Measuring Safety Index for Pedestrian Path by Using AHP-GIS

*Athirah Illaina Mohammad Azlan and Nabilah Naharudin**
Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA,
40450 Shah Alam, Selangor, MALAYSIA
nabilahnaharudin1290@uitm.edu.my

ABSTRACT

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Pedestrian crashes account for approximately 7 percent of road death in Malaysia. Although the percentage is lower than other road crashes, this is still alarming. This is because, no matter what vehicles used by people, they still need to walk. This includes riding rail transit services as people need to walk to access the service and walk again to their destination after getting off the rail service. Rail services' providers and government had been committed to provide a safe walking environment to the transit riders. Therefore, this study attempted to propose a framework to measure the safety index by using AHP-GIS. The integration of the two techniques had been widely implemented in decision making related to spatial problems. In any spatial problems, there is always more than one criterion that needs to be taken into consideration in the analysis with each of them have different degree of importance in the analysis. Thus, the role of AHP in this framework is to derive the weightage for the criteria while GIS will use the weightage in the spatial analysis. In this proposed framework, GIS analysis that will be used in analysing the pedestrian safety is the assessment based on the parameters located along the road together. In short, this framework will first indicate the degree of importance of the criteria influencing safety by using AHP which will then be used to determine the safety index for pedestrian path using GIS. The proposed framework is expected to help in deriving the safety index for pedestrian path to access selected rail transit stations which can be used as a reference by pedestrian to choose the safe route that they can used to reach their destination. It also can be used by the local authority for improving the walking environment in future.

Keywords: pedestrian, safety, walkability, rail-transit, AHP, GIS

INTRODUCTION

"Pedestrian" can be translated differently. According to the Concise Oxford dictionary, pedestrian is defined by "a person walking in the street and not travelling in a vehicle" (Al Bargi et al., 2017). Walking is the most basic human activity and pedestrian's area part of every roadway environment. Everyone can be a pedestrian at one point or another. A person's decision to walk or use other modes of transportation can be greatly influenced by his safety concerns (Poyil et al., 2014). This is because, 1.24 million people were killed every year due to road crashes as reported by the World Health Organization and more than one fifth of it involves pedestrian. This shows that mostly pedestrians were killed due to road traffic and there are also other factors that leads to pedestrian safety.

In Klang Valley, traffic can be very congested all day long each day. The most frequently featured news is about pedestrian accidents. In fact, pedestrians are the third highest in the statistics of road accidents in Malaysia. Some of the factors of pedestrian safety are the traffic safety where lack of safe infrastructure for pedestrian such as zebra crossing, sidewalk, street lighting, traffic light. This forces most of the pedestrian likely to use the nearest road and walk alone where it could harm themselves and risk their safety. To be exact, such as dark alleyways and constructions site nearby which can expose them to street crimes.

There are many factors that related to pedestrian safety and cause the statistic of death among pedestrian increase year by year. Some of the factors are traffic safety, perceived security, the infrastructure of the sidewalk and so on. The problem lies when there is lack of standard set of criteria that had been used in previous studies which is perceived security in order to measure pedestrian safety.

When the desired criteria are already known, the factors will be located using mobile GIS which is on site and georeferenced in google earth. Once it has been collected, the analysis to determine the pedestrian-attractiveness can be conducted. Proximity Analysis and Network Analysis are often used to determine the safeness of route. The problem is, the factors hold different degrees of importance for expert and public. each has its own opinion. That is why, it is important to prioritize the factors first before conducting the analysis using GIS tools so that the analyst can make the path selection based on the factors they have. Of this reason, there are several methodologies previously applied but there is one that most suits pedestrian study: Analytical Hierarchy Process (AHP). The expected outcome of this study is the safety index of street in studied area, which is Hang Tuah, KL Sentral and Masjid Jamek and the accessibility to LRT stations.

LITERATURE REVIEW

Factors Influenced Pedestrian's Safety

It's a fact that people can walk more if they consider the environment that allows them to walk comfortably. There are several factors that can influence the pedestrian-friendliness. Basically, there are few parameters or factors that could influence pedestrian comfort such as connectivity, traffic safety, perceived security, shelter, conspicuous and so on but this thesis only focusses on traffic safety and perceived security since the focused of this thesis is about pedestrian safety to access rail transit station nearby. In this study, seven criteria were used representing two major factors influencing pedestrian safety. The criteria were adapted from various walkability studies conducted previously as summarized in Table 1.

