of commercial podium and official or residential on tower get 2 score. Furthermore, low-level mixed land use, mostly small-scale retail and support facilities for community at first floor and residential on top, occurs mainly at south of square. Existing single land use is chiefly occupied by headquarters of financial institutions distributied along Minzu Avenue. The current mixed score of Wuxiang Square Station area is 0.43.

Future development continues to strive for mixed –use in the future (Figure 37). Projects along Minzu Avenue and Jinhu Road are all planned as commercial-podium plus residential-tower, while a few new buildings will develop single function, particularly governmental official buildings. The future 40,000 $m^2$ underground commercial center under Wuxiang Square is viewed as single function (scale=0) since the main function of the plot is open space. A slight increase of mixed scale in the future (0.52) shows mixed land use will be widely accepted in new city area.

The existing high–density, public road network contributes to a relatively comprehensive sidewalk system in research area (Figure 38). Sidewalks along the main road system, Minzu Avenue, Jinhu Road and public Wuxiang Square (more than four meters per side) comprise the pedestrian network. Similarly, the other local streets are also provide around 2m-wide (per side) sidewalk, covering the northwest, the southwest and part of the southeast of research area offering direct entrances to most main buildings. Moreover, a small number of existing alleys also promote the permeability in the area. However, a few residential districts are also linked by private road system. A relatively integrated sidewalk system increases the total length of public sidewalk to 9,925m and total area to 33,524m².

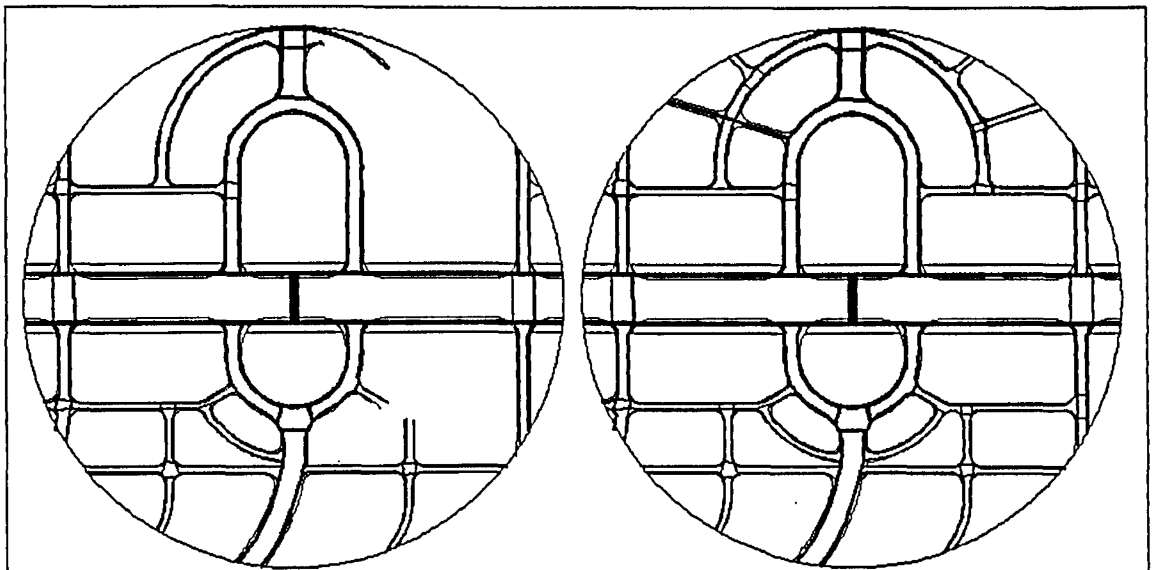


Figure 38 Sidewalk System of Wuxiang Square Station

In the future, the sidewalk system will be promoted by new development of local roads (12m-width, delegated sidewalk) and alleys (7m -width, mixed traffic lane), especially at the northeast and part of the southeast of research area (Figure 38). Newcomers of road network family, contribute to a denser sidewalk system. After enhancement of entire road network, the total length of public sidewalk network will be 12,351m representing an area is 38,065m².

### 5.3.4 Fengling Station

Largely covered by existing forest and mountainous area, undeveloped land use occupies

79% of the total land surrounding Fengling Station (Figure 39 and 40). Scattered residential land use occupies only 5% of total land. Both official and institutional land use account for 2% of the total land, providing small-scale support facilities like day care, community office and administrative facility. The only road, 100m-wide Minzu Avenue, occupies 12% of the total land in research area.

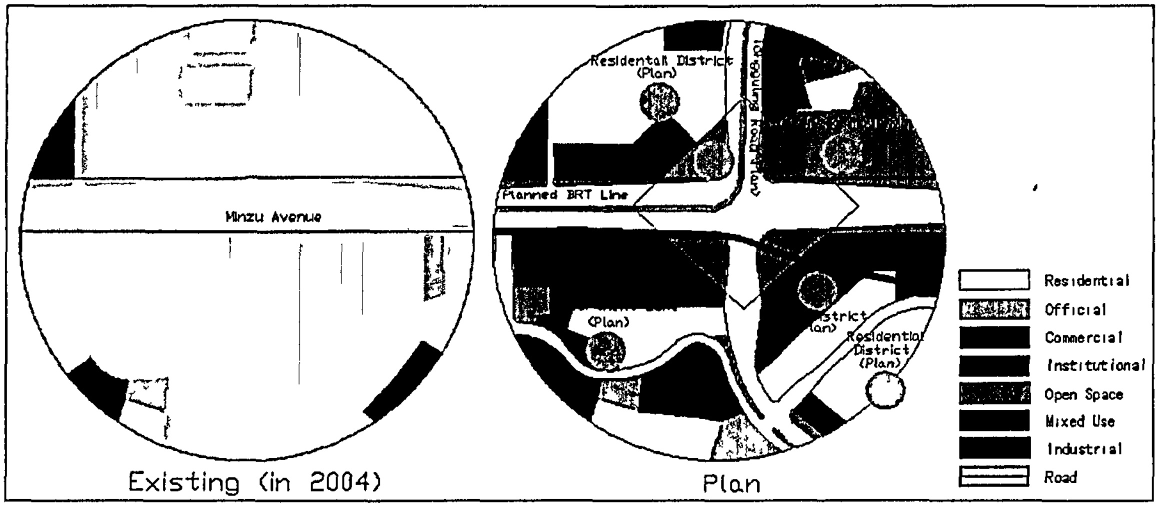


Figure 39 Land Use Distribution of Fengling Station

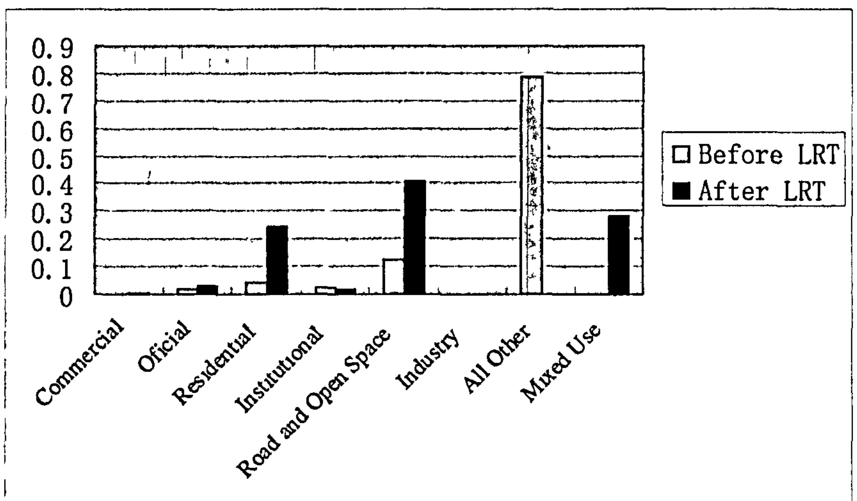


Figure 40 Land Use Classification of Fengling Station

The 100m-width Minzu Avenue runs through the research area from west to east, and planned underground Fengling Station will locate under the southern of Minzu Avenue.

Depending on MPNC (2004-2020), a planned 40-meter-width, Tongguling Road, will be presented in the near future, and a large-size interchange right plans at the intersection of Minzu Avenue and Tongguling Road. These two main roads split the entire research area into four parts: mainly sharp-slope mountain area north-eastern part, a relative flat landform developing two large-size residential districts south-eastern part, the mixed residential district north-western part and south-western part, mainly composed by ASEAN Liaison Department Zone. A planned BRT lies on Tongguling Road and Minzu Avenue, and transfers with LRT Route 1 at the planned intersection (Figure 39).

