UNIVERSITI TEKNOLOGI MARA

ROAD INFRASTRUCTURE RISK ASSESSMENT FOR THE UITM MAIN CAMPUS ENVIRONMENT USING THE INTERNATIONAL ROAD ASSESSMENT PROGRAMME (IRAP) APPROACH (IRAP@UITMCAMPUS)

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MSc

July 2026

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AINATUL-FATIMA BINTI MD MUROZI

Thesis submitted in fulfilment
of the requirements for the degree of
Master of Science
(Transport and Logistics)

Malaysia Institute of Transport

July 2026

CONFIRMATION BY PANEL OF EXAMINERS

I certify that a Panel of Examiners has met on 6th November 2025 to conduct the final examination of Ainatul-Fatima binti Md Murozi on her Masters of Science thesis entitled "Road Infrastructure Risk Assessment for the UiTM Main Campus Environment Using the International Road Assessment Programme (iRAP) Approach (iRAP@UiTMCampus)" in accordance with Universiti Teknologi MARA Act 1976 (Akta 173). The Panel of Examiners recommends that the student be awarded the relevant degree. The Panel of Examiners was as follows:

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I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

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ABSTRACT

This study addressed the pressing issue of road traffic accidents, which claimed over 1.3 million lives annually and disproportionately affected low- and middle-income countries (LMICs), where 93% of fatalities occurred despite representing only 60% of global vehicles. Aligned with the United Nation's Decade of Action for Road Safety 2021-2030, the research focused on Universiti Teknologi MARA (UiTM) Shah Alam, a high-traffic academic hub, to evaluate road infrastructure risks for diverse users. The International Road Assessment Programme (iRAP) methodology was employed, involving comprehensive road surveys, speed studies, and structured coding validated via iRAP's ViDA platform. Results showed that compliance with posted speed limits yielded an average 5-star safety rating, while observed operating speeds reduced ratings to between 3 and 5 stars. Strategic interventions, such as optimising pedestrian crossings and increasing roadside severity distances, significantly improved average ratings to 4-5 stars across all user groups. Benefit-cost analyses identified high-impact countermeasures including pedestrian facility, street lighting, and sidewalks. These measures aligned with iRAP's Star Ratings and Safer Roads Investment Plans, addressing data limitations common in LMICs. The study's outcomes enhanced campus safety, guided infrastructure planning, and supported global road safety targets, offering a replicable model for institutional campuses in Malaysia and beyond.

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LIST OF ABBREVIATIONS

Abbreviations	
BCR	Benefit-Cost Ratio
FSI	Fatal and Serious Injury
GDP	Gross Domestic Product
iRAP	International Road Assessment Programme
JSPT	Jabatan Siasatan dan Penguatkuasaan Trafik
LMICs	Low- and Middle-Income Countries
MCOs	Movement Control Orders
MDBs	Multilateral Development Banks
MyRAP	Malaysia Road Assessment Programme
RADIS	Road Attribute Datalogger and Inspection System
RSA	Road Safety Audit
SR4D	Star Rating for Design
SR4S	Star Rating for Schools
SRIP	Safer Road Investment Plan
UiTM	Universiti Teknologi MARA
VRU	Vulnerable Road User
WHO	World Health Organization

CHAPTER 1
INTRODUCTION

1.1 Problem Statement

Road traffic crashes claim approximately 1.19 million lives each year, representing the leading cause of death among children and young adults aged 5 to 29 years globally (Global Road Safety Facility, 2024; World Bank, 2024b; World Health Organization (WHO), 2023a, 2023b, 2025), with vulnerable road users, including pedestrians, cyclists, and motorcyclists, accounting for over half of these road fatalities. Alarmingly, 92% of these deaths occur in low- and middle-income countries (LMICs) (World Health Organization (WHO), 2023a), which possess only 60% of the world's vehicles (World Health Organization (WHO), 2023b, 2025). In regions like the WHO African Region, the road death rate reaches 19.4 per 100,000 population, far exceeding the global average of 15 (Figure 1.1) (WHO African Region, 2024). The economic toll is profound, costing nations 2% to 6% of gross domestic product (GDP) in medical treatment, lost productivity, and the broader financial burden on families (Global Road Safety Facility, 2024; World Bank, 2024b), yet advancements towards the United Nations' 2030 goal of halving road deaths remain insufficient, as evidenced by the European Union's mere 1% reduction to 20,400 fatalities in 2030 (Directorate-General for Mobility and Transport, 2024).

Promising initiatives, including the International Road Assessment Programme (iRAP), the Bloomberg Philanthropies Initiative for Global Road Safety (BIGRS), and World Bank projects, have demonstrated impact through star rating systems, strengthened legislation, and infrastructure enhancements (Bloomberg Philanthropies, 2024; International Road Assessment Programme (iRAP), 2021g; United Nations Office for Project Services (UNOPS), 2023; World Bank, 2024a).

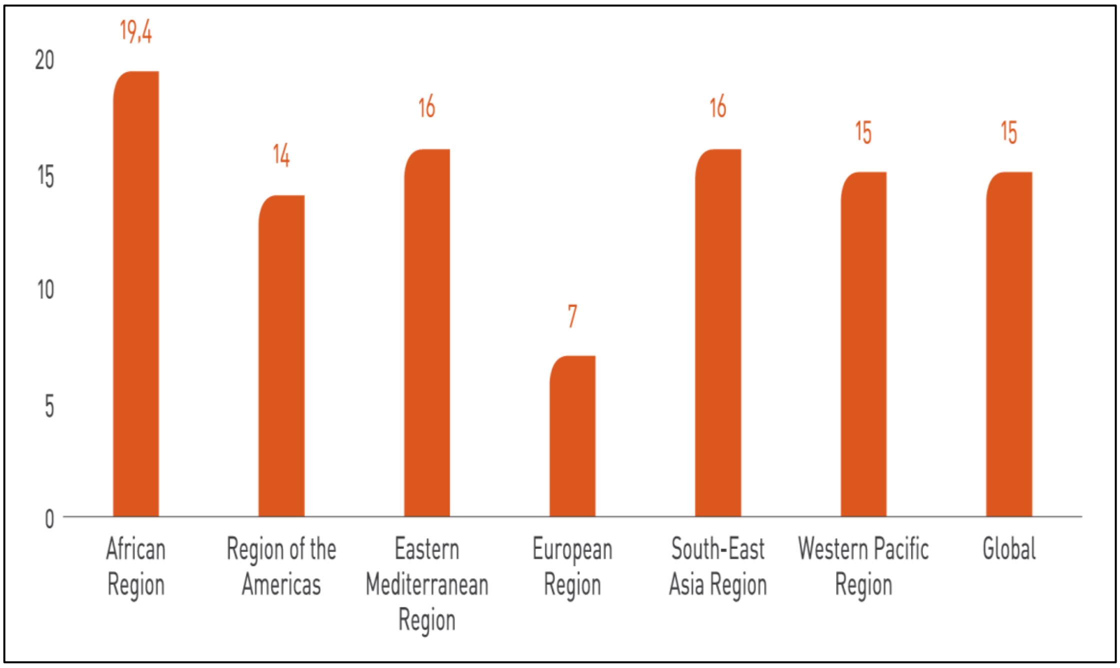


Figure 1.1 Traffic Deaths per 100,000 Population by WHO Region, 2021 (WHO African Region, 2024)

Malaysia reflects this persistent global challenge. Between January and October 2024, the nation recorded 532,125 road crashes resulting in 5,364 fatalities, with 68% involving motorcyclists and pillion passengers (BERNAMA, 2024), with incidents rising 79% since 2011 and projections estimating 200,000 accidents in Selangor by late 2024 (Figure 1.2), driven by population density and vehicle proliferation (Baskara et al., 2023). Substandard infrastructure plays a tangible role. The Malaysian Institute of Road Safety Research (MIROS) attributes 12 to 13% of the country's 500,000 annual crashes to road deficiencies such as surface damage and weather conditions (Malay Mail, 2025), while road service quality accounts for 7.6% of variance in expressway incidents (Zahidy et al., 2024). Daily data reveals volatility where reduced incidents coincide with elevated fatalities, highlighting road lethality (Figure 1.3) (Jabatan Siasatan dan Penguatkuasaan Trafik (JSPT), 2025).

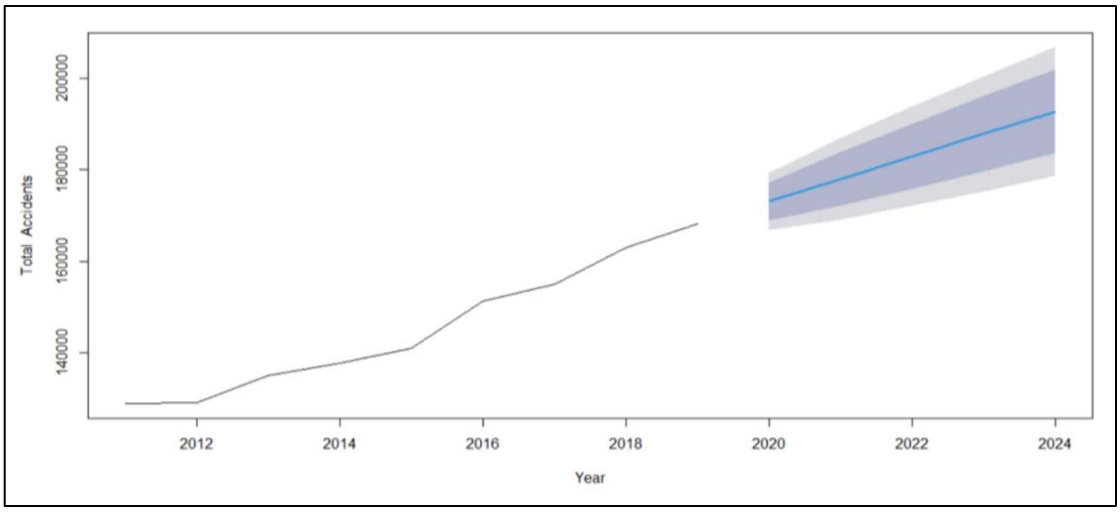


Figure 1.2 Projected Road Accidents in Selangor (Baskara et al., 2023)

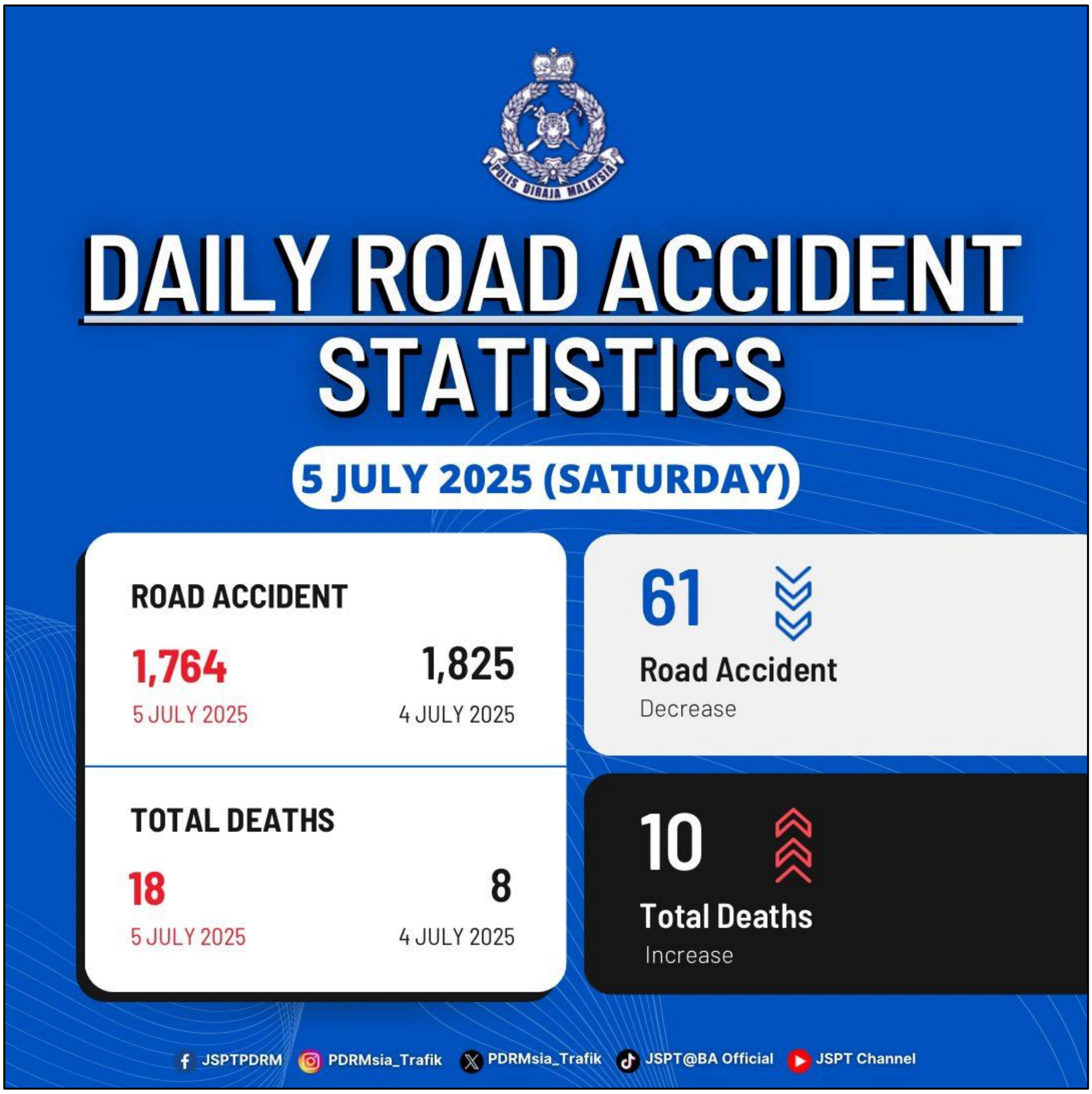


Figure 1.3 Malaysia's Daily Road Accidents and Fatalities (Jabatan Siasatan dan Penguatkuasaan Trafik (JSPT), 2025) Highlighted to Exemplify Typical Surges in Fatalities and Incident Variability

National responses, such as the Malaysia Road Assessment Programme (MyRAP) in collaboration with the International Road Assessment Programme (iRAP) and the Road Safety Plan 2022-2030, prioritise upgrading 1- and 2-star roads to align with halving mortality targets (International Islamic University Malaysia (IIUM) Entrepreneurship and Consultancies Sdn. Bhd. & United Nations Development Programme Malaysia, 2024; International Road Assessment Programme (iRAP), 2019, 2025b).

University campuses intensify these vulnerabilities, given their concentrations of young adults and heterogeneous traffic. Data from 2018 to 2021 reveal 63% of incidents at Universiti Teknologi MARA (UiTM) Shah Alam, the largest campus in Malaysia with 196,055 diverse students enrolled (Universiti Teknologi MARA (UiTM), 2022, 2024a), involved cars, 29% involved motorcycles, and 2% involved pedestrians (Figure 1.4) (Mohd Nusa et al., 2023). Recent UiTM Shah Alam audits confirm hotspot clustering at junctions near the Engineering College, Kolej Melati, and Teratai, where poor geometric design, including faded markings on humps, potholes, damaged kerbs and pedestrian walkways, blocked signage by foliage, and inadequate lighting, heightens crash severity (Wan Ibrahim et al., 2023). Despite UiTM's dedication to sustainability through the Ui Green Index (Universiti Teknologi MARA (UiTM), 2024b), inadequate bus stop distribution and last-mile connectivity further force reliance on private vehicles (Andi & Mohd Amin, 2024), heightening risks to vulnerable road users.

Despite these concerning patterns, significant knowledge gaps remain regarding campus-specific infrastructure contributions to crashes, the heightened safety risks facing young vulnerable road users due to pedestrian facilities and design shortcomings, and the lack of systematic iRAP surveys or star rating assessments, collectively justifying targeted institutional research.

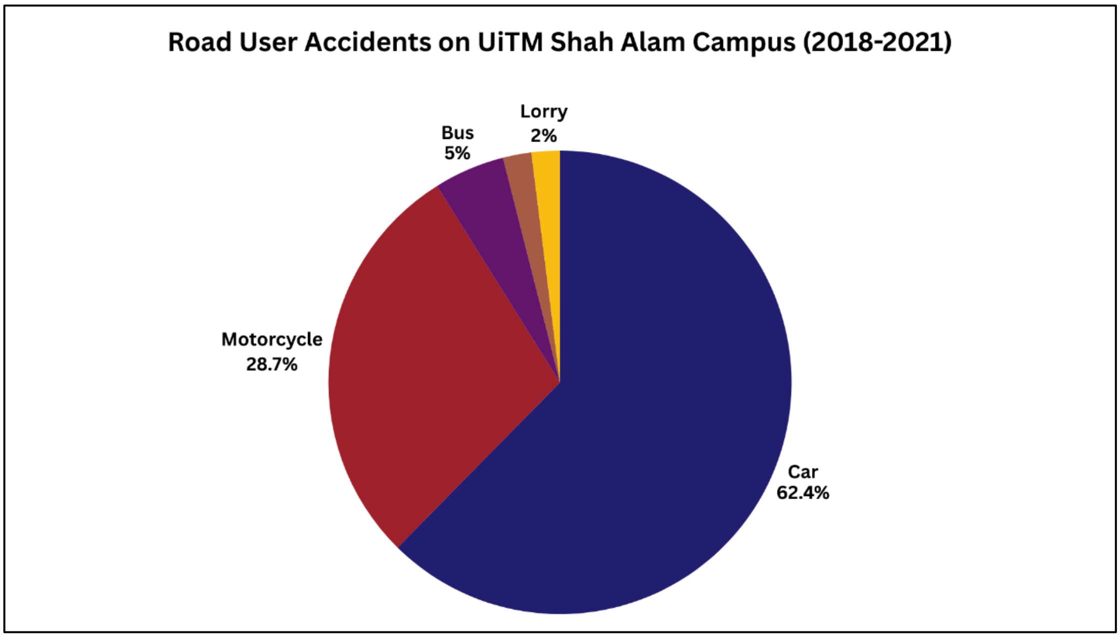


Figure 1.4 Distribution of Road User Accidents by Vehicle Type at UiTM Shah Alam Campus, 2018 to 2021 (Mohd Nusa et al., 2023)

These deficiencies forge direct pathways to the study's objectives. The entrenched global, LMIC, and Malaysian infrastructure crisis (12 to 13% causation from poor conditions), coupled with UiTM's unassessed road inventory and pedestrian gaps, directly supports the first research objective: to assess road safety risks at UiTM Shah Alam by inspecting road inventory through iRAP survey protocols and identifying contextual gaps, such as pedestrian vulnerabilities and infrastructure deficiencies. Recent UiTM Shah Alam audits confirm persistent hotspot clustering at junctions near Engineering College, Kolej Melati, and Teratai, where poor geometric design heightens crash severity and reveals the unadapted nature of existing star rating protocols for low-speed institutional environments. These documented infrastructure deficiencies and the absence of validated iRAP star ratings for campus settings directly justify the second research objective: to evaluate and customise the iRAP star rating protocol using ViDA for campus roads, validate its effectiveness across varied speeds in institutional settings, and reveal necessary adaptation requirements for educational settings. Enduring data gaps, rising projections, and the imperative for contextually feasible interventions in educational settings underpin the third research objective: to propose evidence-based improvement strategies that contribute a tailored iRAP framework for UiTM-like campuses, enhancing safety while ensuring feasibility within educational settings. This research addresses these voids by adapting validated iRAP methodologies such as Star

Rating for Schools and CycleRAP, thereby advancing campus safety in alignment with Sustainable Development Goals.