Table 1. Factors Influencing Pedestrians' Safety Based on Previous Studies

	Factors Influencing Pedestrian Safety						
	Traffic Safety				Perceived Security		
Authors	Zebra Crossing	Sidewalk	Street Light	Traffic Signal	Construction Sites	Abandon Building	Dark Alley
(Naharudin et al., 2017)	✓			✓	✓	✓	✓
(Hyari et al., 2015)				✓	✓		
(Moura et al., 2017)	✓	✓	✓	✓		✓	
(Kim et al., 2011)	✓	✓	✓	✓		✓	
(Ha et al., 2011)	✓	✓	✓	✓	✓	✓	
(Basile et al., 2010)	✓	✓	✓	✓			
(Zainol et al., 2014)	✓	✓	✓	✓			
(Lin et al., 2019)	✓	✓	✓	✓			

Spatial-MCDA in Walkability Studies

Multi-criteria decision-making (MCDM) is an independent discipline which deals in choices involving the best alternative from several potential candidates in decision-making, subject to several specific criteria that may be concrete or vague (Pavan et al., 2009) while Multicriteria Decision Analysis (MCDA) is an alternative or a decision-making technique that can be used to evaluate more than one criterion at a time. It is possible to perform with a wide variety of techniques including Weightage Linear Combination (WLC), Ideal Points (IP) and Pairwise Comparison (Malczewski & Rinner, 2015).

As discussed earlier, GIS and MCDA can be integrated to provide a better analysis in any decision making. This includes study related to pedestrian's safety. There are several studies that had been conducted in analysing pedestrian's safety using Spatial-MCDA. Some studies even focused on the pedestrian's safety for accessing LRT stations where the study also uses the same method which is pairwise comparison but different method for GIS tools (Kang et al., 2012; Naharudin et al., 2017).

There was a study that used for GIS analysis were Space Syntax in analyzing the pedestrian's safety (Lee et al., 2013). Space Syntax is a topological depth-based technique for examining the connectivity of urban or architectural spaces. Since existing evaluations of service levels on roads have only considered sidewalk networks, they are not sufficient for evaluating overall pedestrian roads. This analysis therefore quantifies the area of the stations using a Space Syntax template within 600 m. In other words, in order to quantitatively calculate the connectivity of the pedestrian networks in the subway-adjacent areas. This study used the Space Syntax method, and specifically intelligibility, which can simultaneously consider integration and connectivity from the model's outputs to quantify the recognition and connectivity levels of the pedestrian networks.

Other previous study which used different GIS tools which aimed to develop a Spatial Walkability Index (SWI). (Naharudin et al., 2017). This study proposed a method for creating a Spatial Walkability Index (SWI) by integrating ANP and the network analysis. Network analysis tools were used to measure the SWI where two parts which is the overall length of the route in a station's catchment area and the optimal walking routes in a catchment area. The idea here is to create a catchment area for the LRT station using a common system to identify the region that certain facilities will serve. It is a good method to consider how a facility is accessible from its demands

METHODOLOGY

Figure 1 illustrates the methodology conducted in this study to measure the safety index for the pedestrian access to rail transit services. It comprises two parts of AHP and GIS. The AHP was used to derive the weightage of each of the criteria while GIS analysis was used to measure the safety index based on the weightage of the criteria.

