Analytical Research of Public Transportation Accessibility on the Wushan Campus of South China University of Technology

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Abstract. As China's city development shifts from high-speed growth to high-quality development, the rational and coordinated construction of public transportation has become one of the most important directions to urban land and space planning and transformation development. By consulting on the highly effective Public Transport Access Level (PTAL) Technology in London, a quantitative analysis method can be found to evaluate the rationality of public transport and land-use layout, thereby supporting the sustainable development of the city. This article firstly summarizes the basic steps of London's PTAL technology and then applies these methods to the public transportation accessibility evaluation on the Wushan Campus of South China University of Technology (SCUT) in Guangzhou. PTAL values and relevant maps generated by those methods can quantitatively measure the supply level of public transportation, which provides a reference for the construction and optimization of public transportation stations and lines.

Keywords: Public transport access level, travel time, waiting time, access index, coordinated development

1. Introduction

Over the past few decades, a series of urban problems have gradually emerged with cities' rapid urbanization, such as traffic congestion, low land-use efficiency, environmental degradation, etc., which are generally considered "urban diseases". The traditional development model, namely " urban sprawl" and "personal vehicle-centered", is no longer suitable for the current situation of limited land resources. Therefore, it is vital to support urbanized areas to achieve efficient economic and population agglomeration, while promoting a new type of urbanization—people-centered.

Currently, urban development is in transition from high-speed growth to high-quality development, and public transportation plays an important role in leading the development of urban space. However, there is a lack of a quantitative analysis method that assesses the degree how which public transportation and land use layout match. In 2015, London adopted the Public Transport Access Level (PTAL) technology, which is a representative research example widely referenced in the coordinated development of transportation and land use [1, 2].

This article mainly summarizes the key points of PTAL technology and applies these methods to analyze the public transportation accessibility of the Wushan Campus of South China University of Technology (SCUT) in Guangzhou (the area is approximately 2,740 acres, or 1.8267 square kilometers), to provide innovative tools to promote high-quality and coordinated development of land use and public transportation stations and lines.

2. Public Transport Accessibility

Generally, accessibility refers to the number of development opportunities that residents can access from a certain area by using a certain transportation system or the difficulty of achieving a certain purpose. A systematic connection has been established between the transportation system and the land layout [3]. As part of the urban transportation system, Public Transport Accessibility is the opportunity for people to approach and use public transportation services, reflecting the cost of people obtaining public transportation services, including walking time, waiting time, etc. [4].

Under the urban transportation development strategy of "public transport priority", public transport accessibility analysis and evaluation are of great significance in guiding public transit system development. This process helps ensure that the system can better serve citizens and improve the efficiency and sustainability of urban transportation; it also helps solve traffic congestion and environmental problems, and improves the quality of life of city residents, making cities more attractive and competitive.

3. Data Collection at SCUT

Based on existing research, this article conducts practical research on public transportation accessibility analysis in 4 areas: east, west, south, and north on the Wushan Campus of SCUT, summarizes the current situation of public transportation development in this area, and provides guidance for future development.

The article calculates PTAL based on the Access Index to analyze the accessibility of public transportation. Before conducting the analysis, it is essential to define the boundaries of the 4 areas and traffic zones of each area and specify the names and locations of all public transportation stations on and around the campus, which is the definition of travel points and service points. In addition, the basic assumptions of the model need to be made to standardize the research content.

3.1. Area Boundary Division

Using the 3D map of the Wushan Campus of SCUT as the base map, 4 areas can be divided according to the daily life of teachers and students and the relevant expressions in school documents, as shown in Table 1 and Figure 1:

Table 1. Define the boundaries of each area

Area	Boundaries
East	The east of Banshan West Road; the East Residential Community
South	The south of Huashan Road; the west of Wushan Road
West	The north of Huashan Road; west of Huangshan Road
North	The north of Dongguan Zhuang Road