1.2 Research Aims

This study aims to systematically evaluate the existing road conditions at the Universiti Teknologi MARA (UiTM) Shah Alam main campus using the International Road Assessment Programme (iRAP) structured assessment framework. The goal is to enhance road safety and infrastructure.

1.3 Research Objectives

The study is guided by the following objectives:

a) To assess road safety risks at the UiTM Shah Alam campus by inspecting road inventory via iRAP survey protocols and identifying contextual gaps, such as pedestrian vulnerabilities and infrastructure deficiencies aligned with the campus safety problem.
b) To evaluate and customise the iRAP star rating protocol using ViDA for campus roads, validating its effectiveness across varied speed environments in institutional settings and revealing adaptation needs.
c) To propose evidence-based improvement strategies that contribute a tailored iRAP framework for UiTM-like campuses, enhancing safety while ensuring feasibility within educational settings.

1.4 Research Questions

The research questions for this study are as follows:

a) What road inventory attributes and safety gaps are present within the UiTM Shah Alam campus, as identified through iRAP survey protocols?
b) How effective is the customised iRAP star rating protocol via ViDA across varied speed environments in institutional settings, and what adaptations are needed?

c) What adapted improvement strategies can be proposed using the validated iRAP framework to enhance campus road safety while respecting institutional constraints?

1.5 Scope of Study

The research was conducted at the UiTM Shah Alam main campus (Figure 1.5), Malaysia's largest public university system with 34 campuses nationwide (Figure 1.6) (Universiti Teknologi MARA (UiTM), 2022, 2025). This study assesses a strategically selected 7.4 km and covers an area of approximately 960,542 m^2 using the International Road Assessment Programme (iRAP) methodology to evaluate infrastructure risks for four road user groups: car occupants, motorcyclists, cyclists, and pedestrians. Malaysian Public Works Department (JKR) standards (JKR/SPJ/1988, JKR 8.07/85) provide the geometric/safety baseline framing this analysis. The scope excludes behavioural factors, per the iRAP protocol.

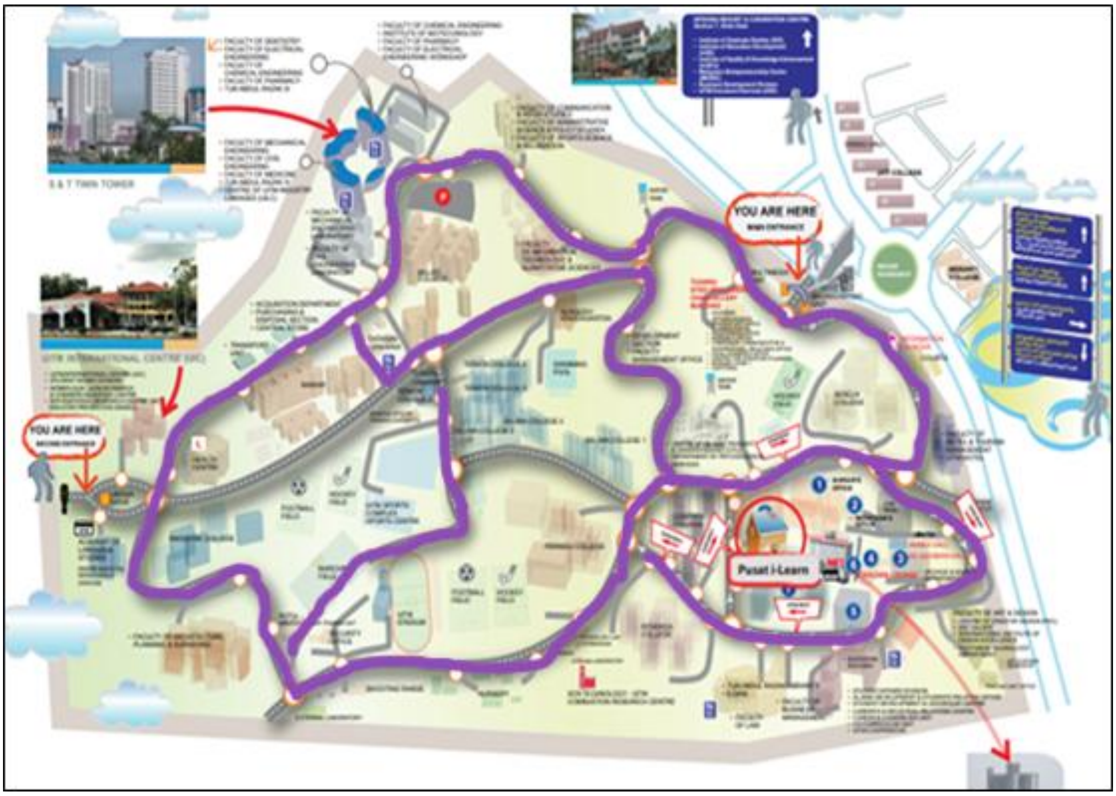


Figure 1.5 Campus Map and Selected Roads

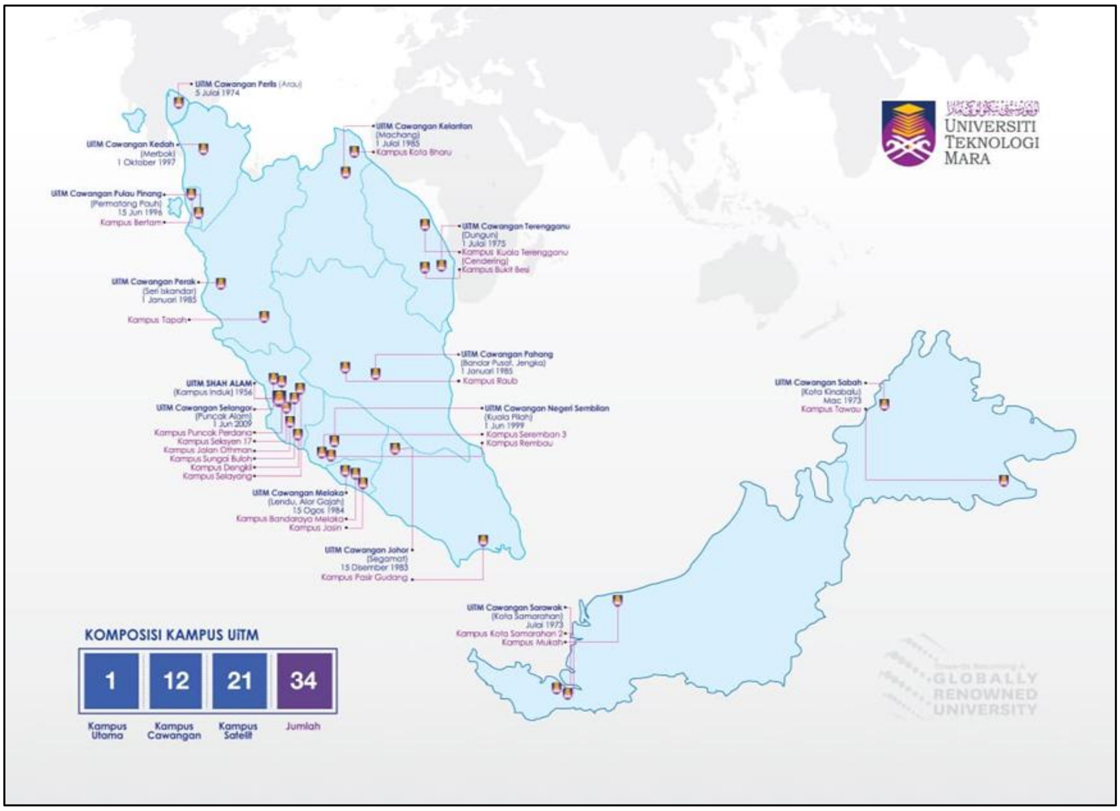


Figure 1.6 UiTM Locations (Universiti Teknologi MARA (UiTM), 2025)

Road segments were selected based on three primary criteria: (1) high traffic activity, (2) user diversity involving mixed vulnerable road users (VRUs) and motorised vehicles, and (3) identified crash-prone locations (Mohd Nusa et al., 2023). This selection approach ensured representative coverage of key functional zones within the campus, including academic areas (Jalan Utama), residential zones (Kolej areas), and central activity hubs. The designation of certain segments as high traffic activity areas was based on their functional role as primary access corridors within the campus road network. Preliminary site observations indicated continuous vehicular movement and frequent interactions among vehicles, motorcycles, and pedestrians, particularly during peak academic periods. This classification was further supported by a supervisory recommendation that was informed by institutional knowledge of established campus traffic patterns.

1.5.1 Research Area

This research focuses specifically on the UiTM main campus (Figure 1.7), located in the vibrant city of Shah Alam, Selangor. Established in 1967, the main campus is not only the oldest but also the largest within the UiTM system, covering an expansive area of approximately 1,587,464 m^2 (UiTM Green Centre (UGC), 2022; Universiti Teknologi MARA (UiTM), 2022).

Figure 1.7 Research Area

The main campus is embraced by its lush greenery, creating a tranquil atmosphere that enhances the academic experience for both students and faculty. Its strategic location in Shah Alam, which was granted city status on October 10, 2000 (UiTM Green Centre (UGC), 2022), underscores the rapid urban development and significance of this area.

Table 1.1 presents detailed information regarding several road sections surveyed in a specific research area, accompanied by figures for enhanced clarity. The first entry included Jalan Cemerlang 1/19 and Jalan Dataran Cendekiawan 2, which extends 0.9 km from the intersection near the Akademi Kepolisan UiTM-PDRM towards Padang Kawad UiTM Shah Alam, passing notable landmarks such as the UiTM Shah Alam Sports Complex and the Kolej Delima gate before reaching the intersection of Kolej Teratai 2 and Prima Siswa Complex. The survey route concluded at the intersection between the Kolej Mawar gate and Dataran Cendekia, facing the Engineering College building. The second entry encompasses Jalan Pintar 1/21A and Jalan Dataran Cendekiawan 2, which span 0.6 km, starting from the Bukit Tonggek intersection and ending at the intersection next to the Kolej Mawar gate and Dataran Cendekia, facing the Engineering College building. The road survey passed key locations, including the Ibu Pejabat Polis Bantuan UiTM Shah Alam and the Prima Siswa Complex. A more extensive survey includes Jalan Ilmu 1/1, Jalan Bijak 1/22, and Jalan Sarjana 1/2 along the main road of UiTM Shah Alam, with a total length of 4.3 km. Additionally, Kawasan Central UiTM, which is formed of Jalan Ilmu 1/1 and Jalan Bernas 1/10, is surveyed, extending approximately 0.6 km from the roundabout known as Bulatan Kolej Seroja, featuring the Nexus Arca. This route passes significant landmarks such as the Koperasi UiTM Berhad, the Tun Abdul Razak Library, and the Law Faculty, ultimately concluding at the exit junction of the Kolej Cempaka/Kenanga gate. Meanwhile, Jalan Cendekiawan 1/15 within the Kawasan Pembangunan UiTM, also covering 0.6 km, begins at the first intersection after passing by Dataran Tuanku Fauziah and concludes at the exit junction between a public parking space and Masjid UiTM Shah Alam, facing the ACIS building. This route features several significant landmarks, including the Kompleks Pembangunan Infrastruktur & Infostruktur and the Jabatan Pengurusan Kewangan Pembangunan & Fasiliti.

The selection of these road segments was guided by specific criteria related to traffic conditions, user characteristics, and potential safety risks. These criteria include high traffic volume, the presence of vulnerable road users (such as pedestrians and cyclists), proximity to residential and academic hotspots, and areas undergoing active development. Such considerations ensure that the selected roads capture a diverse range of operating conditions and risk profiles within the campus road network.

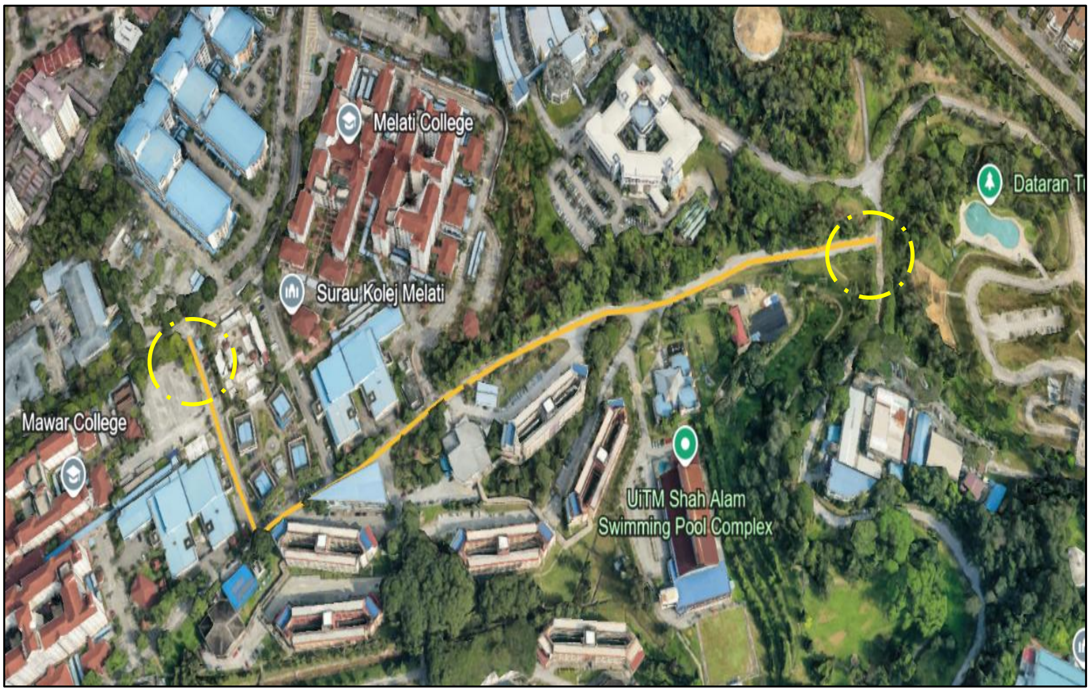
By incorporating roads with varying characteristics, ranging from high-volume main routes to pedestrian-dominated and development areas, this study provides a representative assessment of infrastructure safety. This approach supports a comprehensive evaluation aligned with iRAP methodology, enabling the identification of critical risk locations and the formulation of targeted improvement strategies.

Overall, the selected road segments offer a balanced representation of the UiTM Shah Alam road network, allowing for a systematic assessment of infrastructure risks affecting different categories of road users, including motorists, motorcyclists, cyclists, and pedestrians.

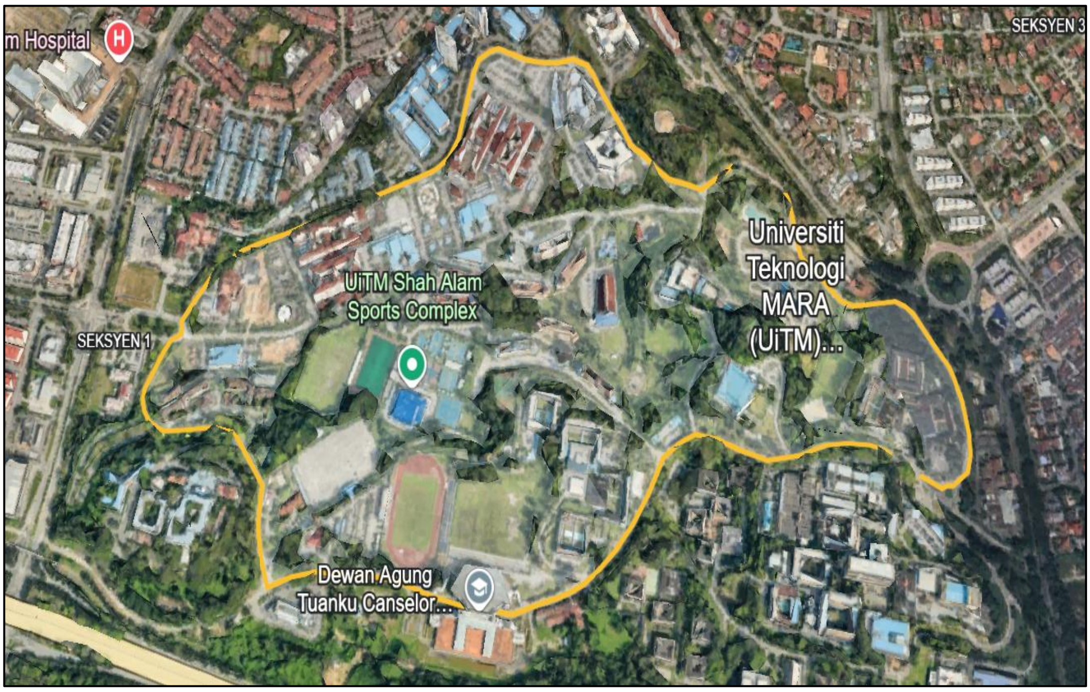
Table 1.1
Overview of Road Surveyed

Road name	Jalan Cemerlang 1/19 & Jalan Dataran Cendekiawan 2
Road section	Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction
Length	0.9
Selection criteria	High volume, residential hotspot, mixed users, one lane, median type: one way and centreline
Overview	

Road name	Jalan Pintar 1/21A & Jalan Dataran Cendekiawan 2
Road section	Bukit Tonggek – Kolej Mawar Exit Junction
Length	0.6
Selection criteria	Pedestrian-heavy, vulnerable road user (VRU) hotspot, one lane, median type: one way and centreline
Overview	



Road name	Jalan Ilmu 1/1, Jalan Bijak 1/22, & Jalan Sarjana 1/2
Road section	Jalan Utama UiTM
Length	4.3
Selection criteria	Highest volume, all user types, one and two lanes, median type: wide centreline, centreline, one way, and physical median
Overview	



Road name	Jalan Ilmu 1/1 & Jalan Bernas 1/10

Road section	Kawasan Central UiTM
Length	0.6
Selection criteria	Academic hub, cyclist/pedestrian focus, one and two lanes, median type: one way
Overview	

Road name	Jalan Cendekiawan 1/15
Road section	Kawasan Pembangunan UiTM
Length	0.6
Selection criteria	Development zone, emerging risks, one lane, median type: one way, centreline, and flexible posts
Overview	