In the future there will be a transition from undeveloped to developed land with the appearance of an increasing amount of mixed- use (Figure 39 and 40). Pure commercial and official, primarily ASEAN Liaison Department Zone, occupies only 1% and 3% of the total land use, while residential use will raise form 5% to 26% due to introduction of several residential districts in the south-eastern and the north-western, along Minzu Avenue where the underground Fengling Station will be located as well as the planned 40m-wide Tongguling Road where a planned BRT line will run. Institutional land use will remain the same at 2%. Part of mountain area will be reserved as public Municipal Park. Thus, road and open space will sharply climb to 41%, increasing by 29%, benefited from appearance of planned road network, the huge interchange and park. A large number of mixed-use (commercial/official/residential), totally 28%, distribute along Minzu Avenue and planned ASEAN Liaison Department Zone.

The existing building location (Figure 41) and building coverage (Figure 42) indicate that few existing buildings (support facilities and temporary building) disperse within Fengling Station research area. The existing average building coverage of Fengling Station is only 2%.

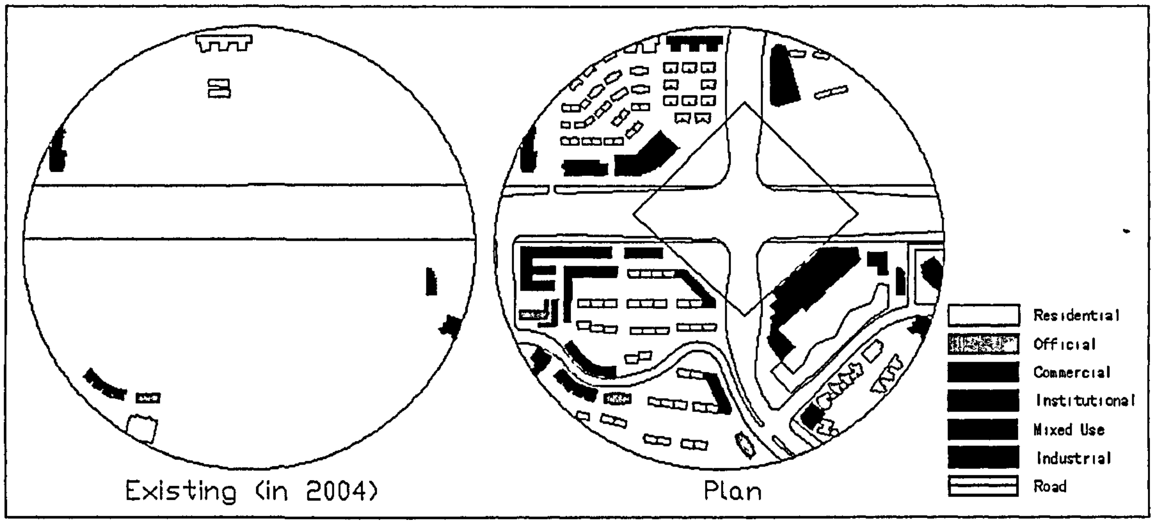


Figure 41 Building Location of Fengling Station

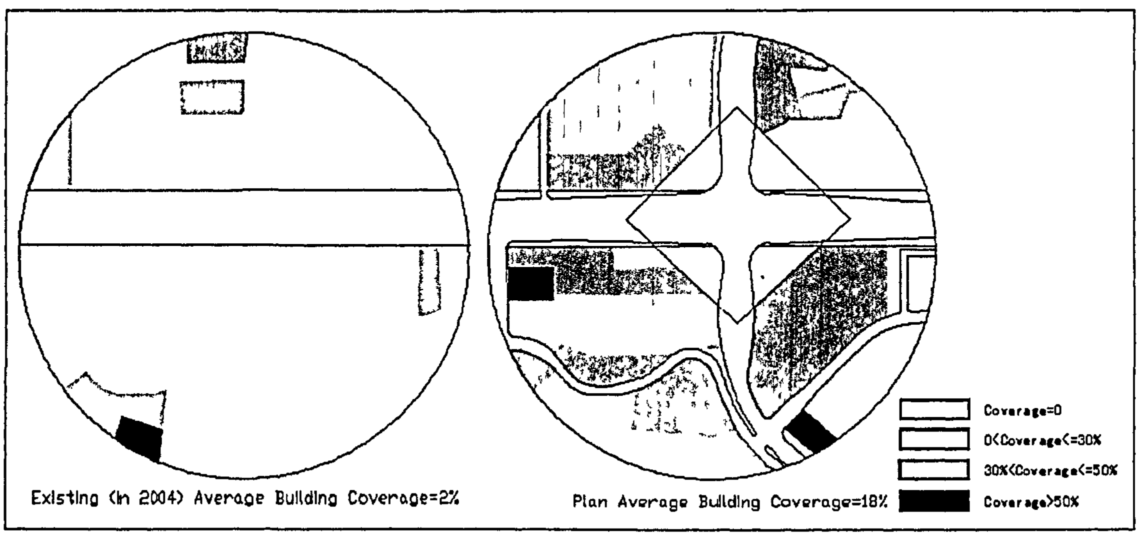


Figure 42 Building Coverage of Fengling Station

Fengling will be developed as the official and residential hub after development of

ASEAN Liaison Department Zone (Figure 41 and 42). There are several high-rise buildings at the north-eastern part, mixed by commercial at ground level and residential on top. Meanwhile, in the southeast portion, a large-scale residential district with a relative low building coverage (less than 30%) and a commercial/residential mixed district with middle building coverage (30%-50%) are under construction. Another large-scale district, mixed by dense (30%-50% coverage) commercial/official complexes and disperse low-rise and multi-storey residential buildings (less then 30% coverage) is also under construction in the northwest. The ASEAN Liaison Department Zone will shape a comprehensive commercial/official/residential mixed district with a relative compact form (above 30%) at south of Minzu Avenue and a relative disperse form (less than 30%) in the rest of lands. In sumary, after development is complete, the average building coverage of Fengling Station will be 18%.

The current FAR of Fengling Station is nearly zero because few buildings are in existence. After development, the future FAR will increase significantly (Figure 43). Due to the physical constraints creased by the mountains, new development is mainly relative low-rise and with low-intensity. Some high-intensity (FAR>4.0) development is encouraged in the southeast and the northwest, along Minzu Avenue. Mid-intensity developments (2.0>FAR>4.0) are all high-rise buildings and are distributed in all research area. To coordinate with characteristics of mountain area, low intensity (0.5>FAR>2.0) distribution is the commonplace in ASEAN Liaison Department. At the same time, lower-intensity (FAR<0.5) development, consisting of low-rise residential buildings and support facilities, will emerge in the future. The future average FAR will be 1.49.

