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Investigation of Pedestrian Safety Problems and Its Countermeasures: A Case Study in Nekemte City, Ethiopia

Hayu Alemgena, Prof. Emer Tucay Quezon, Tarekegn Kumela

Abstract— **The actual growth of urban economic activities and simple movements of peoples and goods measured through its primary transport system. The requirements of the pedestrian should be considered in the design of the urban environment and transportation facilities. Since road infrastructure improvements and designed pedestrian environments are an essential part of road safety enhancements that increase walking and decrease fatalities. This study investigated the pedestrian safety problems and its countermeasures on road segments in Nekemte city. This study examined the existing issues affecting the safety of pedestrian movement, evaluates the service quality of walking facilities, and finally identified the most significant factors affecting pedestrian safety with engineering countermeasures in the city.**

For the data analysis, the study used both objective measurements and subjective assessments to model PLOS using Australian methods. As per field study indicates 60% of the respondents' think the sidewalk is not user-friendly. In the city, the built road infrastructure is lacking pedestrian facility management and appropriate maintenance activities. Since the walkways in Nekemte city, in general, have almost the same problems like non-continuous, crack, and non-covered utility holes which are difficult especially for pedestrians with disabilities. The current sidewalk is encroached either by vendors, utility poles, parking carts or illegal construction materials in different places, and crosswalk facilities are not visible and not enough provided at a logical distance. The Pedestrian LOS analysis indicates that poor pedestrian conditions exist and the factors that negatively affect pedestrian LOS are wide-ranging in this city road segment.

It concluded that Pedestrian facilities and all the concerned factors should be provided and maintained to more efficient for both encouraging people to walk and improve pedestrian safety.

Index Terms— **Pedestrian facility, Pedestrian Level of Service, Pedestrian safety problem**

I. INTRODUCTION

In the Development of one's country, urban economic activities and movements of peoples and goods measured through its primary transport system. The adequate transport system is needed to facilitate a more excellent choice of the peripheral areas if urban transport provided by the nearby authorities. A comfortable environment makes a journey by foot pleasant and enjoyable.

Walking is the most common mode of movement between places, irrespective of towns and cities. In Ethiopia, most daily trips are made on foot for different purposes, just as they did in many other low-income, developing countries. A pedestrian-friendly environment plays a vital role in encouraging walking as a mode of travel, and this will prove health and environmental benefits [16].

This research was considered the various factors that influence people's willingness to walk, and other contributing safety issues in the area of a walkway. The study also investigated on pedestrians' perception of their environment and the expectations they have of pedestrian facilities and sought to identify the benefits that can result from improved pedestrian facilities. In situations where sidewalk facilities are either encroaching or occupied by vendors and hawkers or poorer sections, the pedestrians are forced to walk on a portion of the carriageway or shoulders.

The objectives of this research were: (a) to investigate the conditions of pedestrian walking facilities in the city; (b) to evaluate the service quality of pedestrian facilities at road segments in the city; (c) to identify the most significant factors affecting pedestrian safety based on PLOS analysis; and (d) to recommend engineering countermeasures for the identified problems.

II. RESEARCH METHODOLOGY

A. *Research design*

The methodology conducted in this study is statistical analysis; the data were used to show the present pedestrian level of services of the road segments in Nekemte city, Ethiopia. The collection of data includes both quantitative and qualitative data. The subjective assessment is done by pedestrians' perception over their safety, whether the facility is environmentally friend or not which is collected by questionnaire. The objective measurement is implemented using a pedestrian level of service to show the extent of the problems in qualitative aspect. The PLOS which is a qualitative measure is chosen as an overall approach to its ability to incorporate different methods and techniques in the collection and analysis of data that focuses on the various issues of the study.

B. *Sampling techniques and data collection*

Purposive and random sampling approached used for area and population selection. The method of sampling based on the areas where pedestrian movement is reasonably complicated. These are the market area, commercial area, education area and residential area roadway segments in Nekemte city.

For this study, the primary and secondary data used. The primary data was collected from the site using questionnaire, field investigation (actual field observations), and pedestrian

count (volume) data. The secondary data obtained from Nekemte city municipality like a standard master plan etc.

III. DATA ANALYSIS

A roadway characteristics based measurement of safer pedestrian walking environment is dependent on the provision and quality of the walkways or pedestrian facilities. These methods use pedestrian perceptions and attempt to quantify the comfort level of pedestrians while encountering specific roadway characteristics [15].