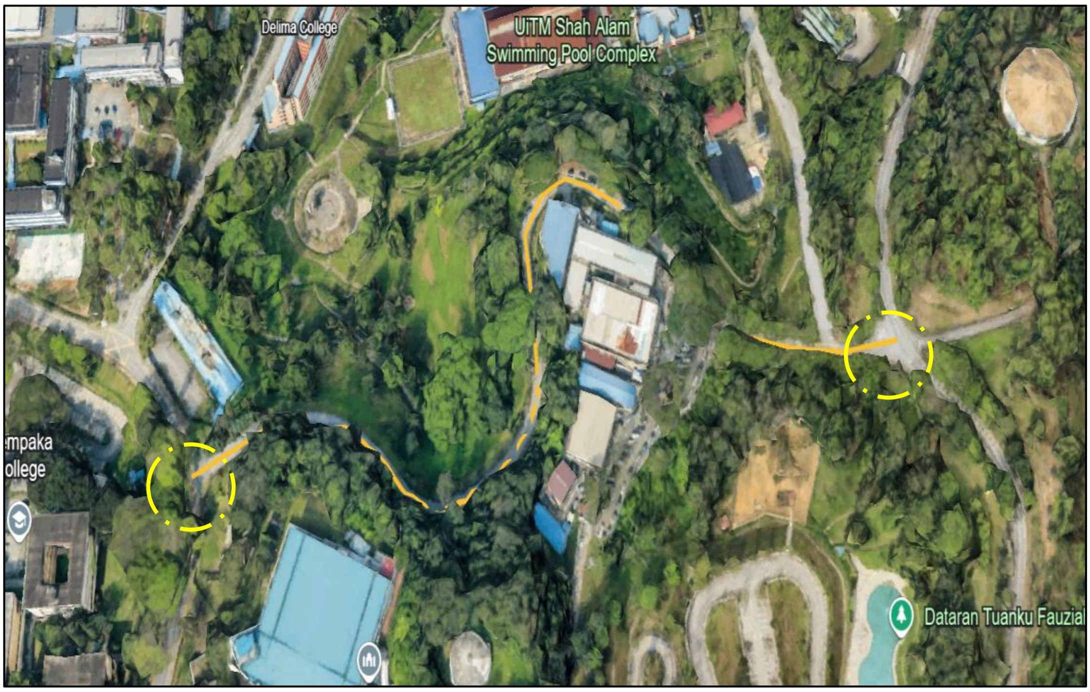
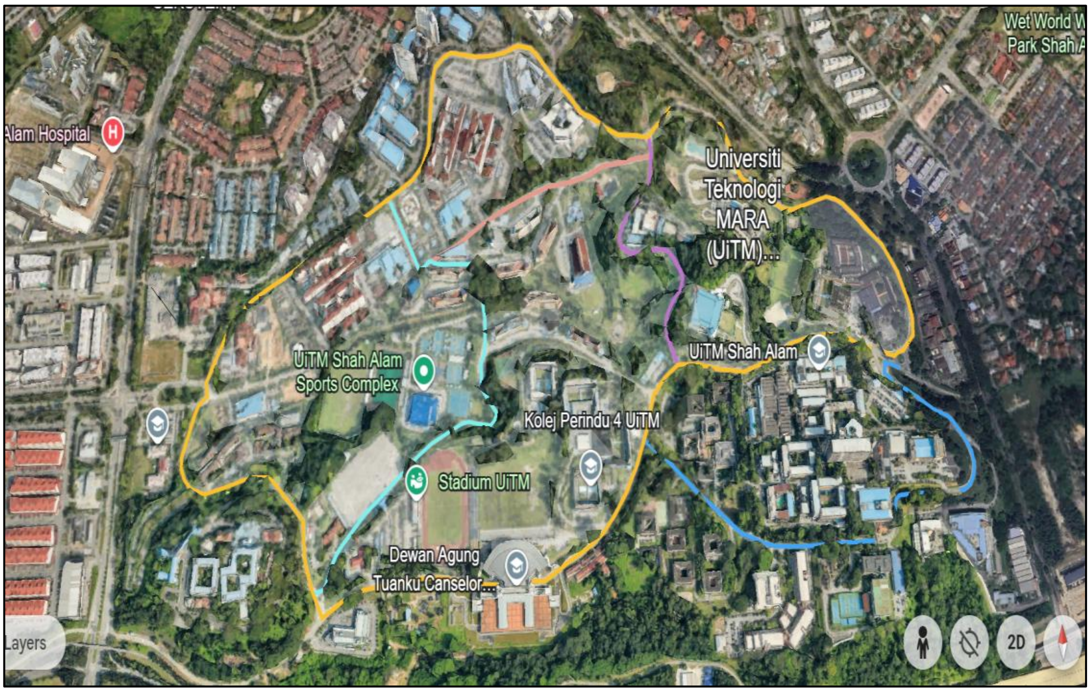


Table 1.2 summarises the overall road survey and features a figure that highlights all the surveyed road sections. Different colours are used to distinguish the various road segments, enhance clarity, and facilitate a better understanding of the surveyed area.

This study examines the distinctive characteristics of the UiTM main campus and its roadways to address critical infrastructure challenges that facilitate academic pursuits and contribute to broader urban planning initiatives.

In conclusion, the iRAP road inventory survey, conducted via ViDA software across the delineated 7.4 km network, systematically evaluates infrastructure risks for car occupants, motorcyclists, cyclists, and pedestrians, generating star ratings and exposure indices benchmarked against JKR minimum standards for lane widths, sight distances, signage, and pedestrian accommodations. From this empirical foundation, a prioritised risk matrix emerges, integrating star ratings ($\leq$3 stars = critical), traffic exposure levels, and documented hotspot prevalence to systematically sequence intervention strategies based on implementation urgency and institutional feasibility. These evidence-derived recommendations, spanning geometric realignments, enhanced road markings, and vulnerable road user provisions, furnish scalable blueprints applicable across Malaysia’s 34 UiTM campuses, thereby harmonising national JKR compliance imperatives with global iRAP safety benchmarks to meaningfully advance the country's goal of reducing road trauma.

Table 1.2
Summary of Road Surveyed



Road name	Road section	Length	Legend
Jalan Cemerlang 1/19 & Jalan Dataran Cendekiawan 2	Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction	0.9	
Jalan Pintar 1/21A & Jalan Dataran Cendekiawan 2	Bukit Tonggek – Kolej Mawar Exit Junction	0.6	
Jalan Ilmu 1/1, Jalan Bijak 1/22, & Jalan Sarjana 1/2	Jalan Utama UiTM	4.3	
Jalan Ilmu 1/1 & Jalan Bernas 1/10	Kawasan Central UiTM	1.0	
Jalan Cendekiawan 1/15	Kawasan Pembangunan UiTM	0.6	
Total (km)		7.4	

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

2.1.1 Global Road Safety Crisis

Road traffic accidents remain a critical global public health crisis, with low- and middle-income countries (LMICs) disproportionately bearing the world's annual road fatalities, despite possessing only 60% of vehicles and 10% of paved interurban roads (World Bank, 2025). Vulnerable road users such as pedestrians, cyclists, and motorcyclists comprise 53% of all fatalities, exacerbated by inadequate infrastructure such as the absence of pedestrian lanes in 80% of LMIC roads (European Transport Safety Council (ETSC), 2023; World Health Organization (WHO), 2025). Between 2018 and 2024, Multilateral Development Banks (MDBs) mobilised USD 6 billion for LMIC road safety, yet financing shortfalls persist relative to 2030 targets (World Bank, 2025).

Road crashes cost LMICs 3% of their gross domestic product (GDP) annually due to medical costs, lost productivity, and disability burdens (World Health Organization (WHO), 2023b, 2025). Recent regional trends reveal alarming setbacks, with the United States reporting 21,400 fatalities in the first half of 2025 alone, a 19.7% increase from 2024, while Australia saw a 6% annual rise in road deaths, including a 15.5% spike among vulnerable users (Heidari Law Group, 2025; National Road Safety Data Hub, 2025). These figures underscore systemic failures in policy enforcement, with only six countries meeting WHO standards for all road safety laws (European Transport Safety Council (ETSC), 2023). Although the UN's 2030 target aims to halve road deaths, current trajectories, such as the Americas' mere 9.37% reduction from 2010 to 2021 indicate a pressing need to take accelerated action on vehicle safety standards, infrastructure redesign, and equitable resource allocation for low- and middle-income countries (Pan American Health Organization (PAHO), 2025; World Health Organization (WHO), 2025). Persistent risk factors—speeding, alcohol-impaired driving, inadequate helmet and seatbelt use—reinforce road safety's multisectoral imperative, particularly where institutional environments amplify LMIC infrastructure deficits.

2.1.2 Road Safety in Malaysia

In Malaysia, road safety remains a pressing concern, as transport accidents ranked fourth among causes of death in 2023 (3.5% of total fatalities) and 2024 (3.3%), despite a slight downward trend (Figure 2.1). This aligns with reports of nearly 7,000 fatalities in 2023 (Gimino & Ibrahim, 2024; Mardhiah, 2024). Official Royal Malaysia Police (PDRM) statistics further underscore the issue, recording 638,060 road accidents in 2024 nationwide, with Selangor leading at 187,156 cases, followed by Johor (97,466) and W.P. Kuala Lumpur (76,763). Selangor also had the highest number of fatalities from transport accidents, surpassing Johor and Kedah, consistently exceeding 700 deaths annually, peaking at 786 in 2017 (Figure 2.2) due to its dense population and road networks (Department of Statistics Malaysia (DOSM), 2025). This aligns with the principal causes of death for transport accidents by state, supported by figures in Figures 2.2 and 2.3.

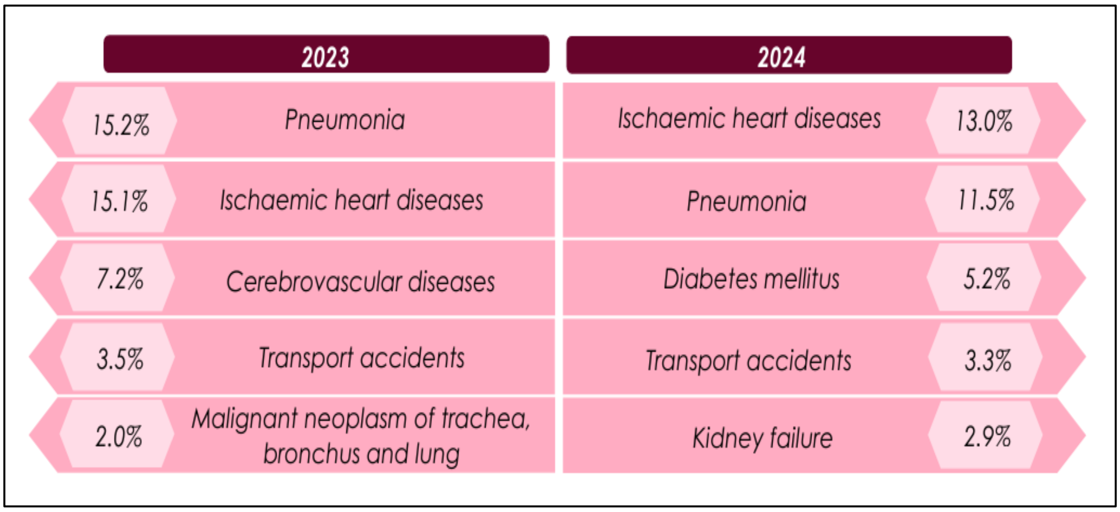


Figure 2.1 Five Principal Causes of Death, Malaysia, 2023 and 2024 (Department of Statistics Malaysia (DOSM), 2025)

Furthermore, according to the Malaysian Institute of Road Safety Research (MIROS) 2018 Value of Statistical Life (VSL) report, each road fatality incurs an economic loss of at least RM 3.12 million to the government. Road accidents pose a significant public health challenge, claiming an average of 18 lives daily in Malaysia.

The Ministry of Transport Malaysia thus underscores the urgent need for robust policy interventions (Department of Statistics Malaysia (DOSM), 2025).

Table 2: Number of deaths caused by transport accident by state, 2014-2024

State/Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Johor	511	551	628	624	624	647	434	392	509	612	663
Kedah	497	509	535	507	476	438	347	369	513	469	505
Kelantan	266	253	231	270	251	219	183	164	228	206	245
Melaka	183	175	211	196	147	166	124	88	121	143	183
Negeri Sembilan	268	244	277	264	266	179	171	152	219	249	239
Pahang	309	277	314	296	286	256	212	168	258	300	290
Perak	455	473	528	467	472	453	305	319	411	429	410
Perlis	64	63	57	68	63	77	55	38	59	44	50
Pulau Pinang	310	269	345	278	309	311	233	247	297	311	290
Sabah	101	99	100	135	155	161	136	143	181	181	209
Sarawak	268	251	237	229	254	220	157	192	168	153	121
Selangor	709	670	768	786	708	700	537	529	700	775	807
Terengganu	194	197	245	218	181	198	155	140	192	214	205
W.P. Kuala Lumpur	159	149	153	143	188	162	111	113	144	140	198
W.P. Labuan	6	6	8	5	7	5	3	4	4	6	4
W.P. Putrajaya	4	10	3	13	4	9	6	3	7	12	9

Figure 2.2 Number of Deaths Caused by Transport Accidents by State, 2014 to 2024 (Department of Statistics Malaysia (DOSM), 2025)

Additionally, as shown in Figure 2.4, motor vehicle accidents (MVAs) trended upward year-on-year, dipping briefly in 2020–2021 amid COVID-19 movement control orders (MCOs) that reduced traffic. Cases climbed from 4,011 in 2022 to 4,428 in 2023, averaging annual rises outside the pandemic (Department of Statistics Malaysia (DOSM), 2025). Motorcycles featured disproportionately, with Selangor showing elevated rates that reveal geographic vulnerabilities (Mohd Azami et al., 2024).

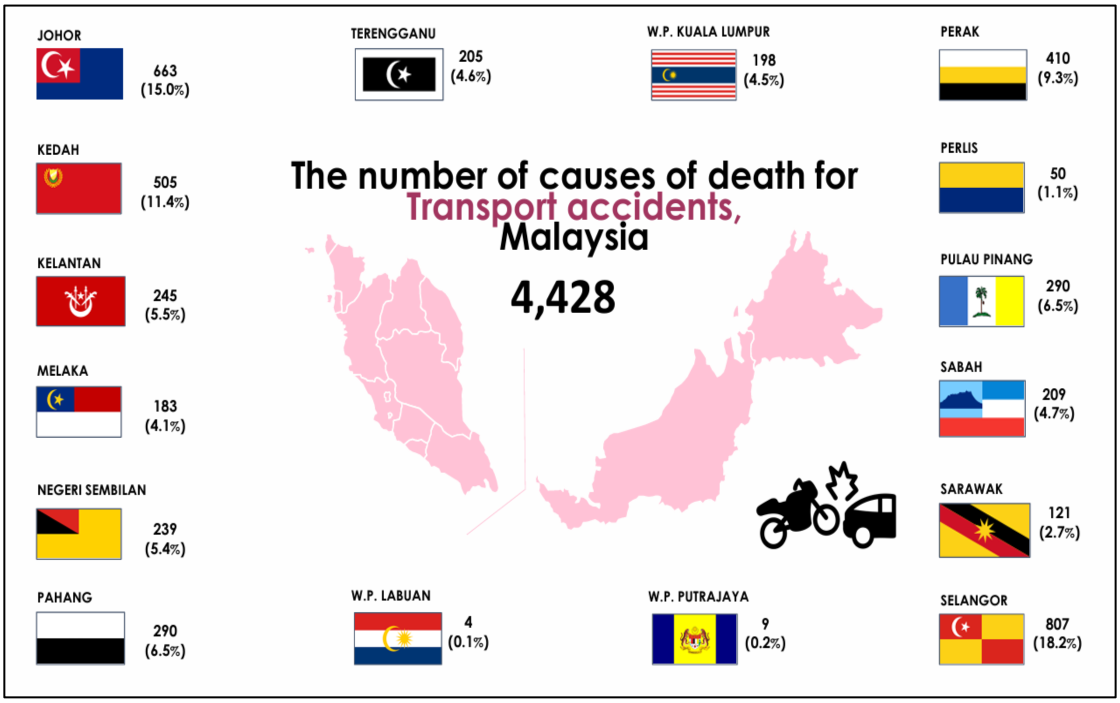


Figure 2.3 Cause of Death for Transport Accidents by State, Malaysia 2024 (Department of Statistics Malaysia (DOSM), 2025)

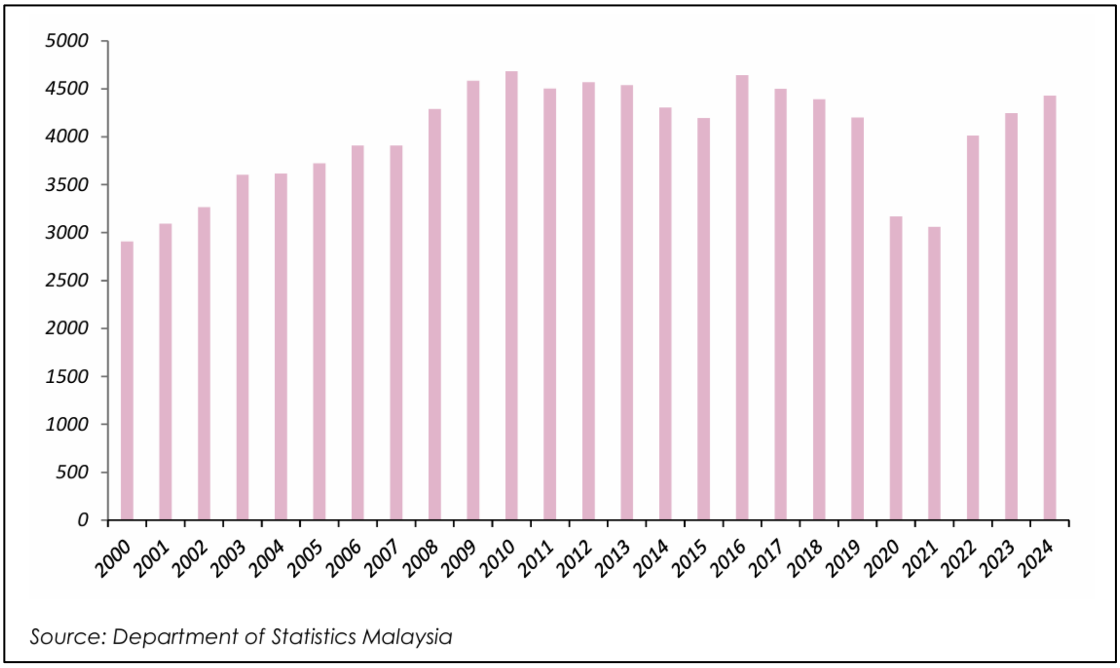


Figure 2.4 Number of Deaths Caused by Transport Accidents in Malaysia, 2000 to 2024 (Department of Statistics Malaysia (DOSM), 2025)

These patterns extend to university settings, where Selangor's high-traffic campus roads, such as those at institutions like Universiti Teknologi MARA, mirror urban risks for students. PDRM data highlights the urgency of targeted interventions in these student-dense zones.

Malaysia addresses this challenge through the Road Safety Plan 2022–2030, which targets a 50% reduction in road fatalities by 2030 via enhanced governance, infrastructure improvements, and public awareness initiatives aligned with United Nations goals (Gimino & Ibrahim, 2024; International Road Assessment Programme (iRAP), 2023b). Public campaigns, such as daily PDRM accident reports and radio broadcasts, help these efforts by encouraging safer driving habits (Gimino & Ibrahim, 2024; Khairuddin et al., 2024). Academic research further stresses integrating robust legislation, responsible driving practices, and a pervasive safety culture to align policy with public perception and ensure long-term progress (Lee & Ng, 2025).

2.1.3 Risk Factors Contributing to Road Accidents

Road accidents arise from four primary risk domains—human factors, vehicle characteristics, environmental conditions, and road infrastructure—underscoring the Complicated Nature Of Safety Challenges (Cociu Et Al., 2023; Garg Et Al., 2025).

2.1.3.1 Human Factors

Road accidents stem primarily from human factors, encompassing speeding, distracted driving, and impaired driving (Sarkar et al., 2025). Speeding exponentially elevates crash severity, with each 1% increase in mean speed correlating to a 4% higher fatal crash risk and a 3% greater serious injury risk (World Health Organization (WHO), 2023b, 2025). Distracted driving, particularly mobile phone use, quadruples crash likelihood (World Health Organization (WHO), 2023b, 2025), while even low blood alcohol concentrations dramatically increase fatal crash probability (Kiwango et al., 2024). Contextual studies confirm these patterns, as Bangladeshi research identifies human error as dominant (Rozars et al., 2025), while Malaysian analysis highlights driver attitudes and fatigue as primary contributors (Bahari et al., 2022).

Within institutional settings, these risks intensify among young drivers (18-24 years), who dominate campus crash statistics. (Mohd Nusa et al., 2023) document that 63% of university junction crashes result from speeding and distraction—behaviours exacerbated by academic pressures and peer dynamics. Jen Sim et al. (2025) further reveal non-standard helmet compliance exceeding 50% among campus motorcyclists, compounding Malaysia's national 68% motorcycle fatality rate. Conventional iRAP protocols, calibrated for highway speeds, systematically underestimate these low-speed institutional behavioural risks, necessitating methodological adaptations to accurately capture campus-specific human factor vulnerabilities and inform targeted interventions.

