

Considering Non-motor Vehicle and Pavement Safety Measures in Transit-oriented Development

Zehua Chen^{1,†}, Ye Tan^{2,†}, Tianyi Ye^{1,†}, Siqi Zhang^{1,*,†}

¹Chang'an University, Xi'an, China

²Fuzhou University, Fuzhou, China

*Corresponding author: 2021901469@chd.edu.cn

†These authors contributed equally.

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Abstract: The accident rate of pedestrians and non-motor vehicles is high in China now. Therefore, how to reduce the accident rate of pedestrians and non-motor vehicles become the most important task, and it is also the issue which must be faced. The high accident of pedestrians and non-motor vehicles is greatly related to Chinese road traffic setup; setting better road traffic system can improve the issue from the source. In this research, an index system is built to evaluate the friendliness of urban walking and non-motor vehicle. Quantitative analysis on urban sectional sidewalk and non-motor way design. In the end, the research come up with the planning and design suggestions of how to improve the sidewalk and non-motorway around the college in the city.

1. Introduction

At present, pedestrian and non-motor vehicle safety in China is area point of concern. In 2021, 11,485 traffic accidents occurred in China, resulting in 5,799 deaths and 8,018 injuries. Compared with most developed countries, traffic accidents in China have a significant feature, that is, 75 percent of traffic accident deaths happen to transportation vulnerable groups. Pedestrians and non-motor vehicles, as the main part of the vulnerable groups in China, are frequently involved in traffic accidents and their life safety is seriously threatened. Therefore, solving the problem of high accident rates among pedestrians and non-motor vehicles has become a challenge that needs to be dealt with as soon as possible. The high probability of pedestrians and non-motor vehicles accident is closely related to the design of road. Setting up a better road design system can address the problem fundamentally. At present, the transit-oriented development (TOD) walking environmental index evaluation system, which uses systematic indices to evaluate the safety of the walking environment, has made great contributions to improve the evaluation of pedestrian safety, but has not factored in the safety of non-motorized lanes into the system. Therefore, the non-motor vehicle driving environment is still relatively complex and the safety factor is low. In order to integrate sidewalks and non-motor vehicle travel environment into an organic whole and effectively improve the safety of non-motor vehicle travel, this paper aims to introduce non-motor vehicles into the TOD walking environmental index evaluation system by adding non-motor vehicle related indices.

2. Literature Review

TOD was proposed by American scholar Peter Calthorpe from the late 1980s to the early 1990s, and it is widely recognized as one of effective ways to reduce traffic congestion and environmental pollution. Through many years of practice and theoretical exploration, it has become a relatively mature principle of urban planning and design to harmonize urban traffic and development effectively [1]. An excellent walking environment is one of four characteristics of TOD and the walking accessibility is the core of planning and design during the fundamental development of TOD. At present, there are evaluations about environment-friendly walk ability, but there are a few