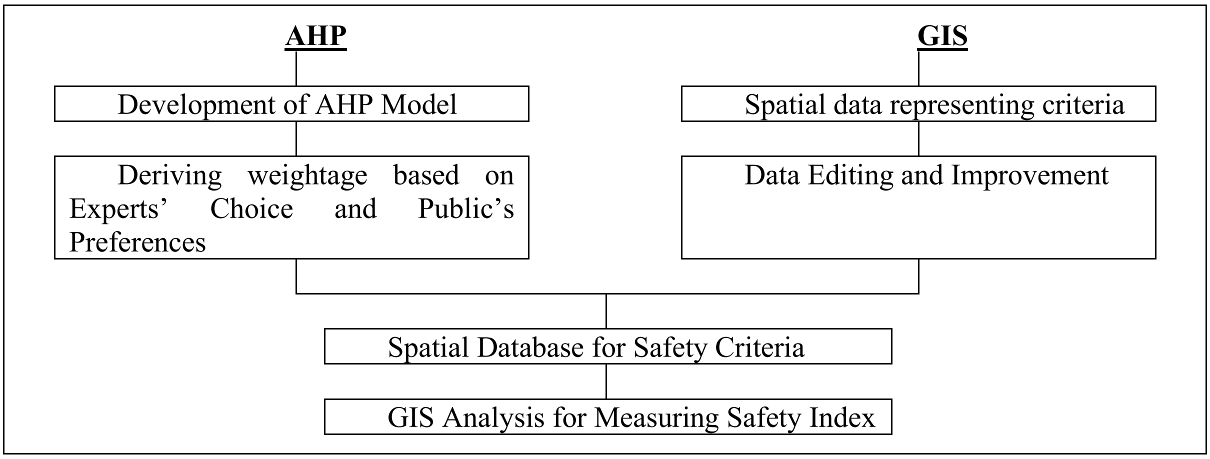

Figure 1. Methodology to Measure Safety Index

AHP

The AHP part in this study was conducted in two (2) stages. Based on the safety criteria described in Table 2, the AHP model was developed. Then, experts' choice and public's preferences were obtained by interviewing them.

Development of AHP Model

The criteria for the factors that affect pedestrian safety are selected through the visuals that occur around us. For this study, something that could relate with that statement are zebra crossing, in which case they will cause pedestrians to cross the street as they please and may cause accidents among road users. Not only that, in the absence of pedestrian walkways, most pedestrians will use the main road for passing and it will take space for vehicles to pass through it even though they are only using a quarter of the road, but it will still dangerous for the safety of road users and also the pedestrians. Table 2 shows the criteria of the pedestrian's safety and their sub-criteria.

Table 2. Criteria of Pedestrian's Safety and their Sub-Criteria

Criteria	Sub-Criteria
Traffic Safety	Zebra Crossing Sidewalk Streetlight Traffic Lights
Perceived Security	Construction Sites Abandon Buildings Dark Alleyways

The process of developing the AHP model began with the identification of criteria and their sub-criteria that will be used in analyzing the pedestrian's safety. In this study, the goal for this study is focusing on pedestrian's safety and under the goal, there are two control criteria which is traffic safety and perceived security, and at least three to four sub-criteria are listed to be included in the AHP model. Such criteria and sub-criteria are then modelled in the Super-decisions system where the system can produce a model by simply filling in the criteria and sub criteria as nodes within their respective clusters using AHP rules as illustrated in the Fig. 2. The nodes and clusters will then be linked according by their dependencies.