2.1.3.2 Vehicle-Related Factors

Vehicle factors represent significant yet preventable contributors to road crashes, encompassing worn tires, faulty brakes, and inadequate safety equipment that amplify injury severity, particularly in high-motorcycle-use contexts (Adanu et al., 2024). Regular vehicle maintenance proves essential, as mechanical failures exacerbate human error consequences, with helmet non-compliance further compounding risks in Malaysia (Jen Sim et al., 2025; Mohd Azami et al., 2024; Mohd Nusa et al., 2023).

In institutional environments, Malaysia's campus vehicle fleets mirror national trends, where motorcycles comprise 47% of vehicles but account for 68% of fatalities due to helmet non-compliance and vehicle defects (Jen Sim et al., 2025). Mohd Azami et al. (2024) demonstrate how vehicle-road interactions intensify risks within high-density campus corridors. Standard iRAP motorcycle star ratings, designed for highway speeds, remain unvalidated for low-speed campus environments (<40 km/hr), suggesting that there must be tailored calibration to address these context-specific vulnerabilities and enhance institutional safety assessments.

2.1.3.3 Environmental Factors

Environmental conditions interact dynamically with human and vehicle factors, with high traffic volumes, urban land use patterns, and poor weather increasing the frequency of crashes (Chen et al., 2025). Peak congestion periods and complex urban intersections amplify collision risks, particularly where mixed traffic flows converge—a prevalent Malaysian campus characteristic. Mohd Azami et al. (2024) document spatial crash clustering in university-adjacent high-density areas, driven by traffic volume peaks and complex junction geometries inherent to academic land use. Chen et al. (2025) further establish that urban environmental stressors—such as congestion and heterogeneous traffic mixes—significantly contribute to crash incidence within campus precincts. Standard iRAP methodologies require campus-specific traffic calibration to accurately model these dynamic environmental risk amplifiers, which remain unaccounted for in conventional highway-focused protocols.

2.1.3.4 Infrastructure-Related Factors

Road infrastructure deficiencies represent modifiable systemic risks amenable to engineering interventions (Chen et al., 2025). Inadequate pedestrian facilities, missing guardrails, insufficient crossings, and poor geometric design directly elevate vulnerable road user exposure (World Health Organization (WHO), 2023b, 2025). Additionally, well-designed sidewalks, traffic signals, and protective barriers demonstrably reduce pedestrian crashes, solutions proven effective globally (Chen et al., 2025; World Health Organization (WHO), 2023b, 2025). The 2025 Malaysia Road Safety Profile quantifies this crisis starkly, where 51% of assessed roads achieve only 1- to 2-star ratings for vehicle occupants, while 97% score below 3 stars for motorcyclists, as in Figure 2.5, Malaysia's dominant road user (47% of vehicles), despite 6,431 km already evaluated through iRAP protocols, yielding 17 fatalities per 1,000 km of road length (Asian Transport Observatory (ATO), 2025). These findings underscore infrastructure's pivotal role within Malaysia's LMIC context, where safety features remain inconsistent.

Critical research gaps persist: (1) domain interactions remain underexplored within institutional contexts, (2) LMIC campus environments lack systematic infrastructure audits, and (3) evidence-based intervention prioritisation methodologies require validation beyond public highways. This study addresses these voids by adapting iRAP protocols to Malaysia's largest university campus, generating actionable infrastructure interventions calibrated against JKR standards while accommodating the unique traffic profiles and geometric constraints characteristic of educational precincts. Such campus-level validation extends Safe Systems principles to understudied institutional networks, informing scalable trauma reduction across Malaysia's 34 UiTM campuses and contributing methodologically to national road safety advancement.

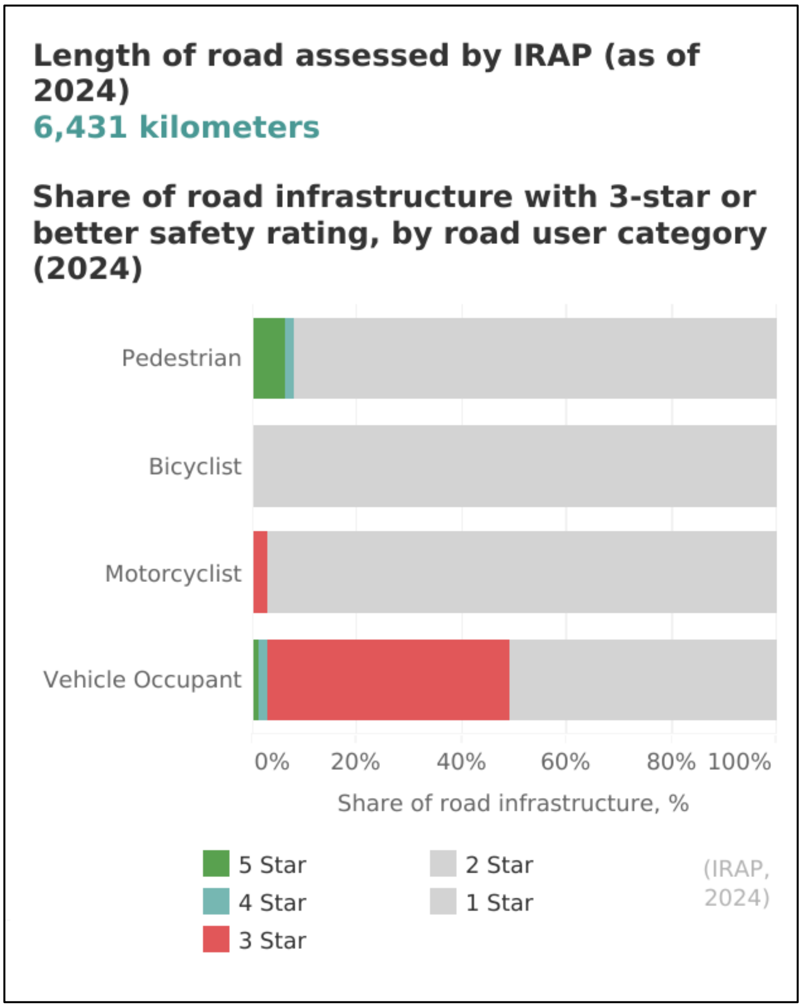


Figure 2.5 iRAP Assessed Roads and Their Star Rating by Road User (Asian Transport Observatory (ATO), 2025)

2.2 Introduction to the International Road Assessment Programme (iRAP)

The International Road Assessment Programme (iRAP) is a global umbrella organisation for Road Assessment Programmes (RAPs), dedicated to saving lives by eliminating high-risk roads worldwide (Radhakrishnan & Athiappan, 2021). As a UK-registered charity, iRAP collaborates with governments, development banks, mobility clubs, research institutions, industry partners, and NGOs across over 100 countries to ensure safe driving conditions for all (International Road Assessment Programme (iRAP), 2025b). Furthermore, it coordinates partners such as BrazilRAP (Brazil), ThaiRAP (Thailand), MyRAP (Malaysia), IndiaRAP (India), usRAP (United States), KiwiRAP (New Zealand), ChinaRAP (China), AusRAP (Australia), and SARAP (South Africa) to promote standardised road safety evaluations and high-risk road elimination worldwide (International Road Assessment Programme (iRAP), 2026).

The mission of iRAP is to eliminate high-risk roads globally, in line with the Sustainable Development Goals (SDGs) of the United Nations and the Global Plan for the Decade of Action for Road Safety. This effort aligns with broader global initiatives aimed at reducing road casualties, as highlighted by A. Jameel & Al-Nuaimi (2020) and Md Murozi et al. (2022). Specifically, iRAP supports Targets 3 and 4, which aim to ensure that all new roads meet a 3-star or higher standard for all users by 2030 and that more than 75% of travel occurs on such roads. The UN Sustainable Development Goal 3.6 also targets halving road deaths and injuries by 2030, with iRAP contributing to this effort through its methodologies (International Road Assessment Programme (iRAP), 2025b; McInerney & Smith, 2025).

iRAP's star rating methodology systematically evaluates roads using over 50 evidence-based attributes, which trained teams code at 100-metre intervals or for single locations via tools such as ViDA software. These attributes encompass core categories such as the following (see Appendices 1 and 2): roadside hazards (including poles, trees, ditches, slopes, barriers, buildings, and clear zones); road geometry (such as lane widths, curvature, and gradients); junctions (types including signalled and roundabout); pedestrian facilities (such as crossings, refuges, and sidewalks); cyclist provisions (like dedicated lanes, paths, and motor traffic separation); motorcyclist risks (involving delineation, skid resistance, and roadside protection); speed characteristics (including limits and calming features like humps, bumps, chicanes, and narrowing); traffic volumes and mix (hourly or annual counts for vehicles, motorcycles, pedestrians, and cyclists); surface conditions; and access points. Each attribute receives a score calibrated against global crash risk models, yielding differentiated 1-star (highest risk) to 5-star (safest) ratings for specific road user groups. Identification of high-risk attributes subsequently informs Safer Road Investment Plans (SRIPs) that detail cost-effective countermeasures (International Road Assessment Programme (iRAP), 2024b; McInerney & Smith, 2025).

iRAP has made significant strides globally, with its star rating system adopted by the World Health Organization (WHO) to monitor the global target for road safety performance. iRAP methodologies contributed to preventing approximately 700,000 deaths and serious injuries on safer roads worldwide by the end of 2024 (International Road Assessment Programme (iRAP), 2024c; Li et al., 2024; McInerney & Smith, 2025). Additionally, iRAP's Star Rating for Schools (SR4S) programme has reviewed over 1,940 schools, highlighting its commitment to enhancing safety in critical areas like schools (International Road Assessment Programme (iRAP), 2024h; McInerney & Smith, 2025). Recent collaborations include the Ten Steps to 2030 for Safer Road Infrastructure initiatives, developed in partnership with the International Road Federation (IRF) and the World Road Association (PIARC), which aims to tackle high-risk roads through infrastructure upgrades and capacity building (International Road Federation (IRF), 2025). iRAP also supports the ITF's new Safe System Tool, fostering coordinated action towards zero road deaths and serious injuries (McInerney & Smith, 2025).

iRAP is financially supported by the FIA Foundation and other donors, ensuring its core methodology and tools are freely available worldwide (FIA Foundation, 2024; International Road Assessment Programme (iRAP), 2020, 2022a, 2024b, 2024a). The programme's impact extends beyond road safety, addressing global priorities such as child health, climate change, and urban mobility (International Road Assessment Programme (iRAP), 2025b). Recent initiatives include partnerships with organisations like the African Road Maintenance Fund Association (ARMFA) to enhance road safety capacity in Africa (International Road Assessment Programme (iRAP), 2025a).

2.3 iRAP Methodology Components

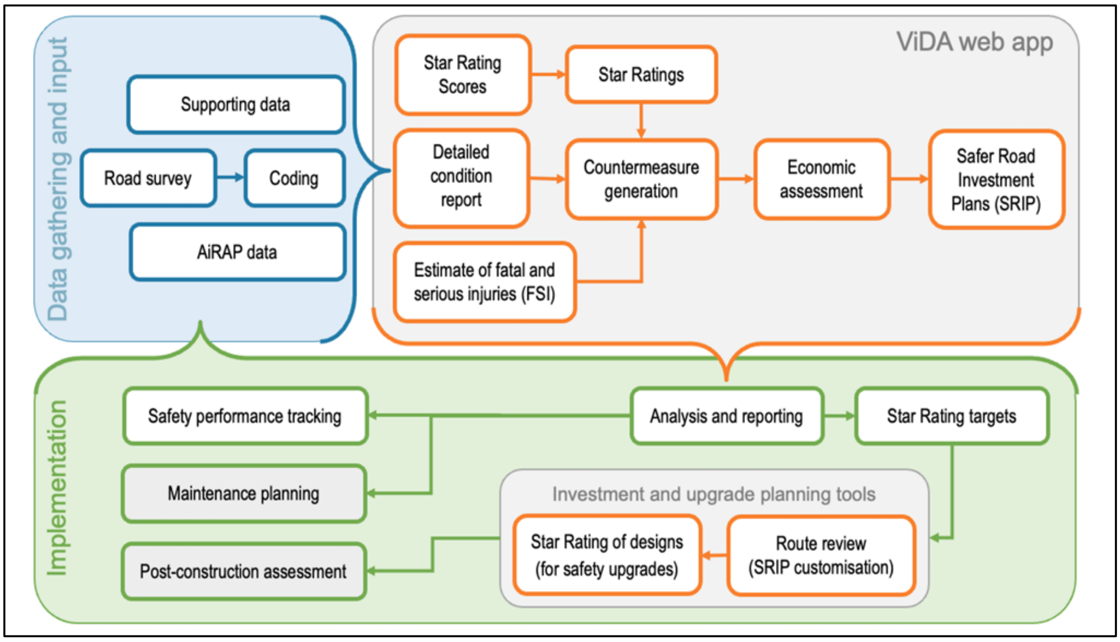


Figure 2.6 The Procedure of an Extensive iRAP Assessment (International Road Assessment Programme (iRAP), 2024b)

Figure 2.6 illustrates the systematic process used to conduct Star Rating, Fatal and Serious Injury (FSI) estimations, and develop Safer Road Investment Plans (SRIPs). This approach is grounded in research that identifies high-risk areas where severe crashes are likely to occur and provides proactive strategies for prevention, ultimately informing a comprehensive road infrastructure risk assessment and renewal strategy (International Road Assessment Programme (iRAP), 2024b).

2.3.1 Road Attribute Data Collection

The International Road Assessment Programme (iRAP) employs a systematic and evidence-based approach to enhance road safety through rigorous data collection during road inspections. This process is divided into two key components: road surveys and road coding (International Road Assessment Programme (iRAP), 2015b).

2.3.1.1 Road Survey

In the road survey phase, trained inspectors gather essential data that includes high-resolution images or videos of the roadway, precise GPS location details, and accurate distance measurements. This multimedia documentation is essential for providing a comprehensive view of road conditions and features, which is vital for subsequent risk analysis. The integration of advanced technologies, such as video mapping and Global Positioning Systems (GPS), ensures that the information collected is both precise and reflective of real-world circumstances, facilitating better decision-making (International Road Assessment Programme (iRAP), 2015b).

2.3.1.2 Road Coding

Following the survey, the road coding phase involves the classification of various road attributes based on the visual data collected. This classification encompasses descriptive elements such as road names and sections, as well as specific characteristics that may influence crash risks for various road users, including vehicle occupants, motorcyclists, pedestrians, and cyclists (see Appendix 1). For instance, if a 100-metre segment of roadway displays differing conditions, such as safety barriers in one half and roadside hazards in the other, iRAP's method dictates that this segment be coded according to the more hazardous conditions. This approach prioritises safety by ensuring that assessments reflect the most significant risks (International Road Assessment Programme (iRAP), 2015b).

The iRAP methodology places a strong emphasis on recording attributes for each 100-metre segment of roadway. In cases where an attribute's condition fluctuates within this segment, the most detrimental condition from a safety perspective is documented. This approach guarantees that safety assessments accurately reflect potential risks and facilitates targeted interventions aimed at improving road safety (International Road Assessment Programme (iRAP), 2015b).

In conclusion, iRAP's organised data collection process not only assists in identifying existing road hazards but also underpins the development of effective strategies intended to reduce serious injuries and fatalities on roads globally (International Road Assessment Programme (iRAP), 2025b; International Road Federation (IRF), 2022). The comprehensive documentation provided by iRAP serves as a foundational resource for ongoing research and investment in enhancements to road safety (Asia Pacific Road Safety Observatory (APRSO), 2022; International Road Assessment Programme (iRAP), 2025b). By systematically assessing road attributes and prioritising hazardous conditions, iRAP plays a crucial role in advocating for safer roads worldwide (International Road Assessment Programme (iRAP), 2025b; International Road Federation (IRF), 2022).

2.3.2 Risk Assessment Models

2.3.2.1 Star Rating Score (SRS)

The International Road Assessment Programme (iRAP) employs a systematic methodology to assess road safety by calculating the Star Rating Score (SRS) for each 100-metre road segment through its online platform (International Road Assessment Programme (iRAP), 2014; Md Murozi et al., 2022). The SRS is an indicator of both the likelihood and severity of crashes, derived from an evaluation of various road design features. The scoring system is informed by models developed by the European Road Assessment Programme (EuroRAP), which focuses on the protection offered to vehicle occupants in the event of a crash, and the Australian Road Assessment Programme

(AusRAP), which assesses both crash likelihood and occupant protection (Choocharukul et al., 2018; García-Ramírez, 2023; McInerney & Smith, 2009).

A fundamental aspect of iRAP's approach is its commitment to global consistency. This enables the programme to be applied across diverse countries, even in contexts where detailed, location-specific crash data may be lacking. This adaptability is essential for producing reliable predictions regarding potential fatalities on road networks, thereby forming the basis for estimating deaths and generating effective countermeasures (McInerney & Smith, 2009).

The SRS is structured to support road safety initiatives by providing a clear framework that elucidates how various road attributes contribute to crash risks. By systematically evaluating these attributes and prioritising hazardous conditions, iRAP is crucial in promoting safer roads globally. The extensive data collected through this process not only aids in identifying existing hazards but also informs the development of strategies aimed at reducing serious injuries and fatalities on a worldwide scale (McInerney & Smith, 2009).

2.3.3 iRAP Star Rating

The International Road Assessment Programme (iRAP) employs a systematic method to evaluate road safety by assigning star ratings, which objectively measure the likelihood and severity of road crashes. This approach focuses on identifying and documenting road attributes that contribute to the most common and severe types of accidents, grounded in evidence-based scientific research. The iRAP star ratings provide a quantifiable measure of risk to road users, including vehicle occupants, motorcyclists, pedestrians, and cyclists. This assessment is crucial in environments where detailed crash data may be lacking, such as in low- and middle-income countries where data quality is often compromised. iRAP overcomes this limitation through a proactive, engineering-led methodology that encodes global evidence on road safety risks into over 50 quantifiable attributes (see Appendix 1), such as pedestrian crossings, lane widths, and barriers—without relying on local crash records. This data-independent approach enables star ratings (1-5 stars) and prioritised interventions, even in data-scarce settings like Malaysian university campuses where mixed traffic heightens vulnerability.

The star rating system categorises roads from 1-star (highest risk) to 5-star (lowest risk), reflecting the likelihood of fatal injuries for individual road users (Shokat & Jameel, 2023a; Xu, 2018). For instance, vehicle occupants face the highest risk on 1-star roads and the lowest on 5-star roads. This stratification helps in understanding the collective risk of a road, which is influenced by both individual risk (star ratings) and traffic volume. Additionally, the iRAP star ratings are particularly useful for assessing new road designs where crash data is not yet available. They facilitate evidence-based decisions regarding safety improvements by quantifying the level of risk associated with different design elements.

2.3.3.1 Raw and Smoothed Star Ratings

Creating a network-level map of star ratings viewable via ViDA, iRAP's online platform, requires a balance between detail and comprehensiveness. Initially, the 100-metre segments used for star rating assessments may be too detailed for effective mapping and analysis at a broader scale (International Road Assessment Programme (iRAP), 2013d, 2024b). To address this, iRAP utilises a smoothing technique, aggregating these segments into longer sections to yield more interpretable results. This process entails averaging star rating scores over extended lengths, typically 3 km for rural roads and 1 km for urban roads, to generate smoothed star ratings (International Road Assessment Programme (iRAP), 2024b). This approach facilitates more informed decision-making by enabling policymakers to assess road safety at a broader scale, which is crucial for implementing targeted road safety improvements.