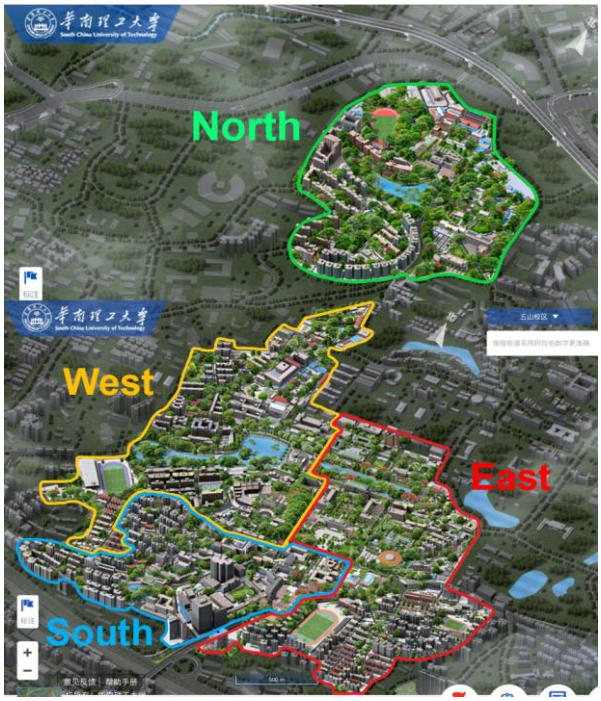

Figure 1. Schematic diagram of each area on the Wushan Campus of SCUT (Picture credit: Original)

3.2. Division of Traffic Zones

(1) Principles of division: Mainly based on motor vehicle lanes or sidewalks on campus as boundaries. Each traffic zone includes several representative buildings or facilities and is divided based on the walking distance of about 3 minutes. After defining the traffic zones to which each building belongs, the centroids can be used to represent the travel points.

(2) Division details:

Taking the Eastern Area as an example, it is divided into 7 traffic zones, as listed in Table 2:

Table 2. The division of traffic zones in the Eastern Area

Traffic Zone	Buildings and Facilities
East 1	Electric Power Laboratory Building, Computer Center, Liwu Science and Technology Building, Shaw Science Museum, Construction Engineering Training Building, Architectural Design and Research Institute, building 6-9, Building 20, Building 29
East 2	Building 1-4
East 3	Eastern Student Dormitory, Eastern Canteen, Campus Hospital, Dongxiu Village
East 4	Library, swimming pool, gymnasium, Haili Cultural and Sports Center, Huagong Kindergarten, Building 5
East 5	Xincun Community, Eastern Stadium
East 6	Eastern Residential Community East 1st and East 2nd, Huagong Primary School
East 7	East Residential Community South 1st and South 2nd, Fenghuang New Village

A summary of the traffic zone maps of the four areas are as follows:

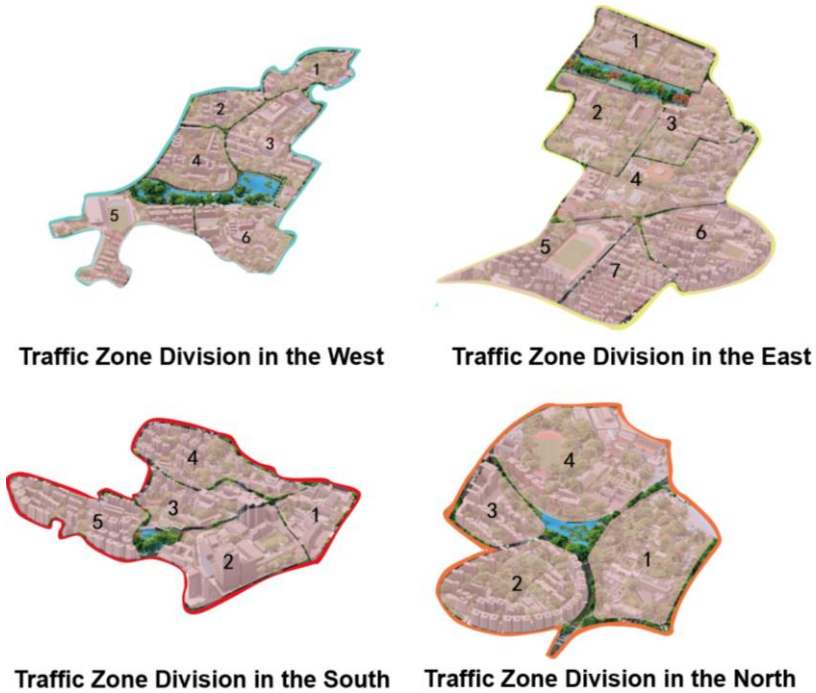

Figure 2. Traffic subdivision map of four large areas (Picture credit: Original)

3.3. Distribution of On-campus Stations (SAPs) and Lines

All the bus stations or public transport sites will be seen as service access points (SAPs). In the study, the campus bus will be regarded as a part of public transportation, and its impact on the public transport accessibility of each area will be considered. Therefore, its stations can be considered as SAPs. The specific routes and station distribution are as follows:

Figure 3. Schematic diagram of SAPs and routes on Wushan Campus (Picture credit: Original)

3.4. Distribution of Off-campus Stations (SAPs)

The distance used when calculating the walking time (WT) from service access points (SAPs) is not the straight-line distance from the demand generation point to the service point, but the length of the walking path. Therefore, it is necessary to clarify the location of public transportation stations within walking distance around the Wushan Campus (outside the campus), as shown in the figure below:

Figure 4. Schematic diagram of (SAPs) within walking distance around Wushan Campus (outside the campus) (Picture credit: Original)

3.5. Model Assumptions

Before calculating PTAL, various and complex actual scenarios need to be standardized. It is better to compare the access levels between different locations under a common standard. Therefore, several assumptions for determining the model are as follows:

(1) Travelers are all connected by walking and non-motorized vehicles, and other transportation modes are not considered.

(2) The average walking speed of pedestrians$v_p$is 4.8 km /h.

(3) When calculating walking and riding distance/time, the geometric center of each traffic zone is used as the origin and destination points.

(4) The number of passengers arriving at public transportation stations obeys Poisson distribution.

(5) The service level of each public transport line is the same in both directions.

4. Calculation and Analysis of PTAL

Based on the travel points and service points determined in 3.2, 3.3, and 3.4, the calculating steps of PTAL are: Calculate Walking Time (WT) - Scheduled Waiting Time (SWT) - Average Waiting Time (AWT) - Total Access Time (TAT) - Equivalent Doorstep Frequency (EDF) - Access Index (AI) - Convert AI to PTAL. Then PTAL maps of the campus can be created to visually display the public transportation access level of each traffic zone [5-8].

4.1. Walking Time

The Walking Time (WT) from each travel point on campus to the bus station or subway station can be calculated according to the following principles:

Assume that the maximum acceptable walking distance to the bus station is 960m (12 min), and the maximum walking distance to the rail transit station is 960m (12 min). The distance is 1200m (15 min), and SAP beyond this range is not included in the calculation. Within the range, if services are available at multiple stations on the same line (such as a school bus station), only the nearest station will be selected as the SAP in the calculation.

The available walking network, walking path selection, and walking distance (m) data come from "Baidu Maps". After obtaining the shortest walking distance (WD) from each travel point to each service point, WD is divided by the average walking speed of pedestriansv_p (4.8 km/h), then the WT from each travel point to each service point can be obtained. The calculation results of SAPs, WD, and WT are partially shown in the table below.

Table 3. Walking time (WT) from travel points 1 to 7 in the Eastern Area to the service point

Travel Point	SAP	WD	WT	Travel Point	SAP	WD	WT
East 1	Main Station of SCUT	1 080	13.5	East 2	Main Station of SCUT	480	6
	Secondary Station of SCUT	1 040	13		Secondary Station of SCUT	480	6
	Wushan Metro Station	760	9.5		Wushan Metro Station	520	6.5
	Main Entrance of SCAU	840	10.5		Main Entrance of SCAU	640	8
	Academy of Agricultural Sciences	1 840	23		Academy of Agricultural Sciences	1 240	15.5
East 3	Main Station of SCUT	680	8.5	East 4	Main Station of SCUT	280	3.5
	Secondary Station of SCUT	480	6		Secondary Station of SCUT	320	4
	Wushan Metro Station	240	3		Wushan Metro Station	320	4
	Main Entrance of SCAU	360	4.5		Main Entrance of SCAU	440	5.5
	Academy of Agricultural Sciences	1 280	16		Academy of Agricultural Sciences	1 000	12.5
East 5	Main Station of SCUT	160	2	East 6	Main Station of SCUT	320	4
	Secondary Station of SCUT	360	4.5		Secondary Station of SCUT	320	4
	Wushan Metro Station	720	9		Wushan Metro Station	240	3
	Main Entrance of SCAU	840	10.5		Main Entrance of SCAU	320	4
	Academy of Agricultural Sciences	720	9		Academy of Agricultural Sciences	880	11
East 7	Main Station of SCUT	520	6.5				
	Secondary Station of SCUT	440	5.5				
	Wushan Metro Station	400	5				
	Main Entrance of SCAU	520	6.5				
	Academy of Agricultural Sciences	520	6.5				

By analogy, the WT of all travel points to service points in the school can be obtained.