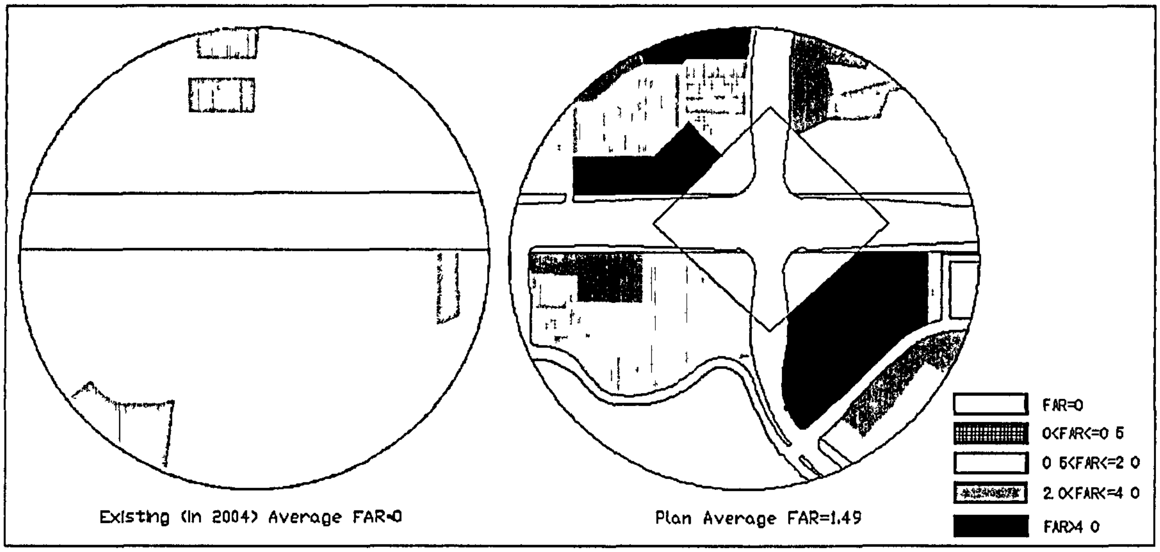


Figure 43 FAR of Fengling Station

The existing mixed degree of Fengling Station area is zero due to a large part of undeveloped land, while mixed land use will widely be developed in the future (Figure 44). Two mixed-use plots, large-scale complexes mixed of commercial at ground level and hotel, business official and residential on top will be located southeast and northwest of planned interchange. Other large-scale, high-rise buildings comprising of commercial-podium and residential-tower are seen as mid-intensity mixed use (score=2). A majority of mixed land scored 1 centralizes in ASEAN Liaison Department Zone. Thus, the future average mixed score of Fengling Station area will be 0.59.

Minzu Avenue has 5.5m-wide sidewalks on both sides and a total length of sidewalk is

1,573 meters and the total area is 8,652 m² (Figure 39).

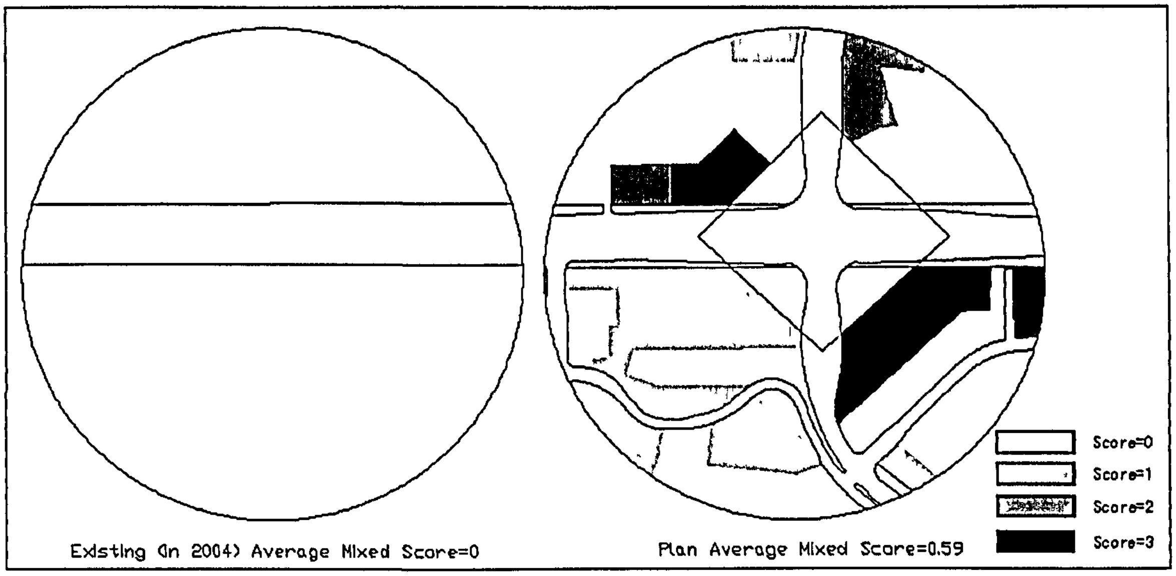


Figure 44 Mixed Score of Fengling Station

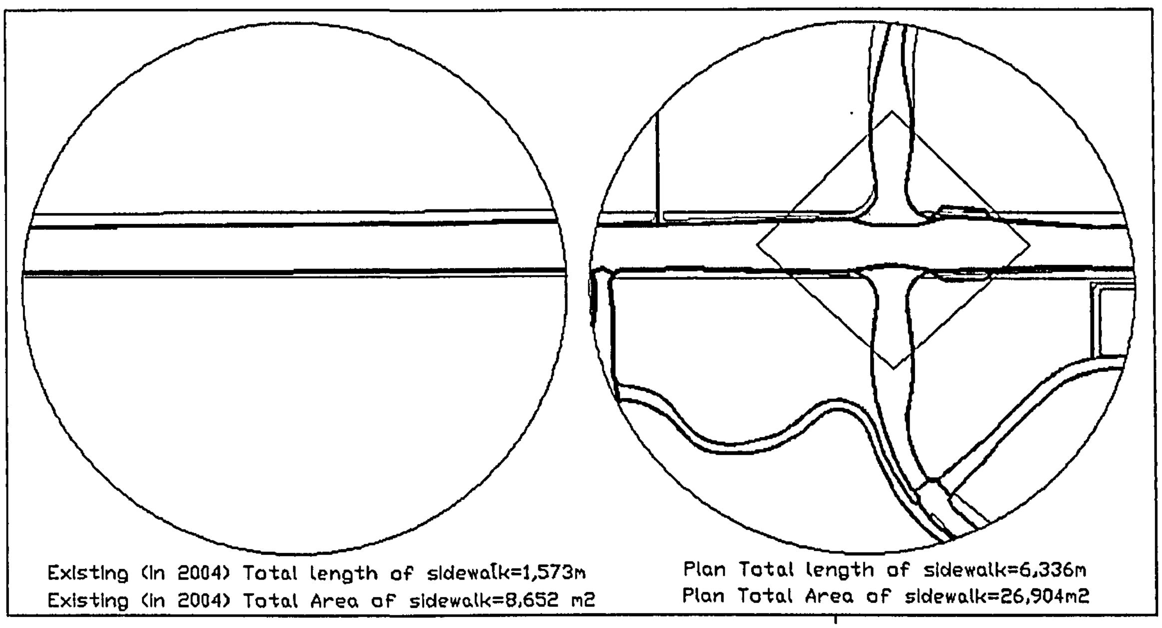


Figure 45 Sidewalk System of Fengling Station

Even though some new road system contributes to promotion of sidewalk system in the future, similar to Minzu University Station area, non-public pedestrian system which partly supports walking travel will be presented within new residential districts in Fengling Station area (Figure 45). Thus, after accomplishment of planned sidewalk system, the total length will rise to 6,336m and total area will go up to 26,904m$^2$.

### 5.4 Comparative Analysis of Station Areas

Land use intensity criterion, average FAR and building coverage, grow universally, which indicates that a majority of lands in the research areas will develop densely in the future. Figures 46 and 47 show that building intensity around the four stations appear an increasing trend except in city core. The sharpest rise occurs in eastern stations, Wuxiang Square Station and Fengling Station, mainly owing to new fill-development on current undeveloped lands. FAR of Chaoyang Square Station has a slight rise after revitalization and reconstruction in old city core, while building coverage declines by 5% which is caused by demolishment of illegal buildings. Although the edge-city location, current low density and large part of undeveloped lands, Minzu University Station gets a slight rise of average building coverage and a sharp rise of FAR in the future.