transportation planning researches considered the area planning walking and non-motorized vehicles, and most of them are connection researches of urban rail public transit under the TOD schema. Generally, TOD planning emphasizes development efficiency but ignores two aspects which are environment quality and social equity [2]. Today, develop of subway in China has been rapidly increased, which relieve the transportation in cities and make citizens life more convenient, but it also brings some developing problems [3]. Develop of subways builds some business quarters where may have the problems between pedestrians and non-motor vehicles. Reuben Tamakloe, et al., explore the efficiency of TOD in Seoul by a two-stage bootstrap Data Envelopment Analysis with truncated regression [4]. Myung- Jin Jun, et al., evaluate the land-use-characteristics of the pedestrian catchment areas (PCA) of subway stations in Seoul metropolitan area (SMA) by TOD principles and they find that the built environments of subways in Seoul is similar to TOD principles [5]. Considering the large amount of people, the possibility of conflict between pedestrians and non-motor vehicles may be increased. Zhao Pengjun and Wang Yue emphasize the mixing functional zone, according to the difference of destinations to evacuate induced abortion and avoid mutual interference of transportation, business, work and other function, in so to achieve the optional utilization of land [6]. This measure is suitable for walking friendly, and it can be combined with non-motorized vehicle lane planning at the same time. This needs to statistic and analysis the using condition of different urban lands and shunt the crowds and vehicles according to directions in advance. For example, improve colorful non-motor vehicle lanes and non-motor vehicle crossing belt and increase non-motor vehicle priority waiting area to avoid the accidents. Wang Hongyan et al., mentioned that the traffic characteristics of mixed road in China is the significant reason for frequent accidents of pedestrians and non-motor vehicles. According to the research of characteristics of these accidents and accidents injury, it will provide begin reference for reducing personal injury effectively [7]. Zhao Pengjun and Wang Yue has mentioned that Beijing Dawang Road station which perimeter is the core of the commercial district, is close to Beijing East railway station with a great stream of people and vehicles [6]. Therefore, it is recommended to combine the entrance and exit of the railway station with the large public architectures, developing underground space and construct air corridor where the traffic is in congestion at the same time. This measure can effectively separate people and traffic flow in different planes without interference, which not only can ensure the safety and continuity of the walking environment, but also can make the city car traffic from interference. To reduce pedestrian and non-motor vehicle accidents from the aspect of reducing mixed road traffic has great significance for improving the current high traffic accident rate in China.

Xiong Wen et al., propose a demonstration design for improving continuity of non-motorized traffic, and indicate pedestrian and bicycles' commuting corridors, bottlenecks and risk points [8]. For example, not only can we improve the color non-motor vehicle lanes and non-motor vehicle crossing belt, but also add non-motor vehicle priority waiting area, non-motor vehicle phase, non-motor vehicle parking facilities, signs and lines, channelized railings and crossing parasols and so on [8]. The concept of non-motorized transport planning based on humanism, health and wisdom, TOD mode and the concept of promoting the development of urban public transport coincide [9]. However, most of the current articles focus on how to coordinate and reasonably cooperate with other travel modes in order to give full play to their own advantages. As an emerging force in the public transport system, rail transit is more and more popular. How to make more efficient use of urban rail transit [10]. However, at present, researches on TOD rarely involves the evaluation of walking environment and non-motor vehicle friendliness.

3. Methodology

3.1 Yong Jia market

The survey area is an entire metropolitan area and conform to TOD, characterized by "mixed-use" for work, business, culture, education and residence. Yong Jia market is chosen as the survey area to analyze non-motorway and pavement safety measures. Yong Jia market is a large integrated business district near Fuzhou University. There is one middle school, one university, two markets and a

residential area around the survey area. TOD research the area which radius are around 500 meters. This research chose the radius of 500 meter around Yong Jia market, the specific area can be seen in figure 1.

