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School of Transportation Sciences

Master of Transportation Sciences

Master's thesis

Assessment of Road Facilities in School Zones in Lipa City, Philippines using International Road Assessment Program (iRAP) methodology

Reina Isabel Tenorio

Thesis presented in fulfillment of the requirements for the degree of Master of Transportation Sciences, specialization Traffic Safety

SUPERVISOR :
Prof. dr. Davy JANSSENS

CO-SUPERVISOR :
Prof. dr. An NEVEN

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PREFACE

The author of this paper chose the topic of assessment of safety around school zones because of the aim of taking part on the improvement of the level of road safety in the country. I have more than three years of work experience in the road design engineering and I wanted to expand my understanding with the other aspects of transportation engineering and sciences. This is the reason I decided to study a master's degree in Transportation Sciences-Road Safety. The Philippines have numerous traffic problems and one of these is the road safety especially of the vulnerable road users. Currently, the local agencies are focused on improving the level of services of the roadways through improving the road infrastructures. With this, I noticed that these road infrastructures are majorly built for cars, which lead to low level of safety for pedestrians. I also studied during my elementary years in Lipa City, Philippines, which is the scope of this study, which is why I am aware of the situation of travelling to and from the schools. Discipline among the road users is also an issue in the country wherein there are numerous of behavioural issues relevant to traffic regulations. There are also gaps with the traffic rules itself. Thus, through this research paper, I am aiming to increase the level of awareness of the road users especially school heads, students, parents, and other road users. Then, they can implement effective countermeasures to improve the protection level of the pedestrians especially students around the school zones.

I am taking my master's degree in Hasselt, Belgium and I had been observing the transportation system and the road users' behaviour during my stay. Based on my observations, I noticed that there is major difference between the behaviour of the road users between Hasselt, Belgium and Lipa, Philippines. I noticed that Filipinos are less likely to follow traffic rules if there is no present traffic enforcer or crossing supervisor. Furthermore, I am also hoping to reach the road safety awareness to the personnel with higher authority in the region.

This master thesis was written during the COVID-19 crisis in 2020. This global health crisis has had an impact on the (writing) process, the research activities and the research results that are at the basis of this thesis because the necessary on-site data collection was difficult/impossible.
This research paper utilized the methodology factsheets of the International Road Assessment Program (iRAP) as a reference to assess the school zones.

ACKNOWLEDGEMENTS

This research paper will not be possible without the guidance of our Almighty God who gives me strength and wisdom to continue this part of journey.

I express my gratitude to my UHasselt advisors, Prof. dr. An Neven and Prof. dr. Davy Janssens who always give me feedback based on their expertise and guide me through in finishing my thesis paper.

I also express my gratitude to my local adviser in the Philippines, Dr. Ricardo Sigua, for allowing me to be one of his advisees and for providing me ideas about the topic that I have chosen for this research paper.

I am also grateful for having a supportive family who constantly reminds me that I am strong enough to go through any challenges thrown to me.

This research paper is written during a pandemic crisis which added to the challenges in writing this paper. Fortunately, I have a loving and supporting boyfriend, Julio Dela Cruz, who helped me in studying the coding program of Visual Basic and sharing me his ideas with regards to my research paper. I cannot thank him enough especially for cheering me up during difficult times.

Lastly, I wanted to thank my Hasselt family, Kuya Kimjay, Ate Meg, Lovely, Mel, MJ, Paolo, Roxanne, Bryan, Nuria, Rodrigo, Audinda, and Sasa whom made my stay in Belgium extra special.

SUMMARY

This paper aims to improve the safety of the school zones in Lipa City, Philippines through increasing the awareness level of the road users including the school heads, parents, students, etc., regarding the road safety. The level of safety of school zones are assessed via the Star Rating for School methodology of International Road Assessment Program (iRAP). The star ratings range from 5-star, being the safest rating, to 1-star, being the least safe. This paper focused on assessing the level of safety of pedestrians, especially children, while travelling to and from their schools.

iRAP has available fact sheets about the methodological process and risk factors associated with different road attributes. These attributes are categorized through how these attributes affect the likelihood and severity of the crash. Data gathering comprises of two parts. The first one is the online gathering of data from Google Earth, Geopunt, and TELRAAM. Verification of the gathered data are done through the on-site data gathering. However, due to the COVID-19 crisis, lockdowns are imposed; thus, on-site data gathering was not completed, and this research was limited to utilize the best available data for the assessment.

Research methodology comprises of a pilot study in a school zone in Hasselt, Belgium and six school zones in Lipa City, Philippines. Four school zones lie along the national highway while the other two school zones lie along a city or municipality road. Inclusion of a pilot study on this research provided comparison of the star ratings between the two regions. The researcher correspondingly distinguished which are the common and the different attributes that yielded the respective star ratings. This study includes a deterministic sensitivity analysis which identified the road attributes that are more likely to affect the star ratings in the school zones of Lipa City. Moreover, the data gathering, and analysis of the pilot study provided the researcher to identify efficient approach in gathering data, data analysis, and for quality checking of the coded Visual Basic (VB) program.

Common practices and behaviours of the road users have effects on the level of safety of pedestrians. However, inclusion of behaviour on the research design would be challenging and complicated. This is one of the limitations of the iRAP methodology. Some of these behaviours are compliance of the road users to the traffic rules and regulations, utilization of proper crossing and walking facilities for pedestrians, aggressiveness of the road users especially drivers, and other risky behaviours. Strengthened enforcement can take part as a solution for the behavioural challenge on road safety.

Results of the assessment showed that schools along the national highway are unsafe for pedestrians while the schools along a city or municipality road are relatively safer with a star rating of 3. However, star rating of 3 is the minimum rating to be considered as a safe school zone. This shows that the school zones in Lipa City need to be improved. Moreover, comparison between the pilot study in Hasselt and school zones in Lipa City has a huge difference on their Star Rating

Score (SRS). Pilot study in Hasselt has relatively higher level of pedestrian safety compared to the schools in Lipa City. Average SRS for Lipa City is based on the average of the least safe and safest school zones which are equivalent to 123.73 and 23.65, respectively. For Hasselt, the average SRS are based on the least safe and safest sections which are 6.83 and 2.85, respectively. Analysis of countermeasures for Lipa city incorporated the comparison of the two regions. Some of these road attributes are traffic calming measures, number of lanes, crossing facility, speed, and traffic volume.

A tornado plot is graphed based on the deterministic sensitivity analysis; it is limited to the difference between the road attributes of the least safe and safest school zones. Based on the plot, 'Operating Speed', 'Crossing facility', 'Traffic Volume', and 'Number of lanes' have the widest range of star rating scores among the other road attributes. It showed that the assigned maximum and minimum values of these road attributes have higher effect on the final star rating score. On this analysis, it is important to note that the road attributes do not have equal number of categories. Due to the discrepancy between the number of categories, the researcher assigned typical or average values to calculate for the baseline value. Also, utilization of maximum and minimum value of road attributes will yield to unrealistic scenario. For instance, road sections with 120 km/h with 4-lanes each direction is not a realistic scenario for a school zone. Thus, this analysis is limited to the collected data in Lipa City. The maximum and minimum values are obtained based on the worst and best collected existing condition. Having wider range of values of the road attributes means that these attributes are more probable to have higher impact as they have higher discrepancy with the nominal value.

Based on the investigation of the countermeasures, Grade-separated crossing facility and pedestrian fencing have the highest improvement percentage (change in the final SRS). Grade-separated crossing facility obtained an average of 91.49 % for schools along national road and 45.17% for along the municipal road, while pedestrian fencing showed an improvement of 97.40 % for along national road and 46.03 % for along municipal road. Unsignalized crossing with refuge island and lower speed showed improvement percentage ranging 16.04%-54.96%. Physical barrier has more effect on schools along municipal road which obtained 57.67% and only 1.66% for school zones along national road. Thus, with the analysis of the common attributes and the SRS equation, the most effective intervention for the school zones in Lipa City is to improve the crossing facility together with the installation of a full-length pedestrian fencing. Ideally, presence of the fencing will restrict the pedestrian to cross in any point of the road and allow them to cross in the proper crossing facility. Moreover, the road attributes that have high impact on the final SRS is not limited to the ones listed in the tornado plot. These road attributes shown in the tornado plot are the difference between the least safe and safest school zones in Lipa City.

Generally, new schools are recommended to be located along a road which has lower speed (e.g. city or municipality streets) since speed has a major impact on the level of safety. Reduction of speed along school zones is also recommended, but based on RA 4136 (Sy, 2017b), local governments do not have the authority to alter the speed. On the other hand, traffic calming measures can yield to reduction of speed. Additionally, a stringent planning is needed before constructing any facilities near the school zones to prevent unnecessary costs and effort. Also, inclusion of pedestrian safety on the education program of the students, social media campaigns, and informative posters can further improve the behavior and awareness of students and other road users. School heads, together with the division office, can coordinate with the local government unit (LGUs) who can provide funding and allocate traffic enforcer to strengthen the enforcement pertaining to road safety. Thus, engineering, education, and enforcement are the main components to have a road safety.

Furthermore, the researcher also recommends that this methodology can incorporate factors for the level of aggressiveness of the drivers and level of compliance of the road users to the traffic rules. This can be achieved through long-term observations, surveys, and setting a baseline through comparing two regions. Other recommendations for future researches include incorporation of cost-benefit analysis, more advanced technology, and more updated platform for data collection; and to also assess the level of safety of other road users.

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1. INTRODUCTION

The research focused on the methodological aspect of Star Rating for Schools in improving the safety of pedestrians especially children in school zones in Lipa City, Philippines. Lipa city lies in the southern part of Luzon with land area of 191 km^2 and has a population of 332,386 ("Lipa (City, Philippines) - Population Statistics, Charts, Map and Location," 2015). Road crash related deaths in the Philippines has reached 10, 012 in year 2015 and the working-age group constitute approximately 82% of this fatalities (Sy, 2017a). This age group has the highest exposure compared to other age groups. Even though the working age groups has the highest percentage of road crash deaths, planners should also give attention to the other age groups. Sy (2017a) stated that an average of 667 (year 2006-2015) children (14 years old and younger) die every year due to road crashes in the Philippines. Based on the data on year 2005, there was an average of 11 crashes every day near schools and this rose to 14 per day on year 2010. On the average, there is one out of five child pedestrian involved on a road crash happening on school zones (Barrientos-Vallarta, 2012). Children ages nine years-old and below may still have difficulties in following and understanding the traffic regulations, and they still have low level of perception of the approaching vehicles (Barrientos-Vallarta, 2012). Moreover, children have smaller body structure compared to older people and drivers have difficulties on noticing their presence on the roads. With these situations, it is viable to improve the road facilities near/on school vicinities.

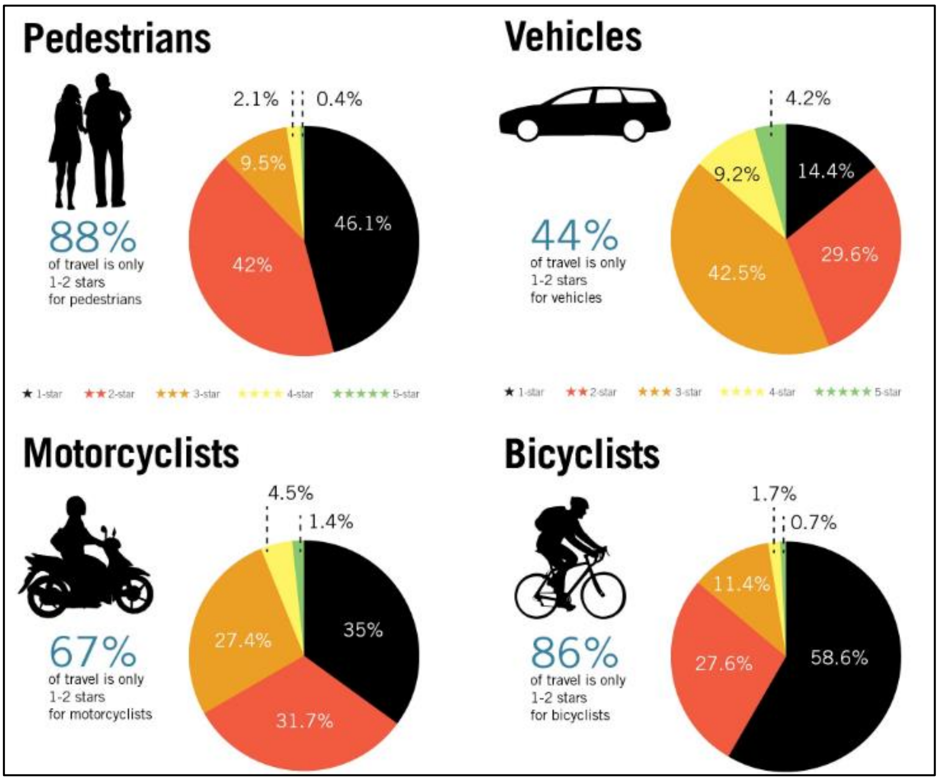

FIGURE 1. Summary of the star rating for different road users across 54 countries (iRAP, 2017a)

International Road Assessment Program (iRAP), an organization that aims to improve the level of road safety, developed the Star Rating for Roads and Star Rating for Schools (SR4S). Star rating provides a powerful measure in assessing and keeping track of the level of safety (iRAP, 2017a). FIGURE 1 shows the summary of the star ratings based from the 358,000 km sample or roads from 54 countries and the percentages of each road users which rated as 1 and 2- stars only (iRAP, 2017a). SR4S is a pro-active approach in assessing the risk of schools with different attributes and how this risk can be reduced or prevented. It also shows the level of how the roads and school facilities protect the road users. SR4S basically use the pedestrian component of the Star Ratings for Roads to know the risk of the pedestrians in terms of the road design `and traffic management in the area (iRAP, 2017b).

In this rating, 4- and 5-star roads are considered safe, while rating 1- and 2-star are considered as least safe (iRAP, 2014f). Evidence-based researches show that the risk of dying in road crashes are halved for every increment in Star Rating (iRAP, 2017a). FIGURE 2 shows the relationship between the costs of killed and seriously injured per vehicle-kilometer and the Star Rating of the road. On this case, the risk of death and serious injuries are associated to monetary value. It was found out that 2-star rating roads have lower crash costs than 1-star rating, 61% difference between 2- and 3-star roads, and 43% difference between 3- and 4-star roads (iRAP, 2017a).

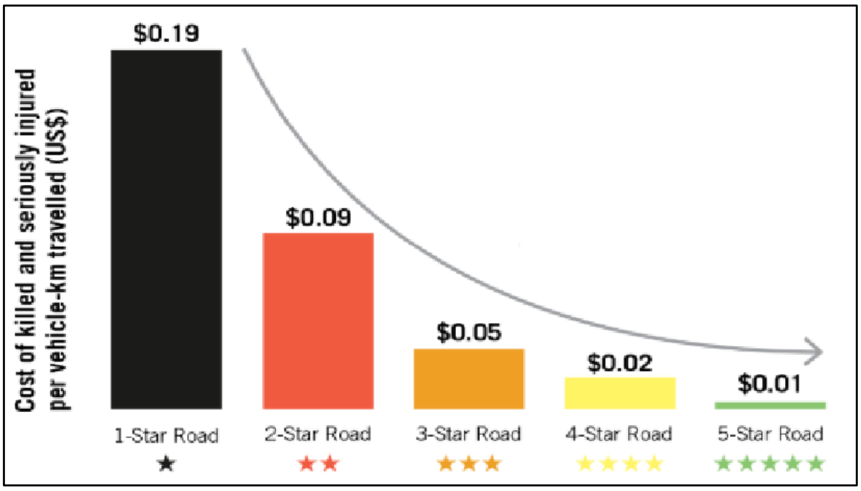

FIGURE 2. Cost of killed and seriously injured per vehicle-km travelled on each Star Rating (iRAP, 2017a)

In line with the goal of iRAP, star rating for schools is also developed to give emphasis on the safety of the children while traveling to-and-from their schools; iRAP (2014d) also stated that road crashes is one of the highest cause of pedestrian-related deaths and serious injuries among the school-age children worldwide. Lastly, the star ratings aim to determine the attributes that have major impact on the likelihood and severity of road crashes based from scientific researches; and further utilize this information in assessing the roads which do not have available detailed road crash data, which is the usual case for low- and middle-income countries.

1.1. Objectives

- To assess the rating of the school zones in Lipa City, Philippines using the iRAP methodlogy, and various attributes of road facilities in the school zone (Visual Basic software is used as tool for this methodology)
- To improve the road safety awareness of the school heads, students, parents and other road users
- To provide options of countermeasures that would improve the safety in school zones

1.2. Sub questions of the Research

- Which attributes are the most significant in the safety of pedestrian in school zones in Lipa City?
- What are the common road attributes that caused lower star rating of school zones Lipa City?

1.3. Scope and limitation of the study

In line with the main objective of this research, this research is limited to the assessment of six public elementary schools in Lipa City, Philippines and one school in Hasselt, Belgium. Four schools lie along a national road while two schools lie along a city or municipality road in Lipa, Philippines. Kindercampus tuinwijk, the school for the pilot study, lies in Lazarijstraat which is classified as a street or a municipality road. The purpose of including a school from Belgium is to identify the difference between the road attributes in the two regions and to test the methodology. The researcher gathered data between February and March 2020. The scope of this study is limited in assessing the star rating of schools wherein a Visual Basic (VB)-based application acted as a tool. As part of the aim to improve the awareness of the road users within school zones, this research includes a summary report of the assessment of the school zones to be submitted to the school division office. The summary report includes a provision of general list of feasible countermeasures. During the data gathering and submission of the summary report, a COVID-19 crisis occurred. Due to this, schools and other establishments temporarily closed; thus, this summary report is submitted to the school division office. The division office can disseminate the information to the school heads, and school heads can further disseminate them to the students, teachers, and other concern personnel.

Multiple factors are considered in choosing countermeasures in improving the safety of schools in the Philippines. One of the major factors is the financial aspect; thus, discussion within the school board members is essential in decision making. Individual recommendations for each school are not part of this research. On using the iRAP methodology, the research design cannot incorporate the behavioral characteristics of the road users. Due to this, this research utilized the school facilities and road attributes which majority of the road users use (e.g. usable lane width is less than the actual width due to obstructions, presence of pedestrian overpass but majority of pedestrians do not use, etc.). Additionally, this research assumed that road users follow the posted speed near the school zones.

For the traffic volume of the school in Hasselt, it is limited to gather one-month (2019) traffic volume due to availability of data (TELRAAM) on the Lazarijstraat, Hasselt. For the traffic volume in Lipa City, there are annual data for national highways. The latest data available is the traffic volume in 2017. To support the data of the annual traffic count, the researcher was supposed to collect the traffic data during rush hours to compare with the available traffic count and to know the actual traffic volume during rush hours (daytime). This portion was also affected by the discussed crisis. Even though all the data required for the assessment can be gathered via online platforms; there are areas wherein the available data (e.g. maps and images) are not up to date. Initially, road delineation, road surface, skid resistance, road condition are supposed to be verified on-site as the images may not reflect the actual conditions. Also, there is also possibilities wherein there are modifications with the other road attributes (e.g. driving lanes, school warning zones, traffic calming measures, crossing facility, median type, etc.). Thus, this research is limited to the assessment based on the gathered data from online platforms. It is also limited to the assessment of 17 sections per school zones. This is based on the 400-meter average walkability of a person.

Effect of the countermeasures are also presented in the discussion section of the report. The calculation of improvement percentages is based on the available data collected in Lipa City. The countermeasures are based on the iRAP, comparison of road attributes between the two regions, and the assessed road attributes that highly affect the star rating scores as shown in the tornado plot.

2. RELATED LITERATURE

2.1. iRAP Methodology

Based on iRAP (2014e), it is expected to increase the deaths due to road crashes up to 2.4 million on year 2030. Majority of these deaths are from the group of vulnerable road users. The major objective of iRAP is to improve the road safety and one way to achieve this is to improve the rating of roadways. Due to this situation and objective, iRAP developed the four protocols: (1) Risk Maps, (2) Star Ratings, (3) Safer Roads Investment Plans, and (4) Performance Tracking (iRAP, 2014f). iRAP methodology also developed ratings for schools and it also includes the capability to localize important road attributes. This research focused on the protocol for Star Ratings of Schools.

Star Ratings

Basically, the iRAP methodology classifies the safety of roadways through 5-star ratings. Safest roads are rated 4- and 5-star and 1- and 2- star for the least safe roads. The ratings are based on the relevant road attributes. Some of the attributes that yield to higher ratings are presence of medians, visible road markings, presence of bike paths, pedestrian crossings, operating speed, etc., (iRAP, 2014f).

Star Rating for Schools: Pedestrian Star Ratings

Majority of the attributes related to pedestrians that are used in the Star Rating of Roadways are also used in the Star Rating for Schools. These attributes are vehicle speed and volume, footpaths, pedestrian crossings, lighting, number of lanes, median type, driveways, intersection type and traffic calming measures (iRAP, 2014e). Based on the iRAP (2014c), additional attributes are needed for the Star Rating of Schools such as: signings and markings in the School Zone, pedestrian crossings, and presence of enforcements in the school zones. However, presence of traffic enforcers at school zones is not included on the attributes due to the difficulty of assessment. For the assessed road segments, 100 meters per segment is used for the roads while 50 meters for schools to account for the higher network density around school zones (iRAP, 2014e).

ViDA

iRAP developed an online software wherein users can check the rating of a certain roads with the road attributes. The most recent version of ViDA is limited to assessing roadways. FIGURE 3 shows the interface of the online software. As shown in FIGURE 3, Vida shows the star rating of the road in terms of individual road users such as vehicles, motorcycles, bicycles, and pedestrians. The road attributes are classified into Cross-sections, Roadside attributes, flow, and speeds. This software provides guidance on this research since the researcher can cross-reference the flow of this study in reference to this online software. Even though

Vida do not have star rating for schools, the researcher can gather information regarding the relevant road attributes.

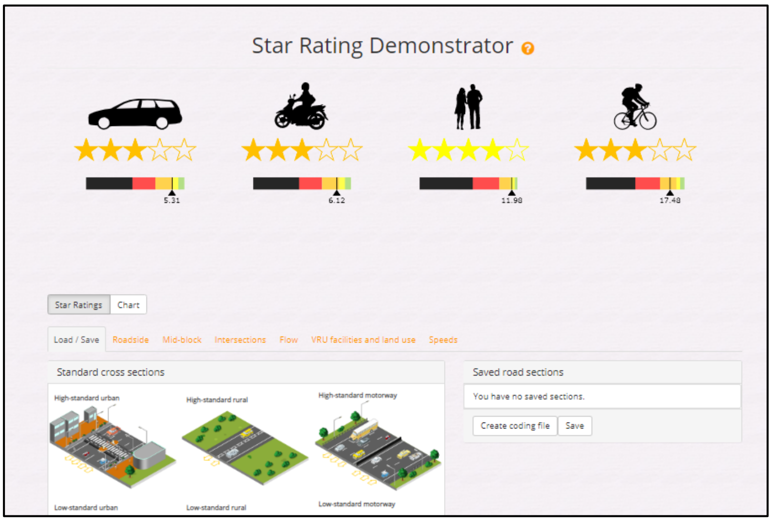

FIGURE 3. Interface of Vida (sample)(iRAP, 2016)

2.2. Review of iRAP risk parameters (ARRB) (Turner et al., 2009)

Australian Road Research Board (ARRB) review the risk factors used in the iRAP assessment of roads and school facilities. On this report, the authors listed the road attributes used in iRAP and how they come up with the risk factor values. The ARRB report aims to give support to the iRAP. They based this review on various literatures, implications of infrastructure designs on a 5-year span (Turner, Affum, Tzoitis, & Jurewicz, 2009). TABLE 1 shows an example of the comparison of iRAP and ARRB suggested values. TABLE 1 shows that there are some discrepancies with the values but the recent fact sheets of iRAP referenced the ARRB report of 2009. With this, it can be observed that majority of the ARRB values are used in iRAP (e.g. Refuge only and No facility) as shown in TABLE 2 which is the latest version. Furthermore, one of the knowledge gaps of this report is the basis of data from low and middle income countries (Turner et al., 2009). As discussed on the Star Ratings for Schools: Pedestrian Star Ratings, majority of the attributes used in roads are also used for the schools.