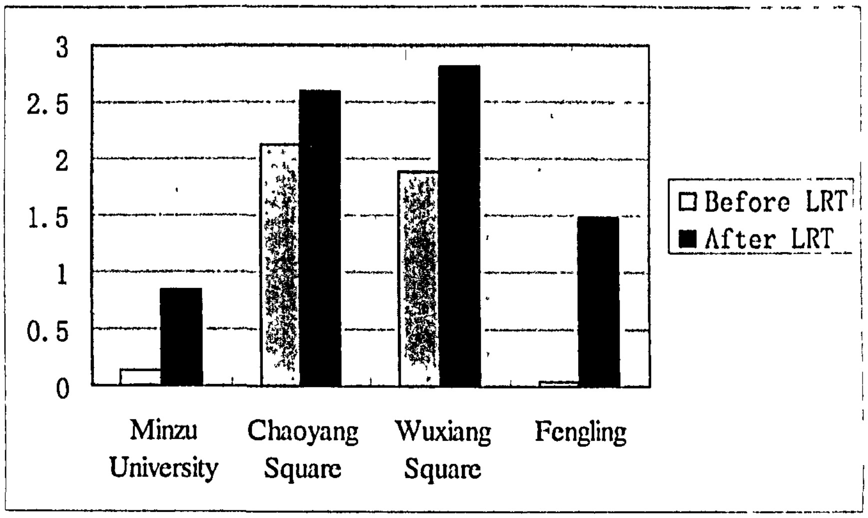


Figure 46 Comparisons on Average FAR

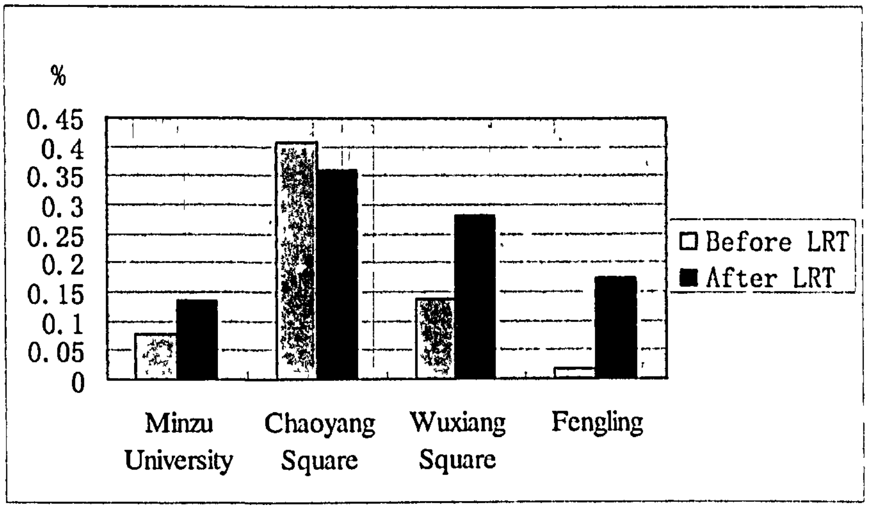


Figure 47 Comparisons on Average Building Coverage

Furthermore, mixed-use, primarily presented as commercial/residential/official mixed, will increase in the future to difference degree (Figure 48). Specially, three stations will change into high-degree mixed use in the future. Minzu University station, Chanyang Square Station and Wuxiang Square Station increase their mixed score slightly, while eastern Fengling Station gets a sharp rise from near Zero to 0.59, a similar level as Chaoyang Square Station (0.60).

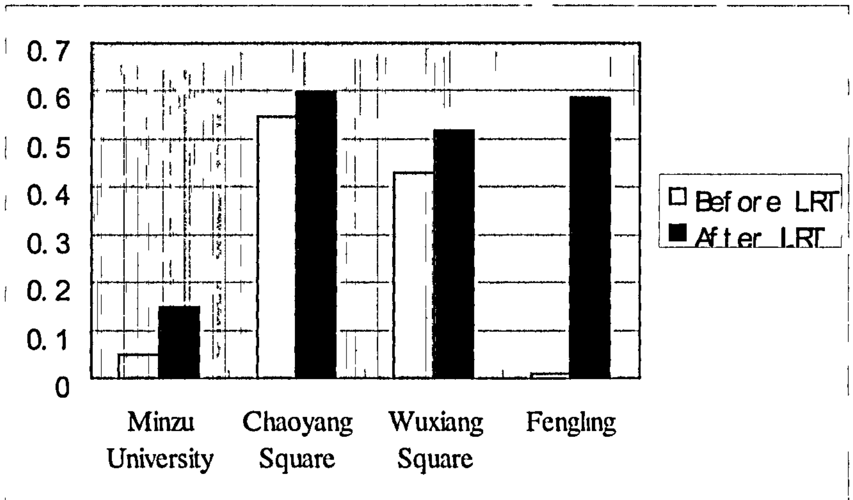


Figure 48 Comparisons on Average Mixed Score

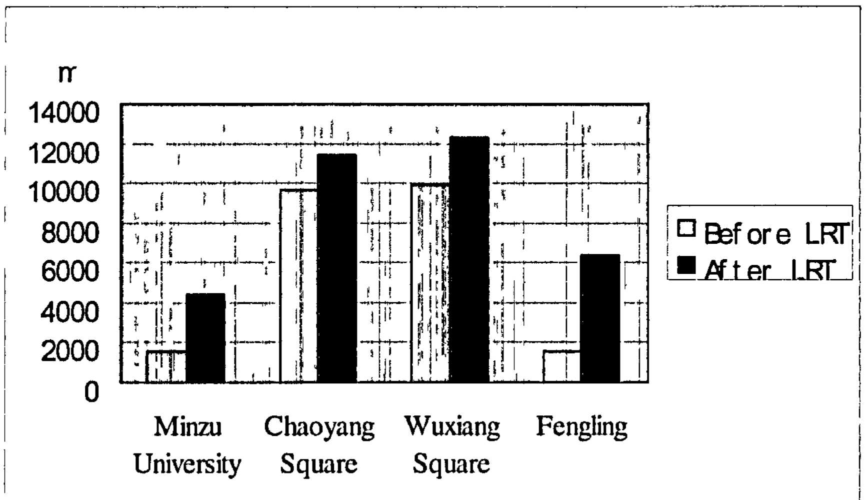


Figure 49 Total Length of Sidewalk

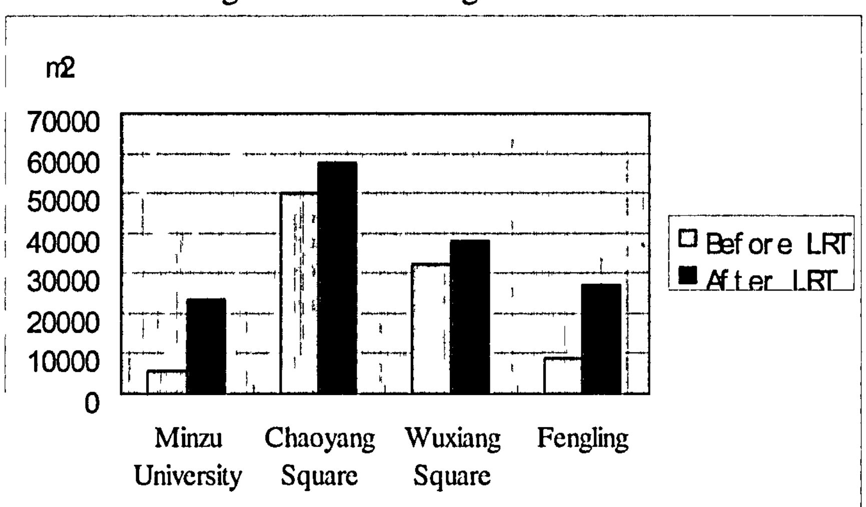


Figure 50 Total Area of Sidewalk

The increase in total length and area of sidewalk system indicates promoted pedestrian permeability and accessibility to planned LRT due to new construction of road network system in all four stations (Figure 49 and 50). Improvements in the main road system surrounding the outer station and construction of alleyways in the old city core and new city centre contribute to accessibility to planned LRT stations.

# CHAPTER 6: FINDINGS

The previous chapters quantified existing land uses surrounding all 20 stations at a general level and for representative stations at a much more detailed level. This chapter assesses the extent to which existing and planned land uses are compatible with proposed LRT stations.

## 6.1 Future Land Use Changes at all Four Stations Are Integrated With Land Use and Rapid Transit

According to the analysis, the transit orientation of all four station areas studied in detail will improve if the plans for 2020 are realized. Ultimately this will promote compact, diverse and walkable urban developments. In these areas, the land use pattern is consistent with the goals of TOD because of a shift from undeveloped land use to developed usage. Within four selected station areas, only Chaoyang Square Station area is currently completely built-up, whereas the other three stations contain undeveloped lands, farmland, forest and mountain areas. These kinds of undeveloped land use will change to residential, commercial, official and institutional usage in the future.

## 6.2 Current and Future Land Uses Vary Significantly between Four Stations

At a general level existing land uses surrounding proposed stations are compatible. However, there are big differences between stations.

Higher density development is planned near the old city core and new city centre, while lower density usage is planned and is already occurring in the outer areas (Figure 8). Compared with the existing compact and mixed use old city core, the new city centre and the outer stations have far less developed land. Even though development around these outer stations will occur in the future, the development intensity of outer stations will still be lower than around the two inner-city stations.