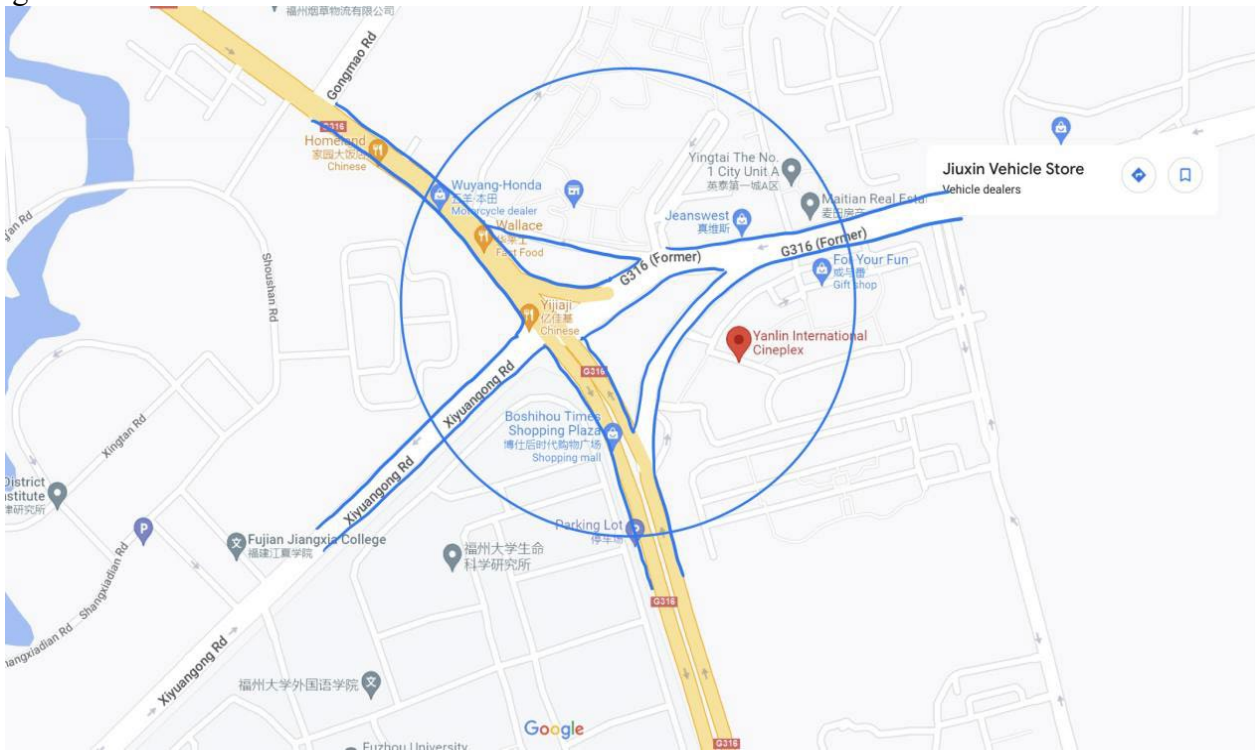


Figure 1. Survey area.

3.2 Evaluation index system and quantitative criteria

To collect residents' and riders' needs for the environment, an evaluation index system was built on the walking feeling of residents and the problems existing in the walking environment [7]. A questionnaire survey and in-depth interviews are conducted among the residents around the subway station, and the characteristics of pedestrian walking are analyzed and discussed [7]. The authors gave an evaluation index system and quantitative criteria and used this system to study the walking environment around subways. Health and wisdom selected specific areas, road sections, and time periods randomly shot the behavior of walkers and cyclists in streets and squares and summarized the needs of walkers and cyclists based on the classification, frequency division and cluster analysis of massive data [9].

Referring to the questionnaire survey results of the above two articles and the feedback on the environmental needs of walkers and cyclists, safety, comfort, and convenience are the three aspects that walkers and non-motor vehicles are most concerning mainly.

This research uses an evaluation index system [7]. The indexes system can be seen in Table 1.

Table.1. Evaluation index system and quantitative criteria.

Index	Factor	Evaluation method
Safety	Pedestrian safety	Proportion of overpasses and pedestrian crossings in intersections
	Pedestrian area ratio	Ratio of pedestrian road area in the area to the area of the area
Comfort	Avenue coverage	Greening on both sides of pedestrian roads Ratio of coverage area to the whole
	Sunshade and rain shelter	Ratio of non-motorized waiting areas with sunshade and rain shelter facilities
	Student access and transportation needs	Ratio of passing time during general study to the time required in normal period
Convenience	Road network density	Ratio of the length of pedestrian roads
	Conflict rate between non- motorized lane and sidewalk	Ratio of sidewalk parking occupied by non- motor vehicles
	Pedestrian road scale	Ratio of total pedestrian road area to whole area

3.3 Questionnaire survey

To collect residents' and riders' needs regarding travel conditions in the Yong Jia market, this questionnaire survey is granted to Fuzhou university and other schools which are located nearby. In consideration of the English level situation of students, Chinese and English questionnaires were prepared and set for students. The English questionnaire content is summarized in Table 2.