TABLE 1. Comparison between iRAP and ARRB in Road Attribute: Pedestrian crossing facilities (Turner et al., 2009)

Category ID	Category	iRAP	ARRB suggested values
1	Grade separated facility	1	1
2	Signalised with refuge	1	1
3	Signalised without refuge	2	-
4	Unsignalised marked crossing with refuge	2	-
5	Unsignalised marked crossing without a refuge	4	4.8
6	Refuge only	4.8	5.1
7	No facility	8	6.7

TABLE 2. iRAP Risk factors—Pedestrian Crossing facilities (iRAP, 2014b)

Pedestrian Crossing Facilities	Pedestrian likelihood - not at a school	Pedestrian likelihood – at a school with a school zone crossing supervisor during school start and finish times	Pedestrian likelihood – at a school without aschool zone crossing supervisor	Pedestrian severity
Grade separated facility	0.40	0.30	0.40	90
Signalised with refuge	1.00	0.95	1.00	90
Signalised without refuge	1.25	1.20	1.25	90
Unsignalised marked crossing with refuge	3.80	1.00	3.80	90
Unsignalised marked crossing without a refuge	4.80	1.25	4.80	90
Refuge only	5.10	3.80	5.10	90
No facility	6.70	4.80	6.70	90
Grade separated facility – pedestrian fencing present *	0	0.00	0	90
Unsignalised raised marked crossing with refuge	2.50	1.00	2.50	90
Unsignalised raised marked crossing without refuge	3.20	1.00	3.20	90
Raised marked crossing with refuge	3.40	2.50	3.40	90
Raised marked crossing without refuge	4.50	3.20	4.50	90

2.3. Road Safety Audit

Department of Public Works and Highways (DPWH) has been conducting road safety audits (RSA) which comprise of design standards of the roadways (e.g. vertical and horizontal alignment, road markings, traffic signs, etc.). RSA assists engineers and planners in the Philippines to ensure the safety of road users through setting defined standard on different attributes of the roads (Lagunzad, 1999). In assessing the existing roads, RSA methodology starts with the identification of a black spot area; then they will further assess the spot in reference with the standards of the RSA; then, after finalizing the audit, planners will identify which could be the best measure to improve the area (Lagunzad, 1999). For this, crash data is an important factor in utilizing this methodology. Similarly, with the objective of the iRAP's star rating, RSA also aims to improve the level of safety of the roads in the country.

Comparing RSA with the SR4S, SR4S is more focused on improving the safety of the pedestrians around the school zones, and due to accumulation of different studies regarding the different road attributes, SR4S can be used without prior knowledge of the crash data. SR4S is also capable of providing ratings wherein planners and engineers can keep track of the level of safety of the school zones (iRAP, 2017a). Lastly, RSA can provide specific issues on different attributes but cannot provide the accumulated impact of the road attributes on the safety of the roads.

2.4. Pedestrian Safety: A Road Safety Manual for Decision-Makers and Practitioners

Risk factors pedestrian traffic injury

The key factors that influence pedestrian safety are speed, alcohol, quality of pedestrian facilities, and law enforcement (WHO, 2013). Speed is related to the risk and severity of a crash which is associated with the relationship between and speed and stopping distance; higher speed has shorter time to stop the vehicle before the occurrence of a crash (WHO, 2013). High level of alcohol consumption yields to poor judgement of the drivers, thus, increase the likelihood of a crash and speeding (WHO, 2013). Level of pedestrian safety depends on the quality and presence of facilities which protects and separates them from other road users (WHO, 2013). High-quality pedestrian facilities and low-speed road provision should be reinforced with traffic law enforcement.

Road design and pedestrian safety in New Delhi

The pedestrian safety was improved in New Delhi through the effort of the city to improve the road design which includes installation of traffic signals, provision of continuous footpaths which are adjoined with marked crossings and refuge islands, and installation of rumble strips (WHO, 2013). According to (WHO, 2013), after these interventions, there was a 60-90% reduction in pedestrian fatalities in the high-risk areas in New Delhi; and reduction of pedestrians crossing freely in any road section was observed.

Improving pedestrian safety in The Hague, the Netherlands

Through the sustainable implementation of pedestrian safety in The Hauge, the Netherlands, number of pedestrians killed and seriously injured declined (WHO, 2013). The sustainable pedestrian safety measures include allocation of financial resources, decentralization of tasks to local government, integration of pedestrian safety measures into the urban planning, and consistently reviewing and implementing measures of pedestrian safety (WHO, 2013).

2.5. Road Attributes and Risk Factors

The following road attributes are the required data to calculate the star rating of the road facilities. It is important to understand how iRAP come up with the values of the risk factors associated with each road attributes. iRAP is continuously updating these values (current version is 3.0). On the road attribute factsheets of iRAP, some of the explanations are still based on the previous version. Due to this, definite explanation of the origin of some values cannot be included. Moreover, it was stated on some factsheets that the values are based on researches, discussions between the board members and pedestrian-safety experts.

Crossing Facilities and Quality

The pedestrian crossing facilities risk factor is categorized based on its location and presence of crossing supervisor. On this study, the risk factors used are from the category of school as the location and without a crossing supervisor (as shown in TABLE 3). For the grade separated crossing facility with fencing, iRAP assumed that there will be no pedestrian-related crash since they are not mixed with the other road users; but without fencing, there is an assumption that pedestrians will not utilize the facility(iRAP, 2014b). The current risk factors, with consideration of crossing supervisor, are based on the study of Mead, Zegeer and Bushell (2013) and the discussion between iRAP and experts in risk of pedestrian, but concise explanation of risk factors are not yet available (iRAP, 2014b). Due to this, the previous risk factors are shown in TABLE 4. The factor of 4.5 for the 'refuge only' is based on (Turner et al., 2009) report that there is a reduction of 0.55 in pedestrian-related crashes with the presence of a refuge without signalization in reference to 8.0 for 'no facility', and 2 to 1 for signalized (iRAP, 2014b). The risk factors for marked crossings are also based on Turner et al. (2009) and found out that there will be a 50% reduction in pedestrian for marked crossing without signalization, and 75% reduction for marked crossing with signalization.

This attribute also influences the severity of the crash. There is a 90 severity factor applied for any type of facility and this value considers the difference between the protection level between pedestrians and vehicle occupants (iRAP, 2014b). The quality of these facilities is also important since having poor facilities is as bad as not having the facility at all (iRAP, 2014b). For the latest version of iRAP methodology, 1.5 is used for the poor quality which refers to the signs and markings present on the road (iRAP, 2013s) (shown in TABLE 5).

TABLE 3. Road crossing facilities risk factor for pedestrians (iRAP, 2014b)

Pedestrian Crossing Facilities	Pedestrian likelihood – at a school without a school zone crossing supervisor	Severity
Graded separated facility	0.4	90
Signalized with refuge	1.0	90
Signalized without refuge	1.25	90
Unsignalized marked crossing with refuge	3.8	90
Unsignalized marked crossing without refuge	4.8	90
Refuge only	5.1	90
No facility	6.7	90
Graded separated facility-pedestrian fencing present*	N/A	90

Unsignalized raised marked crossing with refuge	2.5	90
Unsignalized raised marked crossing with without refuge	3.2	90
Raised marked crossing with refuge	3.4	90
Raised marked crossing without refuge	4.5	90

* No recorded value

TABLE 4. Road crossing facilities risk factor for pedestrians (previous version) (iRAP, 2014b)

Pedestrian Crossing Facilities	Pedestrian and bicyclist likelihood	Severity
Graded separated facility	1.0	90
Signalized with refuge	1.0	90
Signalized without refuge	2.0	90
Unsignalized marked crossing with refuge	2.0	90
Unsignalized marked crossing without refuge	4.0	90
Refuge only	4.5	90
No facility	8.0	90
Graded separated facility-pedestrian fencing present*	0.0	90

TABLE 5. Road crossing facility quality risk factor for pedestrians (iRAP, 2013s)

Pedestrian Crossing Quality	Pedestrian Crossing
Adequate	1.0
Poor	1.5

Curvature Type and Quality

The risk factors used in iRAP for the curvature type and quality are based on the ARRB report. TABLE 6 shows the road curvature risk factors for pedestrians. These values are based on the New Zealand study by Mathews & Barnes (1988) as cited in (Turner et al., 2009). FIGURE 4 shows the comparison of the studies conducted for the risk factors of different curvature of the roadways.

TABLE 6. Road curvature risk factor for pedestrians (iRAP, 2013b)

Curvature	Risk of Pedestrian being struck by vehicle (Along)
Straight or gently curving (> 900m)	1.0
Moderate curvature (500-900m)	1.8
Sharp curve (200-500m)	3.5
Very Sharp (0-200m)	6.0

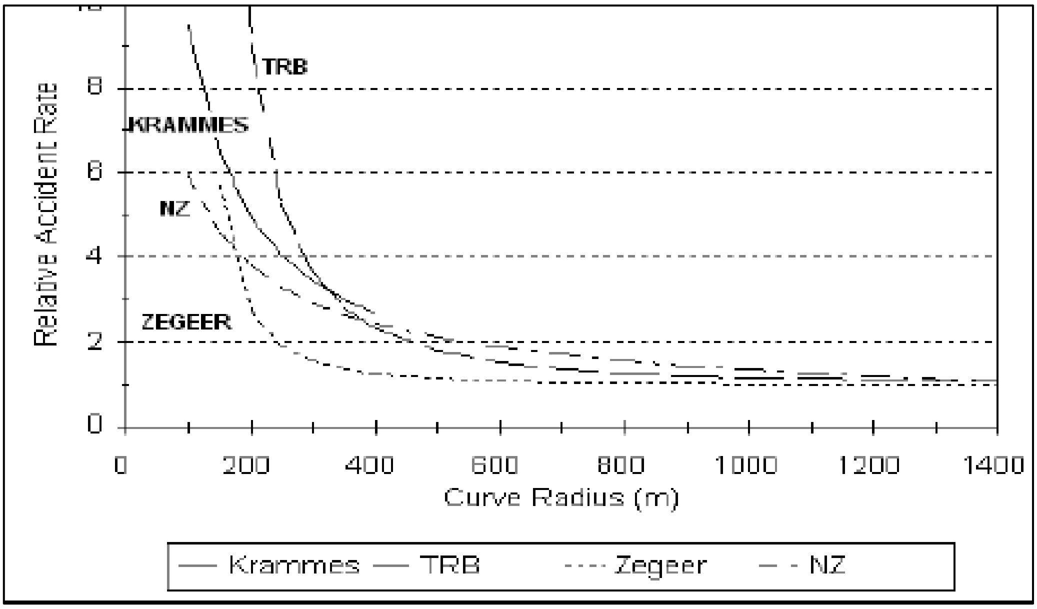

FIGURE 4. Comparison of rash rates on curvatures (McLean (1996) as cited in (Turner et al., 2009))

The quality of the road curvature can be assessed through the curve delineation and how road signage, markings, and chevron guide the drivers in recognizing the sharpness of the road curvature (Turner et al., 2009). Based on iRAP (2013b), the author opted to use 1.25 for an inadequate quality of road curvature and 1.0 for adequate and no applicability (e.g. in straight roadways). Moreover, there is a 10-30% crash reduction for roads with advanced warning signs while 20-40% for roads with directional markings (Elvik and Vaa (2004) as cited in iRAP (2013b)).

Delineation

According from Lynam (2012) as cited in (iRAP, 2013c), there is an assumed 20% reduction on head-on and run-off crashes on roads with good road signs and markings. This percentage is based on the level of safety of vehicles since based on ARRB report (Turner et al., 2009), the report did not have enough information regarding the safety of pedestrian with respect to delineation. However, ARRB discussed that it is logically safer for pedestrians on roads with adequate delineation rather than poor delineation; thus, the risk factor used for vehicles, bicyclists, and pedestrians is 1.0 for roads with adequate delineation and 1.2 for poor delineation.

Intersection Type and Quality

The risk factors for different intersection types are presented in TABLE 7. These values are based on the iRAP Road Attribute Risk Factors-Intersection Type (iRAP, 2013d) and stated that there is 10% higher risk for pedestrians in 4-legged intersection than 3-legged intersections; and 50% higher in roundabouts. The risk factors for the quality of the intersections has the same research background as of the 'Delineation' that stated that there is a 20% reduction (that lead to 1.2 risk factor) on overall crashes (iRAP, 2013u) (as shown in TABLE 8).

TABLE 7. Intersection type likelihood risk factors for pedestrians (iRAP, 2013d)

Intersection type	Pedestrian-likelihood
Merge lane	1.05
Roundabout	1.5
3-leg (unsignalized) with protected turn lane	1.1
3-leg (unsignalized) with no protected turn lane	1.1
3-leg (signalized) with protected turn lane	1.1
3-leg (signalized) with no protected turn lane	1.1
4-leg (unsignalized) with protected turn lane	1.2
4-leg (unsignalized) with no protected turn lane	1.2
4-leg (signalized) with protected turn lane	1.2
4-leg (signalized) with no protected turn lane	1.2
Unused code (non-major inters.)	1.0
None	1.0
Railway Crossing- passive (signs only)	1.0
Railway Crossing- active (flashing lights/boom gates)	1.0
Median crossing point – informal	1.1
Median crossing point – formal	1.1
Mini roundabout	1.3

TABLE 8. Intersection type likelihood risk factors for pedestrians (iRAP, 2013j)

Intersection Quality	Pedestrian
Adequate	1.0
Poor	1.2
Not applicable	1.0

Lane Width

On the current version of iRAP methodology, lane width has effect on the risk of pedestrians walking along the roadway and not to the crossing pedestrian. The effect on the crossing pedestrian was considered on the road attribute 'number of lanes' with corresponding assumption pertaining to lane width. The values shown in TABLE 9 was based on the ARRB study wherein the speed limit was 80 km/h on a rural and urban arterials (TABLE 10). Additionally, based on Heimback et. al (1983) as cited in iRAP (2013d), urban arterial roads have relatively lower effect on the risk of a crash.

TABLE 9. Lane width risk factor for pedestrians (iRAP, 2013e)

Lane Width	Pedestrian-Along	
	Rural	Urban
Wide (>= 3.5 m)	1.0	1.0
Medium (>=2.75 m to <3.25 m)	1.2	1.05
Narrow (>=0m to 2.75m)	1.5	1.1

TABLE 10. Relative risk of lane width on urban and rural roads with 80 km/h speed limit (Turner et al., 2009)

Lane Width	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8
Relative Risk	3.4	3.4	3.3	3.2	3.0	2.9	2.7	2.5	2.3	2.1	1.8	1.6	1.3	1.0

Median Type

The risk factors shown in TABLE 11 are based on the exposure and protection of the pedestrians against the vehicular flow in the area (iRAP, 2013f). King et. al (2007) as cited in (iRAP, 2013f) stated that there is a 28% reduction on the pedestrian exposure risk if there is a raised median. Moreover, a study conducted in New Zealand shows 30% reduction of pedestrian-related crashes if there is a provision of median islands (Turner et al., 2009). The baseline of the risk factors for median type is the provision of barrier and median with the risk factor of 1.0; thus, absence or narrower width (e.g. physical median width) of these facilities lead to higher risk factor (iRAP, 2013f).

TABLE 11. Median type risk factor for crossing pedestrians (iRAP, 2013f)

Median Type	Pedestrian-Crossing the road
Safety barrier - metal	1.0
Safety barrier - concrete	1.0
Physical median width >=20.0m	1.0
Physical median width >=10.0m to <20.0m	1.0
Physical median width >=5.0 m to <10.0m	1.0
Physical median width >=1.0 m to <5.0m	1.0
Physical median width >=0 m to <1.0m	1.6
Continuous central turning lane	3.0
Centreline rumble strips (or flexipost)	2.7
Central hatching (>1m)	2.4
Centre line	3.0
Motorcyclist friendly barrier	1.0
One-way	1.0
Wide centre line (0.3 m to 1.0m)	2.7
Safety barrier-wire rope	1.0

Number of Lanes

As shown in TABLE 12, the pedestrian risk factors for median types increase as the number of lanes increases. Based on Corben et. al (2008) as cited in (Turner et al., 2009), increasing width inflict higher risk to due to: difficulty with the gap selection, increasing exposure to traffic flow, mean speeds are generally higher in wider roads, and uncertainity with the lateral position of approaching vehicle. This is also explained in the relationship found in the study which is *crash risk* ∞ *(road width)*$^{1.5}$ (Corben et. al 2008) as cited in Turner et al. 2009). On the current version of iRAP methodolgy, the risk factors for 'number of lanes' includes the assumption of lane width of 3.5m (iRAP, 2013g).

TABLE 12. Median type risk factor for crossing pedestrians (iRAP, 2013g)

Number of lanes	Pedestrian-crossing the road
One	1.0
Two	2.8
Three	5.2
Four or more	8.0
Two and one	1.8
Three and two	4.0

Operating Speed

For this study, the approximate risk factors (using eyeball test) are used since there is no provided equation to obtain the exact risk factor. There is a 90% probability of pedestrian death on a crash with 80 km/h (iRAP, 2014a). FIGURE 5 shows the graphs of the risk factor of operating speed for different road users. These risk factors are based on the power model of speed which in general is the consolidated likelihood factor, where speed and likelihood have a linear relationship; and a severity factor, where speed and severity of crash have a power of two relationship (iRAP, 2014a) (an example of power model of speed is shown in FIGURE 6). Based on Turner et al. (2009), there is no direct relationship between the speed and risks; and contrary to the graph (FIGURE 5), there are instances that the level of safety is higher on higher speed since these roadways are more well-designed compared to lower speeds. As can be observed, at 75 km/h speed, the graph for pedestrians becomes linear due to the assumption that the death and serious injury is certain from this speed and higher (the severity factor is equal to one) (iRAP, 2014a).

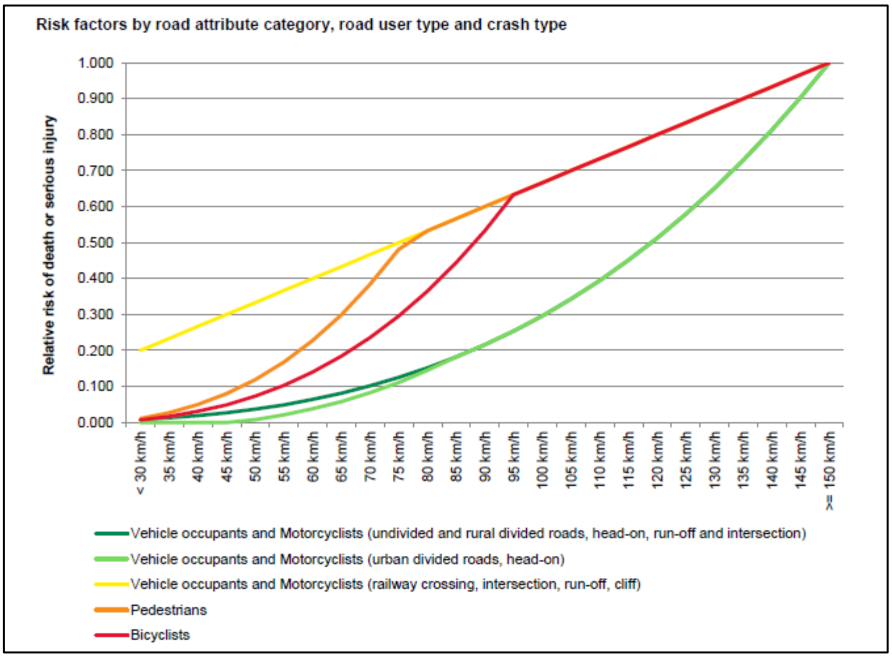

FIGURE 5. Operating speed risk factor for pedestrians (iRAP, 2014a)

$$\frac{\text{Fatal accidents after}}{\text{Fatal accidents before}} = \left(\frac{\text{Speed after}}{\text{Speed before}}\right)^4$$

FIGURE 6. Example of Power model of Speed (Elvik, Christensen, & Amundsen, 2004)

In the Philippines, national highways have a speed limit of 80 km/h and RA 4136 states that speed limits for similar road hierarchy have the same speed limits (Sy, 2017b). Moreover, this research utilized the 85th percentile speed as there are instances that the capacity of the road is exceeded and there is a slower vehicle speed than the speed limit.

Pedestrian Fencing

The risk factors used for the pedestrian fencing (as shown in TABLE 13) are based on the assumption that pedestrians will not cross any section of the roads with the presence of the fencing (iRAP, 2013i). Turner et al. (2012) as cited in (iRAP, 2013i) stated that provision of fencing can reduce crashed by 20% and higher percentage if pedestrians are visible through the railings ; thus, the utilization of 1.25 factor.

TABLE 13. Pedestrian fencing risk factor for crossing pedestrians (iRAP, 2013i)

Pedestrian Fencing	Pedestrian Crossing
Full length	0
At pedestrian crossing	1.0
None	1.25

Pedestrian and Traffic Volume

Based on iRAP (2013a), the effect of traffic flow on the crossing pedestrian (shown in FIGURE 7 and FIGURE 8) uses the same external flow factor relationship as for the risk factors for the vehicles; but more focused on the level of lane saturation. For this version, iRAP methodology adapted 0.05 as the highest risk factor for intersecting road and 0.1 for inspected road (iRAP, 2013a).

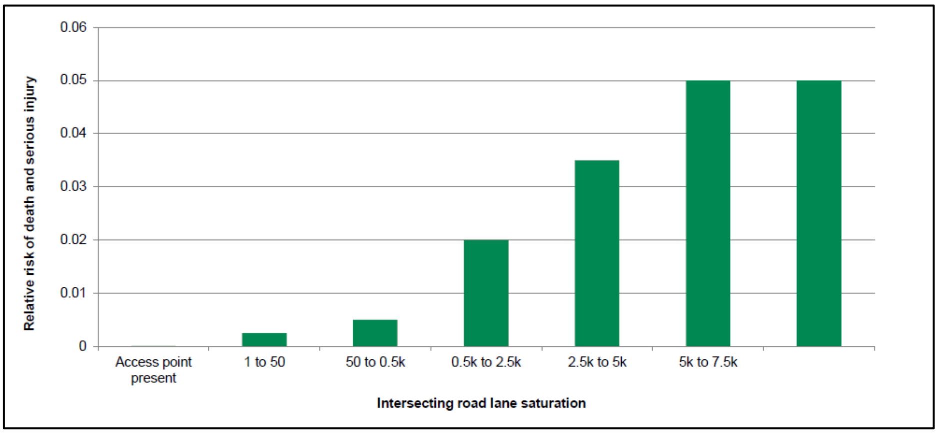

FIGURE 7. External flow risk factor for crossing pedestrians of side road (iRAP, 2013a)

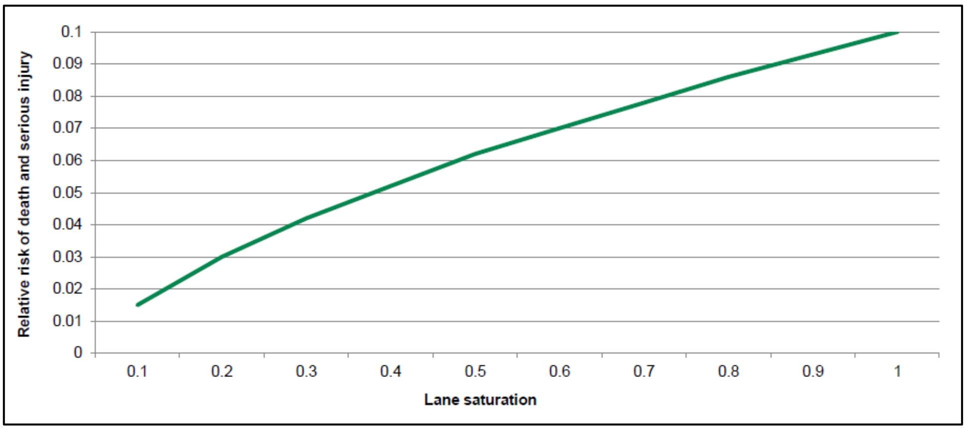

FIGURE 8. External flow risk factor for crossing pedestrians of inspected road (iRAP, 2013a)

The risk factor for the pedestrian flow reflects the level of risk of individual pedestrian which approaches zero for low traffic flows (iRAP, 2013a). On this study, the pedestrian volume acts as switch-button wherein if the program detects any numerical value for this attribute, it will proceed in the calculation; otherwise, it will exclude this part of the equation.

For some of the side roads which do not have available AADT, it can be assumed that the volume of the side road is between 1,000- 5,000 vehicles. This is applicable for side road which is undivided with one-lane, two-way section, as shown in FIGURE 9 (iRAP, 2014c).

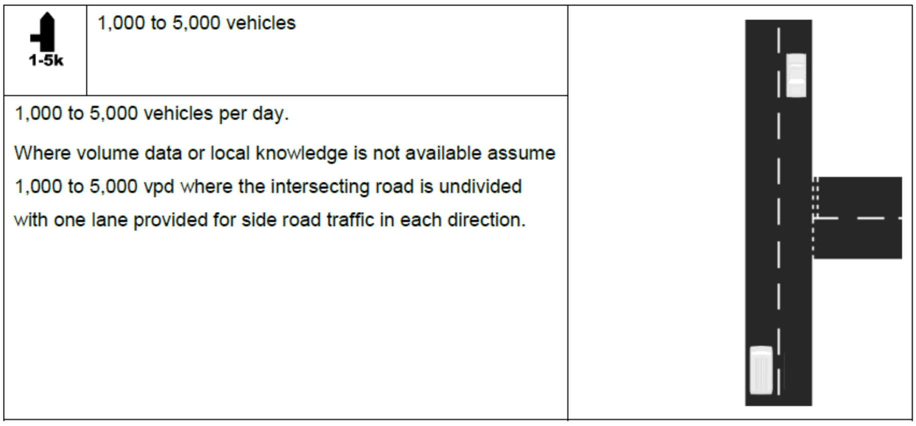

FIGURE 9. Side road traffic volume (iRAP, 2014c)

Road Condition

The risk factors for road condition are shown in TABLE 14. This road attribute is based on the quality of the road surface, whether the road has defects (e.g. deformations or uneven surface, pot holes, and edge defects) (iRAP, 2014c). Elvik and Vaa (2004) as cited in (iRAP, 2013k) stated that there is a 20% reduction of crashes for rehabilated and resurfaced roads, while improving the friction of roads can reduce crash by 40%. As explained in other road attributes, the values shown in table are not only based on the researches.