Figure 46 shows that the existing average FAR of outer stations is near zero, while the average FAR around inner-city stations is around 2.0 (2.13 around Chaoyang Square Station and 1.88 around Wuxiang Square Station). Future average FAR around Wuxiang Square is planned to rise to 2.87, while Chaoyang Square will be higher than 2.6. However, despite a large number of new developments around Fengling, future FAR is planned to be only 1.49, and only 0.85 around Minzu University Station.

The site coverage of buildings follows the same pattern as FAR. Currently, the highest site coverage is around Chaoyang Square (41%), and future building coverage will maintain at a high level of 36% even though policy of dispersing old city core is encouraged by government (GPI, 2005; TUPRI, 2005). Wuxiang Square Station presents a sharp rise in building coverage in the future after development of the currently vacant land: from 14% to 28%. By contract, disperse development contributes to relative low average building coverage in outer stations, current 8% in Minzu University Station and a slight rise by 5% in the future, and existing 2% in Fengling Station and future 16% (Figure 47). The highest individual FAR and building coverage are also seen in inner station areas. For example, the highest building coverage scores of individual plot is in Chaoyang Square Station, up to almost 100%, and the highest FAR emerges in Wuxiang Square Station where the highest skyscraper in Nanning contributes to a FAR up to 18.

All inner stations received high level mixed scores, while less mixed development occurs near outer stations to varying degree (Figure 48). The existing mixed scores of inner stations are relative high (0.55 in Chaoyang Square Station and 0.43 in Wuxiang Square Station), because of the large number of mixed use buildings. This character will remain due to mixed-use new constructions and large–scale, mixed redevelopment. Comparing with current low mixed degree score (0.01), Fengling Station receives a relatively high future mixed score (0.59) because of new commercial/residential/official mixed complexes. Neither existing nor future mixed level of Minzu University Station is far less than other stations.

The integrated sidewalk systems of inner stations contribute in principle to a relative greater degree of accessibility. Figure 49 and 50 show how the entire public road network results in current high-level, dense walking systems in Chaoyang Square and Wuxiang Square stations, and walking environment will be enhanced by creating pedestrian-only district, reconstructing old sidewalk, increasing small-scale alleys and enhancing sidewalk pavement in the future. However, even new main road systems will be constructed in outer station areas, the pedestrian systems in both outer stations are less mature than inner stations especially because of lack of public local road and alley.

Secondly, both traditional and new city center near Chaoyang Square Station and Wuxiang Square Station area strengthen their center role via high-intensity development and mixed function whereas the two edge stations, Minzu University Station and Fengling Station remain much purer function. It is generally agreed upon the transit is supported best by mixed-use development such as commercial use, multi-family residential uses, offices with high employee counts, civic facilities and entertainment use (Dunphy et al., 2001). Both inner stations, traditional old city core focusing on commercial, residential and official function and new city center concentrating on commercial/official function, develop mixed land use. Chaoyang Square Station continuous to enhance its commercial function by a large-scale, commercial reconstruction projects. In order to promote commercial function in this traditional, historical district, giving commercial applicability to residential land use is especially encouraged within the whole reservation area. Meanwhile, new construction of large-scale, dense, commercial/official/residential usage high-rise complexes in Wuxiang Square Station area is to emphasize its permanent position as new city center of Nanning City. Conversely, Minzu University Station only focuses on institutional and educational facilities. Fengling Station emphasizes residential and official functions which mainly serve ASEAN Liaison Department Zone.

Thirdly, low-density, single-function land use and low-level sidewalk system located at outer stations might not be developed enough to support LRT. Despite fast development, criterion of outer station areas are still far less than inner stations. For instance, future criterion of Minzu University Station is proximately one in third of Chaoyang Square Station, and situation of Fengling Station is still far less than Wuxiang Square Station.

## 6.3 Factors Favour Integration of Land Use and Rapid Transit in Nanning

As noted above, high-density, high-rise, compact urban form could make rapid transit successful in terms of ridership and developing on the fare levels, cost recovery. Areas characterized by compact land use, or intense development which could encourage planned LRT system operation appears partly along Route 1 (Phase I). The overall trends are toward higher intensity, more mixed-used development and better walking environment.

Mixed land use is prevalent within the four research areas. This mixing if used takes a variety of forms, including horizontal mix such as residential plots mixed with commercial plots found largely in historic, traditional district, but also vertical mixed achieved by residential, commercial and official usages in high-rise buildings. This vertical mixing has been encouraged by public policy and real estate markets over the last two decades. Except Minzu University Station with the dominance of a single use (educational facilities), the other three stations are highly mixed-use. Both horizontal mixed consisting of old, small-size commercial, residential and mixed land use in historical, traditional district, and vertical mixed form presented by new, large-scale mixed use high-rise buildings can be found in Chaoyang Square Station area, which contributes to a commercial/official/residential mixed function. Wuxiang Square Station area is dominated by vertical mixed of large-scale, commercial/official/residential high-rise buildings.

Secondly, land use intensity criterion on individual plot of inner stations appears at a high level. High density developments are suitable for urban rapid transit since this urban form enables rapid transit system to access many people and to serve various urban activities. For instance, Metropolitan Toronto encouraged high-rise development along the Yonge Street subway line be allowing a liberal FAR (up to 12) (Huang, 1996). In Nanning, high level intensity development, especially with a FAR over 4.0, could not always be accepted by all developers due to associated construction period and investment, but it is widely adopted within both inner stations in terms of their special position and high land value in central area. Within the research area, large-scale, high-rise buildings are developed depending on land and real estate market. The highest FAR on individual plot is currently up to 18 (Wuxiang Square Station), and new developments are usually adopted a high FAR (more than 4.0, or even up to 10.0 in both inner stations).

Thirdly, Chaoyang Square Station and Wuxiang Square Station are favourable for LRT because they are compact, active city centers. Official, commercial buildings tend to be the CBD land use that is most supportive of transit ridership. Downtown residential development also creates a reliable market for rapid transit. In Nanning City, old city core and new city center are the economic centers in the whole city area. Planned inner cities stations collect difference scales of commercial, official and residential facilities, and much denser, large-scale, mixed use complexes. Dense workplaces in these two city centers result in generation of more daily trips, creating dense employment zone and high population density to encourage more transit use between workplace and home.

Fourthly, industrial land use, currently less dense and small-scale, will be transferred into dense, mixed land use in the future. Rapid transit is discouraged to run through predominantly industrial lands because industrial land use has negative influence on rapid transit operation. In LRT Route 1 case in Nanning City, current industrial land use in Chaoyang Square Station area will be replaced by a cluster of high-rise residential buildings which generates more trips and has a higher level population density.

Finally, pedestrian infrastructure surrounding inner stations are mature, continuous and connective when non-motorized modes, such as walking and biking, receive more and more attention. The quality of pedestrian connections between rapid transit stations and destinations (e.g., home. workplace. store. school, entertainment facilities) is basic element of transit/land use relationship. A pedestrian-friendly system, connecting neighbourhoods to transit stations as transit-oriented landscape and characterizing by high-quality sidewalks, street trees, and street light, is encouraged to promote pedestrian activities and the use of rapid transit in many North American TOD programs . Within Chaoyang Square Station area there is a clear hierarchy of road network contributing to a high density, small-scale, pedestrian-friendly sidewalk system, including dedicated pedestrian-only streets and district adjacent to planned LRT station. In the future, pedestrian-only environment will be promoted by implementation of redevelopment in historical, traditional district, providing more safety, attractive walking environment and less convenience for motor vehicle usage. Because of the current pedestrian-friendly environment in the old city core, current 26 regular bus lines on Chaoyang Road which will be replaced by planned LRT Route 1, carries 147,284 persons per day (SCUTPI, 2005). Similarly, sidewalk system in Wuxiang Square Station area is also integrated. Every road offers dedicated, double-side sidewalk, which strongly enhances permeability in the area and accessibility to LRT. New, continuous sidewalk system in Wuxiang Square Station area will be provided with more green coverage, more street furniture, wider pedestrian lane, higher-quality pavement and brighter street illumination. In a word, the quality of sidewalk system in new city center is far better than other areas in the city.

### 6.4 Barriers to Integrated Land Use and Rapid Transit in Nanning

Land use planning plays an important role in creating dense developments that can be effectively served by rapid transit. Coordinating urban development and transit stations would make urban rail system successful. The importance of coordinating transit and land use planning for increasing the effectiveness of new urban rail systems in North American and European cities whereas land use-transportation integration has not received enough attention in Nanning case.