2.3.3.2 Star Ratings and Their Impact on Road Safety

In line with the Sustainable Development Goals (SDGs), the United Nations has outlined 12 global road safety targets to accelerate the implementation of effective road safety measures worldwide. Two of these targets focus on iRAP assessments. The third target is to ensure that all new roads meet or exceed a 3-star safety standard for all users. Meanwhile, the fourth target aims for more than 75% of travel to occur on roads with a 3-star or better rating by 2030 (Ayuningtyas et al., 2024; International Road Assessment Programme (iRAP), 2024b, 2025b).

iRAP plays a crucial role in helping road agencies improve the safety of their networks by setting ambitious star rating goals. For road upgrade projects, a recommended approach is to aim for a smoothed 3-star rating for all road users, including vehicle occupants, motorcyclists, pedestrians, and cyclists, provided that economically viable infrastructure improvements are available. In cases where achieving a 3-star rating is not economically feasible, reducing operating speeds can be an alternative strategy. Importantly, any upgrades should ensure that the star ratings do not decline. This strategy aligns with the United Nations Decade of Action for Road Safety principles, which emphasise comprehensive and sustainable road safety improvements (International Road Assessment Programme (iRAP), 2024b).

The current Decade of Action for Road Safety (2021-2030) builds upon past successes, aiming to significantly reduce road traffic deaths and injuries by promoting holistic approaches to road safety, including safer road environments and enhanced safety standards for vehicles and users (World Health Organization (WHO), 2021).

2.4 iRAP Tools and Applications

2.4.1 Road Attribute Datalogger and Inspection System (RADIS)

The process of collecting georeferenced road images often involves the use of diverse technologies and systems. Typically, survey equipment is mounted on vehicles such as cars and vans, although motorcycles and bicycles can also be utilised for this purpose. Many road agencies have well-established data collection programmes in place (International Road Assessment Programme (iRAP), 2022a). In Malaysia, for example, the Malaysian Institute of Road Safety Research (MIROS) employs a sophisticated system known as the Road Attribute Datalogger and Inspection System (RADIS). Developed collaboratively with Universiti Teknikal Malaysia Melaka (UTeM) and Recogine Technology Sdn. Bhd., RADIS comprises several key components: a video recording system, a GPS coordinate streaming system, an image calibration module for measuring road widths, and a system for assessing road geometric parameters (Figure 2.7). This comprehensive system enables the capture of high-definition images alongside GPS data, facilitating detailed analysis and ensuring consistent assessment outcomes by minimising subjective interpretation (Figure 2.8). Furthermore, the data collected through RADIS is designed to be compatible with iRAP's ViDA web-based data processing tool, thereby supporting seamless integration with global road safety evaluations (Malaysian Institute of Road Safety Research (MIROS), 2017a).

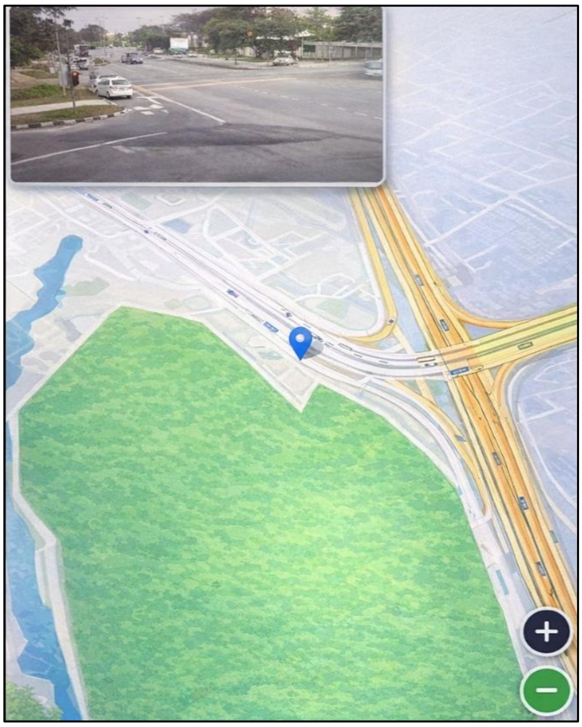


Figure 2.7 Illustration of RADIS on a Tablet

Figure 2.8 The 360˚ Camera View on RADIS 2.0 (Malaysian Institute of Road Safety Research (MIROS), 2018)

2.4.2 ViDA

ViDA, developed by iRAP, is a free-to-use online platform that serves as the central data processing engine for star ratings, Fatal and Serious Injury (FSI) estimates, and investment plans (Figures 2.9 and 2.10). It hosts a vast amount of road safety data, analyses results, and provides access to iRAP's tools, including the Star Rating Demonstrator (Asian Development Bank, 2022; International Road Assessment Programme (iRAP), 2020). ViDA integrates seamlessly with road authority systems via API, facilitating efficient data transfer from asset management tools and streamlining the analysis process (International Road Assessment Programme (iRAP), 2021f).

Utilising ViDA for road safety assessments offers several benefits. It enhances reporting capabilities through interactive tools, allowing users to conduct detailed assessments of road safety performance. Users can leverage flexible filtering and search mechanisms to gain deeper insights into risk factors along road sections or networks (International Road Assessment Programme (iRAP), 2021f). Additionally, ViDA supports the implementation of safety measures that benefit vulnerable road users, making it a valuable resource for enhancing overall road safety (eDriving, 2023).

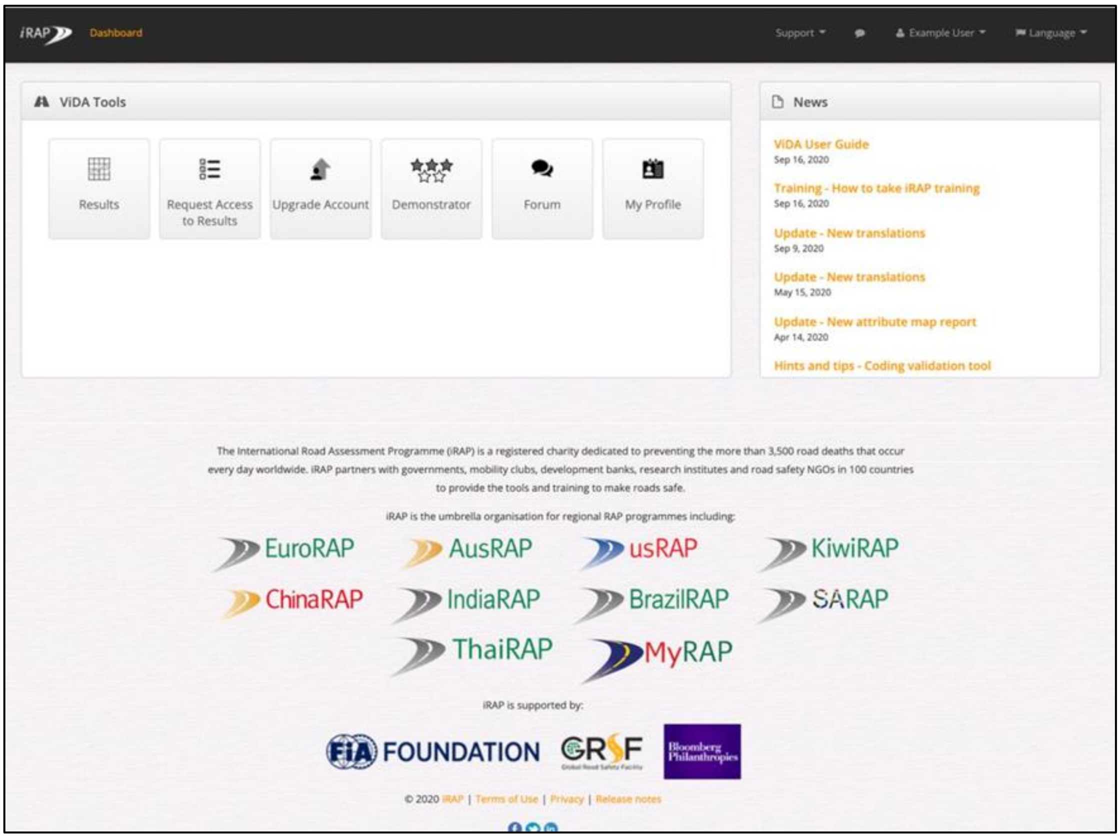


Figure 2.9 ViDA Dashboard

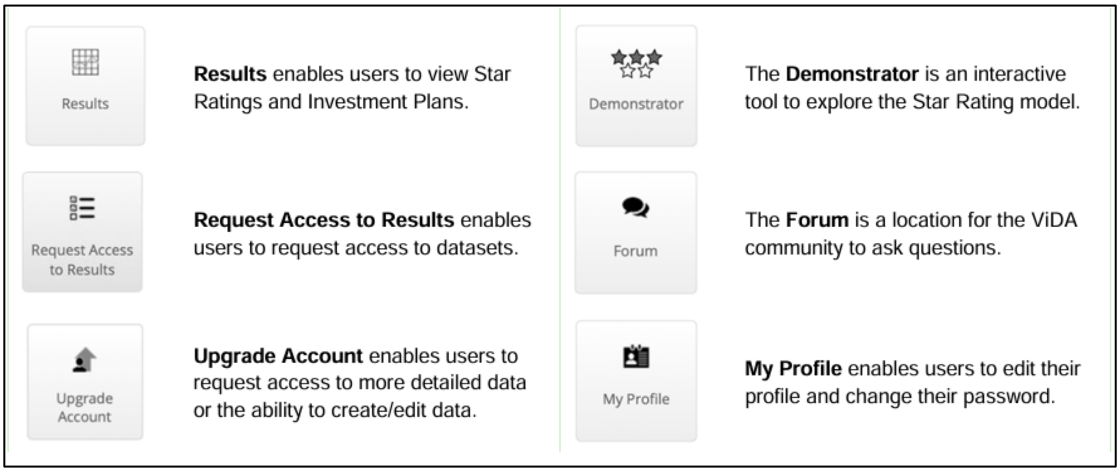
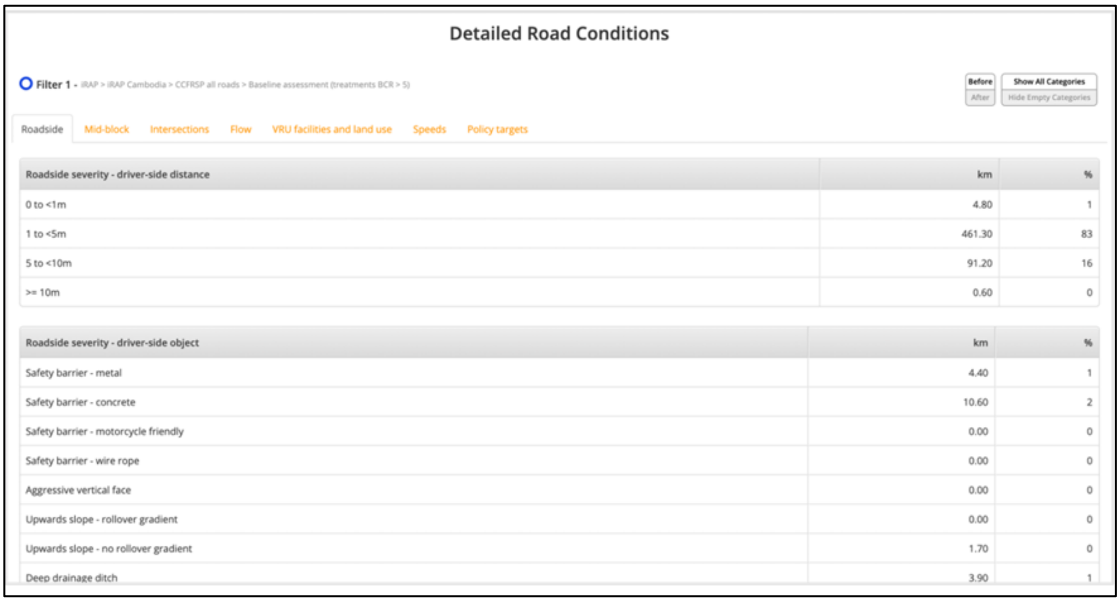


Figure 2.10 ViDA Tools

ViDA's approach to road safety assessments is unique due to its integration of data-driven methodologies with practical tools. The platform utilises the iRAP star rating methodology, providing quantifiable safety metrics such as star ratings and fatality estimates (International Road Assessment Programme (iRAP), 2024g). This enables systematic and evidence-based assessments, allowing users to make informed decisions about road design and improvements (Byaruhanga & Evdorides, 2024). ViDA offers a cost-effective solution that is accessible to all users, by supporting data-driven decision-making and safer road investment strategies, further enhancing its utility in road safety assessments and planning (Asian Development Bank, 2022).



Detailed Road Conditions

Filter 1 - iRAP > iRAP Cambodia > CCFRSP all roads > Baseline assessment (treatments BCR > 5)

Before / After | Show All Categories / Hide Empty Categories

Roadside | Mid-block | Intersections | Flow | VRU facilities and land use | Speeds | Policy targets

Roadside severity - driver-side distance	km	%
0 to <1m	4.80	1
1 to <5m	461.30	83
5 to <10m	91.20	16
>= 10m	0.60	0

Roadside severity - driver-side object	km	%
Safety barrier - metal	4.40	1
Safety barrier - concrete	10.60	2
Safety barrier - motorcycle friendly	0.00	0
Safety barrier - wire rope	0.00	0
Aggressive vertical face	0.00	0
Upwards slope - rollover gradient	0.00	0
Upwards slope - no rollover gradient	1.70	0
Deep drainage ditch	3.90	1

Figure 2.11 Detailed Road Conditions Report

Figure 2.11 illustrates the Detailed Road Conditions report, which provides a comprehensive overview of the attributes recorded in the selected dataset via ViDA. This report offers insights into the length and percentage of each attribute, such as roadside hazards, which are crucial for assessing road safety. The attributes are organised into categories, accessible via tabs, allowing users to focus on specific types of attributes quickly. This feature is particularly useful for comparing infrastructure attributes across different roads or sections, helping to contextualise star ratings and inform targeted countermeasures that can modify road attributes and reduce risk (International Road Assessment Programme (iRAP), 2020).

The Detailed Road Conditions report aligns with iRAP's methodology, which involves detailed road surveys and data collection to assess attributes influencing crash likelihood and severity. The iRAP star rating system provides a standardised measure of road safety, enabling the identification of high-risk areas and the development of effective countermeasures (International Road Assessment Programme (iRAP), 2020). By leveraging this report, users can make informed decisions about road improvements and safety interventions, contributing to safer road networks.

Figure 2.12 Star Rating Map

Filter 1 - South Africa RAP > RTMC 2017 > RTMC 2017 v3.02 > GP N14 Section

Star Ratings | Length / Travel | Smoothed / Raw | Before / After

	Vehicle Occupant		Motorcyclist		Pedestrian		Bicyclist	
Star Ratings	Length (km)	Percent	Length (km)	Percent	Length (km)	Percent	Length (km)	Percent
5 Stars	3.10	11.70%	0.00	0.00%	0.00	0.00%	0.00	0.00%
4 Stars	20.30	76.60%	0.00	0.00%	0.00	0.00%	0.00	0.00%
3 Stars	3.00	11.32%	17.50	66.04%	0.00	0.00%	0.00	0.00%
2 Stars	0.10	0.38%	8.70	32.83%	0.60	2.26%	0.00	0.00%
1 Star	0.00	0.00%	0.10	0.38%	5.20	19.62%	0.00	0.00%
Not applicable	0.00	0.00%	0.20	0.75%	20.70	78.11%	26.50	100.00%
Totals	26.50	100.00%	26.50	100.00%	26.50	100.00%	26.50	100.00%

Figure 2.13 Star Rating Table

ViDA also offers users a range of star rating reports, including maps, tables, charts, and risk worms, each providing unique insights into road safety. The star rating maps display results on a Google Map (Figure 2.12), allowing users to visualise star ratings for different road user types, such as vehicle occupants, motorcyclists, pedestrians, and cyclists (International Road Assessment Programme (iRAP), 2020). This feature supports up to two maps at once using filters, enabling users to compare different scenarios. Additionally, star rating tables provide detailed breakdowns of results by length or travel, offering both raw and smoothed data for all four road user groups (Figure 2.13). These reports are accessible to all users, providing a foundational understanding of star ratings results. In contrast, more advanced reports like risk worms require analyst or creator access, offering deeper analytical capabilities for those with specialised roles (International Road Assessment Programme (iRAP), 2020).

2.4.3 Safer Road Investment Plan (SRIP)

The iRAP Investment Plan represents a systematic approach to prioritising infrastructure upgrades to optimise road safety through evidence-based interventions. By evaluating over 90 proven countermeasures, such as hazard mitigation and pedestrian facility enhancements, the methodology employs cost-benefit analyses to identify cost-effective treatments that offset implementation costs with projected reductions in crash-related economic losses (International Road Assessment

Programme (iRAP), 2020, 2024b). Each plan provides detailed assessments for 100-metre road segments, including road attribute data, proposed interventions, and economic viability metrics, supporting targeted improvements to elevate star ratings and reduce fatalities (International Road Assessment Programme (iRAP), 2020, 2024b).

Implementation follows a three-stage process: collaborative stakeholder workshops, feasibility studies, and detailed design phases preceding construction (International Road Assessment Programme (iRAP), 2020, 2024b). This approach integrates infrastructure upgrades with behavioural interventions such as speed management and vehicle safety standards, aligning with Safe System principles (International Road Assessment Programme (iRAP), 2024b).

However, several factors impede the development of a Safer Road Investment Plan in ViDA. Limitations in data quality and availability are critical barriers, as accurate safety assessments rely heavily on comprehensive data, including crash histories (World Bank, 2019). Other factors include technical constraints (International Road Assessment Programme (iRAP), 2021f), resource constraints (Asian Development Bank, 2022; World Bank, 2019), and methodological limitations (NSW Government, 2024). Moreover, inadequate stakeholder engagement undermines the contextual relevance and feasibility of proposed safety interventions, emphasising the importance of collaborative engagement in ensuring effective implementation (World Bank, 2019).

Table 2.1
Summary of iRAP Tools

Tool/Protocol	Description
Crash Data	**Tools for analysing crash data to identify risk areas and inform safety interventions.**
Crash Risk Mapping	Visualise crash risk through detailed mapping.
DRIVER	An open-source system for managing crash data.
Infrastructure ratings	**Tools for assessing road safety infrastructure.**
Star Ratings	Evaluates the safety of roads for various users.
Star Rating for School (SR4S)	Assesses safety around schools.
CycleRAP	Focuses on bicycling safety assessments.
Trauma Estimation	**Tools for estimating road trauma.**

FSI Estimates	Provides estimates of fatalities and serious injuries.
Enhanced FSI Estimates	Offers enhanced estimates using Star Ratings and crash data.
Investment Planning	**Tools for planning safety investment.**
Safer Road Investment Plans (SRIPs)	Identifies cost-effective safety upgrades.
Urban Countermeasures	Incorporates urban safety interventions.
Route Review Tool (RRT)	Facilitates translating safety ideas into action.
Design	**Tools for designing safer roads.**
Star Rating for Designs (SR4D)	Supports designing roads with safety in mind.
SR4RSA Manual	Guides road design to meet safety targets.
Network Scanning	**Tools for assessing road networks.**
EuroRAP RPS 1.0	Assesses road safety based on homogeneous sections.
ThaiRAP Lite Star Ratings	Uses a subset of the Star Rating methodology for Thai roads.
Austroads Stereotypes	Illustrates Star Ratings for typical Australian road scenarios.
LG Stars Tool	Assesses safety of local roads in Western Australia.
ViaSegura	A digital initiative for assessing road safety infrastructure.
Performance Tracking	**Tools for monitoring safety performance over time.**
Performance Tracking	Measures changes in road safety performance.
Star Rating Certification	Verifies achievement of high safety ratings.
Safer Schools Tracker	Tracks safety improvements around schools.
Policy and Management	**Resources for guiding road safety policy and management.**
Road Safety Toolkit	Offers information on preventing road crashes.
Youth Engagement App (YEA)	Engages young people in reporting road safety conditions.
Global Infrastructure KPIs	Provides metrics for measuring road safety success.