TABLE 14. Road condition risk factor for pedestrians (iRAP, 2013k)

Road Condition	Pedestrian Along
Good	1.0
Medium	1.2
Poor	1.4

Road Grade

TABLE 15 shows the risk factors for the grade which are based on the US and Australian research (iRAP, 2013l). Hardwood et al. (2000) as cited in (iRAP, 2013l) stated that there is an increase of 20% in risk for road grades of 8-10% while 70% for grades greater than 10%. Based on Choueiri et al. (1994) as cited in (iRAP, 2013l) indicated that there is a lower risk for gradients up to 6% and change of risk rapidly beyond this road grade. FIGURE 10 shows the effect of road grade in crash rates.

TABLE 15. Road grade risk factor for pedestrians (iRAP, 2013l)

Road Grade	Pedestrian-Along
0%- 7.5%	1.0
7.5%- < 10%	1.2
>= 10%	1.7

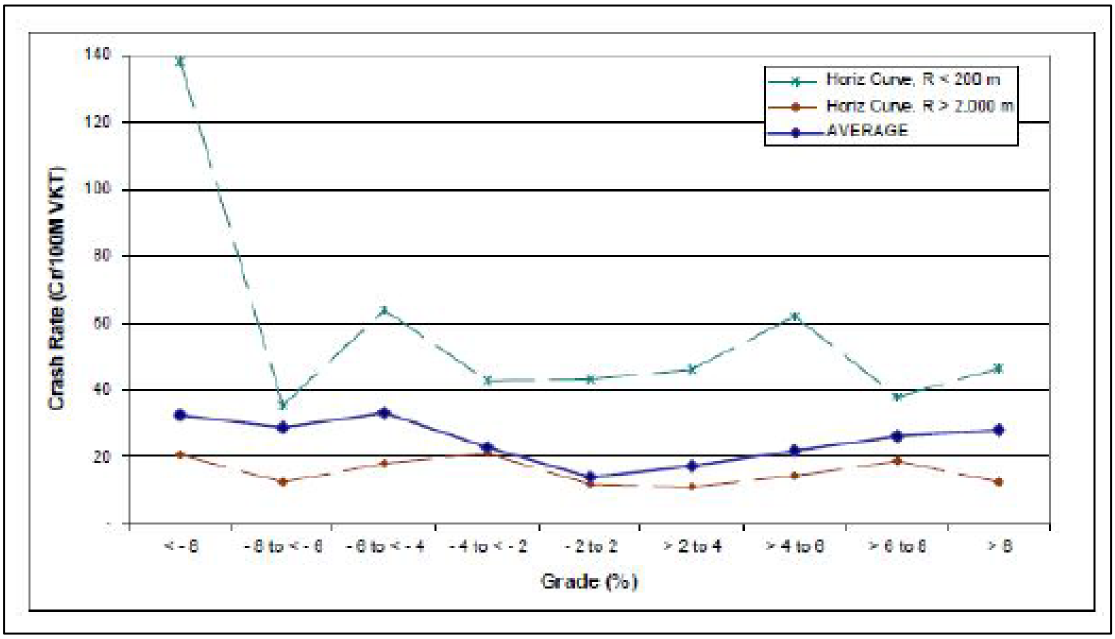

FIGURE 10. Effect of change in road grade in the crash rates in different horizontal curvature (iRAP, 2013l)

School Warning

This attribute was not included in the previous version of the iRAP methodology. This was added to the current version since the current version included the SR4S. University of North Carolina Highway Safety Research center conducted studies and researches for the risk factors of school warnings. Accordint to these, they concluded that there is a 10% reduction pedestrian-related crashes on provision of school zone flashing beacons while 5% for the static signs; and iRAP is still pursuing further research in line with this attribute (iRAP, 2013m). The summary of the risk factors is presented in TABLE 16.

TABLE 16. School warning risk factor for pedestrians (iRAP, 2013m)

School Zone Warning	Pedestrian			
	Crossing Through Road	Crossing Side Road	Along-Driver Side	Along-Passenger Side
School zone flashing beacons	0.9	0.9	0.9	0.9
School zone static signs or road markings	0.95	0.95	0.95	0.95
No school zone warning	1.0	1.0	1.0	1.0
Not applicable (no school at the location)	1.0	1.0	1.0	1.0

Shoulder Rumble Strips

TABLE 17 shows the risk factors for the provision of shoulder rumble strips. This attribute is associated with the delineation of the edge of the carriageway for the vehicles, and they are also known as profile/audible edge lines (iRAP, 2013n). The values shown in the table are based on the study conducted by Turner et al (2012) as cited in (iRAP, 2013n) which found out that there is a 21% reduction on the average crashes with the presence of shoulder rumble strips.

TABLE 17. Shoulder rumble strips risk factor for pedestrians (iRAP, 2013n)

Shoulder rumble strips	Vehicle occupant, motorcyclists, and pedestrian run-off
Not present	1.25
Present	1.0

Sidewalk

The severity and likelihood risk factors for this attribute incorporate the width of the paved shoulder. The values in TABLE 18 are based on the 'iRAP Road Attribute Risk Factors: Sidewalk Provision' (iRAP, 2013o) and 'iRAP Road Attribute Risk Factors: Paved Shoulder Width' (iRAP, 2013h). The risk factors consider the assumption that pedestrians will utilize the best available facility (e.g. informal path in the verge of the road, shoulder, or on the road itself) (iRAP, 2013o). The values are also calculated using the assumed proportion of the pedestrians that will use a certain facility and its corresponding risk. iRAP Technical Working group reassessed and adjusted some of the values in FIGURE 11, FIGURE 12, and FIGURE 13. The sidewalk with physical barrier has 0 risk factor since the pedestrians are well-protected from the vehicles on the road, while the risk for pedestrians on sidewalks without physical barrier decrease as the sidewalk widens (or further from the carriageway) since the vehicles are less likely to encroach on the footpath (iRAP, 2013o). Provision of paved shoulder has also high-risk factor values since it was observed that vehicles tend to utilize this facility; thus, the pedestrian will be mixed with the vehicles. In the Philippines, it is also observed that vehicles use the paved shoulder as an additional carriageway especially during rush hours.

It was discussed in the 'Crossing Facility and Quality' that the risk factor of 90 for the severity considers the difference between the protection level between pedestrians and vehicle occupants (iRAP, 2014b)

Sidewalk (driver and passenger side)	Pedestrians using the facility		Pedestrians walking in carriageway		Sum of total risk
	Proportion (A)	Risk (B)	Proportion (C)	Risk (D)	(A*B) + (C*D)
Physical barrier (between sidewalk and traffic) (Barrier protects pedestrian from errant vehicle)	1	0	0	0	0
Physical separation >3m (No risk from normal flow, only errant vehicles - offset to pedestrian greater than 3m)	1	0.075	0	0	0.075
Physical separation >1m (No risk from normal flow, only errant vehicles - offset to pedestrian greater than 1m)	1	0.09	0	0	0.09

FIGURE 11. Assumed distribution, risk, and behavior of pedestrians in different situations (iRAP, 2013o) (a)

Paved shoulder >=2.4m (Pedestrian needs to choose to use shoulder, cars can use shoulder, offset to pedestrian typically 1m)	0.9	1.08	0.1	10	(14)
Paved shoulder 1< width < 2.4m (Pedestrian needs to choose to use shoulder, vehicles can use shoulder, offset to pedestrian typically approaching 0m)	0.7	3.07	0.3	30	(15)
Paved shoulder 0< width <=1m (Pedestrian needs to chose to use shoulder, vehicles can use shoulder, offset to pedestrian typically approaching 0m or in lane)	0.5	5.05	0.5	50	(18)
None (Pedestrian exposured to all flow assuming they walk in lane)	0.1	9.01	0.9	90	(20)

FIGURE 12. Assumed distribution, risk, and behavior of pedestrians in different situations (iRAP, 2013o) (b)

Informal path ≥ 1.0m (Pedestrian needs to chose use informal path (otherwise in lane). No risk from normal flow (on path), only from errant vehicles, offset great than 1m)	0.5	0.45	0.5	50	5
Informal path 0m to <1.0m (Pedestrian needs to chose use informal path (otherwise in lane). No risk from normal flow (on path) only from errant vehicles, no offset)	0.4	0.4	0.6	60	6

FIGURE 13. Assumed distribution, risk, and behavior of pedestrians in different situations (iRAP, 2013o) (c)

TABLE 18. Sidewalk risk factor for pedestrians (iRAP, 2013o) (iRAP, 2013h)

Sidewalk (driver and passenger side)	Risk factor	Severity
Physical barrier	0	90
Non-physical separation > 3m	0.075	90
Non-physical separation > 1m	0.09	90
Shoulder paved >=2m	14	90
Shoulder paved <1< width < 2.4 m	15	90
Shoulder paved 0< width <=1m	18	90

None	20	90
Informal path >= 1.0m	5.0	90
Informal path 0m to < 1.0m	6.0	90

Sight Distance

This road attribute is associated on the ability of the drivers to perceive the presence of other users (e.g. pedestrians) in the area (iRAP, 2014c). Some of the obstructions in the roads are trees, lighting posts, and other objects that may cause disturbances on the sight of the drivers and pedestrians. The values shown in TABLE 19 are based on the 'Austroads Research Report: Effectiveness of Road Safety Engineering Treatments' (Turner, Steinmetz, Lim, & Walsh, 2012). Based on this report, improvements on the sight distances resulted in the reduction of 30% on roads and intersections.

TABLE 19. Sight distance risk factor for pedestrians (iRAP, 2013t)

Sight distance	Pedestrian along and passenger
Adequate	1.0
Poor	1.42

Skid Resistance

The values shown in TABLE 20 are based on Turner et al (2010) as cited in (iRAP, 2013p). Based on this, it was found out that there is three times higher crash rate for unsealed but adequate, and 5.5 times for poor and unsealed roads. FIGURE 14 and FIGURE 15 describe each type of skid resistance.

TABLE 20. Skid resistance risk factor for pedestrians (iRAP, 2013p)

Skid resistance/ Grip	Pedestrian
Sealed - adequate	1.0
Sealed - medium	1.4
Sealed - poor	2.0
Unsealed - adequate	3.0
Unsealed - poor	5.5

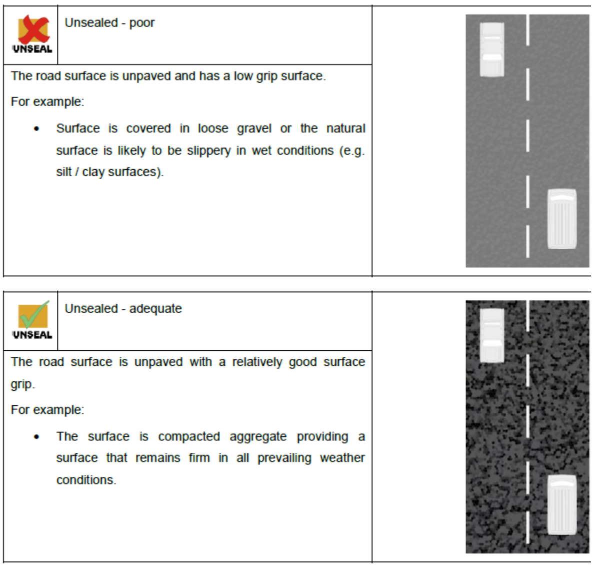

FIGURE 14. Skid Resistance Coding Manual (iRAP, 2014c) (a)

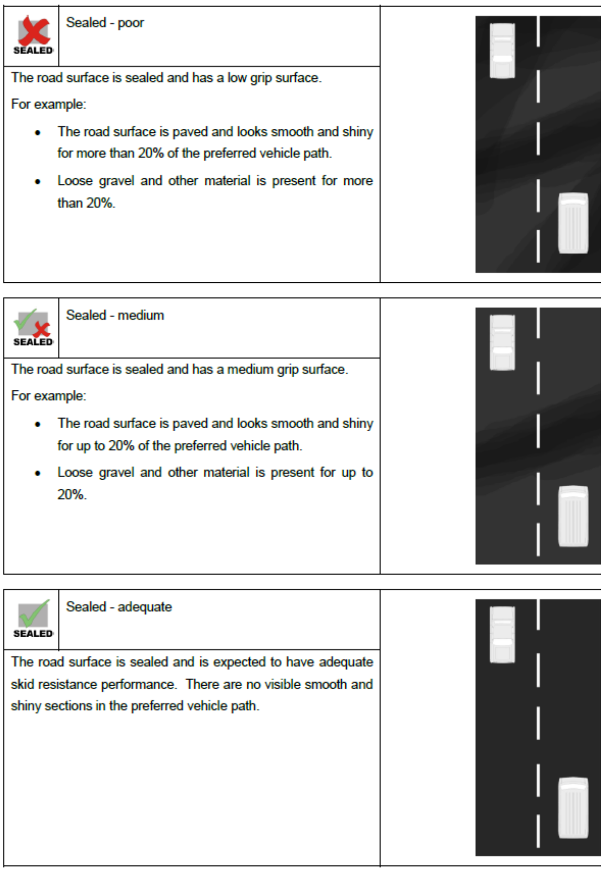

FIGURE 15. Skid Resistance Coding Manual (iRAP, 2014c) (b)

Speed Management

Risk factor of 1.25 is used considering the assumption that the traffic calming can incur a 10 km/h speed reduction and with the coordination of different studies about the speed management (iRAP, 2013q). This risk factor was based on the studies conducted by: (1) Turner et. Al (2010) as cited in (iRAP, 2013q) which found that there is a 20% reduction on crashes, (2) Elvik and Vaa (2004) as cited in (iRAP, 2013q)with 10-30% reduction on number of crashes, and (3) Crash modification factor (CMF) clearing house website with 25-33% reduction on number of crashes (iRAP, 2013q) .

TABLE 21. Speed management risk factor for pedestrians (iRAP, 2013q)

Speed management/Traffic calming	Pedestrians- along and crossing
Not present	1.25
Present	1.0

Vehicle Parking

The basis of the values shown in TABLE 22 were not directly explained in the literature of iRAP but based on (iRAP, 2013r), these values consider the effect to the other road attributes (e.g. obstruction for sight distance, presence of sidewalk, etc.). Considering that there is no designated footpath for pedestrians, the parked vehicles on the sidewalks may encourage the pedestrians to walk along the carriageway (iRAP, 2013r). This also explains the value of 1.0 for vehicle parking with designated pedestrian and bike facility (iRAP, 2013r).

TABLE 22. Vehicle parking risk factor for pedestrians (iRAP, 2013r)

Vehicle parking	Pedestrians
None	1.0
One side	1.2
Two sides	1.22
None (pedestrian or bicyclist facility present)	1.0
One (pedestrian or bicyclist facility present)	1.0
Two (pedestrian or bicyclist facility present)	1.0

2.6. Related Studies

Federative Republic of Brazil: iRAP Pilot Technical Report (Fletcher & Urzua, 2015)

The government of Brazil focused on improving the mobility and reduction of travel times but it is also important to focus on the safety of the road users (Fletcher & Urzua, 2015). In Brazil, there were 35, 155 deaths and approximately 407,685 seriously injured reported in 2006 based on the 2009 WHO Global Status on road safety; but due to issue of underreporting, these values are estimated to be 20% higher than the reported values (Fletcher & Urzua, 2015). Department of Transport Infrastructure (Departamento Nacional de Infraestrutura de Transportes (DNIT), together with the iRAP, conducted a road safety assessment program for approximately 3,400 km of roads (Fletcher & Urzua, 2015). This study used the ViDA program of iRAP which used 100-m stretch of road per interval and smoothed ratings; the summary of the assessed roads are summarized in FIGURE 16. The Star Rating Scores (SRS) are assessed for the four road users with their respective relative risk factors; these risk factors are combined and inputted in a multiplicative model/equation (Fletcher & Urzua, 2015).

Star Ratings	Vehicle Occupant Length (km)	Percent	Motorcycle Length (km)	Percent	Pedestrian Length (km)	Percent	Bicycle Length (km)	Percent
5 Stars	18.0	1%	0.6	0%	3.0	0%	13.2	0%
4 Stars	310.0	9%	110.3	3%	16.4	0%	13.0	0%
3 Stars	1970.0	58%	1581.3	47%	83.1	2%	154.0	5%
2 Stars	838.7	25%	1234.4	36%	111.4	3%	192.7	6%
1 Star	249.8	7%	459.9	14%	327.4	10%	260.1	8%
N/A	9.0	0%	9.0	0%	2854.2	84%	2762.5	81%
Totals	3395.5	100%	3395.5	100%	3395.5	100%	3395.5	100%

Note: the table shows 'smoothed' Star Ratings.

FIGURE 16. Star Ratings, DNIT Pilot Study (Fletcher & Urzua, 2015)

This study also includes the 'Safer Roads Investment Plan' (SRIP) which focuses on the reduction of likelihood of run-off crashes and the risk to other road users associated to this type of crash (Fletcher & Urzua, 2015). This SRIP includes the provision of rumble strips and facilities for pedestrians and bicyclists; and has an estimated 7.6:1 BCR (benefit-cost ratio) (with BCR = 3 as a threshold) with 46 % reduction in number of deaths (Fletcher & Urzua, 2015). The improvement of road safety in Brazil also requires improvement on the behavior of the road users (e.g. following traffic rules such as speeding, wearing seatbelts and helmets, and driving under the influence of alcohol and drugs) (Fletcher & Urzua, 2015). Using star rating targets (e.g. Asian Development Bank set a 4-star rating for pedestrians and cyclists) would pave the way in the improvement of safer infrastructure and easier decision making of road safety policy management (Fletcher & Urzua, 2015). The star rating targets to be set are dependent of the existing standard, purpose of the road network, traffic and pedestrian volume, financial aspect, and political influence; in general, the targets should align with the aim of improving the ratio of saved lives and investment cost(Fletcher & Urzua, 2015). The iRAP recommends to use the 3-star rating as a target rating (Fletcher & Urzua, 2015).

Furthermore, The SRS of roads and SRIP on this report will aid on the DNIT, transport planners, and designers to improve the safety through provision of well-designed roadway facilities and rehabilitation of these facilities. In comparison to the study for SR4S for Lipa City, calculation and explanation of the obtained star ratings are included in the study, but due to limited data (e.g. crash data, available funding, etc.), the SRIP will not be included.

Relationship between Star Ratings and crash cost per kilometer travelled: the Bruce Highway, Australia

This literature includes a total of 20,000-km stretch of roads in Bruce Highway, Queensland, and uses the updated iRAP model which focused on the star rating for vehicle occupants (Mcinerney, Fletcher, & iRAP, 2013). This iRAP model requires road attributes which are known to have impact on the likelihood of a crash and its respective severity (Mcinerney et al., 2013). The authors have available data of the crash rates along these roads which led them to compare the star rating and the crash frequencies.

For the star rating, they used 100-meter per interval and smoothed the consecutive ratings; the output of this is shown in FIGURE 17 (Mcinerney et al., 2013). There was 1,770 fatal and serious injury crashes occurred from 2007-2011 and based on these data, TABLE 23 summarizes the corresponding crash cost per vehicle-kilometer travelled (vkt) (Mcinerney et al., 2013). There is a crash cost reduction of 40% if the road improved from 1-star to 2-star, 61% cost reduction from 2-star to 3-star, and 43% cost reduction from 3-star to 4-star (Mcinerney et al., 2013).

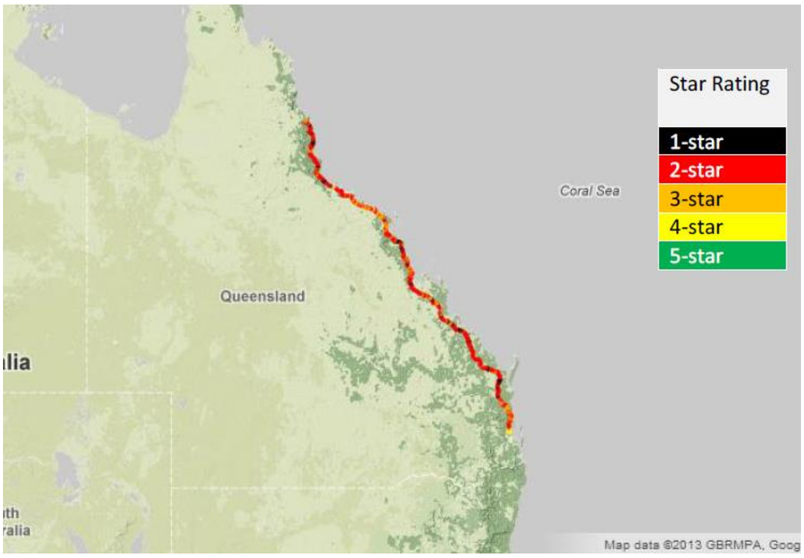

FIGURE 17. Star Rating of Bruce Highway, Queensland (Mcinerney et al., 2013)

TABLE 23. Summary of the crash cost per vkt (Mcinerney et al., 2013)

Vehicle Occupant Star Rating	Fatal and serious injury crashes, 2007-2011	Vehicle kilometers traveled (VKT), 2007-2011	Total KSI crash cost, $ 2011 terms	Average fatal and serious injury crash cost per VKT
1	46	567,667,345	$84,240,100	$0.148
2	616	12,522,941,585	$1,120,844,200	$0.090
3	305	11,983,984,593	$423,319,600	$0.035
4	70	4,582,386,295	$9,0863,200	$0.020
5 *	0	4,854,500	N/A	N/A
Total	1037	29,661,834,318	$1,719,267,100	$0.059

* The sample of 5-star roads is too small to enable a comparison.

This research study was able to calculate for the crash cost per vkt since they have available data of the crash costs and crash frequencies. Comparing the situation in Lipa City, Philippines, this will be difficult due to the limited availability of data. The study conducted in Bruce Highway, Queensland showed that there is a direct relationship between the crash cost and crash frequency and severity.

3. RESEARCH METHODOLOGY

3.1. Data Gathering

The research design for this study followed the iRAP methodology. The most relevant iRAP methodology on this study includes: Star rating score (SRS) equations, star rating bands, star rating for schools, and road attributes (iRAP, 2014e). Star rating of schools have discrepancies with respect to Star rating of roads in terms of the required data. Road markings and signages are different for schools and roads. Pedestrian crossing in schools is also an additional attribute in star rating of schools. TABLE 24 shows the required attributes and their respective methods of data collection. Selection of schools were based on the available traffic volume of the roads (e.g. schools that are along national highways wherein traffic volume is available). The selection of the school for the pilot study was based on the available data for the traffic and pedestrian flow based on TELRAAM. TELRAAM works with the communication between devices installed in vehicles and a central database that will collect the traffic data sent from the users ("Telraam," n.d.). The online platform of TELRAAM shows the volume of the pedestrian, bicyclists, and vehicles per hour. Through this, the researcher was able to obtain traffic data for the star rating.

Kindercampus tuinwijk, situated in Lazarijstraat, Hasselt, has an available traffic and pedestrian volume, and speed data. The pilot study also included a nearby road (Rozenstraat) for sensitivity analysis. The site visit took one day for the researcher to gather data and cross-check with the data from online sites (Google Earth and Geopunt); while gathering data from Geopunt, Google Earth, and TELRAAM took three days for all the road sections.

For the schools in Lipa City, a 400-meter offset for both sides of the schools are analyzed. The 400 meter is based on the average walkability and this totals to 17 sections per school zones. The first four schools lie along the national highway while the other two schools lie along a municipal road which has a lower speed limit and narrower road cross-section. The online platforms used for the schools in Lipa city are GIS web apps (http://www.dpwh.gov.ph/dpwh/gis/rti), Google Maps (https://www.google.com/maps), and Google Earth. The researcher gathered the data of the school zones in Lipa city through the online platforms on the first part of the data gathering. The site visit was supposed to be executed on the second part of data gathering. The on-site visit is for verification purposes of some road attributes, as listed in TABLE 24; however, a COVID-19 crisis came up which hindered the gathering of the on-site data. Due to this, the researcher was limited to using the online gathered data. TABLE 24 shows the road attributes, as collected via online platforms, from the school zone of School 02. Among the road attributes, road condition, skid resistance, and quality of curve have the highest probability of discrepancy between the on-line gathered and on-site gathered data.