Table 2. Non-motorway design survey.

No.	Question
1	Your gender
2	Your school
3	What is the transportation you take from school to Yong jia market?
4	How safe and convenient do you think it is on the way from school to Yong jia through the non-motorized lane?
5	Do you think the design of non-motorized lanes near Yong jia is safe?
6	How many non-motor vehicle parking spots are there?
7	Do you think the number of non-motor vehicle parking spots is sufficient?
8	Do you think the location of non-motor vehicle parking is convenient and reasonable?
9	Do you think the green area near the non-motorway is enough?
10	Do you think non motor vehicle parking seriously occupies the sidewalk?
11	Where would you like to add more parking spots?
12	What do you think are the shortcomings of the sun shading and rain shelter facilities in non-motor vehicle lanes, and do you have any suggestions for improvement?

4. Results

4.1 Evaluation index system

This is the result of TOD index after calculating as shown in Table 3. As the result of research of TOD index, the proportion of number overpasses and pedestrian crossings in intersections is 100%. And the ratio of pedestrian road area in the area to the area of the area is 26%. These indicators illustrate the safety of existing pedestrian is enough, but the number of the existing is not enough in the area of investigation. The result about the comfort of non-motorway shows the Greening on both sides of pedestrian roads is 87%. But the ratio of coverage area to the whole is 0%. That shows that the non-motorway is more comfortable on sunny days, but it is not comfortable on a rainy day. For the results of the survey about the convenience of non-motorway, the ratio of the length of pedestrian roads is only 27%. The ratio of sidewalk parking occupied by non- motor vehicles is 25%-30%. All of these data show that this walkway is not very comfortable for pedestrians. Based on the data from the survey of non-motor vehicle environments into the computing system, we can find that the environment of non-motorway around the Yong jia mark is not safety, comfortable and convenient for people around the mark. That provides an existential necessity for our research.

Table 3. The results of Evaluation index system and quantitative criteria.

Index	Factor	Evaluation method	Data
Safety	Pedestrian safety	Proportion of overpasses and pedestrian crossings in intersections	100%
	Pedestrian area ratio	Ratio of pedestrian road area in the area to the area of the area	26%
Comfort	Avenue coverage	Greening on both sides of pedestrian roads; Ratio of coverage area to the whole	87%
	Sunshade and rain shelter	Ratio of non-motorized waiting areas with sunshade and rain shelter facilities	0
Convenience	Road network density	Ratio of the length of pedestrian roads	27%
	Conflict rate between non-motorized lane and sidewalk	Ratio of sidewalk parking occupied by non-motor vehicles	25%-30%

4.2 Results of the questionnaire survey

The survey surveyed 150 people, most of the respondents were students at Fuzhou University. According to the result of the survey shown in Table 4, 63.09% of the students choose non-motor vehicle to go to Yongjia mark, and 24.83% of the students choose to walk to there. That occupy the majority of students travel method. And there are still 38.67% of students think it is inconvenient to go to Yongjia mark through bicycle lane, 52.67% of students think the non-motorway design around the Yongjia mark is not safe. As can be seen from the results of this part of the survey, students feel that there are many bad designs in the non-motorized lanes near the school, but this incident has been continued and has not changed until now. And most of student think the non-motor vehicle parking point is not enough around the Yong jia mark. There are only about three or four stops for non-motor vehicles. All these prove the necessity of our experiment. 81.21% of students think the number of parking of non-motors is not enough. 65.33% of students think the parking is not comfortable, and about half students think there is not enough green space around non-motorway. And only 10.74% of students think non-motor vehicle parking does not occupy the pavement. The result of questionnaire survey shows the non-motorway is not comfortable for people around the Yong jia mark. That shows people have a lot of comments about the non-motorway environment in their daily life. But the transportation agencies concerned have not improved these problems until now and there are not some suggestions for the transportation agencies concerned. Therefore, this research can add the suggestions to this field to the relevant transportation organizations, so that the relevant traffic workers are aware of the problem and make improvements in the future.