GRSF Guide	Assesses road safety challenges in low- and middle-income countries.
Enabling Software	**Platforms and tools supporting iRAP methodologies.**
ViDA	iRAP's online platform for processing and analysing safety data.
Star Rating Demonstrator	A tool for small-scale safety assessments.
CycleRAP Demonstrator Tool	Helps understand the CycleRAP model.
SR4D Web App	Assists with Star Rating designs for roads.
NetRisk2	Combines iRAP Star Ratings with ANRAM for infrastructure risk assessment.

Source: (International Road Assessment Programme (iRAP), 2021e)

Table 2.1 provides a comprehensive summary of iRAP tools, accompanied by concise descriptions that highlight their respective functionalities and applications in enhancing road safety (International Road Assessment Programme (iRAP), 2021e). This iRAP@UiTMCampus study leverages specific iRAP tools, including infrastructure ratings such as the Star Ratings, policy and management resources like the Road Safety Toolkit, and enabling software such as ViDA to support its objectives.

2.5 Significance of iRAP

The International Road Assessment Programme (iRAP) is a globally recognised initiative dedicated to enhancing road safety through systematic assessments and road star ratings. Its implementation is crucial, providing a data-driven and evidence-based approach to mitigating road fatalities and serious injuries (Li et al., 2024). By integrating scientific methodologies with targeted interventions, iRAP contributes significantly to reducing traffic-related deaths and improving overall road safety (Ayuningtyas et al., 2024; Li et al., 2024).

One of the most important benefits of iRAP is its role in identifying and addressing high-risk roads to prevent accidents and save lives (Asia Pacific Road Safety Observatory (APRSO), 2022; International Road Assessment Programme (iRAP), 2025b). The programme aligns with the United Nations' Sustainable Development Goal

(SDG) 3.6, which seeks to halve global road traffic deaths and serious injuries by 2030 (Li et al., 2024). Through comprehensive risk assessments, iRAP enables policymakers and transportation agencies to implement strategic safety interventions that have a tangible impact on road safety (International Road Assessment Programme (iRAP), 2025b; Li et al., 2024).

A key feature of iRAP is its commitment to evidence-based road safety planning. Using systematic risk assessment tools such as road inspections, crash data analysis, and predictive modelling, the programme provides an objective evaluation of road conditions. The star rating system, which classifies roads on a scale from 1- to 5-star, serves as a benchmark for measuring road safety performance. This rating system helps governments and organisations identify roads that require urgent improvements and prioritise safety measures accordingly (International Road Assessment Programme (iRAP), 2024d, 2024f; Md Murozi et al., 2022; Radhakrishnan & Athiappan, 2021).

Another critical aspect of iRAP is its emphasis on cost-effective infrastructure investment. Instead of advocating for costly overhauls, the programme suggests practical and affordable safety interventions such as pedestrian crossings, improved road markings, and enhanced roadside barriers. By focusing on high-impact, low-cost solutions, iRAP helps governments and organisations optimise their resources while maximising road safety benefits (International Road Assessment Programme (iRAP), 2024b; Li et al., 2024).

In addition to guiding infrastructure improvements, iRAP also plays a pivotal role in shaping road safety policies. By providing policymakers with actionable insights, the programme helps governments develop effective strategies that align with international best practices. This ensures that road safety interventions are not only reactive but also proactive and sustainable in the long term (FIA Foundation, 2024; International Road Assessment Programme (iRAP), 2024c; Li et al., 2024).

One of the most vulnerable groups on the road includes pedestrians, cyclists, and motorcyclists, and iRAP is particularly focused on protecting these users. The programme identifies hazards and promotes the construction of dedicated footpaths, safe pedestrian crossings, and speed management measures to create a safer and more inclusive road environment. By prioritising the needs of all road users, iRAP fosters a more equitable approach to road safety (A. K. Jameel & Evdorides, 2023; Nordqvist & Willingers, 2023; Parra-Quintero et al., 2024; Slootmans, 2023).

Beyond planning and policymaking, iRAP also encourages the adoption of safer road designs. By promoting best practices in road engineering and urban planning, the programme ensures that safety considerations are incorporated into the design phase of new road projects. This proactive approach prevents the creation of hazardous road conditions and promotes long-term improvements in traffic safety (International Road Assessment Programme (iRAP), 2022c, 2024f; Mitra et al., 2022).

To ensure continued progress, iRAP provides a framework for monitoring and evaluating road safety interventions. By tracking the effectiveness of implemented measures, stakeholders can refine their strategies and ensure that resources are allocated efficiently (International Road Assessment Programme (iRAP), 2024e). The programme's standardised methodology also facilitates international comparisons, allowing countries to learn from each other's successes and adapt proven solutions to their contexts (International Road Assessment Programme (iRAP), 2025b).

In summary, iRAP is a vital initiative in the global effort to enhance road safety. By promoting scientific, data-driven solutions, the programme helps reduce road traffic deaths, improve infrastructure investments, support policymakers, and protect vulnerable road users (International Road Assessment Programme (iRAP), 2021a, 2025b). Countries that adopt the iRAP approach can create safer, more efficient transport networks and contribute to the broader global commitment to reducing road traffic casualties (International Road Assessment Programme (iRAP), 2024d).

Recent academic studies have underscored the importance of iRAP's methodologies in evaluating road safety and identifying infrastructure weaknesses. For instance, research conducted in Indonesia found a clear relationship between the iRAP star rating score (SRS) and various crash metrics. The study revealed that roads with higher SRS ratings tend to experience lower crash rates and reduced severity of accidents, particularly on toll roads (Ayuningtyas et al., 2024). This finding highlights how iRAP assessments can proactively address high-risk roads by informing targeted safety improvements.

Another significant development is the launch of the Tanzania Road Assessment Programme (TanRAP), which exemplifies the practical application of iRAP methodologies in a real-world context. TanRAP aims to assess more than 10,000 kilometres of existing roads, leveraging iRAP's evidence-based approach to enhance road infrastructure and reduce fatalities. By striving for a minimum 3-star safety standard for all roads, this initiative seeks to significantly decrease road traffic injuries and deaths in Tanzania (International Road Federation (IRF), 2022).

Furthermore, ongoing research continues to validate the effectiveness of iRAP's risk assessment tools on a global scale. A recent review highlighted both the advantages and challenges associated with implementing iRAP methodologies, emphasising their critical role in creating safer road environments (Md Murozi et al., 2022). Through collaboration with governments and organisations worldwide, iRAP remains dedicated to fostering safer roads by conducting thorough assessments and promoting strategic planning.

In Malaysia, iRAP has actively embraced it as part of its national strategy to improve road safety. The Malaysian Institute of Road Safety Research (MIROS) has been instrumental in leading these efforts, collaborating with various government agencies and private sector stakeholders to assess and enhance the country's road infrastructure (International Road Assessment Programme (iRAP), 2019, 2023b; Malaysian Institute of Road Safety Research (MIROS), 2017b).

A significant milestone in Malaysia's iRAP journey was the launch of the Malaysia Road Assessment Programme (MyRAP) in 2019 (International Road Assessment Programme (iRAP), 2019). This initiative, developed in partnership with iRAP, aims to identify and address high-risk roads across the country. By leveraging local expertise and research, MyRAP enables authorities to implement targeted safety measures. In its initial phase, the programme assessed approximately 2,370 km of highways, revealing that more than 50% of these roads achieved a 3-star or higher safety rating. This assessment provided crucial insights into areas that required safety enhancements (International Road Assessment Programme (iRAP), 2019; Malaysian Institute of Road Safety Research (MIROS), 2017b, 2019).

Further strengthening its commitment to road safety, Malaysia has integrated iRAP metrics into its 2030 Road Safety Plan (International Road Assessment Programme (iRAP), 2023b). This strategic move ensures that data-driven assessments and targeted interventions remain central to national road safety policies. By aligning with global safety standards, Malaysia aims to significantly reduce road fatalities and injuries while fostering a safer transportation environment (Ministry of Transport Malaysia, 2022).

Another key element of Malaysia's iRAP implementation is its collaboration with highway operators. PLUS Malaysia Berhad, one of the country's largest highway operators, has been proactive in incorporating iRAP methodologies into its safety protocols (International Road Assessment Programme (iRAP), 2019; Malaysian Institute of Road Safety Research (MIROS), 2019). The company has undertaken road safety audits and adopted the Road Traffic Safety Management System (RTSMS), leading to its ISO 39001:2012 certification, an internationally recognised standard for road safety management (PLUS Malaysia Berhad, 2024).

Through these comprehensive efforts, Malaysia is making significant progress in creating a safer road network. By embedding iRAP assessments into national policies, enhancing infrastructure, and fostering collaboration between government agencies and private stakeholders, Malaysia is contributing to the United Nations' Decade of Action for Road Safety (International Road Assessment Programme (iRAP), 2019, 2023b; Ministry of Transport Malaysia, 2022). This ongoing commitment ensures that road users, whether pedestrians, cyclists, or motorcyclists, can navigate the country's transport system with greater confidence and security.

2.6 Recent iRAP Studies

A few existing studies that used the iRAP model development were reviewed, and the gaps in the published studies were emphasised. The existing studies are mainly from South America's largest country and other Asian countries.

2.6.1 Thailand

In 2017, during the UN Global Road Safety Week, it was reported that up to 186,300 children worldwide died in road traffic accidents (Choocharukul et al., 2018). Thailand, identified as having the highest fatality rate from road traffic accidents according to the WHO's 2018 global road safety report, faces a particularly alarming situation. Each year, approximately 2,600 Thai children are killed on the country's roads, and an additional 72,000 young individuals sustain injuries in traffic accidents. The primary concern centres on children, especially vulnerable road users, and their safety while walking along and crossing roads.

Addressing this issue, a study by Choocharukul et al. (2018) adapted the Star Rating for Schools (SR4S) framework from the iRAP programme to evaluate and mitigate road risks around schools. While this concept had been applied previously on several highway segments in Thailand by the World Bank and Bloomberg Foundation, its use within school zones was novel. The study focused on four high-risk schools in the Bangkok metropolitan area: Wat Donmuang School, Wat Sing School, Assumption College (Primary Section), and Wat Sutthiwararam School. Researchers collected secondary data on road accidents near these schools and conducted field surveys, gathering more than 50 road parameters critical for assessing pedestrian risk. All data collection and analysis followed iRAP (International Road Assessment Programme) standards to ensure comparability across different roads and countries.

The findings revealed that parts of the access roads to these schools were rated as 1- or 2-star roads, which fall short of the WHO's minimum satisfactory road safety standard of 3 stars. Critical safety concerns included inadequate infrastructure such as sidewalks free of obstructions, lack of safe pedestrian crossings that allow drivers to see and stop safely, and absence of adequate driver information regarding speed and the presence of schoolchildren. In order to address these issues, the study proposed several countermeasures, including the installation of pedestrian fencing, pedestrian footpaths, speed management interventions, signalised pedestrian crossings, and traffic-calming measures. The study contended that these targeted safety modifications would contribute significantly to reducing crash risk at these school locations, thereby enhancing the safety of children as vulnerable road users.

2.6.2 Malaysia

Back in 2009, Malaysia experienced a high rate of road traffic fatalities of nearly 18 fatalities daily, corresponding to 24 deaths per 100,000 people (Rogers & Hashim, 2011). Among ASEAN countries, Malaysia ranked among those with the highest mortality rates, according to the World Health Organization's 2009 report. Vulnerable road users constituted a significant proportion of these fatalities. In 2010, the Malaysian Institute of Road Safety Research (MIROS) reported that over 72% of road deaths involved vulnerable road users, with motorcyclists alone accounting for 60% of the fatalities (Rogers & Hashim, 2011). In response to this escalating road safety challenge, the Malaysian government implemented the blackspot initiative, which targets high-risk road segments with low-cost infrastructure solutions. Despite its importance, evaluating the programme's effectiveness has been hampered by the lack of reliable crash data or insufficient post-intervention crash records needed for a robust assessment (Rogers &

Hashim, 2011). As part of this initiative, the iRAP methodology was employed to assess changes in road safety risk following infrastructure improvements at ten high-risk locations across Malaysia. The assessment considered risks associated with different road user groups, including car occupants, motorcyclists, pedestrians, and bicyclists.

The evaluation showed that four out of the ten sites experienced improvements in overall star ratings, indicating enhanced safety levels. Moreover, nine sites reported decreased Road Protection Scores (RPS), reflecting reduced risk for at least one user group. Notably, the site at FT005 Muar exhibited the most significant risk reduction; here, the pedestrian RPS dropped following the installation of a grade-separated crossing, which elevated the pedestrian star rating from 2 to 4 stars (Rogers & Hashim, 2011). Various countermeasures, such as shoulder widening, application of shoulder rumble strips, delineation, pavement maintenance, and safety barrier installation, contributed to lowering the frequency and severity of run-off-road crashes. However, the study highlighted that many of these interventions had limited or no tangible effect on reducing head-on and junction collision risks.

Importantly, Rogers & Hashim (2011) emphasised that certain low-cost treatments aimed at improving intersection quality, like adding filter lanes, enhancing street lighting, and upgrading signage and road markings, showed minimal impact on RPS outcomes. Where delineation or road surface improvements were implemented in areas where these features were already adequate, the model detected no change in risk scores. This, however, does not necessarily imply a lack of risk reduction, as it may reflect the limitations of the sensitivity of the risk assessment model's sensitivity.

Building on similar methodologies, Hoong et al. (2021) conducted an iRAP-based assessment of school zone safety in Malaysia, applying the Star Rating for Schools (SR4S) approach used by Choocharukul et al. (2018) as well. Their study examined a sample of schools in Selangor featuring diverse physical environments. Data collection included vehicle speed measurements, systematic photography every 20 metres within the school zones, and detailed measurement of road cross-section elements to determine star ratings. The results revealed considerable variation in safety conditions across school zones, with ratings ranging from 1 to 5 stars. The study identified traffic-calming measures, traffic wardens, and continuous sidewalks as critical factors in reducing pedestrian crash risk and enhancing schoolchildren's safety. Ultimately, the study concluded that the iRAP Star Rating methodology is an effective tool for predicting pedestrian crash risk and guiding safety improvement initiatives within school environments.

2.6.3 Korea

By utilising iRAP's comprehensive methodology, which encompassed 78 detailed attributes of road design, Yang & Han (2025) conducted a thorough assessment along a substantial stretch of highway in Korea. This assessment was then integrated with traffic and crash data, offering a nuanced understanding of how various road features influenced safety outcomes. The findings highlighted the critical importance of pedestrian and roadside facilities in reducing accidents, suggesting that these elements were more impactful than other design attributes. This insight offered practical guidance for infrastructure improvements, aligning with broader efforts to enhance road safety and reduce traffic-related incidents.

2.6.4 Bangladesh

A study conducted by Uddin & Raihan (2023) employed the iRAP in Bangladesh and offered several profound insights into the country's road safety landscape. Notably, many of its national highways were classified as high-risk, with a significant proportion rated 2-star or less, indicating a substantial threat to all road users. However, these assessments also underscored the potential for significant improvements through targeted interventions. By applying iRAP's methodology and implementing specific safety measures, such as widening shoulders, installing safety barriers, and enhancing pedestrian facilities, it was possible to achieve substantial reductions in road fatalities and injuries.

Furthermore, Maisha et al. (2023) utilised the iRAP methodology, in conjunction with ViDA software, to evaluate and enhance road safety along an 8 km corridor in Dhaka, Bangladesh. By analysing accident data from the Accident Research Institute (ARI) and conducting field surveys, critical safety deficiencies at intersections and along the route were identified. Using ViDA, engineering solutions were proposed, such as improved pedestrian facilities and traffic management adjustments, through a trial-and-error approach, ultimately achieving a 3-star safety rating target. The research validated ViDA's utility for assessing urban roads in densely populated cities like

Dhaka, highlighting its role in proactive risk identification and cost-effective countermeasure planning. The findings underscored the importance of integrating iRAP tools into road safety strategies to align with Bangladesh's goal of developing safer infrastructure, particularly for high-priority corridors. The study demonstrated the adaptability of the methodology for similar urban contexts, despite relying on localised data.

2.6.5 Indonesia

Ellizar et al. (2023) demonstrated the value of engaging youth in road safety assessments using the iRAP Star Rating for Schools (SR4S) tool. This approach successfully identified seven high-risk locations around Junior High School 1 in Surakarta City, Indonesia, where existing road infrastructure posed significant threats to student safety. Notably, six of these areas received star ratings of 1 or 2, while only one achieved a rating of 3. The study proposed targeted interventions, including improved signage and road markings, enhanced pedestrian crossings, and speed reduction measures, which were projected to substantially improve safety ratings. For instance, these interventions were estimated to reduce pedestrian risk by over 90% and elevate star ratings to 4 or 5. The combinations of qualitative insights from youth participants and quantitative data from the SR4S assessment provided a compelling advocacy tool for promoting road safety improvements with local authorities. However, the implementation of these solutions faced challenges due to budget constraints. Key infrastructure elements highlighted in the study included the Manahan Flyover, which posed risks due to speeding and inadequate pedestrian facilities, and the roads in front of the school, which lacked sidewalks and safe crossings, exacerbating the dangers faced by students.

2.6.6 India

Similar studies have demonstrated the effectiveness of iRAP in identifying hazardous road features and recommending targeted countermeasures to reduce fatalities and serious injuries. For instance, Chakraborty et al. (2025) applied the iRAP Star Rating system and Safer Road Investment Plans (SRIPs) to evaluate road segments and identify high-risk locations. Their assessment highlighted several critical infrastructure deficiencies, including inadequate pedestrian facilities, problematic road geometry such as sharp curves and narrow lanes, poorly designed intersections, a lack of appropriate signage, and traffic control. The findings emphasised that improvements such as enhanced pedestrian infrastructure, traffic calming strategies, and optimised road geometry can substantially mitigate crash risks. Overall, the study reinforced the role of iRAP as an effective decision-making framework for prioritising road safety investments and aligning them with broader road safety objectives.

Large-scale implementation of the iRAP methodology has also been demonstrated through national initiatives. The Global Road Safety Facility (GRSF) and the Bloomberg Initiative for Global Road Safety (BIGRS) supported the star rating assessment of approximately 17,000 km of national, state, and city roads in India, a country accounting for more than one-fifth of global road fatalities (Bhavsar et al., 2019). The assessments incorporated safety star ratings and cost–benefit analyses of various safety treatments, enabling the integration of safety considerations into road design, upgrading, and construction processes. Two detailed case studies were presented in Karnataka and Gujarat, where iRAP assessments were conducted at three stages: baseline (existing road), design, and post-construction. The implementation of recommended infrastructure safety improvements resulted in increased star ratings and contributed to a reduction in traffic fatalities in Karnataka, demonstrating the effectiveness of the approach. Bhavsar et al. (2019) further suggested that India's implementation provides a valuable model for other member countries of the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP).