TABLE 24. Required data and corresponding data collection method

Category	Type of data	Road Attribute	Data Collection Method	
			Primary	Secondary (For Verification)
Likelihood	Road environment			
	Area type	Urban	Research in Google (Philippine Deposit Insurance Corporation) (PDIC, 2008)	---
	Adequacy of sight distane	Adequate	Google Earth/Google Maps	Visual inspection
	Road type			
	Number of lanes	Two	Street view Google Earth/Google Maps	Visual inspection
	Lane width	Medium (>=2.75 m to <3.25 m)	Measure via Google Earth/Google Maps	Approximate measurement on site
	Shoulder rumble strips	Not present	Street view Google Earth/Google Maps	Visual inspection
	Road condition	Good	Street view Google Earth/Google Maps	Visual inspection
	Skid Resistance	Sealed - adequate	Street view Google Earth/Google Maps	Visual inspection
	Grade	0% -7.5%	Profile view in Google Earth/Google Maps	Visual inspection
	Road features			
	Median type	Centre line	Street view Google Earth/Google Maps	Visual inspection
	Delineation	Adequate	Street view Google Earth/Google Maps	Visual inspection
	Curvature	Straight or gently curving	Top View Google Earth/Google Maps	Visual inspection

	Quality of Curvature	Adequate	Street view Google Earth/Google Maps	Visual inspection
	Speed Management	Not present	Street view Google Earth/Google Maps	Visual inspection
	Vehicle Parking	Two (pedestrian or bicyclist facility present)	Street view Google Earth/Google Maps	Visual inspection
	Street lighting	N/A	---	---
	Pedestrian Fencing	None	Street view Google Earth/Google Maps	Visual inspection
	School zone			
	School warning	No school zone warning	Street view Google Earth/Google Maps	Visual inspection
	Intersection			
	Intersection type	None	Top View Google Earth/Google Maps	Visual inspection
	Intersection quality	Not Applicable	Street view Google Earth/Google Maps	Visual inspection
External flow influence	Traffic count	5,401-7,200	Data from DPWH (AADT= 22906 with 2-lane, 2-way	---
	Pedestrian flow	N/A	---	---
Operating Speed Severity	85th percentile speed	60 kph	Land Transportation and Traffic Code	Based from the posted speed
	Sidewalks	Non-physical separation > 1m	Street view Google Earth/Google Maps	Visual inspection
	Pedestrian Crossing	Unsignalised marked crossing without refuge	Street view Google Earth/Google Maps	Visual inspection
	Quality of pedestrian crossing	Adequate	Street view Google Earth/Google Maps	Visual inspection

Pilot Study - Data Gathering

The procedure done in the Pilot study is the same for the gathering of data in the schools in Lipa City. However, the online data collection differs between the two regions as there are different online platforms available in different regions. The online platform available in Hasselt are Geopunt, Telraam, Google Earth, and Google maps; while in the Philippines, there is a GIS web apps wherein annual average daily traffic (AADT) is available, Google Earth, and Google maps (shown in TABLE 24). Geopunt, together with Google Earth and Google maps, the researcher gathered the road attributes (e.g. number of lanes, lane width, curvature, intersection) of the road sections from the 'Likelihood' and 'Severity' category. Telraam was used to gather the 85th percentile of the speed and the traffic count for a month period. For the assessment of school zones, the first step is to analyze and identify the length of road section to be included. For the pilot study, it is limited for the total length of the road where the school zone lies. Then, using the online platforms, required data are gathered. Then, the site is visited to verify the road attributes. Lastly, after checking the required data, these data are entered into excel sheets. The VB program assessed the final star rating score and its corresponding star rating. The step-by-step procedure is explained below using a road section in Hasselt.

Lazarijstraat and Rozenstraat are divided into 50-m interval road sections (as shown in FIGURE 18 and FIGURE 19). The 50-m interval per section is based on the procedures stated in the iRAP methodology. Lazarijstraat has a total length of 415.0 m (eight sections) while Rozenstraat has 175.0 m (three sections). The sample computation and illustrations for data gathering are based on the Section 02 of Lazarijstraat. The Section 02 includes the location of the school zone, has a three-legged intersection, and has Eeuwfeeststraat as a side road.

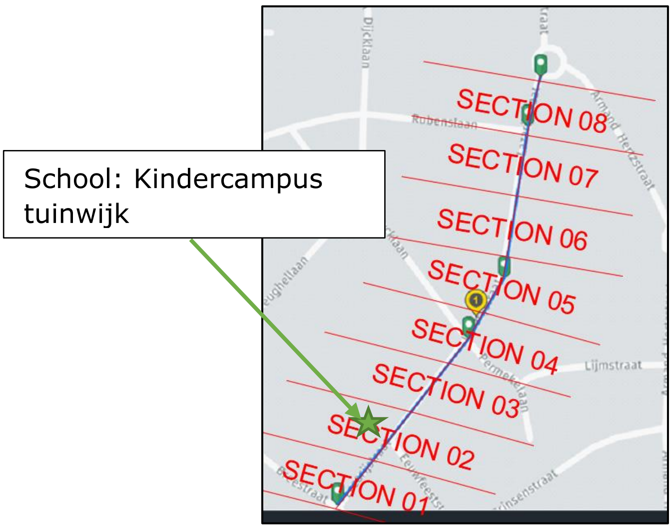

FIGURE 18. Lazarijstraat Road Sections

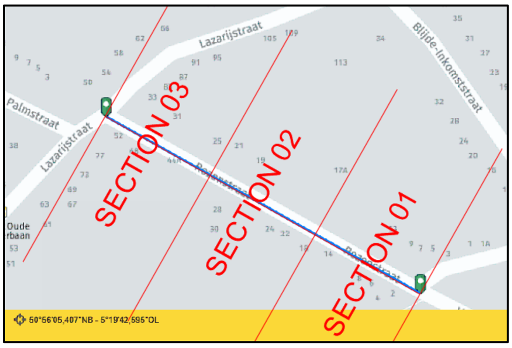

FIGURE 19. Rozenstraat Road Sections

After dividing the roads into 50-m interval sections, online assessment and site visit are performed. FIGURE 20 and FIGURE 21 show the road attributes for Section 02 of Lazarijstraat. The researcher was able to obtain the required data via online platforms for the calculation of the star ratings for the road sections. For verification purposes, the site was visited. Road condition, delineation, and skid resistance are the major road attributes that were verified through the site visit. For the lane width, Geopunt shows that the road section is 5.20 m wide (2.60 m each lane), and for the input data, it was categorized as 'Narrow (>=0m to 2.75m)'. Sidewalk for the driver is 'Informal Path' since the facility is shared with the bicyclists and there is no-to-little separation from the carriageway, while the sidewalk on the passenger side is 'Non-physical separation >1.0m' because there is more than 1.0 m distance between the pedestrian walkway and the carriageway. The median type is set to 'Centerline' because this category has the highest risk factor and there is no category yet for roadways with no centerlines; thus, lead to poor road delineation assessment.

FIGURE 20. Data gathering using Google Earth (Section 02, Lazarijstraat)

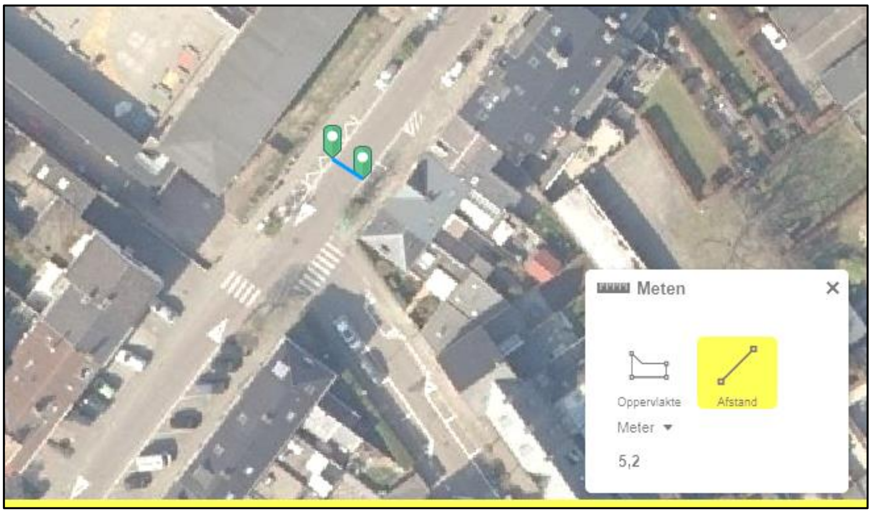

FIGURE 21. Data gathering using Geopunt (Section 02, Lazarijstraat)

These data are entered in the excel sheets first; then, to the VB program. The calculation of the star rating score is done through the Excel and VB program to crosscheck the values.

3.2. Data Analysis

Equation 1 was used in obtaining the SRS for pedestrians in school zones. Star rating score (SRS) has an equivalent star rating (as shown in TABLE 26). This research applied the rating for pedestrians. Based on TABLE 26, to obtain a 5-star rating, a certain road section needs to score within '0 to 0.2' for pedestrians walking along the roadway, '0 to 4.8' for crossing pedestrians and a total of '0 to 5.0'. The SRS equation is divided into four sections; it considered the level of safety of pedestrians along the inspected road, in both sides of the road, the crossing pedestrian in the inspected road and side road.

$$SRS = \sum (likelihood\ x\ \ severity\ x\ operating\ speed\ x\ external\ flow\ influence)$$

$$SRS = \frac{Inspected\ Road_{passenger\ side} + \ Inspected\ Road_{driver\ side}}{2} + Inspected\ Road_{crossing} + Side\ Road_{crossing}$$

EQUATION 1. SRS equation (iRAP, 2014d)

Different attributes have different risk effects on the severity of the crash and likelihood of being involved in a crash. Pedestrians need to walk along the road and cross the road so they can reach their destination (e.g. school, house); thus, it is important to note which attributes can affect these pedestrian travel directions. TABLE 25 summarizes the attributes that have effects on the said pedestrian-travel activities. Attributes that have both effect on both travel directions are highlighted. It should be noted that provision of sidewalk for pedestrians have effect on the severity of the crash that involves a pedestrian walking along the road, and provision of crossing facility on the crossing pedestrians.

TABLE 25. Attributes categorized as how they affect the likelihood and severity of crash for pedestrians walking along and crossing the road.

Attributes that affects the safety of Pedestrian Along the Road	Attributes that affects the safety of Pedestrian Crossing the Road
Lane Width	Intersection type
Shoulder Rumble Strips	Intersection quality
Road Condition	Number of lanes
Skid Resistance	Skid Resistance
Road Grade	Median type
Curvature	Adequacy of sight distance
Quality of Curvature	Vehicle Parking
Adequacy of sight distance	Speed Management/Traffic Calming
Vehicle Parking	Street Lighting
Speed Management/Traffic Calming	
Sidewalk provision	School Zone Warning
Delineation	Crossing facility
Street Lighting	Pedestrian crossing quality
School Zone Warning	Pedestrian Fencing
Traffic Volume-Inspected Road- vehicle flow per lane	Traffic Volume-Inspected Road
Pedestrian Volume- Along Driver	Pedestrian Volume- Along Driver
Pedestrian Volume-Along Passenger	Pedestrian Volume-Along Passenger
Pedestrian Volume-Crossing	Pedestrian Volume-Crossing
Operating Speed (85th percentile)	Operating Speed (85th percentile)
Severity factor of Sidewalk	Severity factor of Crossing facility

TABLE 26. iRAP Star Rating bands and colors (iRAP, 2015)

Star Rating	Star Rating Score				
	Vehicle occupants and motorcyclists	Bicyclists	Pedestrians		
			Total	Along	Crossing
5	0 to < 2.5	0 to < 5	0 to < 5	0 to < 0.2	0 to < 4.8
4	2.5 to < 5	5 to < 10	5 to < 15	0.2 to < 1	4.8 to < 14
3	5 to < 12.5	10 to < 30	15 to < 40	1 to < 7.5	14 to < 32.5
2	12.5 to < 22.5	30 to < 60	40 to < 90	7.5 to < 15	32.5 to < 75
1	22.5 +	60+	90 +	15 +	75 +

VB Program

FIGURE 22 shows the summary of one of the road sections. As shown, there are seven main buttons on the left side of the screen. Each road attributes are categorized into these buttons. All the road attributes should be entered into the program to calculate the star rating. If all the road attributes are already entered, a summary of all the road attributes will be shown if the user click on 'Summary' button. This enables the user to verify all the road attributes.

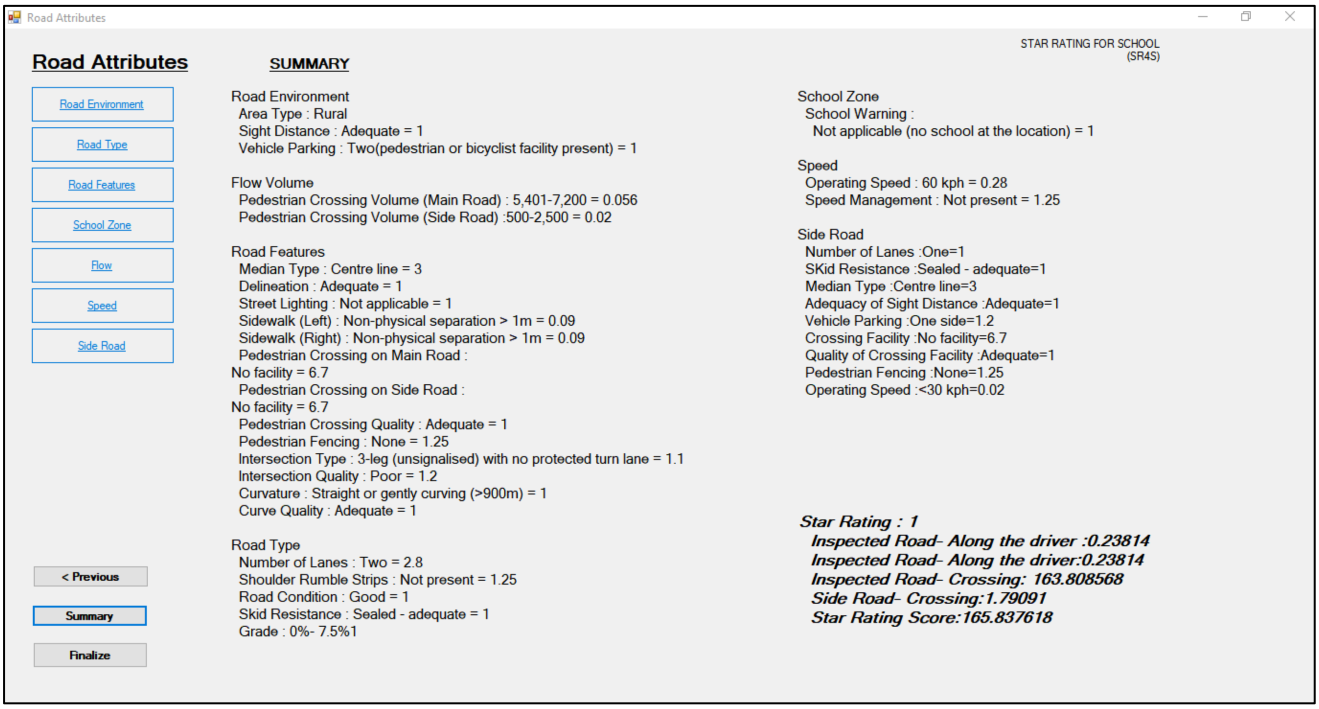

FIGURE 22. Visual Basic Interface-Summary

Once the user verified the road attributes, clicking on the 'Finalize' button allows the user to see the star rating and the lists of countermeasures (shown in FIGURE 23). Further explanation of the VB program is expounded in Appendix 8.2.

FIGURE 23. Visual Basic Interface- Results

3.3. Countermeasures

This research study also includes the provision of lists of countermeasures which can improve the star rating of the road sections with low rating. iRAP has 94 countermeasures ranging from low to high costs, with their respective duration of treatment life and effectiveness. The following list (as shown in TABLE 27), show the countermeasures that are identified as 'low to medium cost', which is more relevant in the Philippines. The data shown in the table below are based from the 'Roadsafety Toolkit' of iRAP (iRAP, 2010). The countermeasures listed are focused on improving the safety of pedestrians, which is the goal of this research. As per the 'Roadsafety Toolkit', the highest effectiveness, with 60%, is installation of grade-separated pedestrian crossing, but this is also tagged as 'High' in cost and has '20+ years' as the treatment life.

TABLE 27. Summary of the countermeasures focused on pedestrian safety and their respective cost, treatment life and effectiveness (iRAP, 2010)

Countermeasure	Outcome	Costs	Treatment Life (years)	Effectiveness
1. Central Hatching	To improve road delineation	Low	1-5	10-25%
2. Centre and edge delineation	To improve sight distance and delineation	Low	1-5	10-25%
3.Well-designed On-street parking (e.g. parallel parking, parking bans)	Provide more space for pedestrian or bicycle facilities	Low to Medium	5-10	10-25%
4. Pedestrian Footpath	To improve the safety of pedestrians and encourage walking	Low to Medium	10-20	40-60%
5. Pedestrian Fencing	Improve pedestrian safety	Low	10-20	25-40%
6. Road signs and crossing supervisor in School Zones	Improve pedestrian safety	Low to Medium	5-10	10-25%
7. Pedestrian Refuge Island	Improve pedestrian safety	Low to Medium	5-10	25-40%
8. Roadside Safety-Hazard Removal	More space for pedestrian/bicyclist facilities and improve sight distance	Low to Medium	5-10	25-40%
9. Rumble Strips	To prevent run-off crashes and to improve visibility of edge lines	Low	1-5	10-25%
10. Resurfacing of Road	Improve Skid Resistance	Low to Medium	5-10	25-40%

11. Adequate Road signs and markings in Pedestrian crossing	Improve crossing pedestrian safety	Low	1-5	25-40%

Aside from the countermeasures suggested in the iRAP, WHO (2013) has also listed countermeasures which are focused on the pedestrian safety. TABLE 28 shows the countermeasures suggested by WHO (2013). They are classified through their evidence of effectivity. 'Proven' indicates that the countermeasure are effective based on robust studies, 'Promising' means that the countermeasure still needs further evaluation, and ' Insufficient evidence' are countermeasures which do not have strong conclusion about effectiveness (WHO, 2013). In general, WHO (2013) discussed six major strategy to improve the safety of pedestrians; however, this report only focused on the four strategies as the other two strategies focused on vehicle design and post-crash trauma. This research focused on the countermeasures that can be done through the improvement of the listed road attributes.

Reducing pedestrian exposure to vehicular traffic

This strategy focuses on the countermeasures that reduce the exposure of pedestrians to the vehicles. Some of these countermeasures are installation and/or improving sidewalks along the roadways, marked crossings in road sections with low speed, and installation of overpass and underpass in conjunction with an effective pedestrian fencing (WHO, 2013).

Reducing vehicle speed

Based on WHO (2013), one of the most effective countermeasures to increase pedestrian safety is to reduce the speed of the vehicles. This strategy focuses on the incorporation of speed management which encompasses measures in engineering (e.g. road design, traffic calming measures), enforcement and education (WHO, 2013).

Improving the visibility of pedestrians

WHO (2013) stated that it is important to improve the visibility of pedestrians through provision of crossing improvements (e.g. raised crossing), street lighting, and removal of obstructions, etc.,

Improving pedestrian and motorist safety awareness and behavior

In the Philippines, behavioral aspect has been a major challenge in road safety. This strategy is complex and requires long-term plan of action. WHO (2013) discussed that education and traffic law enforcement are important for this strategy. Education can be in a medium of school-based activities, raising awareness, and mass media campaigns (WHO, 2013) .

TABLE 28. Interventions specific for improving pedestrian safety (WHO, 2013)

Key measures	Examples of interventions	Effectiveness: Proven	Effectiveness: Promising	Effectiveness: Insufficient evidence
Reduce pedestrian exposure to vehicular traffic	Provide sidewalks	■		
	Install and/or upgrade traffic and pedestrian signals	■	■	■
	Construct pedestrian refuge islands and raised medians	■		
	Construct enhanced marked crossings		■	
	Provide vehicle restriction/diversion measures	■	■	
	Install overpasses/underpasses	■		
	Improve mass transit route design	■		
	Reduce traffic volumes by switching journeys from the car to public transport, walk and cycle for distances and purposes where these options work well	■		
Reduce vehicle speeds	Reduce speed limit	■		
	Implement area-wide lower speed limit programmes, for example, 30 km/h	■		
	Implement road-narrowing measures		■	
	Install speed management measures at road sections	■	■	
	Install speed management measures at intersections	■	■	
	Provide school route improvements		■	
Improve sight distance and/or visibility between motor vehicles and pedestrians	Provide crossing enhancements	■	■	
	Implement lighting/crossing illumination measures	■		
	Reduce or eliminate obstruction by physical objects including parked vehicles		■	
	Install signals to alert motorists that pedestrians are crossing		■	■
	Improve visibility of pedestrians		■	
Improve pedestrian and motorist safety awareness and behaviour	Provide education, outreach and training	■		
	Develop and/or enforce traffic laws on speed, drinking and driving, pedestrian right-of-way, red light disobedience, commercial roadside activity and traffic control	■		
	Implement 'walking school bus' programmes		■	
Improve vehicle design for pedestrian protection	Develop vehicle safety standards and laws for pedestrian protection		■	■
Improve vehicle design for pedestrian protection	Enforce vehicle safety standards and laws for pedestrian protection			■
	Publicize consumer information on pedestrian safety by make and model of car, for example, results of New Car Assessment Programmes		■	
Improve care for the injured pedestrians	Organize pre-hospital trauma care systems	■		
	Establish inclusive trauma care systems	■		
	Offer early rehabilitation services	■		

Note: When the terms 'proven', 'promising' and 'insufficient evidence' appear highlighted in the same line, it shows that there are different measures in the same broad category at different stages of development as already explained above with respect to effectiveness.

Source: *1–7*.

Initially, the researcher is supposed to meet with the school heads to discuss the assessment of their respective school's star rating and the interventions they can apply to improve the road safety of the pedestrians. However, due to lockdowns and early termination of classes in the country, the researcher consulted the school division office for other measures to discuss the research. Based on the division office, the researcher can submit a summary report which comprises assessment of the school zones and the list of countermeasures; this report also explains the importance of the information dissemination to the concerned stakeholders especially parents, students and other school personnel. The division office can disseminate the report to the concerned schools. The personnel from the division office stated that they are currently discussing about the pedestrian safety of school zones, and that this research can guide them through the aim of improving pedestrian safety. This aim is achievable through continuous work and effort in line with the proper enforcement, engineering, and education. The researcher also discussed some measures to increase the awareness of students, parents, and road users. For students, the schools can include pedestrian safety on their syllabus, parents can be more aware through attending Parent Teacher Association (PTA) meetings wherein school personnel educates them about pedestrian safety, and other road users especially drivers can be more aware through informative posters posted in the whole city. Lastly, it was also discussed that the school should have coordination with the local government units (LGUs) with the improvement of pedestrian safety. LGUs have higher authority in the region and they can gather more resources than the schools alone.

4. RESULTS AND DISCUSSION

4.1. Pilot Study

TABLE 29 shows the summary of the input data and the star rating for the Kindercampus tuinwijk, Hasselt, Belgium. Using Equation 1 and the risk factors of road attributes, the computed Star Rating score is 6.27 which falls into 4-star category. The narrow lanes can act as the traffic calming measure in the road section. In the site, an 'Octopus' signage is present which represents a school area. This signage allows the driver to recognize that they are entering a school zone. The 'median type' was set to 'center line' since this option has the highest risk factor but in the actual scenario, there are no painted centerlines. These factors can affect the driving perception since drivers can be discouraged to drive faster on narrow carriageways and with counter traffic flow. The skid resistance is based on the presence of visible shiny and smooth road surface.

TABLE 29. Summary of the attributes and corresponding Star Rating for the Pilot Study

Road Name and Section	Lazarijstraat Section 02 (Kindercampus tuinwijk)	
Location	Lazarijstraat, Hasselt, Belgium	
STAR RATING:		6.27
ATTRIBUTES (Inspected Road)		Risk Factor
Area Type	Urban	
Lane Width	Narrow (>=0m to 2.75m)	1.10
Number of lanes	One	1.00
Median type	Centre line	3.00
Shoulder Rumble Strips	Not present	1.25
Road Condition	Good	1.00
Skid Resistance	Sealed - adequate	1.00
Road Grade	0%- 7.5%	1.00
Curvature	Straight or gently curving	1.00
Quality of Curvature	Adequate	1.00
Adequacy of sight distance	Adequate	1.00
Vehicle Parking	Two(pedestrian or bicyclist facility present)	1.00
Speed Management/Traffic Calming	Present	1.00
Intersection type	3-leg (unsignalized) with no protected turn lane	1.10
Intersection quality	Poor	1.20
Sidewalk- driver	Informal path >= 1.0m	5 (90*)
Sidewalk- passenger	Non-physical separation > 1m	0.09 (90*)

Delineation	Poor	1.20
School Warning	School zone static signs or road markings	0.95
Crossing supervisor	Not Present	N/A
Crossing facility	Raised marked crossing without refuge	4.5 (90*)
Pedestrian crossing quality	Adequate	1.00
Pedestrian Fencing	None	1.25
Traffic Volume	1,521 (two-way)	0.022
Pedestrian Volume- Along Driver Pedestrian Volume-Along Passenger Pedestrian Volume-Crossing	*acts as a switch (if there is an input Pedestrian Volume, the star rating will proceed)	
Operating Speed (85th percentile)	40 km/h	0.06
ROAD ATTRIBUTES -Side Road (Eeuwfeeststraat)		
Number of lanes	One	1.00
Skid Resistance	Sealed - adequate	1.00
Median type	Centre line	3.00
Adequacy of sight distance	Adequate	1.00
Vehicle Parking	Two (pedestrian or bicyclist facility present)	1.00
Speed Management/Traffic Calming	Present	1.0
Crossing facility	No facility	6.70 (90*)
Pedestrian crossing quality	Adequate	1.0
Pedestrian Fencing	None	1.25
Traffic Volume-Inspected Road		
Operating Speed (85th percentile)	40 kph	0.06

*Severity factors

TABLE 30. Summary of the Rating of Lazarijstraat

Name of School	Section	Score	Star Rating		General Star Rating
Lazarijstraat	01	2.30	★★★★★	4.90	★★★★★
	02	6.72	★★★★		
	03	2.29	★★★★★		
	04	5.53	★★★★		
	05	3.42	★★★★★		
	06	3.41	★★★★★		
	07	3.41	★★★★★		
	08 (School)	12.10	★★★★		
Rozenstraat	01	3.41	★★★★★	3.41	★★★★★
	02	3.41	★★★★★		
	03	3.41	★★★★★		

TABLE 30 shows the summary of the star rating per 50-m road section of Lazarijstraat and Rozenstraat. Based on the table, all the sections in Rozenstraat obtained 5-star, with an average SRS of 3.41; it also has a constant road section from 0+000 to 0+150. Lazarijstraat obtained an average SRS of 4.90 which is a 5-star rating. Generally, both Lazarijstraat and Rozenstraat are safe roads for pedestrians.