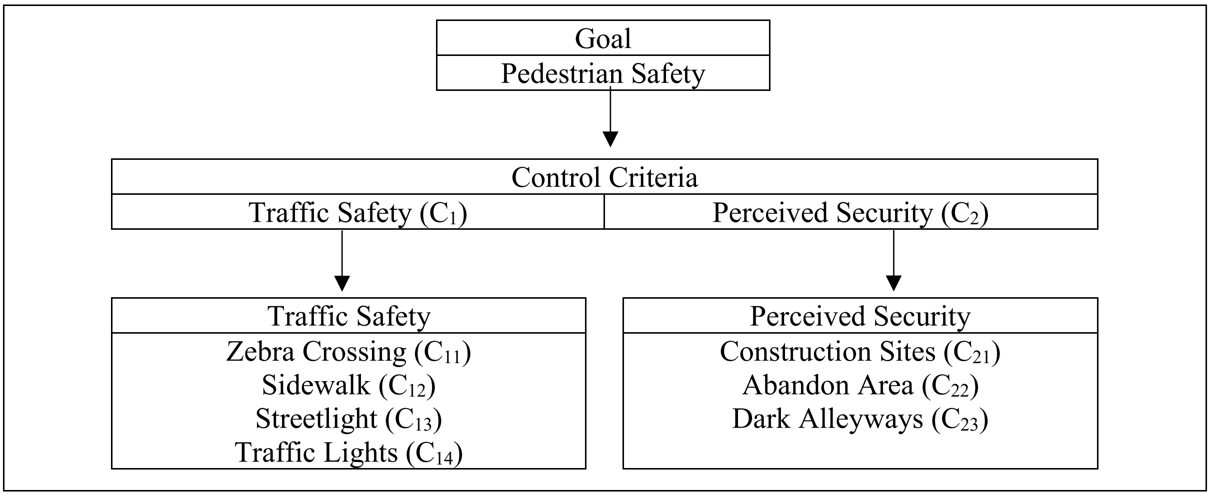

Figure 2. AHP Model for the Factors Influencing Pedestrian's Safety

Obtaining Experts' Choice and Publics' Preferences

Experts is a person who is very familiar or skilled in a specific field. An expert is someone who has wide and deep expertise, skills and experience in a specific field of study and learning. Therefore, a total of 10 experts' decision makers comprising of six academicians and four industrial experts were selected to provide their judgement on factors of pedestrian's safety as described in Table 3.

Table 3. Description of Experts'

Expert(s)		Description
Academician	A1	Professor in Local University
	A2	Professor in Local University
	A3	Professor in Local University
	A4	Graduate Student in Local University
	A5	Graduate Student in Local University
	A6	Graduate Student in Local University
Industry Experts	I1	Local Authority (DBKL)
	I2	Local Authority (DBKL)
	I3	Local Authority (Town Planner)
	I4	Local Authority (Town Planner)

The academicians are the one who study the same or similar to this study which related. Likewise, industrial experts are the urban planners actively involved in the planning and growth of the city's good walking environment. The industrial's experts selected were the local authority from Dewan Bandaraya Kuala Lumpur (DBKL), and Town Planning Shah Alam while Academicians have been selected from local universities that can provide judgment from different perspectives on their country's experience. They are few candidates which is lecturers and someone who have been actively involved in research related to pedestrian's safety and walkability in Malaysia. While for Public, it is those who act as pedestrians in the streets.

Equation 3 is applied to priorities of each criterion aggregated by each expert and public to calculate the group judgment made by the them. The set of group judgment's priorities was calculated by AHP decision rules and described in Table 4.

Table 4. Priorities for Safety Criteria

Criteria	Sub-Criteria	Experts' Choice	Public's Preferences
Traffic Safety	Zebra Crossing	0.17	0.15
	Sidewalk	0.14	0.14
	Streetlight	0.22	0.30
	Traffic Lights	0.26	0.21
Perceived Security	Construction Sites	0.30	0.34
	Abandon Area	0.10	0.12
	Dark Alleyways	0.42	0.33

Measuring Safety Index and Accessibility by using GIS

There were few stages conducted in GIS analytical procedure. Firstly, the transformation process was performed on the data collection of primary and secondary data from data acquisition phase so that the both of the data is identical in terms of the format also their projection system. They were later imported into the ArcGIS environment to accommodate the analysis for data editing process. Then, a data set of the assigned parameters was built to support later GIS analysis

Building Spatial Database

To develop safety index, spatial database needs to be created. Basically, the parameters in a point form. Each of the parameters have their own weightage. The weightage of the parameters and their name need to be added into the attribute table of parameters shapefile itself in order to calculate the safety index of the parameters in data analysis process. Without the attribute of weightage, any analysis tools used could not be created since the weightage is the most important data in order to process the analysis. The weightage must therefore be correct in terms of their name and point and there should be no mistake at this stage. If so, the analysis of the safety index must be carried out again which it is used in processing and is interrelated.

Determining Safety Parameters along the Streets using Proximity Analysis

The safety index was determined after identifying the factors and the judgement result of criteria and sub-criteria of pedestrian's safety. First, the proximity analysis will be used as the method to find the parameters influencing pedestrian safety that exists along the streets. Basically, the process is where points to be snapped to the line layer. Points is referred to parameters while the line is referred to the road. There will be many factors along the way. This method is used to determine which road is closest to the factor. Therefore, under proximity analysis, near tools were used where calculates the distance between the input features and the closest feature in another layer or feature class and additional proximity information. Therefore, the parameters are the input features while road are the near features.

Measuring Safety Index for Streets

Once the parameters have been identified along the road by using proximity analysis, it will then measure the safety index of the streets. To measure, spatial join tools under Overlay is used where the function of the tools is to join attributes based on the spatial relationship from one function to another. To identify whether the parameters lay on the line or not, there will be 2 same field in the attribute after using spatial join tools. Each of the line of road will have their very own identity, so if the parameters have the same identity it means that they lay on the same road line. The spatial join result is then export as (.dbf) to use for calculation using summary statistic where the process will show the total of parameters lay on the line and the sum of the weightage according to their line of road.