4.2. Waiting Time

Waiting time includes scheduled waiting time (SWT) and average waiting time (AWT).

1. SWT is recorded as half of the departure interval (unit: minutes):

$$SWT = 0.5 \times departure\ interval \tag{1}$$

For example, if there are 6 buses per hour and the service interval is 10 minutes, then SWT = 5 minutes. The service interval adopts the public transportation service frequency from 8:00 to 9:00 on weekdays, and the data comes from the "Guangzhou Transportation·Xingxuntong" mobile App.

2. The average waiting time (AWT) is the time that adds some reliability factors based on SWT. Reliability factors vary between modes of public transport to reflect differences in aspects such as buses and rail. In this paper, the time for increasing the reliability factor of buses and trams is 2 minutes, and that of subways is 0.75 minutes.

4.3. Access Index (AI)

1. Calculate the line access time (Total Access Time, TAT)

The sum of walking time and average waiting time:

$$TAT = WT + AWT \tag{2}$$

2. Calculate the line equivalent frequency (Equivalent Doorstep Frequency, EDF)

The line equivalent frequency EDF is:

$$EDF = 0.5 \times \frac{60}{TAT} \tag{3}$$

3. Calculate the access index (AI) of a single SAP

All EDFs of each SAP are weighted and accumulated to obtain the AI of this site. Among them, the largest EDF weight in each SAP is 1, and the weight of other EDFs is 0.5. The calculation formula is as follows:

$$AI_{SAP} = EDF_{max} + 0.5 \sum EDF_{other} \tag{4}$$

4. Calculate the AI of the travel point

Accumulate the AI of all SAPs within the walking range of the travel point to obtain the total AI of the travel point. The formula is as follows:

$$AI_{Total} = \sum AI_{SAP} \tag{5}$$

5. Repeat steps 1-4 until the AI of all travel points is calculated respectively.

4.4. PTAL Value

The range of PTAL is 0~6, and the larger the value, the better the accessibility (connectivity). For historical reasons, the PTAL values of category 1 are divided into 1a and 1b, and values of category 6 are divided into 6a and 6b, so there are 9 PTAL values in total: 0, 1a, 1b, 2, 3, 4, 5, 6a and 6b. PTAL values can be represented on the map with fixed colors.

PTAL is primarily a measure of the density of public transport networks. Places with high PTAL values generally have the following characteristics [9-10]:

1) It is a short walk to the nearby bus stop or subway station;

2) Many vehicles are serving the nearby bus station or subway station;

3) The waiting time at these bus stops or subway stations is very short;
4) A combination of the above characteristics.

The PTAL value can be directly converted from the AI value. The relationship between them and the corresponding colors of the visual map is as follows:

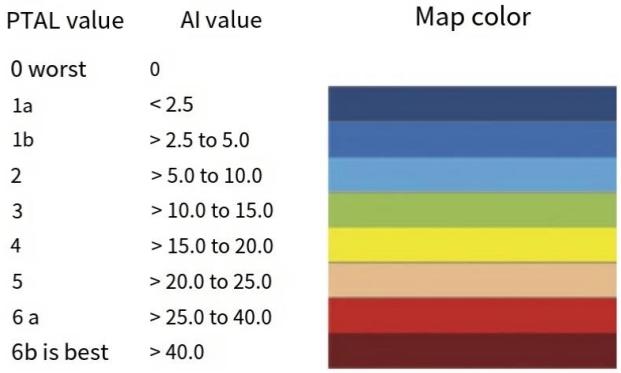

Figure 5. The conversion relationship between PTAL and AI, and the corresponding relationship with map color (Picture credit: Original)

Therefore, the PTAL value corresponding to each travel point is as follows.

Table 4. PTAL at each travel point in 4 areas

Area	Travel Point	PTAL	Area	Travel Point	PTAL
East	East 1	3	West	West 1	1b
	East 2	4		West 2	2
	East 3	5		West 3	2
	East 4	6a		West 4	2
	East 5	6a		West 5	4
	East 6	6a		West 6	5
	East 7	6a		West 7	4
South	South 1	4	North	North 1	1b
	South 2	5		North 2	3
	South 3	5		North 3	3
	South 4	6a		North 4	6b

4.5. PTAL Map

According to the values shown above and their corresponding map colors, the PTAL map of each traffic zone in 4 areas can be drawn as follows.