The pedestrian walking environment in any urban road segments like the footpath and different pedestrian facilities may tend to be affected due to various factors that decrease the pedestrian safety. Pedestrian spaces should be designed in consideration of human convenience and have to be qualitatively suitable to the needs of human beings.

Factors affecting the service quality of pedestrians' are an overall measure of walking conditions on a route, path, or facility. Investigating these affecting factors links directly to the performance measure criteria's such as mobility, comfort, convenience, and safety, which reflects pedestrian perceptions of the degree to which a facility is pedestrian friendly [9].

A roadway characteristic-based Pedestrian Level of Service modeling based on a point system divides the factors into physical/geometric characteristics, location facilities, and other factors. These are those factors affecting Pedestrian LOS. There are about eleven local factors distributed under these three categories to ensure that the assessment process is user-friendly. Physical characteristics considered include sidewalk width, surface quality, obstructions, crossing opportunities, and support facilities. Location factors address issues related to connectivity, path environment, and the potential for vehicle conflict. User factors take into consideration pedestrian volume, a mix of both users and personal security [9].

A. Physical/Geometric Characteristics

A geometric feature is one of the most critical parts of developing a roadway design focuses on the selection and configuration of the elements that comprise the roadway cross-section. There are many important factors and all of them add to the ability of pedestrians to use the provision. Therefore, there are five different significant factors considered under this physical characteristic need to investigate to ensure pedestrian safety.

a. Conditions of sidewalk facilities – Suitability and Connectivity

Sidewalks play an essential role in transportation, as they provide a safe path for people to walk along that separated from the motorized traffic. It is a description of the quality of the path's surface. The continuity of the pedestrian facility is significant for the pedestrian with disability and of old age. Since the walkways in Nekemte city, in general, have the problem of frequent curb cuts along a street both impede traffic flow and create more conflict points between vehicles and pedestrian, thus reducing the effectiveness of footpaths.

Table 3.1: Field study of conditions of sidewalks and level of obstructions in Nekemte city

<table>
<tr><td rowspan="2">Study Area</td><td colspan="3">Conditions of Sidewalk</td></tr>
<tr><td>Continuity of sidewalks</td><td>Illegal Occupancy</td><td>Remark</td></tr>
<tr><td>Market</td><td rowspan="2">Noncontinuous</td><td rowspan="2">Vendors, building portions</td><td rowspan="4">Almost no curb ramps provided and more uncovered utility holes present</td></tr>
<tr><td>Commercial</td></tr>
<tr><td>Educational</td><td rowspan="2">Almost continuous</td><td>Almost None</td></tr>
<tr><td>Residential</td><td>Parking and building portions</td></tr>
</table>

Fig. 3.1: Sidewalk quality problem, absence of buffer and presence of illegal occupancy on walkway in Nekemte city

b) Sidewalk Width

The sidewalk width in different areas of urban in developed and developing countries is different based on the side features they used to enhance the roadside safety. Wherever roadside and land development conditions affect regular pedestrian movement along a highway, a sidewalk or path area, as suitable to the conditions, should be furnished.

Table 3.2: Pedestrian count, walkway width vs. Master plan and standard walkway width

Study Area	Pedestrian count (peak/day)	Existing walkway width (m)	Master plans walkway width	Standard walkway width /ADA/
Market Area	1876	1.90	2.5	3.0
Commercial Area	1765	1.40	2.5	3.0
Educational Area	2,117	2.40	2.5	3.0
Residential Area	1,246	2.10	2.5	3.0

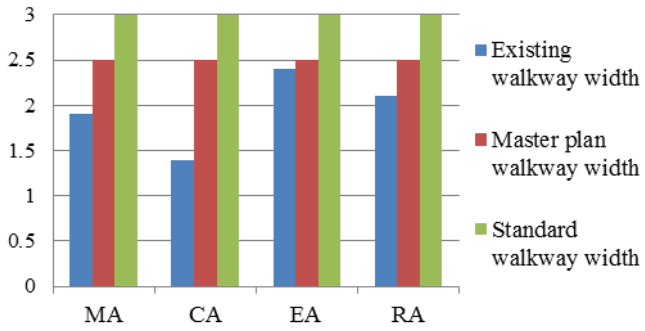

Fig. 3.2: The existing, master plan and standard walkway width description (ADA, AASHTO)

b. Obstructions on pedestrian sidewalk

The pedestrians forced to use the carriageway in either of the two cases; one the pedestrian facility is fully encroached and another in the absence of a pedestrian facility. It encroached the facilities studied is a measure of the number of obstructions per kilometer on the path being assessed. Assessment of this factor is essential to determine the access available to people with disabilities.