Sections 02, 04 and 08 obtained the highest scores for the Lazarijstraat. Compared to the other sections with lower scores, Section 02, 04 and 08 all have intersection present in each road section; this also indicates a presence of a side road. As referred to Equation 1, there is a separate section for side roads which implies that if the section does not have a side road, the 'side road' section of the equation is excluded. The 'Side Road' of Lazarijstraat Section 02 contributed 3.74 to the total star rating score (whole calculation of Section 02 is shown in Appendix 8.1). Aside from this factor, comparing the low-scored and high-scored sections, traffic calming measures and presence of school zone also affected the final star rating scores.

4.2. Schools in Lipa City

Common approach and practice observed in the school zones

Due to some practice and common behavior of the road users, some assumptions were considered. For instance, national highways in the Philippines have a speed limit of 80 km/h (Sy, 2017b) but due to lack of enforcement, drivers can freely speed up. Since the focus of this research is the school zones, and travel of pedestrians especially students are usually during rush hours, wherein there is a peak-hour-volume, it was assumed that majority of the vehicles have a speed of 60 kph or lower. Other practices and common behaviors and their respective considerations are as follows:

<u>Sidewalk</u>: FIGURE 24 shows that there is a constructed grade-separated crossing facility but the columns of the facility obstructed the whole width of the sidewalk. Due to this, the pedestrians are forced to walk into the shoulder of the road. This

shows the lack of planning in the city. Likewise, FIGURE 25 shows that some of the households encroached the space for the sidewalk. This is illegal since the space is a public property but due to lack of enforcement pertaining to these issues, these scenarios are commonly observed especially in the provinces, like Lipa City. This also forced the pedestrians to walk into the shoulder (as shown in FIGURE 25) which decrease the level of safety of the pedestrians. For these road sections, the type of sidewalk was assigned to be 'Paved shoulder' as the sidewalk is not used due to obstructions.

FIGURE 24. Grade-separated facility that obstructed the sidewalk (Google Maps, 2020b)

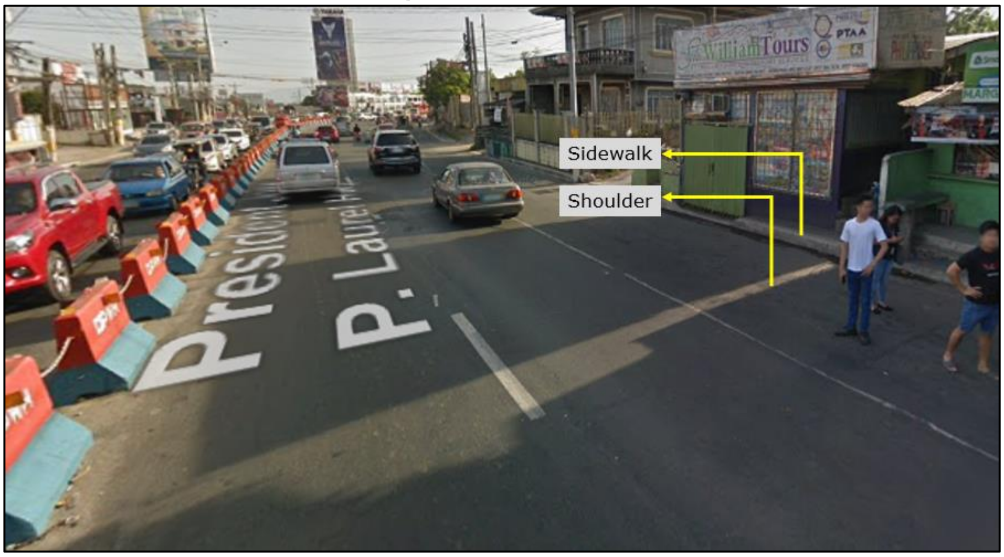

FIGURE 25. Households obstructed the sidewalk (Google Maps, 2020b)

Traffic calming measure: Some schools block one carriageway during school hours that act as traffic calming measure; then, they will remove it once the classes start indicating that students are already inside the schools. This also act as the vehicle parking or dropping-off lane for some students. The school warning zones are placed near the pedestrian crossing to decrease the number of vehicles crossing the road section. School signages used in the Philippines are shown in FIGURE 26.

FIGURE 26. School zone signages (Google Maps, 2020a)

Median: FIGURE 27 shows a pedestrian crossing through the concrete barrier. Presence of barrier indicates that there should not be any pedestrian crossing the street. It is also shown in the figure that there is a nearby traffic lights which indicates a crossing facility. This has been a huge issue with the road safety in the Philippines. Even though there are facilities installed to protect them against the vehicles, they still choose the convenience rather than safety. On this matter, enforcement should be strengthened, or a pedestrian fencing should be installed.

FIGURE 27. A crossing pedestrian with the presence of concrete barrier (Google Maps, 2020b)

It is important to consider the behavior of the road users in the localization of this methodology as this have a huge impact on the level of safety. Pedestrians in the Philippines (observed in Lipa City and Metro Manila) are aware of the danger of walking and crossing the streets but it was still observed that they will rather mix with the vehicles than to walk for a bit to use the pedestrian facilities.

Star Rating

Star rating scores and respective star ratings were calculated using excel and the VB program. The assessment of the school zones in Lipa city are summarized in TABLE 31. Some of sections are combined due to lack of available landmark in the area that can be used as a marker for 50-meter section.

TABLE 31. Summary of the Star Rating of the school zones in Lipa City

Name of School	Section	Score	Star Rating	General Star Rating	
01	01	128.19	★	125.00	★
	02	128.19	★		
	03	128.19	★		
	04	33.65	★★★		
	05	27.48	★★★		
	06	146.45	★		
	07	146.45	★		
	08	167.28	★		
	09 (School)	99.82	★		
	10 (School)	99.82	★		
	11	141.52	★		
	12	141.52	★		
	13	146.50	★		
	14	146.50	★		
	15	146.50	★		
	16	154.64	★		
	17	142.20			
02	01	124.31	★	122.45	★
	02	124.31	★		
	03	124.31	★		
	04	124.31	★		
	05	99.44	★		
	06	119.06	★		
	07	164.81	★		
	08 (School)	89.11	★★		
	09	119.35	★		
	10	124.31	★		
	11	124.31	★		
	12	124.31	★		
	13	124.31	★		
	14	124.31	★		
	15	124.31	★		
	16	124.31	★		
03	01	89.11	★★	67.51	★★
	02	124.31	★		
	03	124.31	★		
	04	124.31	★		
	05	25.13	★★★		
	06	41.57	★★		
	07	41.57	★★		
	08 (School)	24.01	★★★		
	09	41.57	★★		
	10	41.57	★★		
	11	41.57	★★		
	12	45.64	★★		
	13	90.21	★		
	14	90.21	★		

	01	79.91	★★		
	02	79.91	★★		
	03	79.91	★★		
	04	79.91	★★		
	05	79.91	★★		
	06	79.91	★★		
	07	79.91	★★		
	08	79.91	★★		
04	09 (School)	54.42	★★	75.75	★★
	10	79.91	★★		
	11	79.91	★★		
	12	79.91	★★		
	13	79.91	★★		
	14	57.29	★★		
	15	79.91	★★		
	16 (School)	57.29	★★		
	17	79.91	★★		
	01	10.61	★★★★		
	02 (School)	10.61	★★★★		
	03	5.82	★★★★		
	04	10.61	★★★★		
	05	7.25	★★★★		
	06	10.61	★★★★		
	07	10.61	★★★★		
	08	10.36	★★★★		
05	09	10.36	★★★★	21.12	★★★
	10	10.36	★★★★		
	11	10.36	★★★★		
	12	10.36	★★★★		
	13	10.36	★★★★		
	14	57.70	★★		
	15	57.70	★★		
	16	57.70	★★		
	17	57.70	★★		
	01	27.52	★★★		
	02	27.52	★★★		
	03	27.52	★★★		
	04	27.52	★★★		
	05	41.91	★★		
	06	41.91	★★		
	07	41.91	★★		
	08	41.91	★★		
06	09 (School)	21.77	★★★	26.17	★★★
	10	11.56	★★★★		
	11	11.56	★★★★		
	12	11.56	★★★★		
	13	11.56	★★★★		
	14	24.32	★★★		
	15	24.32	★★★		
	16	24.32	★★★		

Based on TABLE 31, School 05 has the lowest star rating score which is 21.12 (Star Rating = 3, safe level) while School 01 has the highest star rating score which 125.00 (Star Rating = 1, unsafe level). Among the star rating scores of the schools' sections, 'School 01 -Section 08' got the highest star rating score which is 167.28 (Star rating =1) while, 'School 05-Section 03' has the lowest which is 5.82 (Star rating =4). These ratings are based on TABLE 26. The difference between the road attributes between the two road sections are shown in TABLE 35 (e.g. lane width, number of lanes, type of sidewalk, etc.). These attributes can help the researcher to identify and narrow down the options in choosing general countermeasures. Assessment of each school zones is still essential in identifying the most effective countermeasure but through these identified road attributes, decision makers can start looking through these lists.

Based on TABLE 31, School 01 and School 02 obtained the highest average star rating score (125.00 and 122.45, respectively). These schools were compared and the similar attributes between the sections that yielded the highest rating score were identified. Similarly, the similar attributes for the lowest average star rating score were also identified. These School 05 and School 06.

TABLE 32 shows that 19 (out of 24) road attributes for the 'least safe sections' have the same type of road attributes while 17 (out of 24) for the 'safest sections'. Comparing the road attributes of the least safe and safest sections, the highlighted road attributes are the differences between the two groups. Therefore, among the school samples in Lipa City, highlighted attributes affected the discrepancy between the star rating scores. Comparably with the list in TABLE 35, this list can also support the recommendation for choosing a countermeasure. However, there are road attributes that have worse condition than the other but still yielded a higher star rating. For instance, in TABLE 32, the type of sidewalk in the 'Least safe sections' is a 'Non-physical separation > 1m' and 'None' for the 'Safest Sections'. Obviously, in this case, 'Non-physical separation > 1m' is a safer facility than having no facility for a sidewalk. This shows that it is important to check on different road attributes rather than focusing on just only one road attribute. SRS equation (Equation 1) is a multiplicative and additive function; thus, all the road attributes have effect on the final star rating score. Moreover, the highlighted road attributes are analyzed using deterministic sensitivity analysis.

TABLE 32. Common road attributes for the Least Safe and Safest Sections

Road Attributes	Least Safe Sections	Safest Sections
Area Type	Urban	Urban
Shoulder Rumble Strips	Not present	Not present
Road Condition	Good	Good
Skid Resistance	Sealed - adequate	Sealed - adequate
Road Grade	0%- 7.5%	0%- 7.5%
Curvature	Straight or gently curving	Straight or gently curving
Quality of Curvature	Adequate	Not applicable
Adequacy of sight distance	Adequate	Adequate
Speed Management/Traffic Calming	Not present	Not present
Pedestrian fencing	None	None

Lane Width	Medium (>=2.75 m to <3.25 m)	---
Number of lanes	Two	One
Median type	Centre line	---
Vehicle Parking	Two (pedestrian or bicyclist facility present)	One side
Intersection type	3-leg (unsignalised) with no protected turn lane	---
Sidewalk- driver	Non-physical separation > 1m	None
Sidewalk- passenger	Non-physical separation > 1m	---
Delineation	Adequate	Poor
Speed	60 kph	
Intersection quality	---	Not applicable
Crossing facility-inspected road	---	No facility
Pedestrian crossing quality	---	Adequate

Comparison of Pilot Study and Schools in Lipa City

Comparing the sample of school zones in Lipa City, Philippines and the pilot school in Hasselt, Belgium, the school in Hasselt has relatively higher level of safety compared to the schools in Lipa City (as shown in TABLE 33). Average SRS for Lipa City is based on the average of the least safe and safest school zones which are equivalent to 123.73 and 23.65, respectively. For the Hasselt, the average SRS are based on the least safe and safest sections which are 6.83 and 2.85, respectively. The least safe school zones in Lipa City lies along the national highway which has a speed limit of 80 km/h, and 40 km/h for school in Hasselt. The average traffic volume has also a huge discrepancy between the two regions; Lipa City = 3,601- 5,400, Hasselt = 0-1800. Crossing facility in 'Kindercampus tuinwijk' is a 'Raised unmarked crossing without refuge' and 'Unsignalised marked crossing without refuge' in schools in Lipa City. The crossing facility in 'Kindercampus tuinwijk' also has an 'Octopus' signage that alerts the drivers that there are nearby school zones. Raised pedestrian crossing also acts as a traffic calming measure in the school zone. Number of lanes in the school zones in Lipa city which lies along the national highway have a two lane, two- way section, while 'Kindercampus tuinwijk' has a one-lane, two-way section. In the design of roadways, design speed and road cross-section especially the number of lanes are always associated with each other. The discussed attributes are the top four road attributes which have higher ranges of values as shown in FIGURE 28 (Tornado plot). Other factors that are not shown or categorized in the road attributes are the level of enforcement and behavior of the road users. There are discussed issues pertaining to these issues (FIGURE 24-FIGURE 27).

A pilot study in Hasselt, Belgium is included to test the methodology to be used in the school zones in Lipa City. However, comparison between the two regions can be used to formulate list of countermeasures. As shown in TABLE 33, there are huge discrepancy between the average SRS of two the regions. The similar road attributes are highlighted. Since there are huge discrepancy, this research can focus on the countermeasures that are related to improving the road attributes that are different between the regions. These road attributes are: Traffic calming measures, number of lanes, crossing facility, speed, traffic volume, etc.

TABLE 33. Comparison between Hasselt (Pilot Study) and Lipa City school zones

Road Attributes	Least Safe Sections		Safest Sections	
	Lipa City	Hasselt	Lipa City	Hasselt
Average SRS	123.75	6.83	23.65	2.85
Area Type	Urban	Urban	Urban	Urban
Shoulder Rumble Strips	Not present	Not present	Not present	Not present
Road Condition	Good	Good	Good	Good
Skid Resistance	Sealed - adequate	Sealed - adequate	Sealed - adequate	Sealed - adequate
Road Grade	0%- 7.5%	0%- 7.5%	0%- 7.5%	0%- 7.5%
Curvature	Straight or gently curving	Straight or gently curving	Straight or gently curving	Straight or gently curving
Quality of Curvature	Adequate	Adequate	Not applicable	Not applicable
Adequacy of sight distance	Adequate	Adequate	Adequate	Adequate
Speed Management/Traffic Calming	Not present	Present	Not present	Not present
Pedestrian fencing	None	None	None	None
Lane Width	Medium (>=2.75 m to <3.25 m)	Medium (>=2.75 m to <3.25 m)	---	
Number of lanes	Two	One	One	One
Median type	Centre line	Centre line	---	Centre line
Vehicle Parking	Two (pedestrian or bicyclist facility present)	Two (pedestrian or bicyclist facility present)	One side	Two (pedestrian or bicyclist facility present)

Intersection type	3-leg (unsignalised) with no protected turn lane	3-leg (unsignalised) with no protected turn lane	---	None
Sidewalk- driver	Non-physical separation > 1m	Non-physical separation > 1m	None	Non-physical separation > 1m
Sidewalk- passenger	Non-physical separation > 1m	Non-physical separation > 1m	---	Non-physical separation > 1m
Delineation	Adequate	Poor	Poor	Poor
Speed	60 kph	40 kph	---	40 kph
Intersection quality	---	---	Not applicable	Not applicable
Crossing facility- inspected road	---	---	No facility	Raised marked crossing without refuge
Pedestrian crossing quality	---	---	Adequate	Adequate
Traffic Volume	---	---	---	0-1800

Generally, the methodology does not include the behavioral aspect of the road users. These behaviors include compliance of the road users to the traffic rules and regulations, utilization of proper crossing and walking facilities for pedestrians, aggressiveness of the road users especially drivers, and other risky behaviors. Human error accounts for 94% of road crashes (National Highway Traffic Safety Administration, 2018). The discussed behaviors of the road users often yield to human error. However, human errors are difficult to eliminate in the transportation safety; thus, the designers should provide ergonomic road designs to road users and further lessen the human error. Furthermore, education and awareness on road safety, and strict enforcement are also important factors in road safety. These measures can further improve the safety especially for pedestrians.

4.3. Sensitivity Analysis

Qualitative sensitivity analysis

This analysis is based on the observed road attributes in the Pilot study. For the pilot study, a qualitative sensitivity analysis is more applicable as there are only two sets of road sections to compare. On this sensitivity analysis, two sections are basically compared and the difference road attributes between the two are identified.

TABLE 34 shows the comparison between a road section in Lazarijstraat and a road section in Rozenstraat. The section from Lazarijstraat obtained a rating of 12.10 which is a 4-star rating while the section from Rozenstraat obtained 3.41 which is a 5-star. Based on the table, the varying attributes that lead to difference in rating are highlighted (presence of intersection, delineation, etc.). Since these roads have the same type of road classification, most of the road attributes are the same such as speed, lane width, number of lanes, etc. Presence of an intersection on the road section has a significant impact on the star rating of the road. Based on the equation of star rating, presence of an intersection or side road will have its own rating, and this will be added on the rating of the other crash types (e.g. inspected road along and crossing).

TABLE 34. Comparison between a road section in Lazarijstraat and Rozenstraat

Road Name and Section	Lazarijstraat Section 08		Rozenstraat Section 01	
Location	Hasselt, Belgium		Hasselt, Belgium	
STAR RATING:	★ ★ ★ ★	12.10	★ ★ ★ ★ ★	3.41
ATTRIBUTES (Inspected Road)		Risk Factor		Risk Factor
Area Type	Urban		Urban	
Lane Width	Medium (>=2.75 m to <3.25 m)	1.05	Medium (>=2.75 m to <3.25 m)	1.05
Number of lanes	One	1.00	One	1.00
Median type	Centre line	3.00	Centre line	3.00
Shoulder Rumble Strips	Not present	1.25	Not present	1.25
Road Condition	Good	1.00	Good	1.00
Skid Resistance	Sealed - adequate	1.00	Sealed - adequate	1.00
Road Grade	0%- 7.5%	1.00	0%- 7.5%	1.00
Curvature	Straight or gently curving	1.00	Straight or gently curving	1.00
Quality of Curvature	Adequate	1.00	Adequate	1.00
Adequacy of sight distance	Adequate	1.00	Adequate	1.00
Vehicle Parking	One (pedestrian or bicyclist facility present)	1.00	Two (pedestrian or bicyclist facility present)	1.00
Speed Management/Traffic Calming	Present	1.00	Not Present	1.25

Intersection type	3-leg (unsignalized) with no protected turn lane	1.10	None	1.0
Intersection quality	Poor	1.20	Not applicable	1.0
Sidewalk- driver	Non-physical separation > 1m	0.09 (90*)	Non-physical separation > 1m	0.09 (90*)
Sidewalk- passenger	Non-physical separation > 1m	0.09 (90*)	Non-physical separation > 1m	0.09 (90*)
Delineation	Poor	1.20	Poor	1.20
School Warning	Not applicable (no school at the location)	1.0	Not applicable (no school at the location)	1.0
Crossing supervisor	Not Present	N/A	Not Present	N/A
Crossing facility	No facility	6.7 (90*)	No facility	6.7 (90*)
Pedestrian crossing quality	Poor	1.50	Adequate	1.00
Pedestrian Fencing	None	1.25	None	1.25
Traffic Volume	1,521 (two-way)	0.022	1,521 (two-way)	0.022
Pedestrian Volume- Along Driver Pedestrian Volume- Along Passenger Pedestrian Volume- Crossing	*acts as a switch (if there is an input Pedestrian Volume, the star rating will proceed		*acts as a switch (if there is an input Pedestrian Volume, the star rating will proceed	
Operating Speed (85th percentile)	40 km/h	0.06	40 km/h	0.06
ROAD ATTRIBUTES (Side Road)				
Number of lanes	One	1.00		
Skid Resistance	Sealed - adequate	1.00		
Median type	Centre line	3.00		
Adequacy of sight distance	Adequate	1.00		
Vehicle Parking	None	1.00		
Speed Management/Traffic Calming	Not Present	1.25		
Crossing facility	No facility	6.70 (90*)		
Pedestrian crossing quality	Poor	1.5		
Pedestrian Fencing	None	1.25		
Traffic Volume- Inspected Road	1000**	0.02		

Operating Speed (85th percentile)	40 kph	0.06	

*Severity Factors, **Assumed value for side roads (iRAP, 2013a)

Furthermore, this sensitivity analysis shows that 'Speed Management/Traffic Calming', 'Intersection type', 'Intersection quality', Pedestrian crossing quality, and presence of a sideroad are the road attributes that caused the discrepancy between the two road sections. However, this type of analysis is not enough to identify which among the road attributes have higher impact than the other road attributes.

Deterministic sensitivity analysis

Deterministic sensitivity analysis is a quantitative method wherein comparison of the relative impact of variables (road attributes) are considered. On this method, more data were utilized to formulate a tornado plot. For each variable, there is an assigned value for the high, baseline, and low values. The road attributes listed in TABLE 35 were based on the difference between the road attributes of the lowest-rated road section and highest-rated road section among the observed sections in the school zones. Also, these road attributes were used to plot the tornado plot.

Other sensitivity analysis utilizes fixed percentage value (e.g. -30%, baseline, +30%) for the maximum and minimum value of the tornado plot. In this study, there is no fixed percentage as there is no single value (percentage) wherein all the values will be equal. Instead, the researcher assigned typical conditions as the baseline value (Star rating score = 255.64). Assigning values with the typical or average condition is better than by just assigning to average since some attributes are not linear and some are limited in a two-option condition (e.g. poor or adequate). Also, utilization of maximum and minimum value of road attributes will yield to unrealistic scenario. It should be noted that this methodology is also used in the assessment of road section without school zones. As for the school zones, there are scenarios that are unrealistic. For instance, road sections with 120 km/h with 4-lanes each direction is not a realistic scenario for a school zone. Thus, this analysis is limited to the collected data in Lipa City. The maximum and minimum values were obtained based on the worst and best collected existing condition per road attributes. However, analysis using the maximum and minimum values is recommended for assessment of road sections without school zones.

Having higher range of values of the road attributes means that these attributes can have higher impact as they have more discrepancy with the nominal value. For instance, crossing facility's baseline value = Unsignalized marked crossing without refuge (risk factor = 3.8), minimum = Grade- separated facility (risk factor = 0.4), and maximum = None (risk factor = 6.7); compared to lane width's baseline = Medium (risk factor = 1.05), minimum = Wide (risk factor = 1.0), and maximum = Narrow (risk factor =1.1). Evaluating the risk factors of the compared road attributes, crossing facility's maximum and minimum values have higher discrepancy from its baseline than the values of lane width.

TABLE 35. Road attributes conditions with respective assigned attributes

Road Attributes	Condition	Assigned Attributes	Risk Factor
Lane Width	Maximum	Narrow	1.1
	Average/ Typical	Medium	1.05
	Minimum	Wide	1.0
Number of Lanes	Maximum	Three and two	4.0
	Average/ Typical	Two	2.8
	Minimum	One	1.0
Vehicle Parking	Maximum	Two sides	1.22
	Average/ Typical	Two sides with pedestrian and bike facility	1.0
	Minimum	One side with pedestrian and bike facility	1.0
Intersection Type	Maximum	Roundabout	1.5
	Average/ Typical	3-leg (unsignalized) with no protected turn lane	1.1
	Minimum	None	1.0
Sidewalk-driver	Maximum	None	20
	Average/ Typical	Paved shoulder >= 2m	14
	Minimum	Non-physical separation > 1m	0.09
Sidewalk-passenger	Maximum	None	20
	Average/ Typical	Paved shoulder >= 2m	14
	Minimum	Non-physical separation > 1m	0.09
Delineation	Maximum	Poor	1.2
	Average/ Typical	Poor	1.2
	Minimum	Adequate	1.0
School Warning	Maximum	No school zone warning	1.0
	Average/ Typical	Not a school zone	1.0
	Minimum	School zone static signs or road markings	0.95
Crossing facility-inspected road	Maximum	None	6.7
	Average/ Typical	Unsignalized marked crossing without refuge	3.8
	Minimum	Grade- separated facility	0.4
	Maximum	Poor	1.5

Pedestrian crossing quality	Average/ Typical	Poor	1.5
	Minimum	Adequate	1.0
Traffic Volume	Maximum	7,201- 9,000	0.066
	Average/ Typical	3,601- 5,400	0.048
	Minimum	0-1,800	0.022
Operating Speed (85th percentile)	Maximum	80 kph	0.55
	Average/ Typical	60 kph	0.28
	Minimum	35 kph	0.04

FIGURE 28 shows the plotted tornado plot. Based on the tornado plot, 'Operating Speed has the highest range of star rating score. The highest value assigned for the speed is 80 km/h while the lowest is 35 km/h. The highest assigned speed is higher than the speed limit in the national highways since due to lack of enforcement, some drivers speed up.