Figure 6. PTAL map of Western, Eastern, and Southern area (Picture credit: Original)

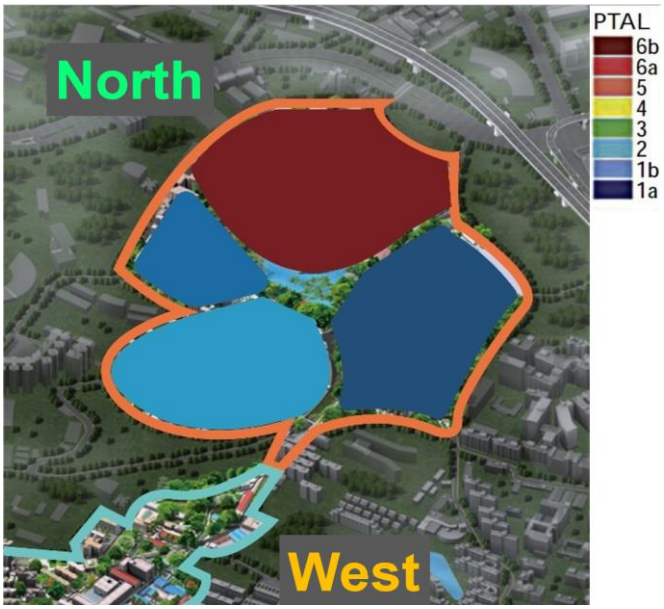

Figure 7. PTAL map of Northern Area (Picture credit: Original)

4.6. Result Analysis

According to the PTAL map, the overall accessibility level in the East Area is relatively good, with 4 of the 7 traffic communities reaching level 6a. This is because they are close to Wushan Road and the school's main road, Zhongshan Road, and the walking range include the Main Station of China University of Technology, there are multiple public transportation hubs such as Huagong University Station and Wushan Subway Station, making traveling very convenient. The remaining traffic communities 1 to 3 in the East Area are backed by South China Agricultural University and the two schools are isolated from each other. The road connectivity is poor and there are relatively few buses stops within walking distance. Therefore, the accessibility levels are 3, 4, and 5 class.

The overall accessibility level of the South Area adjacent to Guangyuan Road and Wushan Road is high, especially South Area 4, which is close to the south gate of the school, has reached level 6a; the rest of the traffic Areas going west and north from the school gate all need to pass through the south gate or south gate. It can only walk to the surrounding bus stops through the side entrance, so the accessibility level gradually decreases. In South Area 1, where the Nanxiu Village residence is located, there is only level 4.

The dormitories near the dining hall of the West Area, the West Second Area, and Dongguan Zhuang Road are far away from each other, and the walking distance from the station on the Guangyuan Expressway is relatively low, so the accessibility level is relatively low, also at level 4. West Areas 2, 3, and 4 are the areas on the north side of West Lake. Since this area is backed by South China Agricultural University, there are only school bus stops and a few buses stops within walking distance. Therefore, the connection coefficient is very small, and the level of bus accessibility is low. Reached level 2. The Affiliated Middle School area in West Area 1 is far away from the school bus stop and also from the off-campus bus stop, so the accessibility level is low.

College buildings in North Area 1 only have school bus stops within walking distance, and the distances are far away. Therefore, this area has the worst bus accessibility in the entire Huagong Wushan Campus, which is 1b. The faculty residences and student dormitories in North Area 2 and North Area 3 are within walking distance of Dongguanzhuang Road Station and the school bus stop. There is bus accessibility, but its accessibility is not high, only level 3. The Boxue Building area in North Area 4 is the area with the highest public transportation accessibility in Huagong Wushan Campus. Because it is close to Tianhe Passenger Transport Station and Changfu Road, there are not only a large number of bus stations within walking distance, but also these stations include Tianhe Passenger Transport There are public transportation hubs such as the Station Bus Terminal, Changfu

Road Terminal, and Tianhe Passenger Terminal Subway Station. Therefore, the bus accessibility of the Boxue Building area is 6b, which is the highest level.

5. Conclusion

This study first divided the Wushan Campus of the South China University of Technology into several traffic areas: east, west, south, and north. Then it analyzed the public transportation accessibility level (PTAL) of these areas. From the perspective of analytical methods, scientific and well-founded calculation methods are used to determine the public transportation accessibility level in the area, and a PTAL map with more reference value can be obtained, which can provide reference and suggestions for the subsequent development of public transportation in the area. In the next step, this study still needs to be improved, including considering the errors caused by travel within the traffic community; considering the walking time errors caused by differences in pedestrian walking speeds, etc.

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