The broader findings from the Indian assessments revealed significant safety concerns related to road infrastructure. A large proportion of road users were found to travel on 1- to 2-star roads, indicating high levels of crash risk. Although roads with a 3-star rating or higher provided improved protection for vehicle occupants, the safety benefits for vulnerable road users (VRUs), including motorcyclists, pedestrians, and cyclists, remained limited. The study reported that 95% of roads lacked formal footpaths, and 55% of roads with traffic speeds of 80 km/hr or higher were undivided, conditions that may contribute to head-on collisions and increased crash severity. The iRAP analysis indicated that targeted investment in safety countermeasures could prevent thousands of fatalities and serious injuries. On a national scale, an estimated investment of INR 32,000 crores in measures such as traffic calming, pedestrian footpaths, pedestrian crossings, paved shoulders, and intersection improvements could potentially prevent up to one million deaths and serious injuries over the next two decades.

Several infrastructure countermeasures were implemented along the assessed corridors to address identified risks. Pedestrian crossing facilities were upgraded through the installation of raised tabletop crossings, some incorporating median refuge islands to enhance pedestrian protection. These crossings function as traffic calming devices by requiring approaching vehicles to slow down before passing. Intersection safety was improved through the addition of right-turn lanes, channelisation using median islands, and the construction of new roundabouts to improve traffic flow and reduce conflict points. Additional safety measures included thermoplastic rumble strips, speed humps, and tabletop crossings to reduce vehicle speeds near pedestrian zones and intersections.

Further infrastructure improvements addressed roadway configuration and roadside safety. For example, additional lanes were constructed along uphill sections to allow light vehicles to overtake heavy vehicles safely. In some locations, dual carriageways were developed with concrete median barriers to prevent head-on collisions, while paved shoulders were installed to reduce the risk of run-off-road crashes. Road delineation was enhanced through improved lane markings and traffic signage, assisting drivers and motorcyclists in navigating roadways more safely. Street lighting was also installed along selected sections to improve visibility and enhance pedestrian safety, particularly near intersections and roadside walking areas.

The implementation of these improvements resulted in measurable safety benefits. Along the Belgaum–Yaragatti corridor in Karnataka, the upgrades increased the proportion of road sections rated 3-star or better to 79% for vehicle occupants, 44% for motorcyclists, 49% for pedestrians, and 49% for cyclists. Similarly, the Mehsana–Himmatnagar corridor in Gujarat achieved 3-star or better ratings for 98% of vehicle occupants, 80% of motorcyclists, 22% of pedestrians, and 52% of cyclists. These outcomes demonstrate the potential of infrastructure-based interventions to improve road safety performance, although disparities remain in protection levels for vulnerable road users.

A similar application of the iRAP methodology was conducted by Vidish Pankajkumar & Vijaykumar Bhatt (2018), who analysed road safety conditions in the West Zone of Surat, Gujarat. The study assessed road infrastructure using the iRAP framework and evaluated multiple factors influencing crash risk, including traffic flow, intersection geometry, mid-block features, roadside characteristics, vehicle speeds, and the presence of vulnerable road users. The analysis focused on four primary road user categories: vehicle occupants, motorcyclists, pedestrians, and bicyclists. While the star ratings indicated relatively favourable safety conditions for vehicle occupants and motorcyclists, the ratings for vulnerable road users were extremely low, with pedestrians and bicyclists receiving no star rating. These findings highlighted substantial deficiencies in pedestrian and cycling infrastructure and indicated a significant need for improvements in road geometry, roadside facilities, and safety measures that prioritise vulnerable road users.

Collectively, these studies prove that the iRAP methodology provides a systematic framework for evaluating road safety performance, identifying infrastructure deficiencies, and prioritising cost-effective safety interventions. The emphasis on infrastructure design, traffic calming measures, and pedestrian facilities are particularly relevant to environments with high concentrations of vulnerable road users. In this context, the application of iRAP principles through initiatives such as iRAP@Campus can play a crucial role in assessing safety conditions within university environments. In adopting similar evaluation frameworks, campus road networks can be systematically assessed to identify risk factors affecting students, pedestrians, cyclists, and other road users, ultimately supporting the development of safer campus transportation systems.

2.7 Adapting iRAP Principles for Enhanced Road Safety at Main Campus

The traffic and pedestrian management strategies at the Universiti Teknologi MARA (UiTM) Shah Alam campus exhibit a comprehensive framework addressing the complexities of a large academic environment, characterised by a significant vehicular presence, diverse road users, and the imperative for inclusivity and sustainability (UiTM Green Centre (UGC), 2025). These multi-layered efforts harmonise well with the integration of the International Road Assessment Programme (iRAP) principles through the iRAP@UiTMCampus initiative, which targets the unique safety challenges arising from mixed traffic flows, pedestrian density, and vulnerable user groups on campus.

The presence of well-designed pedestrian infrastructure, such as covered walkways, segregated pathways, ramps, and well-illuminated routes, provides an existing foundation upon which the proactive, data-informed strategies of iRAP can build to enhance safety outcomes (International Road Assessment Programme (iRAP), 2021d; Road Safety Toolkit, 2022). While UiTM's initiatives demonstrate commendable progress in physical infrastructure and sustainable transport promotion, the adoption of iRAP's star rating systems and Safer Roads Investment Plans (SRIPs) (Road Safety Foundation et al., 2023) introduces a systematic, evidence-based framework for assessing risk in real-time and prioritising interventions, even in the absence of comprehensive crash data—a significant advantage given the campus's complex dynamics and limited historical incident records (International Road Assessment Programme (iRAP), 2024c; Li et al., 2024; Road Safety Toolkit, 2022). This proactive approach complements existing programmes, such as shuttle services and traffic calming measures, by aligning safety enhancement with the broader goals of reducing carbon emissions and promoting low-emission and non-motorised transportation modes (UiTM Green Centre (UGC), 2022, 2025).

Furthermore, iRAP's adaptability to local conditions, focusing on high pedestrian zones near lecture halls, dormitories, and common areas, allows for context-specific countermeasures like dedicated bicycle lanes and improved pedestrian crossings to be efficiently prioritised within operational and budgetary constraints (International Road Assessment Programme (iRAP), 2021d; Road Safety Foundation et al., 2023). Thus, the integration of iRAP principles at UiTM complements the university's evolving mobility and infrastructure framework by providing a robust, risk-based methodology that enhances safety governance, supports inclusivity, and fosters a sustainable, resilient campus transport ecosystem. This strategic synergy not only advances UiTM's commitment to providing a safe and accessible environment for all users but also aligns with global best practices in road safety, positioning the campus as a model for higher education institutions seeking to reconcile mobility demands with safety and environmental sustainability imperatives.

2.8 UiTM Shah Alam Campus Traffic

The current traffic scenario on the UiTM Shah Alam campus reflects a complex and evolving environment influenced by high traffic volumes, mixed road users, and ongoing sustainability initiatives (Andi & Mohd Amin, 2024; Ishak et al., 2022; Johar et al., 2025). The campus accommodates a large population with approximately 172,659 students and over 18,000 staff, generating significant daily traffic, including private vehicles, motorcycles, and pedestrians. The total parking area covers roughly 3.8% of the campus, distributed across multiple zones to manage vehicular access, yet challenges remain related to parking capacity and traffic flow, necessitating strategic parking and traffic management to reduce congestion and emissions (UiTM Green Centre (UGC), 2022, 2025).

In terms of road design, the campus has implemented various infrastructural elements aimed at promoting safety and accessibility. These include well-lit pedestrian paths, covered walkways, and speed bumps, enhancing inclusivity and facilitating vulnerable road users, such as pedestrians. The university also enforces a pedestrian path policy monitored by the Logistics Department to uphold safe walking routes and minimise potential hazards identified in the 2020 Road Safety Audit (RSA) (UiTM Green Centre (UGC), 2025). Despite these efforts, pedestrian vulnerabilities persist in some areas, indicating a need for detailed risk assessments consistent with iRAP methodologies.

Motorcyclist infrastructure is a critical component given the prevalence of motorcycle use in Malaysian campuses (Mohd Nusa et al., 2021, 2023). While specific dedicated motorcycle lanes or facilities are not extensively described, the mixed traffic nature with pedestrians, private vehicles, and motorcycles sharing the same roads creates a complex traffic environment that demands comprehensive safety planning. The campus's efforts to enhance security and the integration of smart campus solutions also hint at potential avenues to improve dynamic traffic monitoring and management, which could be leveraged in adapting iRAP protocols for such mixed-use institutional roads, particularly by implementing real-time data collection systems and safety assessments that address the specific challenges posed by the high-density traffic environment, such as the need for better separation of traffic types and improved signage for both drivers and pedestrians.

Overall, the UiTM Shah Alam campus road environment is characterised by a high-density, mixed-traffic scenario with efforts underway to enhance safety through infrastructure improvements and pedestrian-friendly policies. However, gaps remain in systematic safety data collection and targeted interventions, underscoring the relevance of applying and customising the iRAP star rating protocols to address unique road safety risks and infrastructure deficiencies within this institutional context. This comprehensive overview provides a valuable foundation for your study to assess, validate, and propose tailored strategies for improving road safety at UiTM Shah Alam.

Table 2.2
Summary of Research Gaps Addressed by the iRAP@Campus Study, Aligned with Key Research Objectives and Their Implications for Enhancing Campus Road Safety

Research Gap	Description	Relevance to iRAP	Implication for UiTM Campus
Lack of systematic traffic volume and conflict data.	Limited continuous data collection on mixed-traffic flows and conflict points involving vehicles, pedestrians, and motorcyclists.	iRAP requires detailed traffic and conflict data for risk assessment.	Hinders evidence-based road safety prioritisation.
Absence of standardised road safety star ratings.	No formal application of the iRAP star rating system to evaluate infrastructure safety.	Core iRAP methodology for infrastructure risk analysis.	Limits objective measurement of campus road safety levels.
Insufficient pedestrian risk assessments.	Missing formal pedestrian audits and risk scoring to identify hazards.	iRAP emphasises pedestrian safety through specialised assessments.	Pedestrian vulnerabilities remain inadequately addressed.
Limited focus on motorcyclist safety.	Lack of targeted motorcyclist risk evaluations despite high motorcycle usage on campus.	iRAP integrates motorcyclist risk into its assessments.	Motorcyclist safety risks are under-assessed.
Underutilisation of ICT for safety management.	Although certain security technologies exist, real-time safety data integration and proactive risk mitigation are lacking.	iRAP and related frameworks encourage the use of ICT for dynamic safety monitoring.	Missed opportunity for enhanced safety through technology.
Limited evaluation of sustainable transport impacts.	Sustainability efforts lack research on their effects on traffic risk reduction.	Emerging interest in linking sustainable transport to safety in the iRAP context.	Potential synergy between environmental and safety goals is unexamined.

Table 2.2 identifies six key research gaps relevant to road safety at the UiTM Shah Alam campus and their alignment with iRAP's framework. These gaps include the lack of systematic traffic and conflict data, the absence of standardised iRAP star ratings for infrastructure assessment, insufficient pedestrian risk evaluations, limited

focus on motorcyclist safety, underutilisation of ICT for dynamic safety management, and inadequate evaluation of sustainable transport impacts. Each gap highlights how it impedes evidence-based safety prioritisation and targeted risk mitigation on campus, while also underscoring their critical relevance to iRAP's methodologies and potential benefits if addressed. Overall, addressing these gaps would enhance campus road safety through comprehensive data collection, objective risk scoring, inclusive vulnerability assessments, technology integration, and consideration of sustainability effects.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Introduction

The research methodology employed in this study adopted a systematic approach to evaluate road safety, specifically targeting high-risk areas surrounding university campuses (Figure 3.1). The process commenced with a comprehensive desk study that reviewed existing literature and data relevant to the International Road Assessment Programme (iRAP) and road safety assessments. This foundational step ensured that the research was grounded in established knowledge while simultaneously identifying gaps that the current study sought to address.

Data collection was organised into two main categories: secondary and primary methods. The secondary data collection involved compiling existing information on traffic volume, road geometric elements, campus's budget, and accident statistics, drawing on historical traffic data and police reports to create a comprehensive overview of the study area. Conversely, primary data was collected through direct observations and surveys, which included iRAP road surveys assessing road infrastructure and safety features, alongside spot speed studies that measured vehicle speeds at various locations to evaluate compliance with posted speed limits.

After the data collection phase, the methodology incorporated data coding, which categorised the information into baseline and optimised datasets. The baseline dataset included coding for star ratings based on compliance with speed limits and operating speeds observed during surveys, while modifications accounted for any changes to road attributes identified throughout the research process. The star rating system served as a quantitative measure of road safety, with baseline ratings established using initial speed limit and operating speed data, while the optimised ratings reflected improvements made by adjusting road attributes based on survey findings to enhance safety performance.

Finally, the analysis phase involved integrating surveyed road data with injury records to identify high-risk zones and visualise incident patterns. Subsequently, star ratings were generated for baseline and optimised across three different scenarios: speed limit, operating speed, and optimised road attributes. This phase was followed by a benefit-cost ratio (BCR) assessment to evaluate the economic viability and effectiveness of proposed interventions. Together, this systematic methodology enabled a comprehensive evaluation of road safety in the study area, highlighting actionable improvements and their cost-effectiveness.

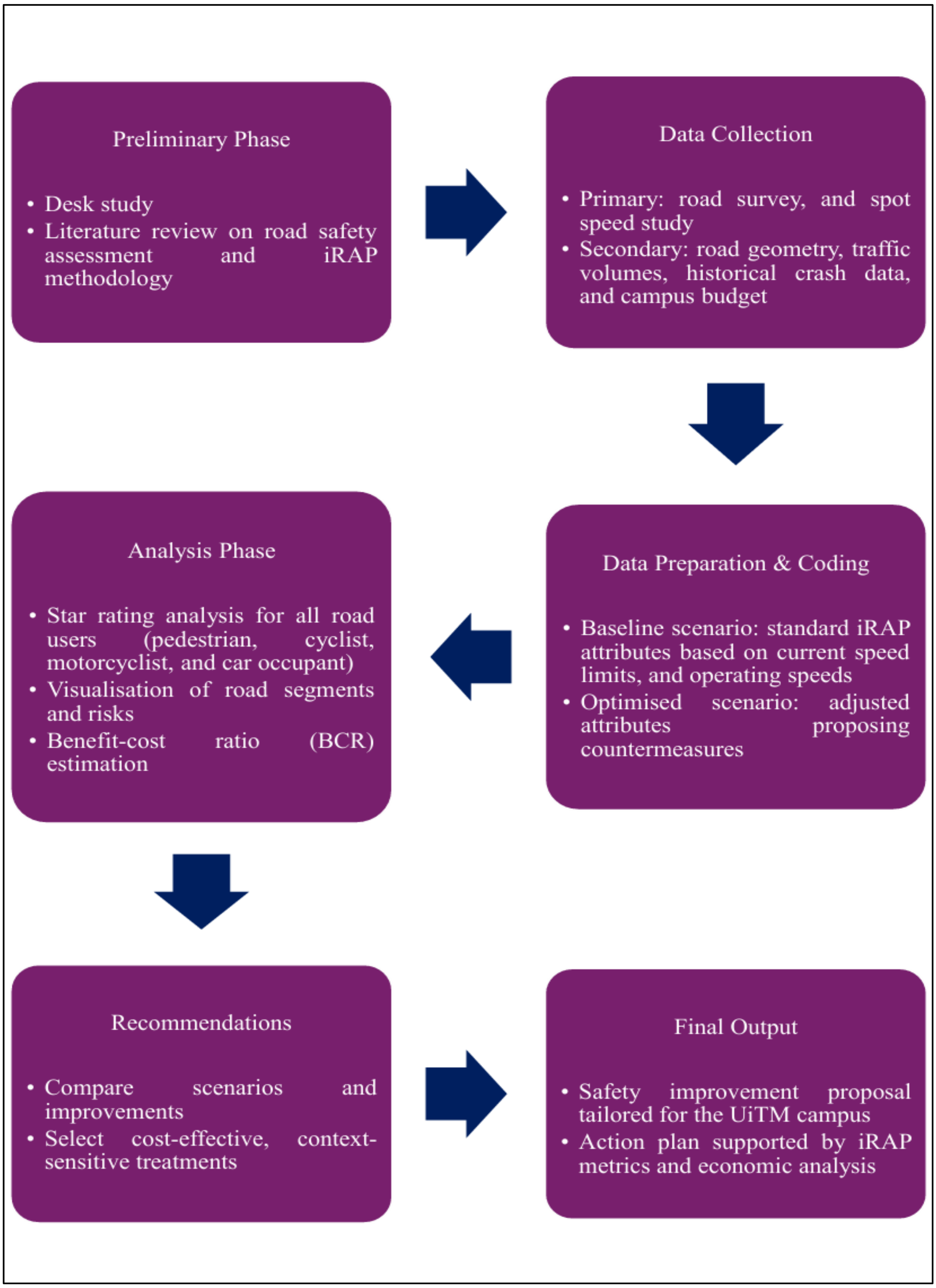


Figure 3.1 Systematic Research Methodology for iRAP@UiTMCampus

3.2 Desk Study

The desk study aimed to gather insights into existing knowledge on assessing risks related to road infrastructure and identify best practices relevant to Universiti Teknologi MARA (UiTM) Shah Alam. In order to achieve these objectives, the study utilised MyKM v4 (Figure 3.2), UiTM's knowledge management system, as a central platform for accessing and organising academic resources. MyKM v4 integrates a wide range of materials, including research publications, digital library content, and institutional data, allowing users to retrieve relevant information efficiently. In addition, targeted search strategies were applied across reputable databases such as Scopus, Web of Science, and ScienceDirect, as well as specialised resources like the iRAP website, the World Health Organization (WHO), the Road Safety Toolkit, the World Bank, and various Malaysian governmental websites. The search was guided by specific keywords related to iRAP, road accidents, road infrastructure, campus sustainability, road safety, and infrastructure assessment to effectively filter the relevant literature.

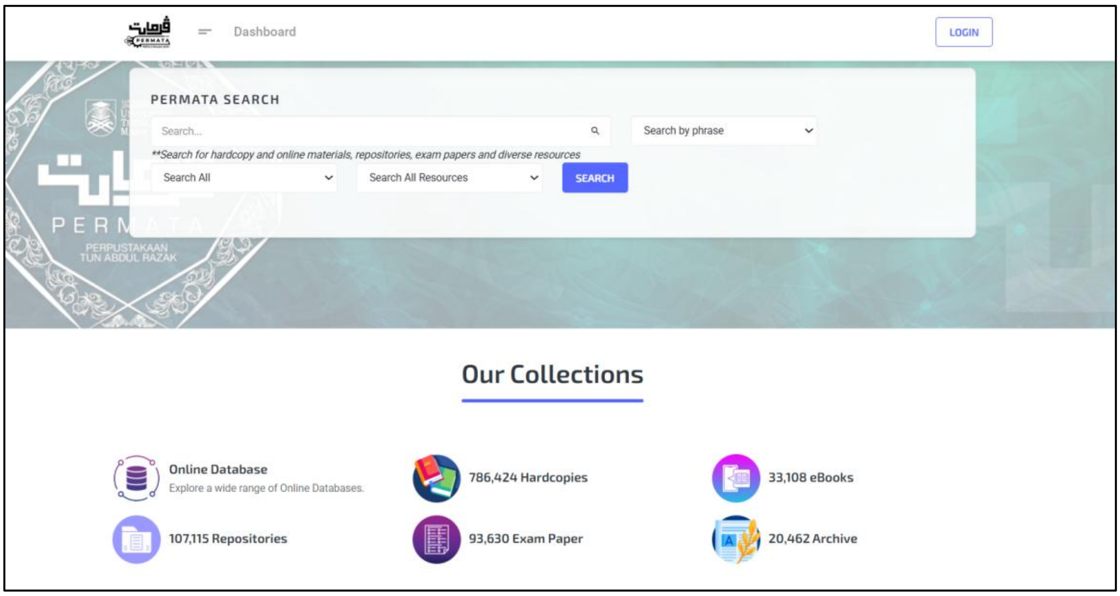


Figure 3.2 Snapshot of MyKM V4

In addition to compiling scholarly articles and reports, the study emphasised evaluating the credibility and reliability of each source so that only authoritative information was included. Ultimately, the insights gained from this desk study informed subsequent phases of the research by guiding recommendations for enhancing road safety measures and infrastructure development at UiTM, thereby contributing to improving campus safety and supporting broader urban planning initiatives aligned with sustainable development goals.