It should be noted that there are more speed categories and traffic volume categories compared to the other attributes. Some of the road attributes have only two categories (poor or adequate). Due to this, some of the road attributes have higher range of values. Limiting the analysis to the assigned values, the tornado plot shows that 'Operating Speed', 'Traffic Volume', 'Crossing Facility', and 'Number lanes' are the road attributes which the star rating score is more sensitive to.

Moreover, the road attributes that have high impact on the final SRS is not limited to the ones listed in the tornado plot. These road attributes are the difference between the least safe and safest school zones in Lipa City. However, due to this limitation, some of the road attributes which have also high impact on the final SRS are not included. For instance, pedestrian fencing has a huge impact on the improvement of pedestrian safety, but since majority of the road sections does not have pedestrian fencing, this is not reflected on the investigated attributes in tornado plot.

FIGURE 28. Tornado plot of Road Attributes

Among the top road attributes, the 'Crossing facility' and 'Number of Lanes' are more likely to be improved or altered. Based on RA 4136, the speed limit per road type is uniform in the country which means provincial or city level agency cannot implement change in the speed limit (Sy, 2017b). Similarly, number of vehicles passing through a road is difficult to change. Normal trends for traffic volume are increasing especially in a developing city, like Lipa City, wherein new establishments are constructed that generates and attracts traffic. Traffic volume can be changed if there will be a new infrastructure wherein the existing traffic will be diverted into. Consequently, this study determined that improving the crossing facility and decreasing the number of lanes are major interventions to consider.

Speed is one of the major factors that affect the star rating scores which is shown in the tornado plot. Section 4.2 of the report discussed the assumption that vehicle speeds are 60 kph and lower during peak-hours. Evidently, higher speed will yield to more hazardous level for pedestrian safety. Installation of traffic calming measures can aid the reduction of speed near the school zones. However, based on (iRAP, 2010), installation of traffic calming measures are costly (tagged as 'Medium to High' cost). For this scenario, stricter enforcement, and higher pedestrian protection by means of separation of pedestrian from traffic flow are needed.

4.4. Effect of Countermeasure implementation on Pedestrian Safety

The countermeasures presented in TABLE 36 are based on the difference between the road attributes between Lipa and Hasselt, road attributes in the tornado plots, and the countermeasures suggested in iRAP (TABLE 27). For this assessment, it should be noted that the first four schools lie along the national highway (speed limit of 80kph) while the last two schools lie in a municipal road. One of the road attributes that highly affect the star rating scores is the type of crossing facility. There are two type of crossing facility presented: the grade-separated facility and the unsignalized with refuge island. According to (iRAP, 2010), grade-separated facility constitutes to 60% improvement in the road safety, while 25-40% for the unsignalized with refuge island. TABLE 36 shows that the schools along the national road have higher percentage of improvement of pedestrian safety with the grade-separated pedestrian facility than the other schools. Low level of existing pedestrian protection may have caused these high percentages. The 'grade-separated facility' has a risk factor of '0' and with multiplicative property of the equation, the 'Crossing of Inspected Road' yields to 'zero'. However, the 'unsignalized with refuge island' as the crossing facility have lower effect on the pedestrian safety but have improvement percentages ranging from 16.04%-42.76%.

Physical barrier as the facility for the sidewalk has a minimal effect on the school zones which are along the national road since the existing sidewalk facility on these sections are better (e.g. Informal path > 1.0m) than the ones along the municipal roads(e.g. no facility). This road attribute mainly affects the protection level of the pedestrian walking along the roadway, not crossing pedestrians. For the school zones along the national road, crossing of pedestrians have higher impact on the final star rating score than the pedestrian walking along the road. Like the effect of grade-separated facility, pedestrian fencing has also higher impact on the schools along the national road. This attribute also affects the protection level of crossing pedestrians. Pedestrian fencing and physical barrier can be in the same material and physical characteristics, but they have different purposes. Physical barrier restrains the vehicle from encroaching the pedestrian facility, while the pedestrian fencing restricts the pedestrians from crossing any section of the road and directs the pedestrian to the pedestrian crossing facility. For the speed as a countermeasure, speed for schools along the national road are set as 10 km/h lower and 5 km/h lower for the schools along the municipal road. This countermeasure has improvement on pedestrian safety ranging from 36.96%- 54.96%.

As discussed, financial issue may arise when deciding for the optimum countermeasure. For this, it is recommended for local government units, with coordination of the school division office, to perform cost-benefit analysis which aims for the maximum benefits whilst considering the costs. The listed measures fall into the 'Low -Medium' costs as per iRAP except from the 'Grade-separated crossing facility. The 'Grade-separated facility' has the highest effective rate (60%) as per the assessment of iRAP (iRAP, 2010). However, there are road sections in Lipa City wherein presence of this facility is observed; thus, the researched opted to include this in the investigated countermeasures.

TABLE 36. Countermeasures and respective safety improvement

Countermeasures	School	Average SRS (Before)	Average SRS (After)	Improvement (%)= $1-\frac{SRS_{after}}{SRS_{before}}$	Cost (iRAP, 2010)
Crossing Facility-Grade-separated facility	1	125.03	11.35	90.92%	High
	2	122.47	8.51	93.05%	
	3	65.98	7.21	89.07%	
	4	75.77	4.70	93.80%	
	5	29.24	13.02	55.47%	
	6	28.11	18.31	34.86%	
Crossing Facility-Unsignalized with Refuge Island	1	125.03	94.43	24.47%	Low to Medium
	2	122.47	75.74	38.16%	
	3	65.98	46.19	29.99%	
	4	75.77	43.37	42.76%	
	5	29.24	20.10	31.26%	
	6	28.11	23.60	16.04%	
Sidewalk-Physical Barrier	1	125.03	124.73	0.24%	Low to Medium
	2	122.47	122.22	0.20%	
	3	65.98	64.22	2.67%	
	4	75.77	75.62	0.20%	
	5	29.24	11.71	59.95%	
	6	28.11	12.54	55.39%	
Pedestrian Fencing	1	125.03	1.03	99.18%	Low
	2	122.47	0.49	99.60%	
	3	65.98	2.62	96.03%	
	4	75.77	0.15	99.80%	
	5	29.24	13.16	54.99%	
	6	28.11	17.69	37.07%	
Speed	1	125.03	63.51	49.20%	N/A
	2	122.47	61.37	49.89%	
	3	65.98	33.42	49.35%	
	4	75.77	37.88	50.01%	
	5	29.24	13.17	54.96%	
	6	28.11	17.72	36.96%	

Another issue is when there is an implementation or provision of a new countermeasure, this can receive negative reaction from the road users. Road users may not utilize the new road facilities or new traffic regulations since they are already comfortable with the previous scenario. In this case, stricter enforcement is required to guide the road users for these new countermeasures and wider scope of dissemination of information about the new countermeasures.

5. RECOMMENDATIONS

Choosing the optimum intervention to improve pedestrian safety is challenging since there are numerous road attributes to consider. This study is focused on the school zones in Lipa city, Philippines and the recommendations may be different to other regions. Decision makers can always go back on the equation and try different interventions and determine which among the interventions will yield into a safer rating. This study can be a guide for decision makers on which interventions to start with.

This study also listed some limitations especially caused by difficulty in data gathering. One of which is the assessment of crossing supervisor. As also discussed with the fact sheets of iRAP, this road attribute has issues with the consistency of the presence of crossing supervisor. However, based on the observations, majority of the drivers do not comply on the traffic rules. There are drivers who do not decelerate even though there is a pedestrian at the end of the crossing facility intending to cross the road. Pedestrians' behavior is also an issue, as discussed, there are pedestrians who do not use proper facility for crossing and walking. Due to this, presence of a crossing supervisor is recommended. Also, this research recommends interventions related to the improvement of the behavior and awareness of the road users pertaining to the hazards on roadways. These measures can be in the form of school-based education and raising awareness, like this research. Moreover, social media can take part on these measures. Benefits of the improved road facilities can be maximized through the measures related to behaviors and awareness. Furthermore, the researcher recommends that this methodology can incorporate factors for the level of aggressiveness of the drivers and level of compliance of the other road users to the traffic rules. These factors can address the relative difference for different regions. For instance, based on the observations of the researcher on both regions, the Philippines will have a higher factor than Belgium. This research might take a longer observation and collection duration to depict the general behavior of the road users. Future researchers can start via surveys which includes situational questions, general observation of the behavior of the road users, and comparison of the crash and injury count data of same road classification of different regions. Through the comparison of crash and injury data, aggressiveness and compliance of the road users can come up to the relative aggressiveness level of each regions.

According to the analysis of the road attributes, it is recommended that new schools are to be located along a road which has lower speed (e.g. city or municipality streets) since speed has a major impact on the level of safety. However, lower speed does not guarantee safety; this research recommends on focusing on the road designs with high protection level of vulnerable road users. In line with this, a stringent planning is highly recommended before putting any facilities near the school zones to prevent unnecessary costs and effort.

For future research, this research recommends a more advanced technology in obtaining 85th percentile of speed. Based on the risk factors of traffic volume and speed, higher speed and higher traffic volume indicates higher risk. There are instances wherein the traffic volume exceeds the capacity of the road. For this instance, higher volume causes the vehicles to have a lower running speed. Thus, this research recommends that these two attributes should have a wider research and their respective risk factors can be in conjunction with each other. Furthermore, it is also recommended to have a wider sample size of school zones and more specific sample, for instance: focusing on school zones which are along the same road classifications. There are mentioned strategies in the related literature. One of which is the strategy done in the Netherlands wherein numerous of stakeholders are included to improve the pedestrian safety. Thus, this research recommends creating a sustainable pedestrian safety through incorporating pedestrian safety into the urban planning and consistently quality check and improve the existing system. Local government units (LGUs) have higher authority with respect to decision making in the city. They can be included as one of the stakeholders. LGUs can also provide financial support and allocate personnel to enforce the traffic rules.

COVID-19 crisis hindered the on-site data gathering portion of this research. The on-site data gathering verifies the actual scenario of the road section which may not be reflected in the online platforms. Also, some of the maps uploaded in the online platforms are not up to date. Thus, it is recommended that on-site data should verify and support the online gathered data.

For other regions with available costing for different type of road facilities or intervention, and crash data; they can perform cost-benefit analysis. There are regions with available costs per type of road crash. Future researches can have more available data to choose for the countermeasures which maximizes the safety of the road users in the region. If there are more data available in the future in Lipa City (e.g. crash data and project costing), it is recommended to incorporate them into the decision making. Moreover, it is also recommended to assess the level of safety of the other road users. Pedestrians are the vulnerable road users, but the overall transportation system should be safe.

6. CONCLUSION

The study presents an assessment of the road facilities in the school zones in Lipa City, Philippines. School rating for schools (SR4S) is a methodology developed by iRAP to evaluate the level of safety of the pedestrians, specifically the students. Road attributes such as 'Street lighting', 'Crossing Supervisor', and 'Pedestrian Volume' are not considered in the assessment of the school zones in Lipa city. Street lightings may be excluded since school hours in Lipa, Philippines is during daytime and this research is focused on the assessment of safety of school zones. However, the 'street lighting' is included in the VB program since the pilot study performed in Hasselt, Belgium shows that this attribute should be considered especially during winter season with shorter day time. Also, due to difficulty with the data gathering and inconsistency with the presence of a crossing supervisor, this attribute is not considered on the assessment of star ratings. However, there is a huge issue relating to the behavior of the pedestrians and drivers which requires the presence of crossing supervisor.

Results of the assessment showed that schools along the national highway are unsafe for the pedestrian while the schools along a city or municipality street are relatively safer with a star rating of 3. As discussed, School 05, which lies along national raoad) has the lowest star rating score which is 21.12 (Star Rating = 3, safe level) while School 01 has the highest star rating score which 125.00 (Star Rating = 1, unsafe level). Among the star rating scores of the schools' sections, 'School 01-Section 08' got the highest star rating score which is 167.28 (Star rating =1) while, 'School 05-Section 03 'has the lowest which is 5.82 (Star rating =4). The common road attributes for the least safe and unsafe sections are identified and these road attributes were compared to determine the difference between the least safe and safest sections. Based on this, Lane width, Number of lanes, Median type, Vehicle parking, Intersection type, Sidewalk, Delineation, Speed, Intersection quality, Crossing facility, and Pedestrian crossing quality are the road attributes that caused the discrepancy between the safest and least safe sections in the school zones of Lipa City. The effects of these road attributes on the SRS are plotted using the tornado plot. The tornado plot is used as the graph for the deterministic sensitivity analysis wherein the baseline value is based on the typical or average conditions. This plot showed that SRS is more sensitive to speed, traffic volume, crossing facility and number of lanes. Analysis of effective countermeasures for Lipa City school zones are based on these road attributes.

Based on the comparison between the school zones in Lipa city and Hasselt, there is a huge discrepancy between the calculated SRS. The difference between the road attributes are considered in the deterministic analysis wherein list of investigated countermeasures for this research are obtained.

On the collected data, pedestrian fencing is usually not present, but looking into the risk factors and Equation 1, the 'Inspected Road Crossing' will be equal to zero if there is a full length of pedestrian fencing. Ideally, presence of the fencing will restrict the pedestrian to cross in any point of the road and allow them to cross in the proper crossing facility. Based on the list of countermeasures (TABLE 27), pedestrian fencing is tagged as a low cost with a 25-40% effectiveness. Investigation on the effectiveness of the countermeasures shows that majority of the countermeasures have a huge impact on the improvement of the pedestrian safety. Based on this investigation, installation of pedestrian fencing and provision of grade-separated crossing facility obtained the highest improvement rate compared to other road attributes especially on school zones along the national road. The improvement for these two countermeasures ranges to 89.07%-99.80% for schools along national road, while 34.86%- 55.47%. These percentages are higher compared to the ones stated in the iRAP, but the percentages presented are based on the data collected in the school zones in Lipa City. This indicates that these countermeasures can have higher impact for Lipa City but may have different effect for other regions. Provision of refuge island and lower speed improve the pedestrian safety that ranges to 16.04%-54.96%. Improvement on the sidewalk facility has minimal effect on improvement of pedestrian safety for schools along national road.

School 05 is the safest rated school with a star rating of 3, but this is the minimum rating to be considered a safe school zone. This shows that the school zones in Lipa City needs to be improved. As discussed in the results and discussion, speed limit and traffic volume would be difficult-to-almost impossible to change since these two attributes are associated with the modification of the law and need for a new infrastructure. Consequently, this study concludes that improving the crossing facility and decreasing the number of lanes are the major interventions to consider. The best crossing facility that can be constructed is a 'Grade-separated facility' but the cost of this facility is high; thus, financial issue may arise. Moreover, the best option for the 'Number of lanes' is 'one-way' which is also difficult to implement especially if there are no other routes to divert the other direction of the traffic.

Therefore, with the analysis of the common attributes, the SRS equation and investigation of the effect of various countermeasures, the most effective intervention for the school zones in Lipa City is to improve the crossing facility together with the installation of a full-length pedestrian fencing. Nevertheless, issues with obedience in traffic regulations are existing, and provision of these facilities will be useless if the road users will not utilize them appropriately. Thus, awareness and proper education of the road users is also important countermeasure to improve the pedestrian safety. This research included a submission of a summary report to the school division office wherein this office will be the one responsible to disseminate the information about pedestrian safety awareness to the school heads. The summary report included list of countermeasures focused on road designs and measures to improve the behavior and awareness of the road users. These measures comprise inclusion of pedestrian safety topics to parent-teacher-association (PTA) meetings and syllabus of the students. Also, informative posters can improve awareness for drivers and other road users. Moreover, school heads and the school division office can coordinate with the local government units (LGUs) for further dissemination of information. Also, LGUs can provide resources such as traffic personnel to strengthen the enforcement of traffic rules along the school zones. Therefore, with the assessment of the school zones in Lipa City, engineering measures are investigated on which among the countermeasures are applicable for the situation of school zones in Lipa City. Also, improving the road safety awareness of the road users are discussed and this is possible through information dissemination and education to the concerned road users. Lastly, enforcement is essential for keeping the road users on following the traffic regulations and utilization of proper facilities. Thus, engineering, education, and enforcement are the main components to have a road safety.

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8. APPENDICES

8.1. Sample Calculation

The sample computation below is based on the road attributes from Section 02 of Lazarijstraat.

<u>Step 1</u>: Multiply all the risk factors (shown in TABLE 29 per type of crash (Inspected road along the driver, along the passenger, etc.)
General equation:

$$SRS = \sum (likelihood\ x\ \ severity\ x\ operating\ speed\ x\ external\ flow\ influence)$$

- Inspected Road (along the driver) - likelihood = $Lane\ Width\ x\ Shoulder\ Rumble\ Strips\ xRoad\ Condition\ x\ Skid\ Resistance\ x\ Road\ Grade\ xCurvature\ x\ Quality\ of\ Curvature\ x\ Sight\ Distance\ x\ Vehicle\ Parking\ x\ Speed\ Management\ x\ Sidewalk\ x\ Delineation\ x\ School\ Warning$
$= 1.05\ x\ 1.25\ x\ 1.0\ x\ 1.0\ x\ 1.0\ x\ 1.0\ x\ 1.0\ x\ 1.0\ x\ 1.0\ x\ 1.0\ x\ 0.09\ x\ 1.20\ x\ 0.95$
$= 0.0135$

Inspected Road (along the driver)-external flow influence = $traffic\ volume = 0.022$
Inspected Road (along the driver)-speed = $operating\ speed\ (85th\ percentile) = 0.06$
Inspected Road (along the driver)-severity = $sidewalk\ (\ driver\ side) = 90$
Rating for Along the Inspected Road (driver side) = $0.135\ x\ 0.022\ x\ 0.06\ x90 =\ 0.016$

- Inspected Road (along the passenger)- likelihood = $Lane\ Width\ x\ Shoulder\ Rumble\ Strips\ xRoad\ Condition\ x\ Skid\ Resistance\ x\ Road\ Grade\ xCurvature\ x\ Quality\ of\ Curvature\ x\ Sight\ Distance\ x\ Vehicle\ Parking\ x\ Speed\ Management\ x\ Sidewalk\ x\ Delineation\ x\ School\ Warning$
$= 1.05\ x\ 1.25\ x\ 1.0\ x\ 1.0\ x\ 1.0\ x\ 1.0\ x\ 1.0\ x\ 1.0\ x\ 1.0\ x\ 1.0\ x\ 0.09\ x\ 1.20\ x\ 0.95$
$= 0.0135$

Inspected Road (along the passenger)-external flow influence = $traffic\ volume = 0.022$
Inspected Road (along the passenger)-speed = $operating\ speed\ (85th\ percentile) = 0.06$
Inspected Road (along the passenger)-severity = $sidewalk\ (\ passenger\ side) = 90$
Rating for Along the Inspected Road (passenger side) = $0.0135\ x\ 0.022\ x\ 0.06\ x90 =\ 0.016$

- Inspected Road (crossing)- likelihood = $Intersection\ type\ x\ Intersection\ quality\ x\ Number\ of\ lanes\ x\ Skid\ Resistance\ x\ Median\ type\ x\ Sight\ distance\ x\ Vehicle\ Parking\ x\ Speed\ Management\ x\ School\ Zone\ Warning\ x\ Crossing\ Facility\ x\ Quality\ of\ Crossing\ Facility\ x\ Pedestrian\ Fencing$
$= 1.1\ x\ 1.2\ x\ 1.0\ x\ 1.0\ x\ 3.0\ x\ 1.0x\ 1.0x\ 1.0x\ 1.0\ x\ 0.95\ x\ 4.50\ x\ 1.0\ x\ 1.25$
$= 21.1613$

Inspected Road (crossing)-external flow influence = $traffic\ volume = 0.022$
Inspected Road (crossing)-speed = $operating\ speed\ (85th\ percentile) = 0.06$
Inspected Road (crossing)-severity = $sidewalk\ (\ passenger\ side) = 90$
Rating for Along the Inspected Road (crossing) = $21.1613\ x\ 0.022\ x\ 0.06\ x90 =\ 2.285$

- Side Road (crossing)- likelihood = $Intersection\ type\ x\ Intersection\ quality\ x\ Number\ of\ lanes\ x\ Skid\ Resistance\ x\ Median\ type\ x\ Sight\ distance\ x\ Vehicle\ Parking\ x\ Speed\ Management\ x\ School\ Zone\ Warning\ xCrossing\ Facility\ x\ Quality\ of\ Crossing\ Facility\ x\ Pedestrian\ Fencing$

$$= 1.1\ x\ 1.2\ x\ 1.0\ x\ 1.0\ x\ 3.0\ x\ 1.0 x\ 1.0 x\ 1.0 x\ 1.0\ x\ 0.95\ x\ 6.7\ x\ 1.0\ x\ 1.25$$
$$= 31.5068$$

Side Road (crossing)-external flow influence = $traffic\ volume = 0.022$
Side Road (crossing)-speed = $operating\ speed\ (85th\ percentile) = 0.06$
Side Road (crossing)-severity = $sidewalk\ (\ passenger\ side) = 90$
Rating for Along the Side Road (crossing) = $31.5068\ x\ 0.022\ x\ 0.06\ x 90 = 3.743$

Step 2: Add all the rating obtained from different type of crashes

- $SRS = \sum(likelihood\ x\ \ severity\ x\ operating\ speed\ x\ external\ flow\ influence)$

$$= \frac{Inspected\ (\ Driver\ side + Passenger\ Side)}{2} + Inpected\ (Crossing) + Side\ Road\ (Crossing)$$

$$= \frac{0.016 + \ 0.016}{2} + 2.514 + 3.743$$

$$SRS_{LAZARIJSTRAAT\ (SECTION\ 02)} = 6.27$$

8.2. Star Ratings for School (SR4S) Visual Basic (VB) Program Manual

Introduction

The program is based on the methodology formulated by International Road Assessment Program (iRAP). This manual is based on the iRAP School Rating for School (SR4S) and the respective factors. The iRAP includes a coding manual to verify the standard for the road attributes. This program assesses the star ratings which is associated to the level of safety of the school zone.

Road Attributes (iRAP, 2014c)

1. *Crossing Facilities and Quality*
   -categorized based from the type of facility (e.g. grade-separated, raised crossing, etc.) present in the road section. The quality of the crossing facility depends on the delineation, presence of signages and markings.

2. *Curvature Type and Quality*
   -this category can be observed on the general alignment of the road. There is a high range of radii for this road attribute. The radius of the curvature can be based on the design speed of the road.

3. *Delineation*
   - acts as a guide to the drivers to stay on the lane. This road attribute is associated with the presence of center lines, edge lines, and other road markings and signages

4. *Intersection Type and Quality*
   -categorized based on the type of intersection present on the road section. Some of these are: 3-leg (unsignalised) with protected turn lane, 3-leg (signalised) with no protected turn lane, 4-leg (signalised) with no protected turn lane, etc. The quality of the intersection depends on its delineation (as shown in Figure 29).

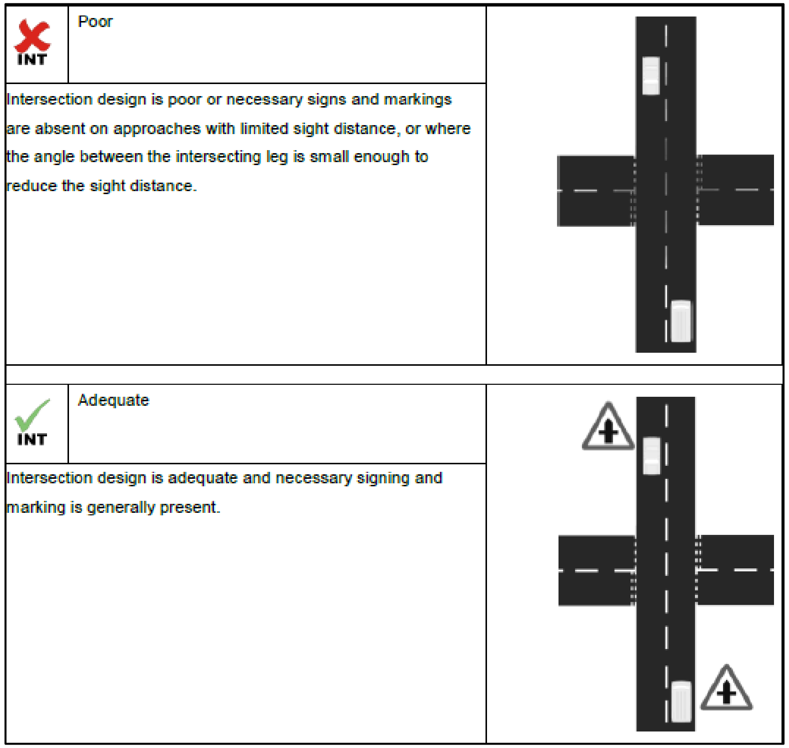


Figure 29. Intersection Quality (iRAP, 2014c)

5. *Lane Width*
   -this road attribute is the width of the usable carriageway of the road. Most of the time, road markings from edge of shoulder and centerline is the lane width for one-lane roads.