Land use planning and transportation planning are not coordinated entirely in Nanning city. They are weakly integrated at master planning level, which recommends principle connection of these two issues, but lost control at detailed planning and implementation process. Planners traditionally have regarded transportation and land use planning as two separate processes. Land use planning commonly is undertaken without much consideration given to transportation system. For instance, even a comprehensive rapid transit system is proposed in Master Planning of Nanning City, high intensity development is not particularly encouraged to support rapid transit use (both LRT and BRT) in detailed planning level because there is lack of special regulation and planning to spur such kind of development along planned rapid transit corridor and around proposed stations. The only task of transportation planning in Nanning is often to focus on solving transportation problem, but pay less attention to land use factors. This could be reflected from land use analysis on typical proposed LRT station areas. A large amount of road and open space occupy a high percentage of land in the research area (34% of Minzu University Station, 34% of Chaoyang Square Station, 49% of Wuxiang Square Station and 41% of Fengling Station), reducing average land use intensity to deep extent, weakening the direct linkage between LRT stations and surrounding areas, and bringing negative influence to usage and operation of planned LRT Route 1.

Firstly, a large number of non-trip-generating lands uses, road and open space surrounding many stations minimizing opportunities to increase ridership. In order to reduce construction phase, minimize construction cost, decline construction difficulty and avoid technology risk, LRT Route 1 is planned along large-scale main road (medium or greenbelt) comprising of either wide lanes for express traffic, motorcycle, bicycle and pedestrian, or 10-20 meter greenbelts on both sides (Figure 51). This kind of alignment appearing in Minzu University Station, Wuxiang Station and Fengling Station area is trafficable but not livable. Not only does it severely cut applicable land by high rate occupancy of main road system, but also has positive influence on LRT ridership because passengers have to cross the main road before arriving to LRT stations.

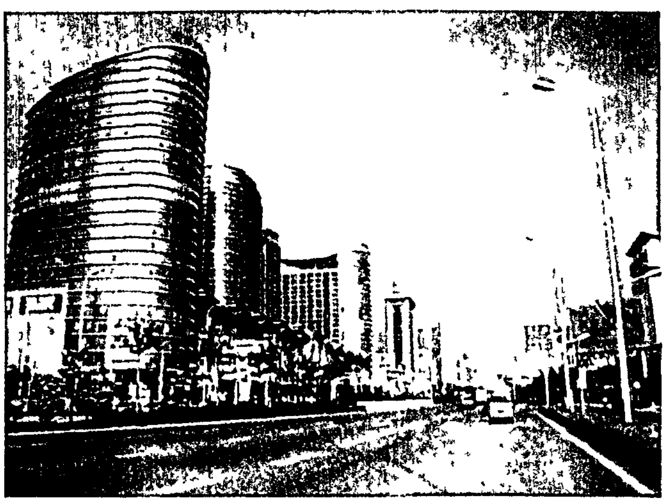

Figure 51 Minzu Avenue, ROW of LRT (Chen, Ming)

Another important consideration is the amount of land needed for a planned interchange between high-level roads. It appears to be commonplace to reserve land to create intersection of two main roads in Nanning; unfortunately, this often leads to elevated and multi-level interchanges. The interchange in Minzu University Station area is planned in this form, linking two highest-level main roads, and will occupy about 3.3ha of land. Such interchanges cut linkage of communities potentially decline spatial accessibility to planned LRT station. Another similar huge interchange was planned in Fengling Station area nine years ago (TUPRI, 1999). Based on the construction layout which was officially permitted in 2004, however, the planned Fengling interchange will only occupy part of conservation lands because it adopts a more simple form. Four parts of surplus land then reserve as open green spaces but not developed usage because it is difficult to layout any new buildings on these irregular shape and small scale lands (Figure 42).

Besides large-scale main road and interchange, some other open spaces also do not generate trips. Large-scale sport yards, squares and dedicated surface parking lots contribute to reducing average land use intensity. In Minzu University Station area, all three educational institutions have large-scale sport yard respectively, as well as some large-size green space. Wuxiang Square, a six hectare new city open square, is located in the heart of the new city center surrounded by many commercial and official buildings. Dedicated surface parking lots appear in Wuxiang Square, which reduces the average land use intensity to some extent. Being unsuitable for development, mountain area along the northeast of Minzu Avenue in Fengling Station area will be reserved as City Park in the future.

The separation of land use planning and transportation planning results mainly from institutional separation. Institutional coordination plays an important role in successful construction and operation of LRT system. It should be particularly recommended in Nanning City. Several governmental agencies are concern about LRT construction and land use issue, including municipal government, land use bureau, construction bureau, economic bureau, financial bureau and transit company of Nanning City. A comprehensive public agency is needed to takes the lead and coordinate relative agencies and all other actors, and to prepare and implement proper planning as early as possible before low-density development emerges around station areas, particularly outer stations in Nanning City. LRT Route 1 (Phase I) will be constructed at present, therefore, leaders and planners should start their work to promote this coordination of planning, especially in current update of policy and planning, by preparing stations area plans connect with preliminary engineering for the LRT.

Low-density institutional land dominates land use pattern in some research areas which contributes to a decrease in the average land use intensity. Most Chinese universities adopt dispersed construction in campus, built in low-rise, low-density and multi-function facilities, as well as large-scale green space and sport yard. Students and faculties usually study and live on campus, which offer both dormitories and farewell houses for students and faculties. Thus, planned LRT Route 1 will be potentially fail to attract and generate activities and high-level of patronage. Minzu University Station area is representative, where three large-size institutions, Minzu University, Machine College and Foreign Language High School, cover almost 40% of total land, both currently and in the future. The low land use intensity on the campus results in low-level average criterion of Minzu University Station. The FARs of Minzu University, Machine College and Foreign Language High School are only 0.87, 0.72, 0.74 respectively, and these three institutions contribute to building coverage of 16%, 17% and 21%, respectively.

Moreover, the isolated work unit (*danwei*) provides work place close to home, so transportation mode between workplace and home is not motor-based, and transit does need to be used. *Danwei* means a land owner or development govern large-size lands to construct isolated work units or settlements, mostly university, college, school, residential district and governmental official buildings, surrounded by walls, gates and creating separated, non-public road system and security system. Generally, '*danwei*' offers workplaces and houses to employees, as well as small-scale support facilities such as grocery, clinic and day care (even primary school), thus, people live in *danwei* can maintain regular life without long-distance trip. On one hand, *danwei* occupies large number of land, such as Minzu University (55ha), Machine College (30ha) and Foreign Language High School (5ha) in Minzu University Station area and several large-scale residential districts in Fengling Station area. On the other hand, development in *danwei* is universally single use and low density. For instance, buildings developed in Minzu University campus are all institutional and educational buildings as well as dormitories and residential buildings. The average building coverage of Minzu University is less than 10%. Another important characteristic of *danwei* is that they develop self-governed and isolated transportation infrastructure which do not support public transit. The above-mentioned characteristics of '*danwei*' lead to a low density and low intensity development. It is likely that an increase of walking and biking as daily trip modes because residents could work and live in the same campus, without long-distance travel, which is good and more sustainable for environment but negative for rapid transit system.

Establishing special planning or regulation to encourage dense development in influencing area is necessary for Nanning City to achieve official goal of well integration of land use and rapid transit system. Nowadays, Nanning City implements the same planning regulation in the whole city, including within station area. Developments in proposed station areas are still built in regular style and intensity, taking no account of upcoming LRT. Change detailed plans in certain district (along corridor and around station) to permit higher intensity development and to prohibit inappropriate auto-oriented land use is recommended. Special land use planning norms and measures such as air rights on proposed stations, enhancement of FAR and density bonus could be adopted by the city, especially around proposed outer stations, where low-density development will probably be pursued without such special planning and regulation.

Spatial separation between planned LRT stations and surrounding areas prevents accessibility to LRT Route 1. Based on international experience, walking is the preferred means of access to transit, because it avoids parking, or bus trip. In some successful case, coordinating rapid transit station and surrounding office, commercial and apartment buildings provides direct access to rapid transit system (Huang, 1996). In Nanning case, actual spatial separation causing by isolated 'danwei', mid-location on wide main road and lack direct link between planned LRT stations and surrounding area is not comfortable for walking.

