

An Empirical Study on the Characteristics of Nanning's Subway System for Alleviating Traffic Congestion

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Abstract— *Subways with suitable characteristics can alleviate traffic congestion and positively influence society, the economy at both household and urban levels, and the overall quality of life. This exploratory research surveyed Nanning's subway system (Nanning Rail Transit: NNRT), which consists of 76 stations across five lines. The survey results show that NNRT has key characteristics that enhance service quality and encourage public transit use, as follows: 1) Accessibility: NNRT covers all major areas of Nanning municipality, with stations located near business districts, residential communities, educational institutions, and other essential urban zones. All five subway lines are seamlessly interconnected. In addition, NNRT provides convenient connections to long-distance bus stations and all railway stations. 2) Affordability: NNRT fares are reasonable and relatively low for trips involving transfers across different lines. These fares fall within the lower range when compared with subway or sky train prices in several ASEAN countries. 3) Safety: NNRT is highly safe for both passengers and their belongings. All passengers and their items are screened by security machines and subway guards to prevent dangerous objects from entering stations. CCTV cameras are installed throughout all station and platform areas. 4) Station Facilities: All stations are equipped with essential facilities to ensure passenger comfort, including amenities for the elderly, individuals with special needs, and passengers carrying large luggage. These facilities include escalators, elevators, and wide entrances for wheelchairs. Additional facilities that improve passenger flow—such as ticket vending machines, escalators, elevators, and staircases—are also installed.*

Keywords— *Subway characteristics; Traffic congestion; Empirical study.*

I. INTRODUCTION

Properly designed rail transit systems, such as subways, can encourage people to shift from private car use to public transportation, thereby helping to alleviate traffic congestion. The opening of a new subway line can increase rush-hour traffic speed on nearby roads by an average of about 4% in the first year and reduce delay times by approximately 15% in the short term (Gu et al., 2021; Yang et al., 2018). Transportation systems are widely regarded as the backbone of urban development, yet traffic congestion remains a persistent global challenge. It has significant adverse impacts on economic productivity, the environment, and overall quality of life (Choudhary et al., 2022). Congestion contributes to increased fuel consumption, higher vehicle operating and parking costs, greater pollution emissions, heightened driver stress, longer

travel times, and increased accident risk (Bhardwaj et al., 2023; Litman, 2025).

Subway expansions, by contrast, have been shown to significantly reduce air pollution levels, improve urban air quality, and decrease traffic congestion, fuel consumption, and accident rates (Li et al., 2019; Xie et al., 2024; Lin et al., 2025). Therefore, an efficient subway system can positively influence both the overall urban economy and the well-being of individual residents.

This empirical research examines the characteristics of the subway system in Nanning City (Nanning Rail Transit: NNRT) that encourage public transit use. The study focuses on several key aspects—including accessibility, coverage and connectivity, station facilities, security and safety, and affordability—to evaluate how NNRT contributes to reducing traffic congestion and improving urban mobility.

II. LITERATURE REVIEWS

Traffic congestion negatively impacts the economy, society, and the quality of life. In contrast, subways help alleviate traffic congestion (Gu et al., 2021; Yang et al., 2018), thereby positively affecting the economy, society, and quality of life in the following ways:

1. Improved air quality: Subways reduce air pollution concentrations (Li et al., 2019; Xie et al., 2024; Lin et al., 2025). Air quality directly affects public health, especially respiratory health. A lower incidence of illness reduces healthcare costs, benefiting household finances and national savings. Moreover, a healthier population can positively impact economic productivity.
2. Reduced stress for passengers and drivers: By alleviating traffic congestion and decreasing travel time, subways reduce the number of passengers on public buses and the stress experienced by drivers (Litman, 2025). This may lead to improved mental health and overall quality of life for both passengers and drivers.
3. Lower fuel consumption: Subways reduce fuel usage (Bhardwaj et al., 2023; Faheem et al., 2024), leading to lower household expenditures and higher savings. On a national level, reduced oil imports can save foreign currency, improve the trade balance and support the overall economy.
4. Reduced household expenses related to car ownership: Subways may decrease hidden costs associated with personal

car use, such as parking fees and vehicle maintenance (Litman, 2025), positively impacting household budgets.

5. Improved accessibility for non-drivers: Subways provide faster and more convenient travel for people without private cars, enhancing mobility and overall quality of life.