Obstructions tend to influence pedestrian movement and reduce the effective walkway width. Therefore. the assessment of obstructions is essential to determine the access available to pedestrians. Thus, the current walkways in Nekemte city entirely encroach especially in Market and Commercial areas by vendors, utility poles, parking carts and illegal construction materials. These segments are not comfortable in general, and it is right to say no walkway in Nekemte market and shopping areas because the behavior of vendors in the city always seen by using only on the sidewalk even where the space available. In a Residential area, parking lot and illegal construction materials are challenging the pedestrians on a sidewalk as an obstruction, and it needs to consider by neighbor authorities to maintain and to take legal actions for further user safety.

Fig. 3.3: Different types of sidewalk obstructions around Hospital, Bordi and in front of Nekemte Auditorium

c. Pedestrian Crossing Facilities

The pedestrian crossing facilities are the most important factors needs consideration in enhancing the pedestrian safety and well normal walking of pedestrians. This service, the type, and some facilities, provided to assist in the safe crossing of roads and paths by pedestrians. Marked crosswalks warn drivers that pedestrians might cross the street. These markings help vehicles yield to pedestrians and provide a safe and designated area for pedestrians to cross. Where walkers choose to cross roadways can significantly expose them to the risk of collisions. Therefore, this study investigated crosswalk facilities based on adequacy and functionality of the facility to make them more comfortable crossing with reasonable distant on the segments in the city.

d. Support Facilities

The presence of this facility assists the pedestrian during their journey and improves pedestrian safety dramatically. This type of facility includes color contrast curbing, provision of rest stops, curb ramps, lane markings, signage and landings on long ramps. Additionally, buffers to sidewalks give pedestrians a safer and more comfortable space separating them from vehicles on the road.

B. Location Facilities

The safety of pedestrians was severely affected by the traffic growth of traffic and inadequate pedestrian network, especially in the Central Business Districts. There are three sub-factors under this location, facilities namely connectivity of paths/roads, sidewalk environment, and potential for vehicle conflict.

Table 3.3: Sidewalk environmental problems in study area of Nekemte city

Study Area	Street Furniture	Greening Environment	Remark
Market Area	None	Not provided	Greening median provided for aesthetic purposes
Commercial Area	None	Not provided	
Educational Area	None	Not provided	
Residential Area	None	Almost provided	

C. User Factors

There are three different user factors those affect the pedestrian walking environments such as pedestrian volume, the mix of path users, and personal security. Pedestrian volume is a count or estimate of the number of pedestrians using the path expressed as an average daily count. A mix of path users is an estimate of the various groups who use the path as a percentage of total pedestrians. Therefore, on all the study segments there are estimated at 80% of the users are pedestrian. The other best factor is personal security which is a qualitative measurement of the degree to which the path is safe for users. Characteristics of this factor include the provision of adequate lighting (from both direct and indirect sources), path visibility of the surrounding environment, sight distance, etc. In Nekemte city the study observes that some people do not walk at night because they are frightened about being attacked. As for the areas observed the lighting facilities are available in the nighttime while walking on the walkways. Unfortunately, most of them are not working correctly due to lack of proper maintenance at a regular interval, and this leads presence of the illegal pickpocketing and the snatch bags.

IV. RESULTS AND DISCUSSIONS

A. *Subjective evaluation - Pedestrian behavior and attitude*

The personal assessment based on the user's perception rating of the service quality of pedestrian facilities. User perceptions toward the operation of pedestrian facilities are of great importance to such an evaluation process. This type of survey is performed among pedestrians to understand the feeling of users while walking at the study locations. Pedestrians themselves are the most appropriate group to identify treatments that create a safe and desirable environment for them and options that increase their likelihood to use of the walker at designated facilities correctly.