6. *Median Type*
   -the type of facility that divides the two opposing traffic flow. Some of median types are center line, safety barriers, and physical medians, etc.

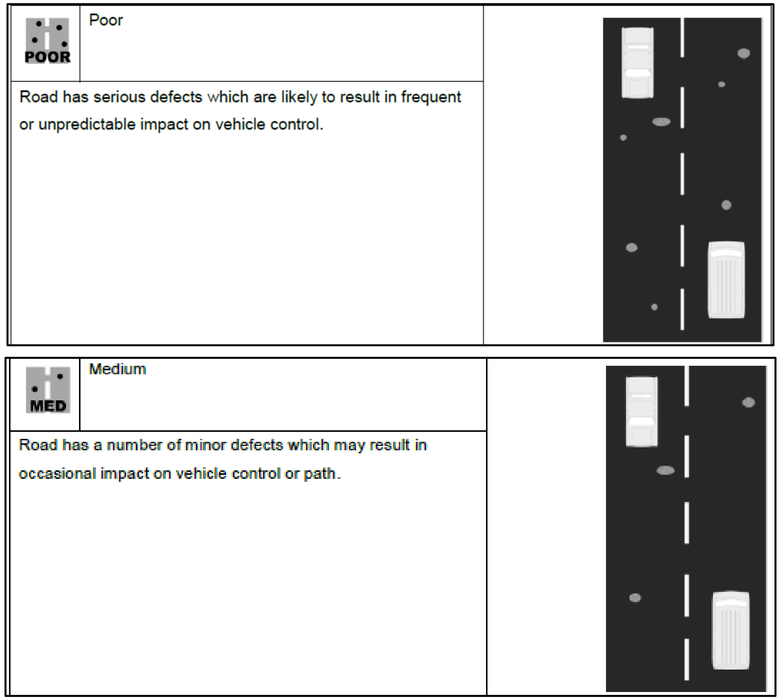
7. *Number of Lanes*
   -describes the number of lanes in a one-way traffic. On this program, 'One' lane means there is a one-lane, two-way traffic.

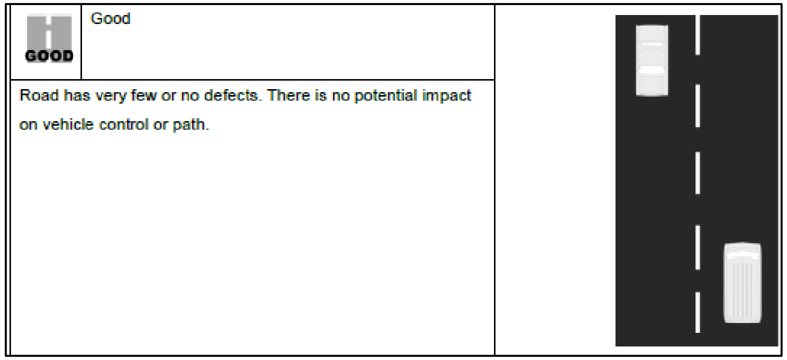
8. *Operating Speed*
   -the speed used in this program is the 85th percentile of the vehicle speed traversing the road.

9. *Pedestrian Fencing*
   -this road attribute is categorized to 'None', 'At pedestrian crossing' and 'Full length'. For the pedestrian fencing to be considered as 'Full length', the 50-m road section should have a full length of fencing.

10. *Pedestrian and Traffic Volume*
   -the pedestrian volume is not included on this program as this program is focused on the pedestrian safety and it was assumed that there are pedestrians in all the road sections.
   -traffic volume is entered as average annual daily traffic (AADT) value per road section.

11. *Road Condition*
   -this attribute depends on the presence of defects of potholes on the road section. Figure 30 shows the different road conditions included on this program.





Good

Road has very few or no defects. There is no potential impact on vehicle control or path.

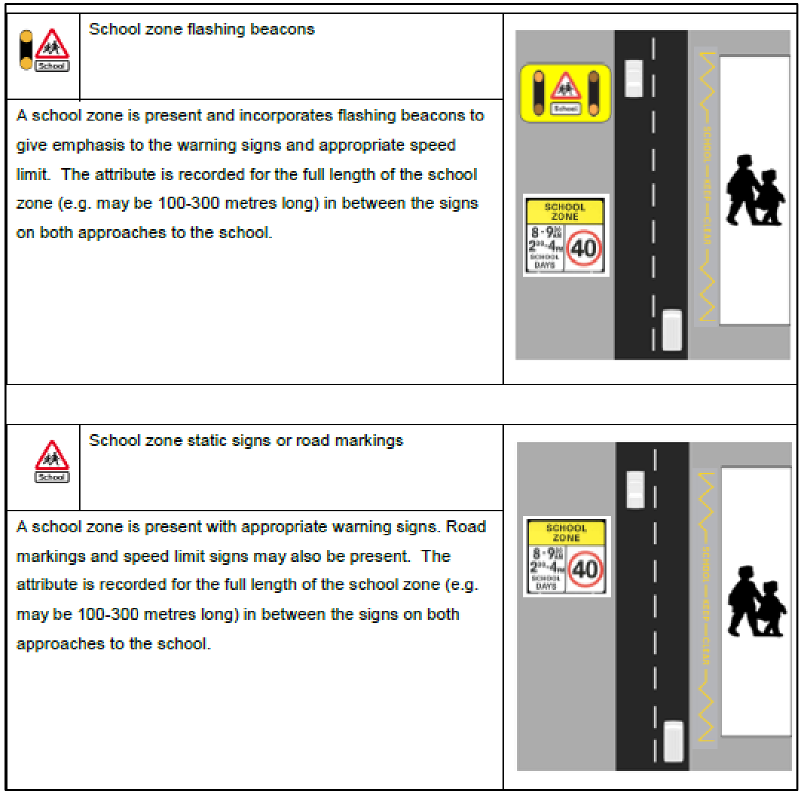
Figure 30. Road Conditions (iRAP, 2014c)

12.Road Grade

-this attribute is associated with the maximum vertical slope or grade of the road profile. Majority of the roadways have 0-7.5 % grade. Higher grades are usually used in entrance ramps with higher difference of elevation and have slow speed.

13.School Warning

-this describes the installed school zone markings or signages present on the road section. Figure 31 shows the example of this signages.



School zone flashing beacons

A school zone is present and incorporates flashing beacons to give emphasis to the warning signs and appropriate speed limit. The attribute is recorded for the full length of the school zone (e.g. may be 100-300 metres long) in between the signs on both approaches to the school.

School zone static signs or road markings

A school zone is present with appropriate warning signs. Road markings and speed limit signs may also be present. The attribute is recorded for the full length of the school zone (e.g. may be 100-300 metres long) in between the signs on both approaches to the school.

Figure 31. School Zone Warning (iRAP, 2014c)

14.Shoulder Rumble Strips

- this attribute basically describes the presence of rumble strips in the road section. Rumble strips are found along the edge of the driving lane which alerts the drivers if they are departing from the lane.

15.Sidewalk

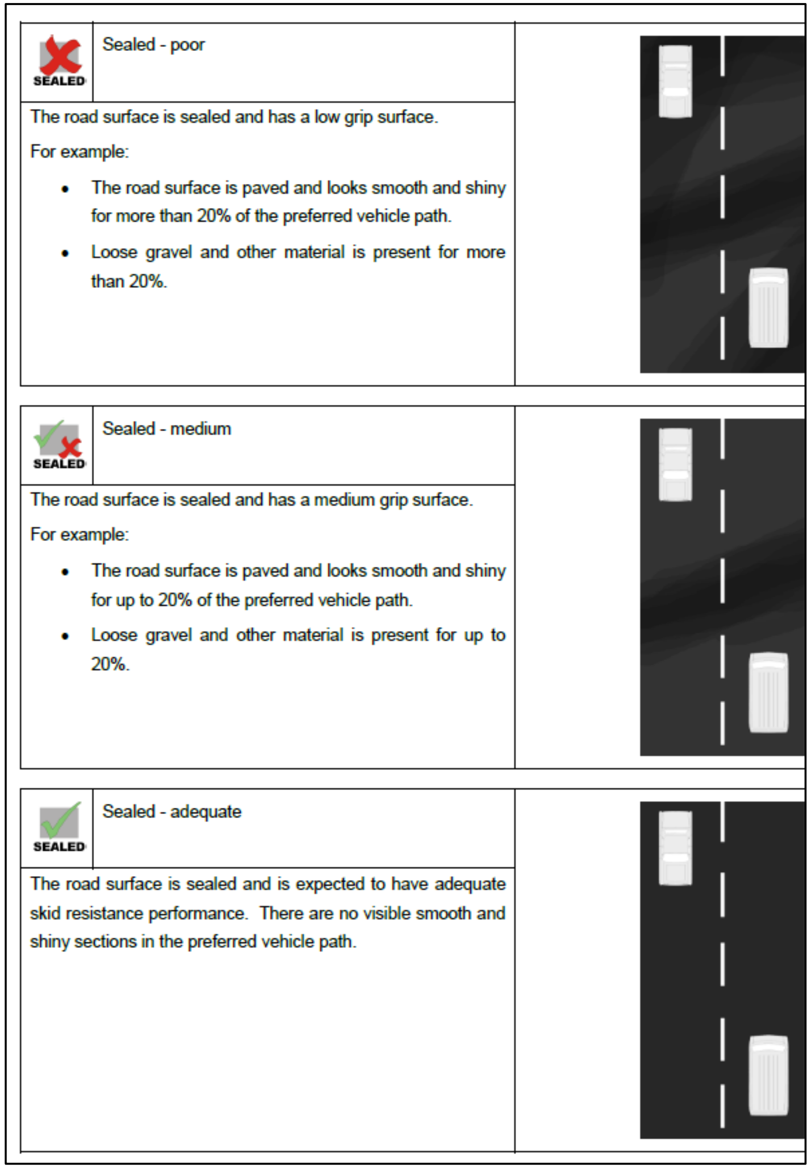
-defines the type of sidewalk present on the road section. The type of sidewalk for the driver side and passenger side should be noted. It is also important to note that this should be the 'usable' sidewalk.

16. Sight Distance

-this is the ability of the drivers to have a clear view within the sight distance dictated by the design speed.

17. Skid Resistance

-related to the surface of the road to prevent vehicles to skid off. Figure 32 shows the different skid resistance categories included in this program.



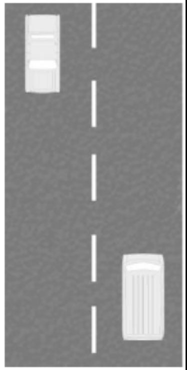
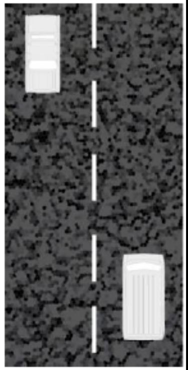
UNSEAL	Unsealed - poor	
The road surface is unpaved and has a low grip surface. For example: • Surface is covered in loose gravel or the natural surface is likely to be slippery in wet conditions (e.g. silt / clay surfaces).		
UNSEAL	Unsealed - adequate	
The road surface is unpaved with a relatively good surface grip. For example: • The surface is compacted aggregate providing a surface that remains firm in all prevailing weather conditions.		

Figure 32. Skid Resistance (iRAP, 2014c)

18.Speed Management

-defines the presence of traffic calming measure present on the road section. Some of these are lane narrowing and road humps.

19.Vehicle Parking

-describes the presence of vehicle parking on the road section. Even if there are no designated vehicle parking space yet vehicles stop in any section of the road to load/unload passenger, this should be considered.

Layout

Figure 33 shows the layout of the Road Features of the software. On this page, all the required road attributes are categorized (e.g. road environment, road type, road features, etc.).

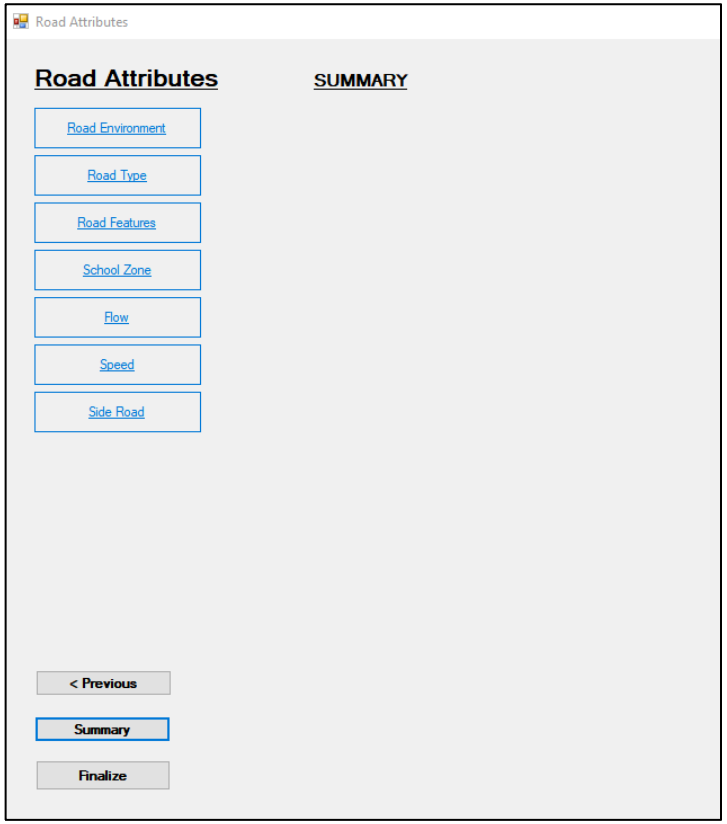


Figure 33. Layout of the VB Program

Once all the data are entered, the user can click on 'Summary' to verify all the entered data. If the user found any errors on the data, the user can go back to which category the user needs to modify.

Output

The ouput of this program includes the name of the school, location, the star rating and the list of the countermeasures. It should be noted that the list of countermeasures is based from iRAP and are tagged as low-medium costs.

Sample Scenario

A sample scenario is based from a road section near the Rafael M. Lojo Memorial School. This road has the following road attributes:

Area Type	Urban
Lane Width	Medium (>=2.75 m to <3.25 m)
Number of lanes	Two
Median type	Centre line
Shoulder Rumble Strips	Not present
Road Condition	Good
Skid Resistance	Sealed - adequate
Road Grade	0%- 7.5%
Curvature	Straight or gently curving
Quality of Curvature	Adequate
Adequacy of sight distance	Adequate
Vehicle Parking	Two(pedestrian or bicyclist facility present)

Speed Management/Traffic Calming	Not present
Intersection type	3-leg (unsignalised) with no protected turn lane
Intersection quality	Poor
Sidewalk- driver	Non-physical separation > 1m
Sidewalk- passenger	Non-physical separation > 1m
Delineation	Adequate
Street Lighting	Not applicable
School Warning	Not applicable (no school at the location)
Crossing supervisor	Not Present
Crossing facility-inspected road	No facility
Crossing facility-side road	No facility
Pedestrian crossing quality	Adequate
Pedestrian Fencing	None
Traffic Volume-Inspected Road	5,401-7,200
Pedestrian Volume-Along Driver	Switch
Pedestrian Volume-Along Passenger	
Pedestrian Volume-Crossing	
Operating Speed (85th percentile)	60 kph
ROAD ATTRIBUTES (Side Road)	
Number of lanes	One

Skid Resistance	Sealed - adequate
Median type	Centre line
Adequacy of sight distance	Adequate
Vehicle Parking	One side
Speed Management/Traffic Calming	Not present
Crossing facility	No facility
Pedestrian crossing quality	Adequate
Pedestrian Fencing	None
Traffic Volume-Inspected Road	
Operating Speed (85th percentile)	<30 kph

First, the name and location of the school will be entered as shown in the figure below.

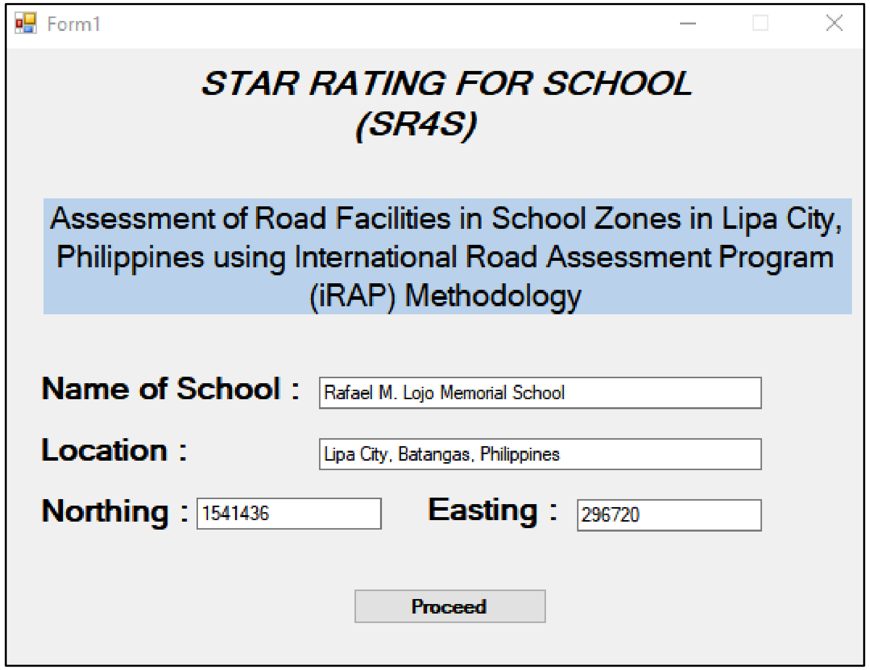


Figure 34. First page of VB program

Next, the form below will show, and the user need to input all the required data. Figure 36 - Figure 42 show the entered data based from the given data.

Figure 35. Summary page

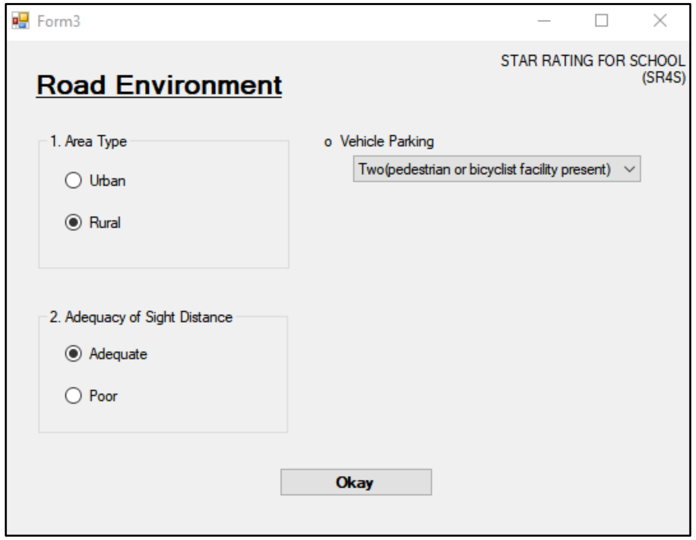


Figure 36. Road Environment page

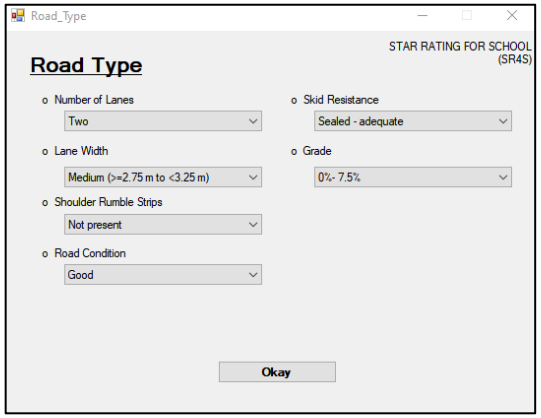


Figure 37. Road Type page

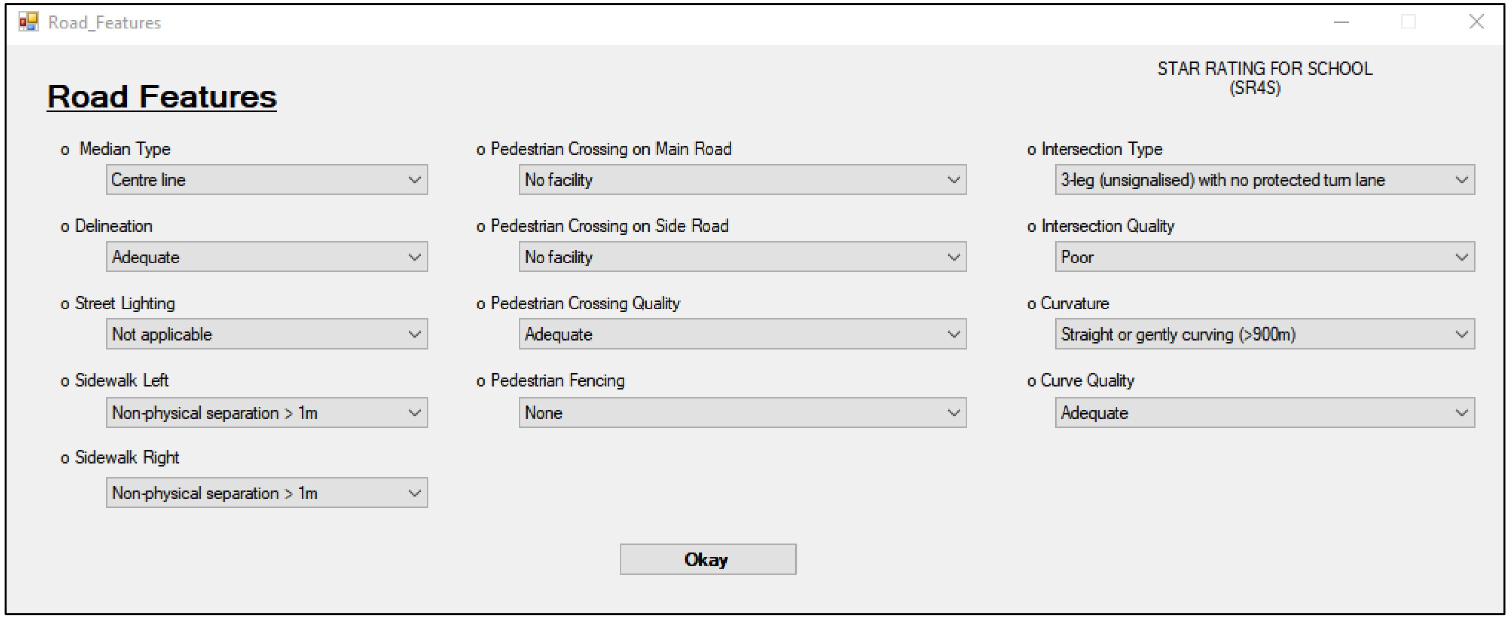


Figure 38. Road Features page

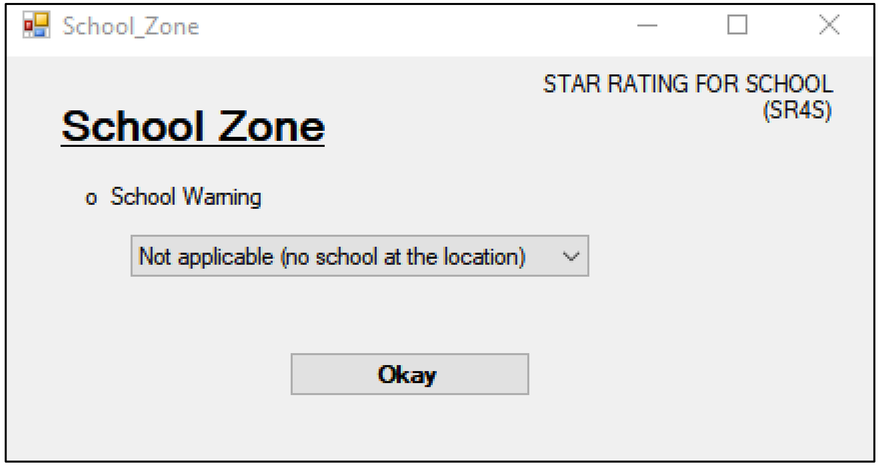


Figure 39. School zone page

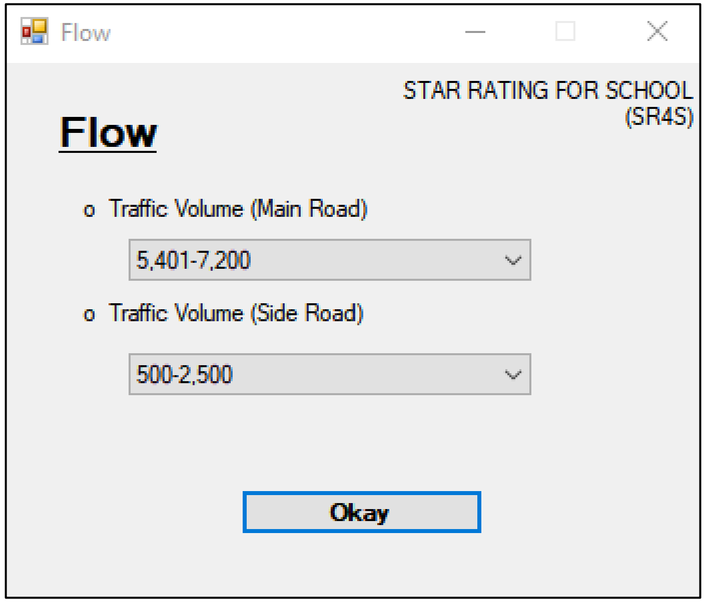


Figure 40. Traffic Volume page

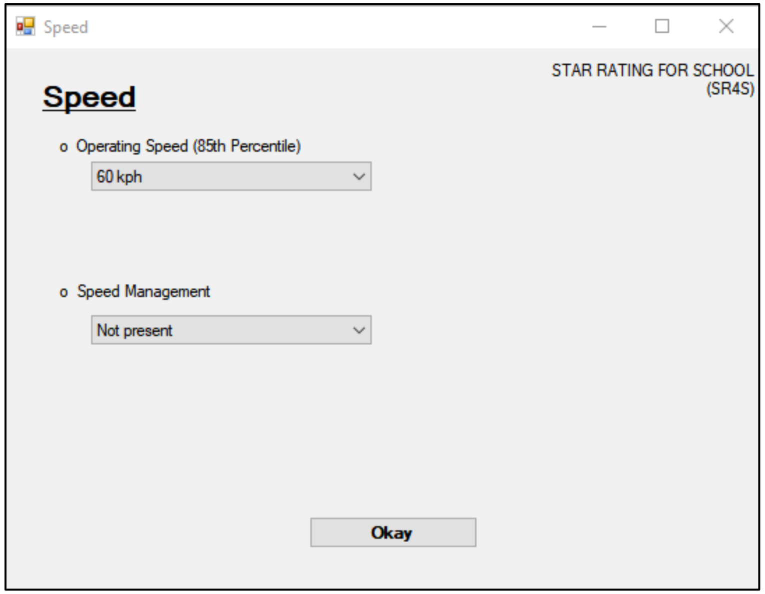


Figure 41. Speed page

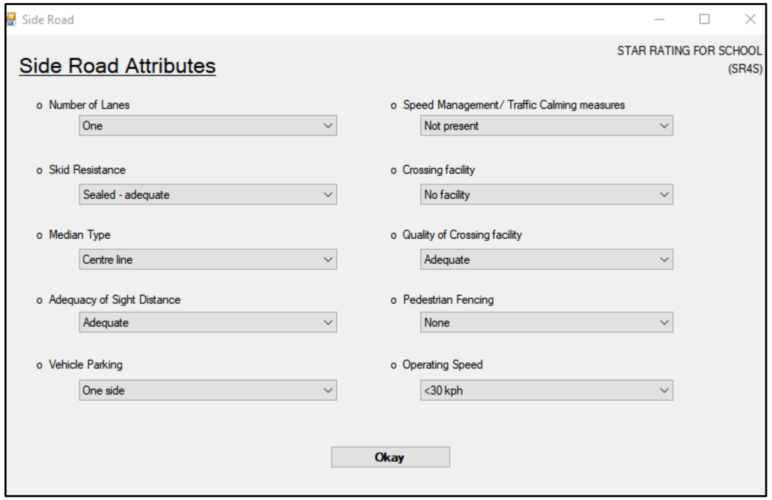


Figure 42. Side road page

Figure 43 shows the summary of the entered data. The user can verify the entered data. This page also shows the star rating score for the inspected road and side roads, and the final star rating.