However, for subways to effectively alleviate traffic congestion, they must have features that encourage drivers to abandon private cars and provide affordability for non-drivers. To address congestion effectively, public transport systems such as subways should offer well-designed and accessible stations, extensive routes, frequent and reliable service, safety and security, reasonable fares, convenient payment systems, and universal design to accommodate pedestrians with disabilities (Litman, 2013).

Subways offer numerous advantages, including high transportation capacity, punctuality, efficiency, convenience, speed, stability, and safety, which enhance travel comfort and meet the basic mobility needs of the public (Wang et al., 2020; Yang et al., 2022; Yan et al., 2022; Yin et al., 2016). Well-designed stations and upgrades to the subway network can improve operational efficiency, reduce travel time, increase punctuality, facilitate smoother transfers, and enhance passenger convenience (Wei, 2023). Such improvements not only enhance the commuter experience but also reduce delays and encourage greater public transit usage.

Subway transfer stations, serving as critical connection points, should ensure the efficient movement of commuters by providing smooth pedestrian flow, minimizing potential safety hazards, and alleviating delays in congested bottleneck areas through reconfigured pedestrian pathways and the installation of transportation facilities such as escalators, elevators, and staircases (Zhen et al., 2024). Corridor width and the design of walking paths within stations are crucial factors influencing passenger circulation efficiency (Xu et al., 2023). Security checks at station entrances help prevent dangerous objects from entering platforms and ensure passenger safety. Although security procedures may create temporary congestion, this can be mitigated through the installation of automated security check machines and ticket vending machines while eliminating traditional ticket windows (Yu et al., 2022).

The primary factors influencing subway usage include distance, income, affordability, and accessibility (Lee et al., 2005). Because subway stations are central nodes in the urban rail network, their accessibility significantly contributes to social and economic activities (Yin et al., 2016). Finally, to improve quality of life and living standards, passengers require a comfortable environment in both subway stations and cars, encompassing thermal conditions, vibration, noise, lighting, air quality, and air pressure. Air quality, in particular, directly affects passenger comfort and has thus become an increasingly important consideration (Yan et al., 2022; Yin et al., 2016).

III. METHODOLOGY

Nanning is the largest city in Guangxi Province, with a permanent resident population of 8.8917 million at the end of 2022 (Publicity Department of the CPC Nanning Municipal Committee, 2025). The public transit system in Nanning consists of 96 stations across five subway lines, as well as

public buses serving all areas of the city. This study used the Krejcie and Morgan sample size table to determine the appropriate sample size, which was 76 subway stations selected through a simple random sampling method. Data were collected using a survey method. The survey covered 76 subway stations, including interchange stations between subway lines, bus stations connected to subway stations, and railway-connected stations. The collected data were primarily analyzed using percentile calculations and qualitative interpretations.

IV. RESULTS

This paper examines the characteristics of Nanning Rail Transit that encourage public transit usage, focusing on accessibility, facilities, security and safety, and affordability.

Accessibility: All groups of passengers, whether Nanning residents or travelers, can easily access NNRT services. Firstly, the NNRT network covers all areas of Nanning municipality, including commercial districts, densely populated communities, educational institutions, public parks for leisure and family activities, as well as areas designated for future urban expansion. These expansions encourage residents to move from congested areas to locations with better living environments, and constructing subways in densely populated communities may cause traffic congestion and both air and noise pollution. Secondly, NNRT stations are strategically located close to major sites to provide convenient access. The distance from home to the nearest station is generally short, which encourages high subway usage, as distance is a critical factor influencing public transit use (Lee et al., 2005).

Thirdly, all five subway lines are fully connected. Lines 2, 3, and 5 can connect with the other lines, while lines 1 and 4 are not directly connected. Nevertheless, passengers can travel conveniently, quickly, and on time, often using a single fare, and can reach their destinations even if multiple line transfers are necessary. Clear signs are provided inside transfer stations, and the connecting distances are manageable. Stairs, escalators, and elevators are available to facilitate movement for all passenger groups.

Fourthly, for travelers, NNRT is integrated with five coach stations: Xixiangtang, Jiangxiao, Jiangnan, Langdong, and Anji. Specifically, Xixiangtang and Langdong connect to Line 1, Anji connects to Lines 2 and 3, Jiangnan connects to Line 2, and Jiangxiao connects to Line 5. Additionally, NNRT is linked to two major railway stations: Nanning Railway Station and Nanning East Railway Station. This integration allows passengers traveling from other cities to reach their destinations conveniently, safely, and with reduced travel time and costs. It also helps reduce road traffic congestion near bus and train stations by discouraging the use of personal vehicles or taxis.