A distribution questionnaire was undertaken to assess the pedestrians' perception of the conditions of pedestrian facilities. The perception rating categories include "Yes" or "No" which expresses the issue in percent, and also "Excellent," "Good," "Satisfactory," "Poor," "Very poor" which is ranked from 4 to 0 score values respectively.

a) Pedestrians' Purpose of Walking

In Nekemte City, pedestrians are walking for different purposes.

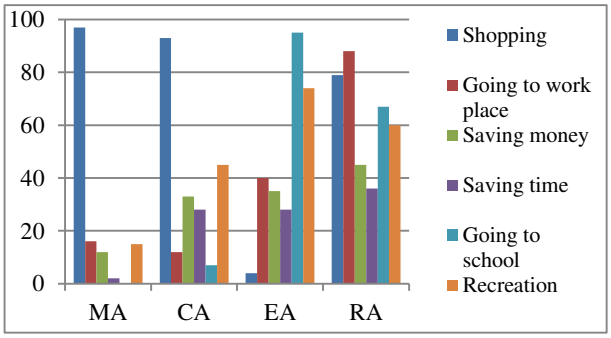

Fig. 4.1: Pedestrians' Purpose of Walking in Nekemte City (source: field survey)

b) Descriptive of survey respondents

According to the questionnaire survey, it found out there are 69% male of the respondents, and 31 % female. The total number of pedestrians at all locations, 49% aged between 15 years to 25years old, 34% between 26 to 35 years old, 14% between 36 to 45 years old, and the rest above 45years old. Twenty-seven percent (27%) of the overall respondents were office workers, and 35% students,

18% Business employees, 5% parents of students and 15% belong to other occupations. Among all distributed, 403 questioners, there are 372 respondents and the rest 31 none respondent. The response rate becomes 92.31%.

c) Pedestrians' Perception about the Sidewalk Condition

The subjects were asked a series of Yes-or-No questions about the present status of pedestrian walking facilities how it is user-friendly. In general, 40% of the respondents' think the sidewalk is user-friendly, and 60% believe not which is saying the sidewalks in Nekemte road networks are at risk and needs to improve for more pedestrian safety.

Table 4.1: Pedestrians‟ view about the user-friendliness of sidewalks

Location	Sidewalks are user-friendly	
	Yes (%)	No (%)
Market Area	12	88
Commercial Area	34	66
Educational Area	58	42
Residential Area	54	46
Total respondents	40%	60%

d) Pedestrians' Preference for Using the Sidewalk

Pedestrians prefer to use the sidewalks in some locations, but, they do not exist in the other areas as shown in Table 4.2. Overall, 57% of the respondents prefer to use the sidewalk while 43% do not.

Table 4.2: Pedestrians‟ preference for using the sidewalk

Location	Pedestrians' Preference for Using the Sidewalks	
	Yes (%)	No (%)
Market Area	8	92
Commercial Area	48	52
Educational Area	83	17
Residential Area	90	10
Total respondents	**57**	**43**

e) Reasons for not preferring the sidewalk

Several options provided for the respondents to choose why they do not prefer the sidewalk. Fig. 4.2 shows that the majority of users of the respondents do not prefer the sidewalks due to street vendors, discontinuity of sidewalk, poor quality of sidewalk respectively.

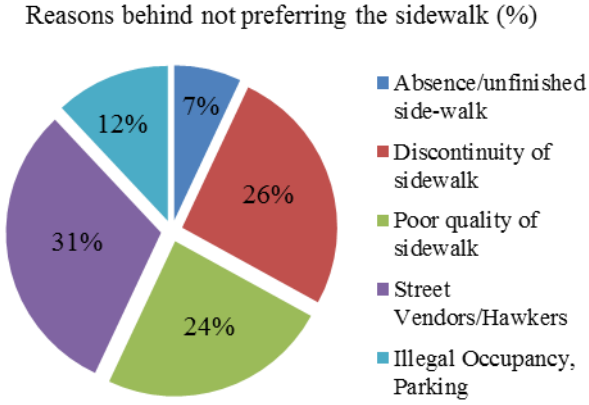

Fig. 4.2: Reasons for not preferring the sidewalk

f) Pedestrians' Perception about the Sidewalk Environment

Pedestrians of the mentioned locations were requested to rate the sidewalk environment using a Likert scale where zero is for the very bad environment, one is for bad, two is for good,

three is for very good, and four is for excellent sidewalk environment. The pedestrians are further affected chiefly by the urban noise pollution due to different snow, and waste materials mixed with liquid flow in the side drainage ditches.