Firstly, the location of LRT stations, on the middle of wide main road and large-scale square block the way of LRT usage, resulting in inaccessible, pedestrian-unfriendly station environment, increasing walking distance, declining accessibility and reducing traffic safety. To minimize construction costs, large part of LRT Route 1 (Minzu Station, Wuxiang Square Station and Fengling Station) is planned to be built along main roads, which are all 40-70m-width plus double 10-20m-greenbelt and 6-8-double-direction lanes. To arrive to these stations, passenger has to cross the wide road filled with heavy, continuous traffic flow, which results in an enlarged walking distance and potential increase of traffic safety. Wuxiang Square Station scores a better safety score due to its links with a planned underground commercial center under Wuxiang Square, but even its passengers must to cross the square before arriving LRT station, which also increases walking distance, and reduce accessibility to LRT.

Moreover, the accessibility to LRT station is also weakened by lack of a comprehensive underground system particularly reflected within underground LRT station areas. An excellent pedestrian system might add to the overall appeal of transit system. Thus, many cities encourage direct connection linking adjacent land use and urban rapid systems to reduce walking time and distance, increase pedestrian access and encourage ridership. This principle has not been adopted in Nanning City. Distance between planned Chaoyang Square Station and adjacent buildings are not far as the other three stations because of its location under a 40m Chaoyang Road. Theoretically speaking, the accessibility to Chaoyang Square Station is excellent under such condition, but the effort is impacted by the absence of a lack of direct link between the underground LRT station and the underground spaces of the surrounding buildings. Due to historical development, underground spaces in old city core do not connect directly with each other and a comprehensive underground system linking all importance building and underground public space, like LRT station has not been formed yet. That is to say, even people are at the same underground level, they have to travel firstly to ground level of buildings, then get down to underground level again after crossing a wide main road to arrive LRT station. This kind of vertical traffic increases the travel distance between LRT stations and surrounding buildings. This kind of isolative underground space might also block the attractiveness of LRT near Wuxiang Square Station, or even worse than Chaoyang Square Station because of there are a far more high-rise buildings which all provide single or multi-story basements as commercial or structural parking lot. People have to arrive at ground level form difference underground level, and then travel to Wuxiang Square through surface road network before getting underground planned LRT station.

Furthermore, '*danwei*' creates several problems such as spatial separation of campus (or residential district) and the surrounding urban environment. Using its own, dedicated road network, including a dedicated pedestrian system, there is only one entrance linking inter campus (or residential district) and outer urban environment which increase travel distance, especially walking distance to LRT stations. For instance, even though workplace is just adjacent to LRT station, people have to travel on inner-campus road system, and go through gate, the only legal entrance, and then arrive to public road system before arriving to LRT stations.

Thus, in urban planning aspect, a new planning structure of station area should be prepared to encourage significant, effective development within influence area. Large-scale main roads, separated underground spaces and isolated system in 'danwei' might be potential positive factors preventing success of planned LRT Route 1, as well as other LRT and BRT lines due to similar characteristics of location of planned rapid transit in Nanning City because they enlarge walking distance and make pedestrian less safe.

Therefore, a proposal planning structure for MRT in Nanning City is described as follow:

1. Relocating all other rapid transit lines which are currently proposed on large-scale, wide main roads with busy traffic flow to small-scale, local streets, or declining street width where rapid system locate on to restrain automobile usage
2. Creating a human-scale environment by reducing existing, traditional large building setback, increasing accessibility and attractiveness of LRT
3. Breaking the barrier between '*danwei*' and public road network to link origins and destinations directly to LRT station
4. Encouraging coordinated station design with the developers desiring direct access from official, retail or apartment buildings

In a word, Nanning City should establish detailed but flexible design guidelines for areas within walking distance of the stations. These guidelines should emphasize on closely coordinating land use planning and rapid transit construction, encouraging dense development around rapid transit stations, creating attractive human-scale circumstance and pedestrian-friendly environment.

# CHAPTER 7: CONCLUSIONS

Rapid transit infrastructure is a critical factor to changing land use patterns, redeveloping central cities and creating sustainable urban centers at both the regional and the community level. However, rapid transit does not automatically influence land use. Its success largely depends on considerations such as the proper way in which urban land use can be managed to support proposed rapid transit infrastructure. The degree of support provided by development varies from one city to the next. Even in the same transit system, intense development may occur near some stations but not others. This warrants the use of planning to encourage appropriate land use patterns. High-density, mixed land use, close spatial integration and pedestrian-friendly environments are keys to the success of rapid transit.

The research undertaken for this thesis sought to answer four questions through a case study of Nanning City where an initial LRT system is in the advanced planning stages and extensive further LRT and BRT planning is being carried out.

*1. In what ways do certain characteristics of built environments such as population densities encourage or discourage the use of rapid transit?*

Based on an extensive literature review, it is concluded that higher densities of residence and workplaces clustered around stations encourage the use of rapid transit infrastructure. Mixed use is encouraged in the literature, and many cities elect to pursue a strategy of mixed-use development around rapid transit stations as a TOD goal. An immediate function of rapid transit is to connect people's homes, workplaces and other places that are separated geographically. If mixed-use widely happens in city area, and if homes, workplaces and other destinations are mixed within a small area--as is common of traditional Chinese cities--is LRT or transit even necessary? China's cities are currently being transformed and activities areas and are being spread out. To identify the optimal method to determine or measure mixed use in China is a challenge. It may be due to the fact that these areas are already mixed; but mixed size and mixed form are difficult to assess whether or not they are more or less transit supportive. For example, mixed use refers not only to a horizontal mixed of land use--residential use located next to commercial use-- it more precisely refers to vertical mixed achieved by permitting two or more use in a single building. It is difficult to determine which form is better for rapid transit ridership and to what degree the mixed-use is needed.

*2. What kind of public policies can encourage transit-supportive urban form?*

Different transportation policies and plans result in the emergence of incongruent international systems. The use of supportive approaches such as encouraging dense development and mixed land use around rapid transit station, establishing urban design guideline to create a transit accessible/pedestrian-friendly environment, developing an attractively strong downtown area, avoiding positive industrial land use along rapid transit corridor and station areas, restraining parking in sensitive areas and integrating urban transportation planning and land use planning, may play an important role in encouraging effective integration of land use around rapid transit stations; which has been evidenced in many successful cases including Toronto's subway, Hong Kong's metro, Calgary's LRT, Ottawa's BRT and Curitiba's BRT.

*3. Will land use patterns around proposed LRT stations in Nanning support a high level of ridership?*

Examination and measurement on both current and future land use classification, land use intensity, land use mixed degree and physical building environment around influencing stations--on both small-scale (overall network) and large-scale (four typical stations)--were conducted to discover the current and emerging trends.

It is likely that existing and future uses of land around twenty proposed LRT stations in Nanning City will support a high level of ridership. However, existing land uses around inner city stations are more supportive of LRT Route 1 because they are much denser, mixed and pedestrian-friendlier than land uses around outer stations; which are non-transit supportive farmland, industrial land as well as low-density, low intensity, single-use and isolated institutional land use.

4. *Will proposed changes to built environment support the use of Nanning's LRT system?*

Current situation may change in the future because general land use changes are consistent with TOD goals; including shifts form undeveloped land use in development use and from industrial land use in commercial, residential and other land use. Increase of land use intensity and good integration of main trip generators with LRT stations--especially several TOD-friendly factors--are encouraged, including widely mixed land use, relative high land use intensity on some individual plots, increasingly strengthened old city core and new city center, and mature non-motorized walking environment near inner stations. However, outer stations may not meet the needs of supporting planned LRT Route 1 (Phase I) because of relative low-density, low-intensity and single-function development as well as relative poor public pedestrian environment, which are blocked by isolated 'danwei' and large-scale residential settlement. Moreover, LRT Route 1 (Phase I) may be less successful due to a large number of roads and open spaces, low-density institutional land uses, isolated 'danwei', mid-road location of LRT stations and spatial separation between planned LRT stations and surrounding areas.

## NOTES:

1. Chinese central government decided to implement economical reform and open door to the world after closing the country to international intercourse for about 3 decades since 1949.
2. Employees could get houses freely or in a very low rent from their state-owner units depending on their age, gender and position in units.
3. The principle of urban planning in Nanning is to encourage moving current population from compact old city core out to new developing area.