Table 4. Survey results.

No.	Option/Statement
1	Female (62%)/Male (38%)
3	Non-motor vehicle (battery car) (63.33%)/ Motor vehicle (12%)/Walking (24.67%)
4	Convenient (61.33%)/Inconvenient (38.67%)
5	Safe (47.33%)/Unsafe (52.67%)
6	2 (25.33%)/3 (36.67%)/4 (22.67%)/5 (15.33%)
7	Enough (18.67%)/Not enough (81.33%)
8	Convenient (34.67%)/Inconvenient (65.33%)
9	Enough (58%)/Not enough (42%)
10	Seriously occupied (37.33%)/Occupied but acceptable (51.33%)/Unoccupied (11.33%)

5. Discussion

5.1 TOD

According to the results, in TOD mode, non-motor vehicle travel mode accounts for a high proportion, but its satisfaction is low. This shows the necessity of this study. In order to quantify the safety factor of non-motor vehicle travel, this paper selected the proportion of sidewalk parking Spaces occupied by non-motor vehicles and the proportion of non-motor vehicle parking Spaces with sun and rain protection facilities. Through investigation and research, these indicators do have practical significance to improve the satisfaction of non-motor vehicle travel. By adding these indicators, non-motorized lanes and pedestrians can be regarded as an organic whole, and the travel safety factor of a certain TOD model area can be evaluated more clearly.

5.2 Reason

According to the results of the questionnaire, people's satisfaction with non-motor vehicle travel is low, indicating that its safety has not received enough attention. In the planning of the TOD model, the safety of pedestrians is fully considered. The possible reason for this result is that people ignore the safety of non-motor vehicle travel. Although non-motor vehicle travel accounts for a high proportion of People's Daily life, non-motor vehicle parking is still difficult to solve. It shows that people do not attach importance to non-motor vehicle travel. More people think that the driving experience of non-motor vehicles is poor, which may be due to the lack of obvious zoning of non-

motor vehicle lanes, the lack of clear travel specifications for non-motor vehicles, and the low safety factor of non-motor vehicle travel. This shows that the safe driving environment of non-motor vehicles has not received enough attention and still needs to be improved. As a part of the TOD model, non-motor vehicle safety was not taken into account. This is the part that this article wants to supplement. This paper hopes to attract people's attention to the safety of non-motor vehicle travel by incorporating the evaluation index of non-motor vehicle safety factor into the safety evaluation system of the TOD model, so as to improve the safety of non-motor vehicle travel.

5.3 Defect

The weight determination of indicators is still subjective: the evaluation system improves universality through surveys and other methods, but there is no objective way to determine the weight of each indicator. Therefore, the evaluation system still has some subjective factors.

6. Conclusion

This project was undertaken to design an evaluation index system and quantitative criteria, and evaluate the sidewalk and non-motorway around the college in the city. This work contributes to existing knowledge of TOD in public transportation on Yong Jia market in Fuzhou. The investigation of TOD which based on evaluation index system and quantitative criteria has shown that area around Yong Jia market has transportation problems: 1. Vehicles and stalls occupy the road phenomenon is serious, this condition decreases the willingness of residents to travel on foot. 2. The mixture of people and traffic flow increases the risk of walking. 3. The lack of open space. Open space can provide a place to rest. Suitable open space increases the willingness of residents to choose walking. The limitation of this research is focuses on the spatial environment and considers less about the management aspects such as policies and regulations. In the future, laws and regulations in Fuzhou will be researched and the solution how to make the design and management of the planning department provide certain theoretical basis and technical support.

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