Table 4.3: Pedestrians' feeling about the sidewalk environment

Location	Pedestrians feeling about the sidewalk environment (%)					Result
	Very Bad	Bad	Good	Very good	Excellent	
MA	34	29	25	8	4	Unpleasant
CA	14	30	22	18	16	Poor
EA	9	12	36	21	22	Acceptable
RA	10	34	22	14	20	Poor

g) Pedestrians' Perception about personal security on the road segments

The feeling of being secure is the most important governing factor for safety. A pedestrian should feel safe during the day as well as night while using a walkway/crosswalk.
Reasons for feeling threatened at night:

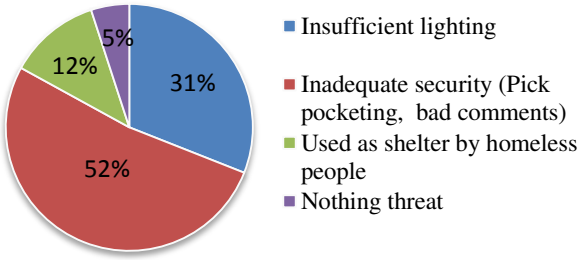

Fig. 4.3: Pedestrians' perceptions about feeling threatened at night

B. Objective measurement

The objective measurement consists of determining PLOS of four different study locations; adopting field and users" perception data on Geometric, Location and User Factors. These are linked directly to factors that affect mobility, comfort, and safety, reflecting pedestrians' perceptions of the degree to which the facility is *pedestrian friendly*.

a) Measurement process for Factors affecting pedestrian LOS

The measurement process for each of the above factors should be measured during site visits, although some can be examined through a desktop assessment and it may depend on the user's perception. Each factor is carefully defined to ensure consistent understanding by a wide audience.
The score allocated to each factor, according to the quality and operating conditions. Minimum Score is "0," and the maximum score is "4". The score "0" represents worst pedestrian facility quality and operating conditions (Discontinuous, narrow sidewalks, unpleasant environment, etc.) While the score "4" represents best facility quality and operating conditions (Continuous, wide, clean, well-paved sidewalks, well-marked crosswalks, etc.).
In a technical description of the factors, five levels of facility quality and operating conditions for each factor described. Hence the weighted cumulative score of each successively lower level could represent lower boundary for the upper level of service grade. Thus, based on weighted cumulative scores, five pedestrian levels of service grades, A to E is defined. These grades relate to the adequacy of pedestrian facilities provided that affect PLOS [9].
Based on this understanding, and the definition of factors influencing pedestrian LOS, the following LOS grades were defined:

- **LOS A** - is a pedestrian environment where ideal pedestrian conditions exist, and the factors that negatively affect pedestrian LOS are minimal.
- **LOS B** - indicates that reasonable pedestrian conditions exist, but a small number of factors impact on pedestrian safety and comfort. As LOS A is the 'ideal,' LOS B is an 'acceptable' standard.
- **LOS C** - indicates that necessary pedestrian conditions exist, but a significant number of factors impact on pedestrian safety and comfort.
- **LOS D** - indicates that poor pedestrian conditions exist and the factors that negatively affect pedestrian LOS are wide-ranging or individually severe. Pedestrian comfort is minimal, and safety concerns within the pedestrian environment are evident.
- **LOS E** - indicates that the pedestrian environment is unsuitable. This situation occurs when all or almost all of the factors affecting pedestrian LOS are below acceptable standards.

Some simple steps need to be completed to determine the pedestrian LOS grade for a selected path segment.

Table 4.4: Pedestrian LOS Grade Scale (Gallin, 2001)

LOS Grade	Range of Scores
A	132 or higher
B	101 to 131
C	69 to 100
D	37 to 68
E	36 or lower

b) Field investigation and users' perception based PLOS

Table 4.5 describes the assessment process for each of the factors in Commercial area, for instance. Most factors should be measured during site visits/investigations, although some can be examined through a desktop assessment. Within the pedestrian LOS definition, there is a range of LOS for pedestrians. Based on this range, some 'LOS grades' are defined. These graded definitions relate to the adequacy of facilities for pedestrians and are intrinsically linked to the eleven factors affecting pedestrian LOS.