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# APPENDICES

## Appendix A: Criterion of Land Use Evaluation

Overall Land Use of LRT Network

The analysis focus on land use classification which is figured as a percentage (%) of the total surface of research area, distinguishing land use into seven main categories: Residential, Commercial, Official, Institutional, Industrial, Road and open space, and All other.

Land Use and Physical Condition of Four Typical Stations

Study Area Subdivision

Study area subdivision is to split land use within study area into small plots in favor of calculating every criterion in each small Land Use Unit (LUU). LUU subdivision will rely on the below principles:

1. LUU is divided firstly by roads (existing and planned), water, mountain, interchange and land use boundary, visual wall and building site boundary.
2. LUU subdivision in historical, traditional district relies on land use division of official Conservation Planning of Historical and Traditional District in Nanning City.
3. Land use subdivision in a large LUU (university, collage and residential district)

should be divided into small parts (library, sport yard, dormitory and educational building plot in university campus).

4. One large-scale building or several small-scale buildings with the same function occupies one LUU.

Land Use Pattern Comparison

Land use classification is based on actual land use functions, which are identified from large-scale maps and the researcher's working experience. In addition to the seven land use categories in the overall land use network analysis, a new category of 'mixed land use' is added to capture buildings or lands which have two or more than two above categories such as residential/commercial mixed, residential/official mixed and residential/light industry mixed. Thus, all land use is distinguished into eight main categories, Residential, Commercial, Official, Institutional, Industrial, Road and Open Space, All Other, and Mixed Use.

Land Use Intensity Measurement

Land use intensity is planned to be measured by two criterion, Floor Area Ratio (FAR) and Building Coverage.

Where, FAR = Total Building Area/Total Land Area

Building Coverage = First Floor Building Area /Total Land Area

FAR of each LUU is calculated and spilt into 5 degrees:

| | |
|---|---|
| FAR=0 | Zero Development (road, open space, farmland, water area, etc.) |
| 0<FAR≤0.5 | Low-intensity land use |
| 0.5<FAR≤2.0 | Medium-intensity land use |
| 2.0<FAR≤4.0 | High-intensity land use |
| FAR>4.0 | Super-high-intensity land use |

Building Coverage is also divided into 5 degrees:

| | |
|---|---|
| Building Coverage =0 | Zero development (road, open space, farmland, water area, etc.) |
| 0<Building Coverage≤10% | Low-intensity land use |
| 10%<Building Coverage≤30% | Medium-intensity land use |
| 30%<Building Coverage≤50% | High-intensity land use |
| Building Coverage>50% | Super-high-intensity land use |

Existing average FAR and Building Coverage of each of the four selected stations is accurately measured. Planned FAR and Building Coverage require estimation. All land use in the research areas, including road and open space area are calculated into average FAR and building coverage.

Land Use Mixed Degree Measurement

Mixed use measures the spatial clustering of different types of land use within local areas (LUUs). Two criterion, land use classification and land use mixed degree, indicate land use mixed level in this research. Land use classification within 400m radii area illustrates land use mixed degree at horizontal level and distribution of mixed use in research area.

Table 3 Mixed Score Division

| Score | Land Use Mixed Degree | Characteristic |
|---|---|---|
| 0 | Without Mixed | Pure land use and building function |
| 1 | Less Mixed | Mixed use of the first floor and top of building. For instance, retail, restaurant at ground level and residential, official on top. |
| 2 | Medium Mixed | Mixed use of podium and tower of building. For instance, commercial, official in podium and residential, official in tower. |
| 3 | High-level Mixed | Entirely Mixed in the whole building. For instance, commercial in podium and official, hotel, restaurant in tower. |

Moreover, to reflect to what extent land use mixed in vertical level, researcher is attempt to evaluate mixed degree in quantitative method via individual LUU mixed score and comprehensive average mixed score, which is based on difference functions mixed in one building. Land Use Unit (LUU) is marked into 4 different scores depending on their mixed form and characteriser (Table 3). Comprehensive land use mixed degree could be compared after calculating respectively mixed scores of individual LUUs and average mixed score of four selected LRT stations, both in existing and planned stages.

Physical Connection Degree Measurement

Due to walkable environment plays a key role in attracting ridership, for understand to what extant physical connection between proposal LRT station and surrounding environment, both total length and area of public sidewalk are measured on large scale maps and plans. Existing length and area of public sidewalk in research area could be read and calculated directly from 1:500 or 1:1000 maps, while length and area of planned roads and sidewalks in the future are estimated based on Nanning road network design documents, or national urban road network design regulations for cases in which local documents do not yet exist. Only public and open roads would be calculated in this research because internal road systems on private LUUs (e.g. universities and colleges, residential districts, or government official buildings surrounded by walls) are limited usage under certain condition, in another word, these roads are non-public and they are not counted into public pedestrian system.

**Appendix B: Data Definition**

Building classification:

Temporal building and simple-structure building are classified depending on their existing function.

Garage is classified depending on what kind of buildings it serves. For instance, it is seen as residential function when it serves as additional support garage for residential buildings, and it is regarded as official usage when it supports official building.

Outdoor locker is mainly one or two stories temporal building serving residential building, and it is classified to residential building.

Dedicated public toilet, as a popular form in Chinese, is separated form any other facilities, and is regarded as institutional building.

Workshop in university campus is primarily serving as examination place for students at university or collage, thus, this kind of special work place is classified as institutional usage.

Illegal building is classified depending on its current function.

Building currently being under construction and planning stage is regarded as 'plan' states.

Buildings are roughly laid out by researcher when these is lack of detailed site planning, and intensity norm such as FAR, building coverage and building height could be found in Nanning Urban Planning and Administration Technical Regulation.

Land use classification:

Lacking the 'mixed-used' land use in overall 20 stations classification, land use classification is defined depending on main function of building on this land. For instance, as a mixed-use building with commercial at ground level and residential on tower, land use could be defined as residential land use.

All mountain area and water area are calculated and classified in this research as open space.

Both large-scale sport yard and green space in university or collage campus belong to institutional land use.

Coach destination is classified as civil and institutional land use.

Day care, primary and high school, collage and university, hospital and research institution belong to institutional land use.

Governmental and business official facilities are all seen as official land use, and they are not sub-divided in this research.

Industrial land use is not sub-divided in detailed such as heavy industrial and light industrial because all industrial lands in research area are not heavy and contaminative industry.

Water supply plant and transformer substation belong to civil and institutional land use.

Gas station is seen as commercial facility.

Lands which currently are under construction, site work and under planning stage, or land bank are all seen as open space because they are demanded to be greened by Nanning government before construction.

Official centers of financial organization, post and telecommunication are seen as official land use, but not institutional land use.

Index calculation:

Commercial facility under Wuxiang Square is calculated in average FAR, but is not in building coverage and mixed score due to the main function of this land is surface public open space.

Green belt on sidewalk is not calculated in total sidewalk area.

Different widths of one existing sidewalk are calculated as an average width to simplify sidewalk area calculation.

Pedestrian-only streets are entirely calculated in sidewalk system.

Non-public pedestrian systems in 'Danwei' and residential settlement are not calculated into public sidewalk system.

All other:

Old city core is a special, around $4km^2$ district with the longest history in Nanning City.

New city center is the new, around 4 $km^2$ center developed primarily near 10-15 years in Nanning City

Center city is the most dense, compact, developed main city area whose function reflects the main city function, consisting of old city core, new city center and south area in Nanning case.

Sub-center is less dense, small-scale city to mitigate the commercial, residential and transportation pressure of center city, whose main functions are residential, institutional and industrial in Nanning City.

City planning area is dedicated group focusing on one or more functions, and is cells of city. Nanning City is planed to separated into 19 city planning areas respectively emphasis on difference city functions.

Land use of Danwei is a traditional land use form in China, and basic cell in society and administration, which is usually surrounded by respective walls, and has independent administrative system, isolated, separated, non-public road system, small-scale support facilities such as small grocery and clinic. Residential settlement are also has the above characteristics, ranging from 1000 persons to 10,000 persons.

# GLOSSARY

ASEAN: Association of South Asian Nations

BRT: Bus Rapid Transit

CBD: Central Business District

FAR: Floor Area Ratio

GDP: Gross Domestic Product

GIS: Geography Information System

LRT: Light Rail Transit

LUU: Land Use Unit

MRT: Mass Rapid Transit

ROW: Right Of Way

TOD: Transit Oriented Development