The scoring for safety index of the streets is by using normalization. Once the sum of weightage along the road is obtained, the safety index of the streets is then being scored by using normalization. Some of the line will have high mark of parameters and some of the line will have lower mark. In this case, there is no standard value for determine the mark of parameters. Therefore, normalization is used to set the highest and the lowest mark. Normalization value is usually between 0 to 1, 0 to 10 and 0 to 100. 100 is use for this calculation to obtain the result as percentage. The higher the score of the route, the higher probability of the route to be safe.

Accessibility to LRT Stations

Finding an accessibility analysis to LRT stations where it is to identify the demand of points refer to route of high safety index or not. For accessibility, closest facility analysis was used. Basically, it is similar to shortest path where instead of doing one by one, it will generate more than 1 route assign to the facilities. The demand points can be anything such as mall, hospital, restaurant etc.

After processing of closest facility analysis, various of route is shown from any demand point to the facility which it does matter about the safe and unsafe route. The line of a road might have high mark regarding to the sum of parameters in the second analysis, but every road does not have the same length as there are short and long ones since every road has their own distance. Instead of calculating the number of safe routes, it used the distance as the calculation for the analysis. The safe and unsafe route can be referred to previous analysis which measuring safety index. Out of the total route assign, some might be safe, and some might not.

RESULTS AND DISCUSSIONS

Table 5. Percentage of Safe Road in KL Sentral, Masjid Jamek and Hang Tuah

Study Area	Classification	Safety Index (Experts)	Safety Index (Public)
KL Sentral	Very Unsafe	16%	13%
	Unsafe	12%	10%
	Neutral	11%	13%
	Safe	25%	26%
	Very Safe	36%	38%
Masjid Jamek	Very Unsafe	15%	13%
	Unsafe	13%	15%
	Neutral	15%	15%
	Safe	20%	21%
	Very Safe	37%	36%
Hang Tuah	Very Unsafe	9%	9%
	Unsafe	8%	16%
	Neutral	11%	14%
	Safe	23%	18%
	Very Safe	49%	43%

The safety index was determined after identifying the factors and the rating or priorities for each of the criteria and the sub-criteria of pedestrian's safety as described in Table 5. The proximity analysis is used as the method to determine the parameters influencing pedestrian safety that exists along the streets. Then, the safety index is calculated based on the parameters exist along the streets. The index was measured with the total of scoring of factors influenced along the routes and simplified into a percentage. The scoring can indicate which road is safe or dangerous for pedestrians. Figures 3 and 4 show the results of safety index for pedestrian path around 3 different LRT Stations which are Masjid Jamek, KL Sentral and Hang Tuah.

According to the Fig. 3, there are slight differences between the safety of routes as based on the Experts' choice and Public's preferences for area around the three (3) LRT stations. This is due to the parameters located along the route (Traffic Safety & Perceived Security) together with opinion or rating given for factors influencing pedestrian safety is approximately the same for both parties. Then there won't be much difference.