Table 4.5: Rating and criteria of the PLOS factors in Commercial area road segment, between Nekemte Auditorium and Anwar Mosque

SN	Geometric, Location and User Factors	Measurement/value	Weight	Score	Weighted Score
1	Average sidewalk Width (m)	1.40	4	2	8
2	Average Surface Quality	Poor quality	5	1	5
3	Number of Obstructions (Per Km)	Utility Poles, illegal construction materials, and vendors	3	2	6
4	Crossing Opportunities	Some provided, but poorly located	4	1	4
5	Support Facilities	Non-existent	2	0	0
6	Connectivity of roads	Good	4	3	12
7	Sidewalk Environment	Poor environment, closed to vehicular traffic	2	1	2
8	Potential for vehicle conflict	Poor, 18 conflict points, i.e., 2-three leg junction on the path segments	3	1	3
9	Pedestrian Volume	Assumed 1765 per day	3	0	0
10	Mix of path Users	Mostly pedestrians, assume more than 80%	4	3	12
11	Personal Security	Poor, limited street light and poor, inadequate security	4	2	8
Total Weighted Score					60
LOS result					**D**

Table 4.6: PLOS results for all studied segments

SN	Study Area	Weighted Score	LOS
1	Market Area	50	**D**
2	Commercial Area	60	**D**
3	Educational Area	78	**C**
4	Residential Area	82	**C**

Based on the results from the commercial analysis area and Market area sidewalks are operating at LOS grade D. This grade indicates that poor pedestrian conditions exist and the factors that negatively affect pedestrian LOS are wide-ranging or individually severe. Pedestrian comfort is minimal, and safety concerns within the pedestrian environment are evident in this commercial area road segment. Comparing with the other study areas, the Educational and Residential area sidewalks were found to operate at a pedestrian LOS of C grade. Since it indicates that basic pedestrian conditions exist, but a significant number of factors impact on pedestrian safety. Therefore, under each study area, it is suggested that factors are affecting as per their listed weighted score and they are required to improve the pedestrian safety.

V. CONCLUSIONS

For safety and comfort purposes, pedestrians need facilities that are safe, attractive, convenient, and easy to use especially appropriate walking facilities in any city. Poor design of pedestrian facilities can lead to endless problems and can discourage the pedestrians due to a feeling of unselfishness, unprotected, or uncomfortable. So, the needs of the pedestrian should be considered in the design of urban environments and transportation facilities.

The users' perception revealed that 60% think the sidewalk is not user-friendly. The sidewalk quality and continuity of the facility is essential for the pedestrian with disability and of old age. Since the walkways in Nekemte city, in general, have almost the same problems like non-continuous, crack, and non-covered utility holes which are difficult, especially for pedestrians with disabilities and also risky at night time for all the users. Frequent ups and downs make the footpath uncomfortable to use and force the pedestrian to share the carriageway along with the vehicles. Since, the reason behind not preferring the walkway indicates that street vendors, discontinuity of sidewalk and surface quality are affecting the pedestrian safety.

In Nekemte city the study observes, almost more than half, feel threatened at night due to inadequate security. As for the areas observed the lighting facilities are available in the nighttime while walking on the walkways. Unfortunately, most of them are not working correctly due to lack of proper maintenance at a regular interval. In the four studied routes, most of the cases there are no lighting opportunities on both sides, and this leads presence of the illegal pickpocketing and the snatch bags.

This research tried to aware the transportation planners and nearby authorities on the existing problems related to the safety of pedestrians in Nekemte city. Hopefully, this study contributes much in enhancing the safety of pedestrians by identifying the affecting factors studied through the investigation of existing problems in the areas of pedestrians and indicated that improving the road infrastructure can increase walking and decrease fatalities in the city. Pedestrian facilities like crosswalks, sidewalks, Curb ramps and the like should be well designed and maintained to be useful for both encouraging people to walk and improve pedestrian safety along specific routes.

Finally, a model for the assignment of a LOS grade of the road segments was developed based on identifying factors, liaison with Stakeholders and a best practice review of available literature. Therefore, based on this method the study was determined the most significant factors affecting

pedestrian safety in Nekemte city. Among the identified safety factors, mainly sidewalk environment, crossing opportunity, support facility, personal security, obstructions, surface quality, and sidewalk width indicate the most affecting factors that need consideration for necessary improvements to make a more pedestrian-friendly environment for each segment in the City.

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