However, congestion can occur at the railway connections during peak hours and major holidays. Transfers between subway and railway systems require passing through security checks, which can slow passenger flow. A more seamless connection, such as direct access to waiting areas, could speed up transfers. On a positive note, both subway and train tickets are available in e-ticket form, eliminating the need for passengers to queue at ticket vending machines or ticket counters.

Affordability: Individual and household incomes are important factors influencing people's decisions to use subway services (Lee et al., 2005). NNRT fares start at 2 yuan and go up to 6 yuan. Additionally, passengers using a prepaid card can receive a 10% discount. These fares are considered low compared to metro rail transit fares in some ASEAN countries. The affordability of NNRT services may encourage higher ridership, particularly among those who do not own private vehicles and individuals with moderate or low incomes.

Station Facilities: NNRT provides comprehensive facilities to serve regular passengers as well as those with special needs, including the elderly, pregnant women, and people with disabilities. Each station has multiple gates connecting to bus stations and surrounding communities, and every gate is equipped with escalators, except entering shopping zones, and wide staircases to accommodate passengers during rush hours. Additionally, an elevator is available at every subway station to assist passengers in need.

NNRT offers a convenient and fast ticketing system, including automatic ticket vending machines that accept both cash and e-money payments through WeChat Pay and Alipay. Passengers can also use prepaid cards or the Ai Nanning app to pay fares, improving convenience and reducing congestion. All stations provide mobile charging points for passengers using mobile apps for fare payment. Station entrances include both standard and extra-wide gates to accommodate wheelchairs and large luggage, facilitating travel for passengers with special needs or baggage.

The subway platforms are located between the rails and offer sufficient space for passenger movement. Elevators, escalators, and staircases are available on all platforms. Essential facilities are provided, including separate toilets for men, women, and disabled passengers, baby care rooms for mothers with toddlers, and staff assistance for visually impaired or wheelchair-using passengers. Station staff also maintain service quality and ensure smooth operation.

Some stations, particularly those in business centers or large communities, include shopping areas and food courts, enhancing convenience for passengers and travelers.

Security and Safety: The safety of passengers' lives and property is a top priority for metro operators. NNRT employs a comprehensive range of security measures and safety tools to ensure passenger protection. These include CCTV monitoring with dedicated staff, regular station staff and subway guards on platforms to provide immediate assistance during emergencies, and security checks of passengers and their belongings at station entrances to prevent weapons, sharp objects, or other dangerous items from entering the subway system. Additionally, subway guards routinely inspect every subway car to ensure passenger safety and prevent potential accidents, providing passengers with peace of mind during their journeys.

V. CONCLUSIONS

Subways can alleviate traffic congestion, which negatively affects the economy, society, and people's quality of life. Subways improve air quality, reduce household expenses, increase savings, enhance economic productivity, and more. To achieve these benefits, subways must have characteristics that

encourage private car drivers to use public transit instead of driving.

The Nanning Rail Transit (NNRT) has several features that inspire people to use its service. Based on survey results, NNRT's characteristics can be categorized into four factors:

1. **Accessibility:** NNRT covers all areas of Nanning municipality, and all stations are located near business districts, residential communities, educational institutions, and other key locations. All five subway lines are seamlessly interconnected. Additionally, NNRT connects to all long-distance bus stations and railway stations, facilitating smooth transfers.

2. **Affordability:** NNRT fares are reasonable and low compared to other modes of travel, as passengers can access all subway lines with a single fare payment.

3. **Safety:** NNRT prioritizes the safety of passengers and their property. All passengers and their belongings are screened by security machines and subway personnel to prevent dangerous items from entering the stations. CCTV cameras are installed throughout stations and platforms to ensure security.

4. **Station Facilities:** All stations are equipped with essential facilities to ensure comfort for all passengers, including the elderly, people with disabilities, and travelers with large luggage. These facilities include escalators, elevators, and wide entrances for wheelchair access. Additionally, infrastructure to improve passenger flow—such as ticket vending machines, escalators, elevators, and staircases—is installed throughout the stations.

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