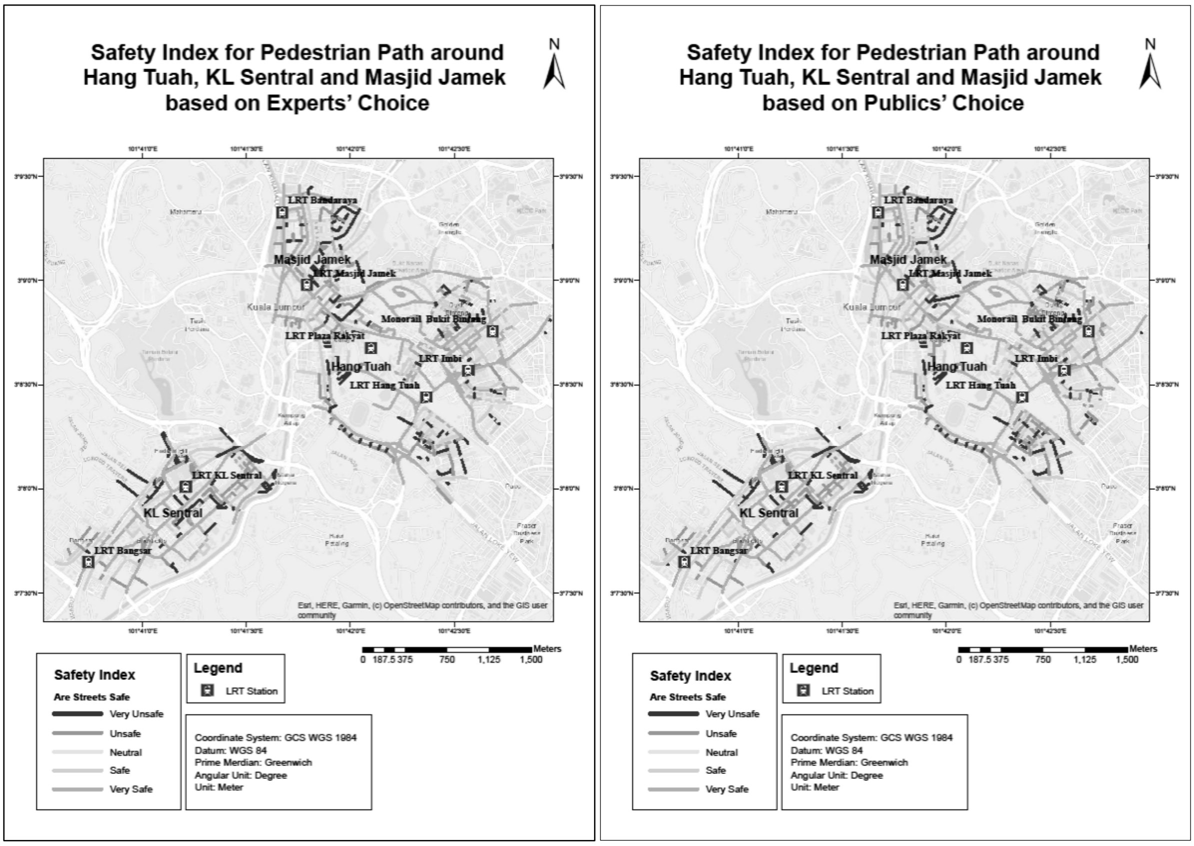

Figure 3. Safety Index for Hang Tuah, KL Sentral and Masjid Jamek Area

For the Hang Tuah area, the majority of these routes are safe where the percentage of "very safe" routes is highest at 49% and even for the "safe" route is also 23% higher. Thus, the overall total for both classifications is 72% which means that the safe route is higher than the unsafe route which is only 28%. The same goes for determining the total safe passage area for Masjid Jamek and KL Sentral. Thus, from there the result of the percentage for each classification is according to the rate of total weightage or value of priorities from Expert and Public at the beginning of the study for each route and therefore the result is difference between Expert and Public. The presence of very unsafe routes is almost in every small junction between the shop lots or buildings as the study area is an urban area not a residential area. Hence, the specified statement is in line with the generated results.

As a result, the resulting map will indicate which path is safe and vice versa. For this analysis, the more factors that are on a road then the safer the road is to travel but the less the factors are there, the road is considered dangerous. So, for the safest route which is the highest score is usually the main road or highway used for vehicles or pedestrians because along that route there will be sufficient streetlights, traffic light and street zebra crossing as well. that's why it's the main road. rarely the main road doesn't have that. For the least score, mostly occur on small and infrequent roads such as a lane between shops or shortcuts to places and dark alley. Clearly, all of them are one of the dangerous routes that should be avoid by pedestrians because the less quantity of streetlights along the route, quiet and is rarely travelled by many.

CONCLUSION

This paper aims to measure the safety index to access LRT stations. This is to find out which road is safe, and which is otherwise for pedestrians. The problem is, which of the parameters are most relevant in deciding the factors influenced pedestrian's safety? Thus, group decision-making by an AHP-based expert's together with public's is conducted to serve this purpose. For GIS tools, Proximity analysis and Network Analyst were used to obtain the percentage of safeness of the route generate by the software. In conclusion, to maintain the safety of pedestrians, then reforms and improvements need to be made. For this study, sometimes the unsafe route is still used by pedestrians who are often the sidewalks for the purpose of reducing the distance and time to a place without expecting anything bad to happen. Maybe a party can consider doing something or improving the road such as turning it into street art area, increasing the quantity of streetlights or installing CCTV to ensure pedestrian safety. As a final word, safe routes will ensure the safety of pedestrians.

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