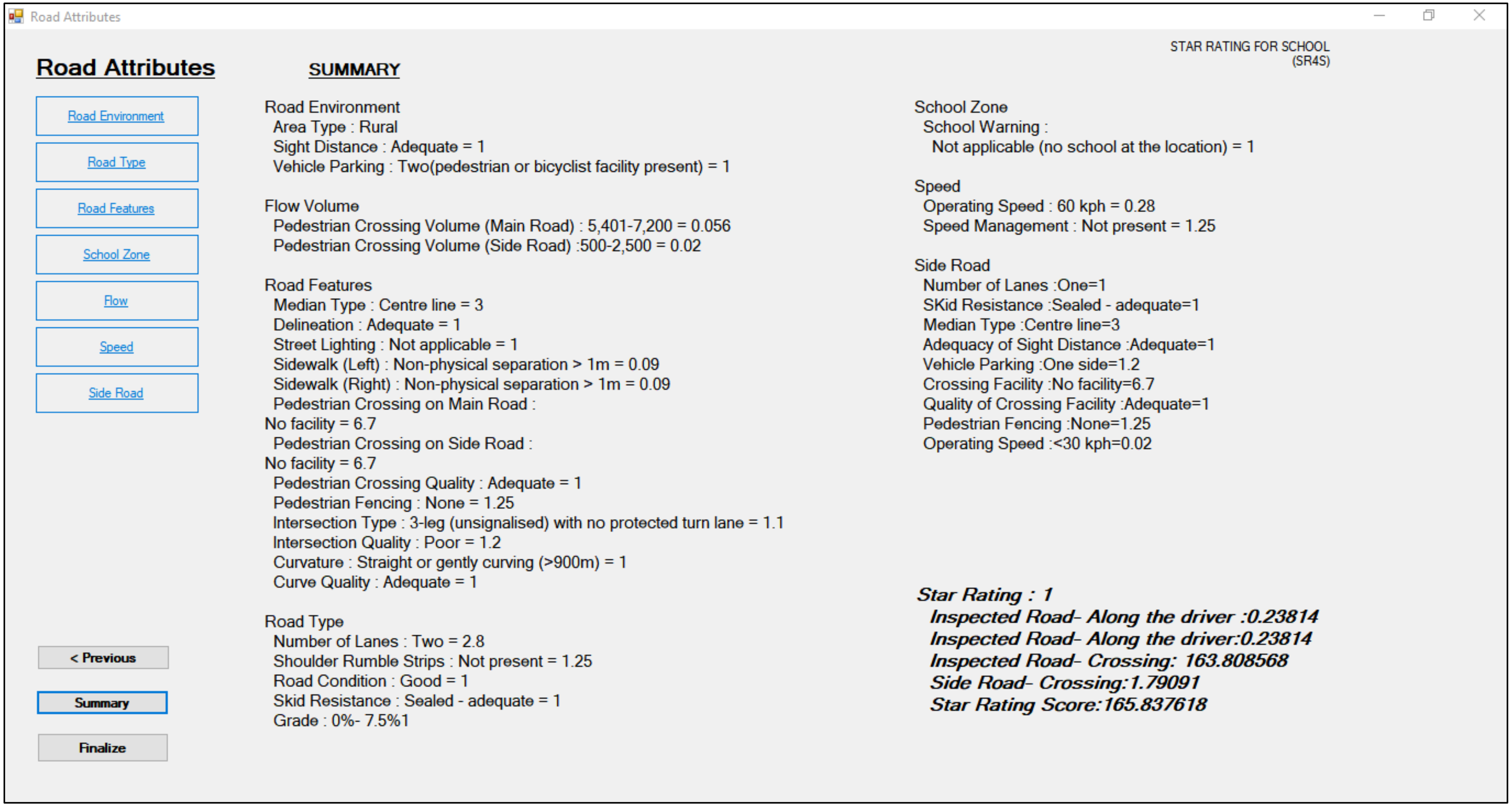


Figure 43. Summary of the entered road attributes

Figure 44 shows the final output of the program. This shows the name and location of school, and the star rating.

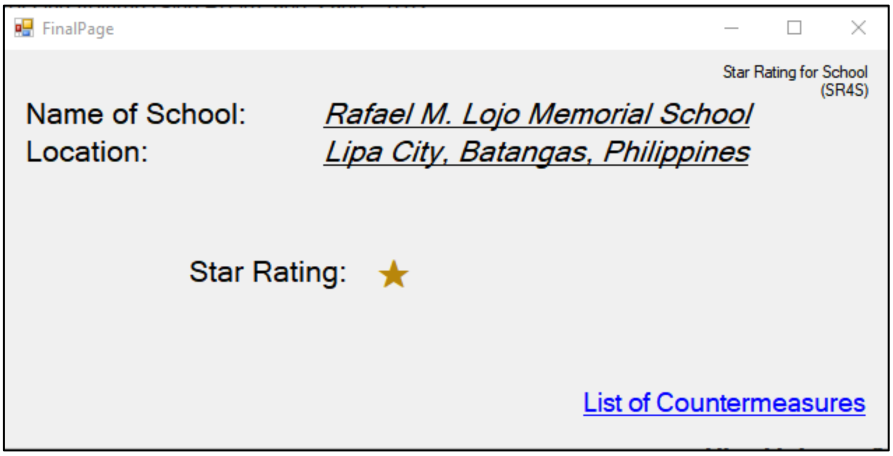
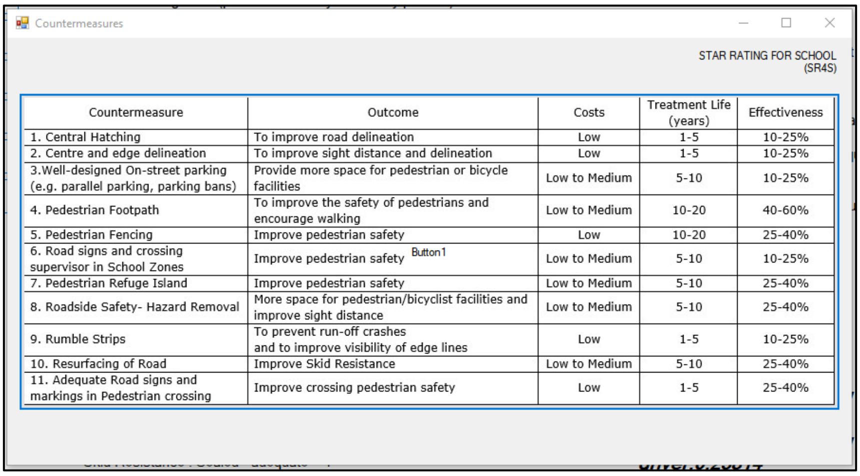


Figure 44. Star rating page

Lastly, Figure 45 shows the list of countermeasures wherein users can gather ideas on which interventions to use to improve the star rating and level of safety. Once they chose a countermeasure, they can go back to the road attributes, modify, and check if the star rating increased.



Countermeasure	Outcome	Costs	Treatment Life (years)	Effectiveness
1. Central Hatching	To improve road delineation	Low	1-5	10-25%
2. Centre and edge delineation	To improve sight distance and delineation	Low	1-5	10-25%
3.Well-designed On-street parking (e.g. parallel parking, parking bans)	Provide more space for pedestrian or bicycle facilities	Low to Medium	5-10	10-25%
4. Pedestrian Footpath	To improve the safety of pedestrians and encourage walking	Low to Medium	10-20	40-60%
5. Pedestrian Fencing	Improve pedestrian safety	Low	10-20	25-40%
6. Road signs and crossing supervisor in School Zones	Improve pedestrian safety Button1	Low to Medium	5-10	10-25%
7. Pedestrian Refuge Island	Improve pedestrian safety	Low to Medium	5-10	25-40%
8. Roadside Safety- Hazard Removal	More space for pedestrian/bicyclist facilities and improve sight distance	Low to Medium	5-10	25-40%
9. Rumble Strips	To prevent run-off crashes and to improve visibility of edge lines	Low	1-5	10-25%
10. Resurfacing of Road	Improve Skid Resistance	Low to Medium	5-10	25-40%
11. Adequate Road signs and markings in Pedestrian crossing	Improve crossing pedestrian safety	Low	1-5	25-40%

Figure 45. List of countermeasures (iRAP, 2010)

8.3. Summary report for Division office of Lipa City

Introduction

Road crash related deaths in the Philippines has reached 10, 012 in year 2015 and the working-age group constitute approximately 82% of this fatality (Sy, 2017a).This age group has the highest exposure compared to other age groups. Even though the working age groups has the highest percentage of road crash deaths, planners should also give attention to the other age groups. Sy (2017) stated that an average of 667 (year 2006-2015) children (14 years old and younger) die every year due to road crashes in the Philippines. Based on the data on year 2005, there was an average of 11 crashes every day near schools and this rose to 14 per day on year 2010. On the average, there is one child pedestrian involved on a crash out of five road crashes happening on school zones (Barrientos-Vallarta, 2012). Children ages nine years-old and below may still have difficulties in following and understanding the traffic regulations, and they still have low level of perception of the approaching vehicles (Barrientos-Vallarta, 2012).Moreover, children have smaller body structure compared to older people and drivers have difficulties on noticing their presence on the roads. With these situations, it is viable to improve the road facilities near/on school vicinities.

This report summarizes the assessment of the six school zones in Lipa City. The actual submitted report to the division office includes the name of the schools. However, due to delays and difficulties in the communication with the head of division office, the approval of including the names of schools was not finalized yet. The assessments are based on the standards of the International Road Assessment Program (iRAP) and are is focused on the pedestrian safety. This report targets the safety of the children travelling to the schools. The iRAP methodology set a star rating band which ranges from 1- to 5-star rating. 5-star rating indicates safest while 1 indicates the least safe zone.

Assessment

Based on the table below, majority of the school zones fall under the 'unsafe level' of the star ratings which indicates that school children are exposed to unsafe road environment. Due to this, countermeasures which are categorized as 'low-costs' as per the iRAP are also included in this report. Moreover, the researcher also consulted the World Health Organization (WHO) which provided a broader range of countermeasures specific for pedestrian safety.

Based from Table 31, School 05 has the lowest star rating score which is 21.12 (Star Rating = 3, safe level) while School 01 has the highest star rating score which 125.00 (Star Rating = 1, unsafe level). Among the star rating scores of the schools' sections, 'School 01 -Section 08' got the highest star rating score which is 167.28 (Star rating =1) while, 'School 05-Section 03' has the lowest which is 5.82 (Star rating =4). These ratings are based on Table 26. The difference between the road attributes between the two road sections are shown in Table 35 (e.g. lane width, number of lanes, type of sidewalk, etc.). These attributes can help the researcher to identify and narrow down the options in choosing of general countermeasures. Assessment of each school zones is still essential in identifying the most effective countermeasure but through these identified road attributes, decision makers can start looking through these lists.

Based from Table 31, School 01 and School 02 obtained the highest average star rating score (125.00 and 122.45, respectively). These schools were compared and the similar attributes between the sections that yielded the highest rating score were identified. Similarly, the similar attributes for the lowest average star rating score were also identified. These School 05 and School 06.Through this report, the researcher aims to increase the awareness of the road users. This is possible with the proper dissemination of information to the road users. For the students and other school personnel, school curriculum can include lectures that tackles road safety.

Summary of the Star Rating of the school zones in Lipa City

Name of School	Section	Score	Star Rating		General Star Rating
01	01	128.19	☆	125.00	☆
	02	128.19	☆		
	03	128.19	☆		
	04	33.65	☆ ☆ ☆		
	05	27.48	☆ ☆ ☆		
	06	146.45	☆		
	07	146.45	☆		
	08	167.28	☆		
	09 (School)	99.82	☆		
	10 (School)	99.82	☆		
	11	141.52	☆		
	12	141.52	☆		
	13	146.50	☆		
	14	146.50	☆		
	15	146.50	☆		
	16	154.64	☆		
	17	142.20			
02	01	124.31	☆	122.45	☆
	02	124.31	☆		
	03	124.31	☆		
	04	124.31	☆		
	05	99.44	☆		
	06	119.06	☆		
	07	164.81	☆		
	08 (School)	89.11	☆ ☆		
	09	119.35	☆		
	10	124.31	☆		
	11	124.31	☆		
	12	124.31	☆		
	13	124.31	☆		
	14	124.31	☆		
	15	124.31	☆		
	16	124.31	☆		
03	01	89.11	☆ ☆	67.51	☆ ☆
	02	124.31	☆		
	03	124.31	☆		
	04	124.31	☆		
	05	25.13	☆ ☆ ☆		
	06	41.57	☆ ☆		
	07	41.57	☆ ☆		
	08 (School)	24.01	☆ ☆ ☆		
	09	41.57	☆ ☆		
	10	41.57	☆ ☆		
	11	41.57	☆ ☆		
	12	45.64	☆ ☆		
	13	90.21	☆		
	14	90.21	☆		

04	01	79.91	☆☆	75.75	☆☆
	02	79.91	☆☆		
	03	79.91	☆☆		
	04	79.91	☆☆		
	05	79.91	☆☆		
	06	79.91	☆☆		
	07	79.91	☆☆		
	08	79.91	☆☆		
	09 (School)	54.42	☆☆		
	10	79.91	☆☆		
	11	79.91	☆☆		
	12	79.91	☆☆		
	13	79.91	☆☆		
	14	57.29	☆☆		
	15	79.91	☆☆		
	16 (School)	57.29	☆☆		
	17	79.91	☆☆		
05	01	10.61	☆☆☆☆	21.12	☆☆☆
	02 (School)	10.61	☆☆☆☆		
	03	5.82	☆☆☆☆		
	04	10.61	☆☆☆☆		
	05	7.25	☆☆☆☆		
	06	10.61	☆☆☆☆		
	07	10.61	☆☆☆☆		
	08	10.36	☆☆☆☆		
	09	10.36	☆☆☆☆		
	10	10.36	☆☆☆☆		
	11	10.36	☆☆☆☆		
	12	10.36	☆☆☆☆		
	13	10.36	☆☆☆☆		
	14	57.70	☆☆		
	15	57.70	☆☆		
	16	57.70	☆☆		
	17	57.70	☆☆		
06	01	27.52	☆☆☆	26.17	☆☆☆
	02	27.52	☆☆☆		
	03	27.52	☆☆☆		
	04	27.52	☆☆☆		
	05	41.91	☆☆		
	06	41.91	☆☆		
	07	41.91	☆☆		
	08	41.91	☆☆		
	09 (School)	21.77	☆☆☆		
	10	11.56	☆☆☆☆		
	11	11.56	☆☆☆☆		
	12	11.56	☆☆☆☆		
	13	11.56	☆☆☆☆		
	14	24.32	☆☆☆		
	15	24.32	☆☆☆		
	16	24.32	☆☆☆		

Countermeasures

Aside from road design issues, Philippines' road safety faces a challenging issue pertaining to the behavior of the road users. There are pedestrians who crosses the sections of the street even though there are no crossing facility. Some drivers do not obey the traffic rules, and some are not well knowledgeable enough with the traffic rules. Enforcement of the traffic rules are also less strict compared to the developed countries. Through the listed countermeasures, this report aims to improve the road safety especially in school zones. iRAP methodology is limited to the road attributes, and behavioral aspects are excluded in calculation since behaviors are complex and difficult to model. The listed countermeasures are mainly to improve the design of roads and improvement of pedestrian facilities. However, if financial aspect is an issue, principals or school heads can focus on increasing the awareness of the students and parents through incorporating lectures about road safety in the PTA meetings and curriculum of the students. Well-educated pedestrians will know how they can protect themselves from other road users. Moreover, schools can post informative posters along roads to educate the drivers about safe driving and traffic regulations specially in school zones.

Coordination of the school heads and school division office with the local government units (LGUs) is highly recommended. LGUs can assist with the resources (e.g. crossing supervisor, traffic enforcers, and finances for countermeasures to improve the road safety) and further dissemination of information to most of the city population regarding pedestrian safety. Aside from education and engineering measures, enforcement is also important to guarantee compliance of the road users to the traffic rules.

Summary of the countermeasures focused on pedestrian safety (iRAP, 2010)

Countermeasure	Outcome	Costs	Treatment Life (years)	Effectiveness
1. Central Hatching	To improve road delineation	Low	1-5	10-25%
2. Centre and edge delineation	To improve sight distance and delineation	Low	1-5	10-25%
3.Well-designed On-street parking (e.g. parallel parking, parking bans)	Provide more space for pedestrian or bicycle facilities	Low to Medium	5-10	10-25%
4. Pedestrian Footpath	To improve the safety of pedestrians and encourage walking	Low to Medium	10-20	40-60%
5. Pedestrian Fencing	Improve pedestrian safety	Low	10-20	25-40%
6. Road signs and crossing supervisor in School Zones	Improve pedestrian safety	Low to Medium	5-10	10-25%
7. Pedestrian Refuge Island	Improve pedestrian safety	Low to Medium	5-10	25-40%
8. Roadside Safety-Hazard Removal	More space for pedestrian/bicyclist facilities and improve sight distance	Low to Medium	5-10	25-40%
9. Rumble Strips	To prevent run-off crashes and to improve visibility of edge lines	Low	1-5	10-25%
10. Resurfacing of Road	Improve Skid Resistance	Low to Medium	5-10	25-40%

11. Adequate Road signs and markings in Pedestrian crossing	Improve crossing pedestrian safety	Low	1-5	25-40%

Interventions specific for improving pedestrian safety (WHO, 2013)

Key measures	Examples of interventions	Effectiveness		
		Proven	Promising	Insufficient evidence
Reduce pedestrian exposure to vehicular traffic	Provide sidewalks	■		
	Install and/or upgrade traffic and pedestrian signals	■	■	■
	Construct pedestrian refuge islands and raised medians	■		
	Construct enhanced marked crossings		■	
	Provide vehicle restriction/diversion measures	■	■	
	Install overpasses/underpasses	■		
	Improve mass transit route design	■		
	Reduce traffic volumes by switching journeys from the car to public transport, walk and cycle for distances and purposes where these options work well	■		
Reduce vehicle speeds	Reduce speed limit	■		
	Implement area-wide lower speed limit programmes, for example, 30 km/h	■		
	Implement road-narrowing measures		■	
	Install speed management measures at road sections	■	■	
	Install speed management measures at intersections	■	■	
	Provide school route improvements		■	
Improve sight distance and/or visibility between motor vehicles and pedestrians	Provide crossing enhancements	■	■	
	Implement lighting/crossing illumination measures	■		
	Reduce or eliminate obstruction by physical objects including parked vehicles		■	
	Install signals to alert motorists that pedestrians are crossing		■	■
	Improve visibility of pedestrians		■	

Improve pedestrian and motorist safety awareness and behaviour	Provide education, outreach and training			
	Develop and/or enforce traffic laws on speed, drinking and driving, pedestrian right-of-way, red light disobedience, commercial roadside activity and traffic control			
	Implement 'walking school bus' programmes			
Improve vehicle design for pedestrian protection	Develop vehicle safety standards and laws for pedestrian protection			
Improve vehicle design for pedestrian protection	Enforce vehicle safety standards and laws for pedestrian protection			
	Publicize consumer information on pedestrian safety by make and model of car, for example, results of New Car Assessment Programmes			
Improve care for the injured pedestrians	Organize pre-hospital trauma care systems			
	Establish inclusive trauma care systems			
	Offer early rehabilitation services			

Note: When the terms 'proven', 'promising' and 'insufficient evidence' appear highlighted in the same line, it shows that there are different measures in the same broad category at different stages of development as already explained above with respect to effectiveness.

Source: *1–7*.

The research includes the investigation om the improvement for the school zones of Lipa City using the countermeasures which are more likely to have higher impact on the final SRS. The table below shows the summary of this investigation. It should be noted that School 01-04 are the school zones located along the national road while the other two lies along a local or municipal road. Therefore, with the analysis of the common attributes, the SRS equation and investigation of the effect of various countermeasures, the most effective intervention for the school zones in Lipa City is to improve the crossing facility together with the installation of a full-length pedestrian fencing. Nevertheless, issues with obedience in traffic regulations are existing, and provision of these facilities will be useless if the road users will not utilize them appropriately. Thus, awareness and proper education of the road users, is also important countermeasure to improve the pedestrian safety. Engineering: improvement on the road designs and facilities, Education: awareness and knowledge of road users to road safety, and Enforcement are the main components to have an effective road safety.

Countermeasures and respective safety improvement

Countermeasures	School	Average SRS (Before)	Average SRS (After)	Improvement (%)= $1-\frac{SRS_{after}}{SRS_{before}}$	Cost (iRAP, 2010)
Crossing Facility-Grade-separated facility	1	125.03	11.35	90.92%	High
	2	122.47	8.51	93.05%	
	3	65.98	7.21	89.07%	
	4	75.77	4.70	93.80%	
	5	29.24	13.02	55.47%	
	6	28.11	18.31	34.86%	

Crossing Facility-Unsignalized with Refuge Island	1	125.03	94.43	24.47%	Low to Medium
	2	122.47	75.74	38.16%	
	3	65.98	46.19	29.99%	
	4	75.77	43.37	42.76%	
	5	29.24	20.10	31.26%	
	6	28.11	23.60	16.04%	
Sidewalk-Physical Barrier	1	125.03	124.73	0.24%	Low to Medium
	2	122.47	122.22	0.20%	
	3	65.98	64.22	2.67%	
	4	75.77	75.62	0.20%	
	5	29.24	11.71	59.95%	
	6	28.11	12.54	55.39%	
Pedestrian Fencing	1	125.03	1.03	99.18%	Low
	2	122.47	0.49	99.60%	
	3	65.98	2.62	96.03%	
	4	75.77	0.15	99.80%	
	5	29.24	13.16	54.99%	
	6	28.11	17.69	37.07%	
Speed	1	125.03	63.51	49.20%	N/A
	2	122.47	61.37	49.89%	
	3	65.98	33.42	49.35%	
	4	75.77	37.88	50.01%	
	5	29.24	13.17	54.96%	
	6	28.11	17.72	36.96%	