3.3 Data Collection

3.3.1 Secondary Data Collection

3.3.1.1 Campus Transportation System Overview

The UiTM Shah Alam campus features a well-organised and multi-modal transportation system designed to serve its large population of students and staff. One key element is the extensive shuttle bus service, which the university actively manages (Andi & Mohd Amin, 2024; Ishak et al., 2022; Johar et al., 2025). With 33 vans and 37 cars, along with additional multipurpose and four-wheel-drive vehicles, the shuttle fleet covers 10 distinct routes both inside and around the campus. Operating from 7:00 am to 10:30 pm, these buses complete 364 trips daily, connecting important locations such as the Commuter Station Padang Jawa and I-City Mall. In addition, the Smart Selangor free bus service is permitted to operate within the campus, further enhancing sustainable mobility options (UiTM Green Centre (UGC), 2025). These shuttle services aim to reduce the dependence on private vehicles, ease parking demand, and promote environmentally friendly transportation choices.

Pedestrian safety and accessibility are also priorities on campus. The university has developed a network of pedestrian paths and walkways that are mostly covered and well-lit to provide comfort and security, especially at night. Features such as pedestrian crossings and strategically placed speed humps contribute to a safe and inclusive walking environment. The campus actively monitors and promotes a pedestrian path policy, supported by a Road Safety Audit conducted in 2020 that identified potential hazards and solutions to improve safety (UiTM Green Centre (UGC), 2025). These efforts demonstrate the university's commitment to fostering a secure and accessible campus for all community members.

Motorcycles constitute a significant portion of daily traffic on campus, with around 2,331 of them entering each day (UiTM Green Centre (UGC), 2022). Although the report does not detail specific motorcycle lanes, the mixed-traffic environment requires diligent management to maintain safety. Parking facilities include designated spaces for motorcycles, but challenges remain in managing parking availability and traffic flow (UiTM Green Centre (UGC), 2022, 2025), particularly due to the high volume of motorcycles entering the campus daily and the lack of sufficient designated parking areas. While the university is advancing Zero Emission Vehicles, these primarily consist of bicycles and electric buggies rather than motorcycles. Enhancing motorcycle-specific infrastructure and segregating traffic would likely improve safety and convenience for motorcyclists on campus.

Overall, the traffic system at UiTM Shah Alam integrates extensive shuttle bus services, safe pedestrian infrastructure, and motorcycle accommodation within a comprehensive framework aimed at sustainability and accessibility. Ongoing initiatives to expand shuttle services, improve infrastructure, and encourage low-carbon transportation reflect the university’s commitment to creating a sustainable and inclusive campus environment.

3.3.1.2 Road Type – JKR Specification

The classification of road types within the UiTM Shah Alam campus was assessed based on the standards outlined by Jabatan Kerja Raya (JKR), specifically referencing the Arahan Teknik Jalan guidelines for urban roads (Figure 3.3). According to JKR classification, roads are categorised primarily into local roads (U1, U2), collector roads (U3), and arterial roads (U4 and above), each defined by parameters such as lane width, design speed, and functional hierarchy (Jabatan Kerja Raya Malaysia, 2015).

GENERAL SUMMARY - GEOMETRIC DESIGN CRITERIA FOR ROADS IN URBAN AREAS (METRIC)

DESIGN CONTROL AND CRITERIA	1	DESIGN STANDARD	-	U6			U5			U4			U3			U2			U1		
	2	ACCESS CONTROL	-	FULL			PARTIAL			PARTIAL/NIL			PARTIAL/NIL			NIL			NIL		
	3	AREA TYPE	-	F	R	M	F	R	M	F	R	M	F	R	M	F	R	M	F	R	M
	4	DESIGN SPEED	km/hr	100	80	60	80	60	50	70	60	50	60	50	40	50	40	30	40	30	20
CROSS SECTION ELEMENTS	5	LANE WIDTH	m	3.65			3.50			3.50			3.25			3.00				(5.00) a	
	6	USABLE SHOULDER WIDTH	m	3.00	3.00	2.50	3.00	3.00	2.50	3.00	2.50	2.00	2.50	2.00	1.50	2.00	1.50	1.50	1.50	1.50	1.50
	7	MEDIAN WIDTH (MINIMUM)	m	4.00	3.50	2.00	3.00	2.50	2.00	2.50	2.00	1.50	2.00	1.50	1.50	N / A			N / A		
	8	MEDIAN WIDTH (DESIRABLE)	m	9.0	6.0	4.0	6.5	4.0	3.0	5.0	3.0	2.0	4.0	2.0	2.0	N / A			N / A		
	9	MARGINAL STRIP WIDTH	m	0.50			0.50			0.25			0.25			0.25			0.00		
	10	MINIMUM RESERVE WIDTH	m	65			65			40			40			30			25		
ELEMENTS OF DESIGN	11	STOPPING SIGHT DISTANCE	m	185	130	85	130	85	65	105	85	65	85	65	50	65	50	35	50	35	20
	12	PASSING SIGHT DISTANCE	m	670	540	410	540	410	345	485	410	345	410	345	270	345	270	200	270	200	200
	13	MINIMUM RADIUS (AT MAX SE 6%)	m	435	250	135	250	135	90	195	135	90	135	90	55	90	55	30	55	30	15
	14	MINIMUM LENGTH OF SPIRAL (AT MAX SE- 2 LANES)	m	48	43	36	43	36	33	39	36	33	36	33	31	33	31	29	31	29	25
	15	MAXIMUM SUPERELEVATION	Ratio	0.06			0.06			0.06			0.06			0.06			0.06		
	16	MAXIMUM GRADE (DESIRABLE)	%	3	4	5	4	5	6	5	6	7	6	7	8	7	8	9	7	8	9
	17	MAXIMUM GRADE	%	3	5	7	6	8	11	8	10	12	9	11	13	7	11	16	7	11	17
	18	CREST VERTICAL CURVE (K)	-	78	39	17	39	17	10	26	17	10	17	10	10	10	10	5	10	5	3
	19	SAG VERTICAL CURVE (K)	-	45	30	18	30	18	13	23	18	13	18	13	9	13	9	6	9	6	3

REMARK :
1) ALL VALUES SHOWN ABOVE ARE MINIMUM/MAXIMUM VALUES. ALL EFFORT SHOULD BE MADE TO ACHIEVE AS HIGH A VALUE AS POSSIBLE
2) FOR DEFINITION OF AREA TYPE, SEE TABLE 3 - 2
3) ABBREVIATION : N/A - NOT APPLICABLE
( )a - TOTAL WIDTH OF PAVEMENT
( )b - RESERVE WIDTH DEPENDS ON ROAD CATEGORY

Figure 3.3 Characteristics of Road Categories (Jabatan Kerja Raya Malaysia, 2015)

An on-site survey and evaluation of the campus road network indicate that the majority of internal roads correspond to local (U2) and collector (U3) classifications, characterised by lane widths generally ranging from 3.0 to 3.5 metres and an operational speed limit of 25 km/hr (Mazerul et al., 2022; Universiti Teknologi MARA (UiTM), 2021; Wan Ibrahim et al., 2023). This speed limit is somewhat lower than typical JKR design speeds for similar road classes but is appropriate given the campus environment prioritising pedestrian safety and mixed traffic conditions. These design features facilitate safe access and circulation within the campus, aligning with the intended function of providing connectivity among academic buildings and parking areas.

However, minor deviations were noted in certain road segments where lane widths fall slightly below JKR's recommended minimum dimensions, potentially restricting vehicle manoeuvrability during peak periods. Additionally, in some locations, the absence of clearly demarcated pedestrian pathways highlights partial non-compliance with JKR standards that emphasise pedestrian safety provisions. Despite these deviations, the existing road design overall adheres to JKR specifications for urban local and collector roads, with speed regulation adapted appropriately for the campus context. This classification and compliance assessment provided the basis for further analysis of traffic operations and safety within the campus.

3.3.1.3 Traffic Volume

Every 100 m segment of road requires a specific traffic volume assessment, typically represented by Annual Average Daily Traffic (AADT), to evaluate the potential distribution of fatalities and serious injuries that could be mitigated across the network (International Road Assessment Programme (iRAP), 2024a). The iRAP methodology employs this traffic data as part of a comprehensive risk assessment, which includes over 30 road attributes known to influence safety outcomes (International Road Assessment Programme (iRAP), 2024b). These attributes contribute to the development of star ratings, which objectively measure the safety level for various road users: car occupants, motorcyclists, pedestrians, and cyclists. iRAP analysed AADT alongside these attributes and recommended targeted infrastructure improvements to reduce crash risks and enhance overall road safety.

Table 3.1
Annual Average Daily Traffic (AADT)

Type of vehicle	Total number of the vehicle entering the university daily (AADT)
Car	2,848 cars/day
Motorcycle	1,386 motorcycles/day
	4,234 vehicles/day

Source: (UiTM Green Centre (UGC), 2025)

The traffic volume on the university campus was analysed by considering the daily counts of different vehicle types (Table 3.1). Data collected indicated that the average number of cars entering the campus daily is 2,848, while the average daily count of motorcycles on campus is 1,386. The sum of these types of vehicles was used to figure out the Annual Average Daily Traffic (AADT), which is the average number of vehicles that pass through a certain area each day over the course of a year. Therefore, the estimated AADT for the university campus is 4,234 vehicles per day. This figure provides a baseline for understanding the overall traffic demand and can be used for infrastructure planning, traffic management, and safety assessments.

During the data processing phase, traffic volume data for the campus road sections were harmonised to ensure a complete dataset for iRAP analysis. The secondary data were sourced from existing traffic counts collected by the university's facilities management and previous campus traffic surveys. Harmonisation involved filling out missing AADT values by assigning representative values to road sections with similar characteristics, such as road type, lane width, and functional classification. Specifically, if a road section lacked traffic data, the AADT of a nearby section with matching road criteria was used as a proxy. This uniform approach allowed for consistent risk assessment and intervention planning across the campus, while acknowledging that actual traffic volumes may vary slightly between sections.

3.3.1.4 Road Geometric Elements

Google Earth has become a widely recognised tool for preliminary and supplementary assessments of road geometry attributes due to its global coverage, ease of access, and high-resolution imagery (Alqahtani, 2024). In this study, Google Earth served to verify lane widths (Figures 3.4 and 3.5) and road slopes (Figure 3.6), complementing field data obtained from the Road Attribute Data Logger and Inspection System (RADIS) as part of the iRAP road survey.

Recent literature confirms that Google Earth imagery can provide reliable approximations of road geometry elements, especially when combined with more precise in-situ data collection methods (Brkic et al., 2023). For example, a lane width measurement derived from Google Earth had an average absolute error margin of ±0.15 metres when compared to laser scanning ground truth data across urban and interurban roads. This level of accuracy is sufficient to identify systematic road attributes, such as lane consistency or deviations that impact road safety assessments. Additionally, this makes Google Earth a viable tool to estimate road gradients, especially for larger-scale typologies or when physical slope data acquisition is constrained.

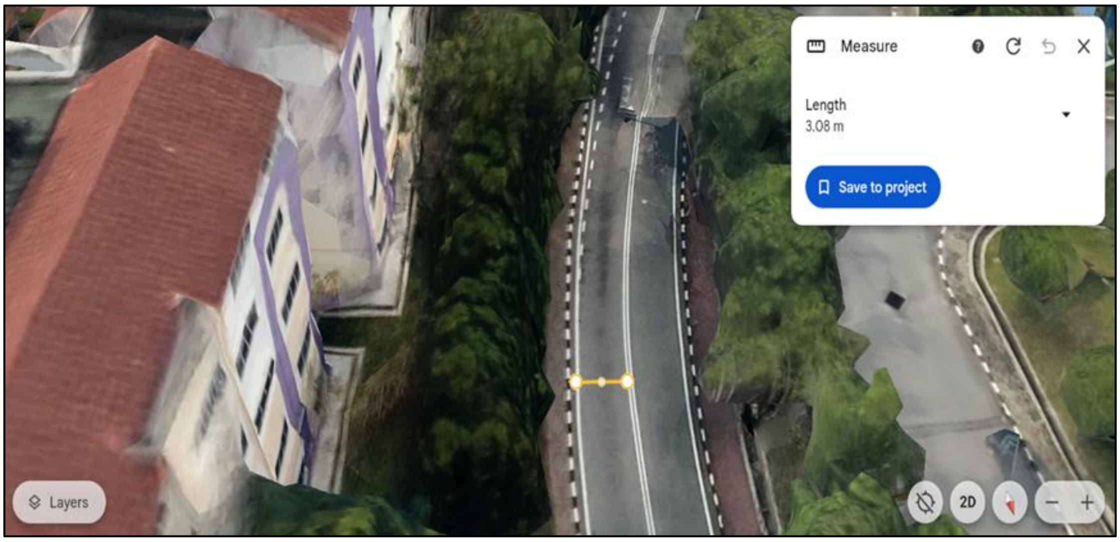


Figure 3.4 Lane Width Ranges 2.75 m to Less Than 3.25 m Near the Engineering College Road

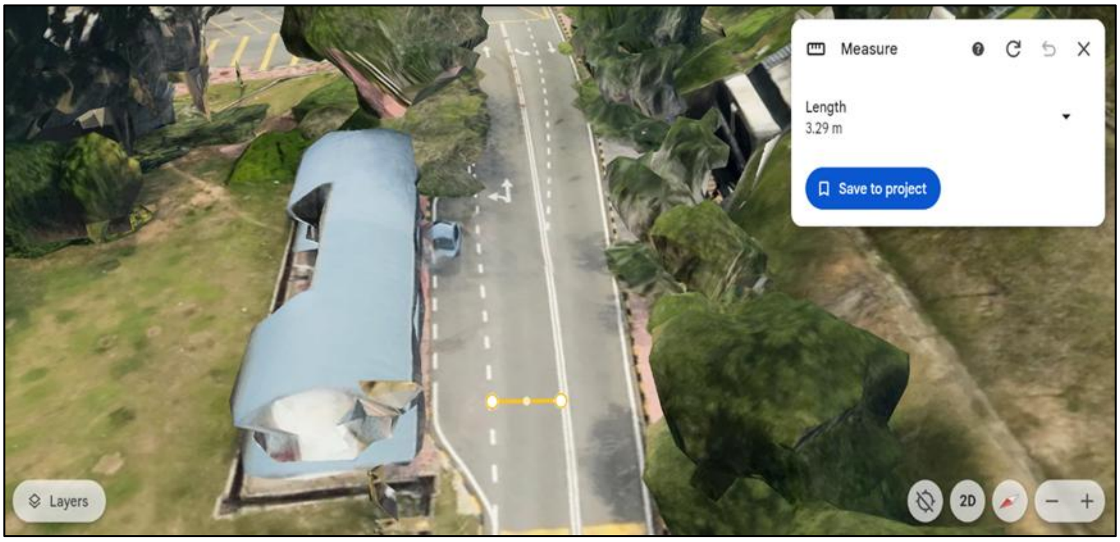


Figure 3.5 Lane Width Greater Than 3.25 m Near the UiTM Main Gate in Section 2

In this study, slope and lane width were measured using the Malaysian Institute of Road Safety Research (MIROS) Road Attribute Data Logger & Inspection System (RADIS), integrated with iRAP protocols. RADIS employed vehicle-mounted lasers and inertial measurement units to capture elevation profiles at driving speeds, deriving longitudinal and cross-slope gradients (>5% deemed high-risk) over 1–5 m intervals, with coder verification in ViDA software against iRAP standards for run-off-road risk assessment. Furthermore, lane widths were determined via lateral lasers and cameras that detect markings and edges, yielding segment averages (<2.5 m flagged for sideswipe risks), followed by data harmonisation in iRAP coding manuals, supported by visual aids for accuracy and star rating computation.

Figure 3.6 Steep Rise of over a 10 m Length at Bukit Tonggek

3.3.1.5 Road Accident Data

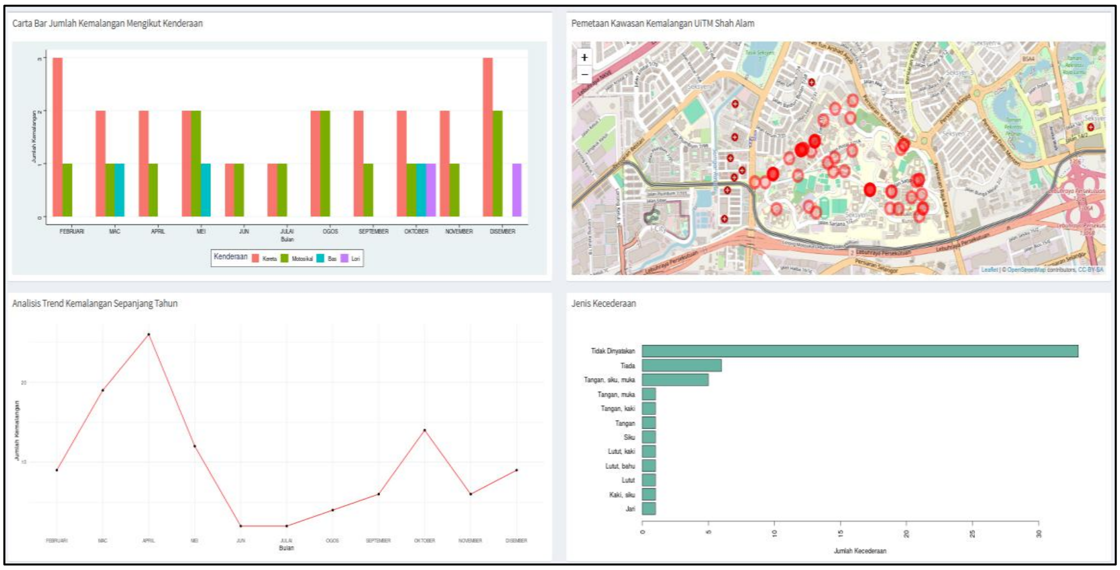


Figure 3.7 SRADA@UiTM Dashboard

This study utilised secondary road crash data from 2018 to 2021, sourced from the Ibu Pejabat Polis Bantuan UiTM Shah Alam at the campus police office. Analysis employed charts and mapping via the SRADA@UiTM platform developed by Mohd Nusa et al. (2023), an interactive R Shiny dashboard that visualises crash frequency by year and month, types of injuries, and collision types and identifies road crash blackspots on campus through dynamic mapping (Figure 3.7).

The highest number of road crashes occurred in 2019, with 23 reported cases, followed closely by 22 cases in 2018. In 2020, the number of accidents decreased to 10, and there was a significant drop to only 1 case in 2021, largely attributed to reduced campus traffic during COVID-19 pandemic (Figure 3.8a). Out of 56 reported cases, 36 were classified as damage-only crashes, where no injuries were sustained. The remaining cases involved slight (minor) injuries, including five cases of hand injuries and one case involving minor injuries to other body parts, while six cases reported unspecified injuries that are likely to fall within the minor category (Figure 3.8b). Importantly, there were no cases of serious or fatal injuries recorded during the study period. According to standard road safety definitions, slight injuries typically involve minor cuts, abrasions, or bruises that require minimal or no hospitalisation, whereas serious injuries would include fractures, internal injuries, or long-term disability. The absence of serious and fatal injuries suggests that crashes on campus generally occur at lower speeds, consistent with controlled traffic environments.

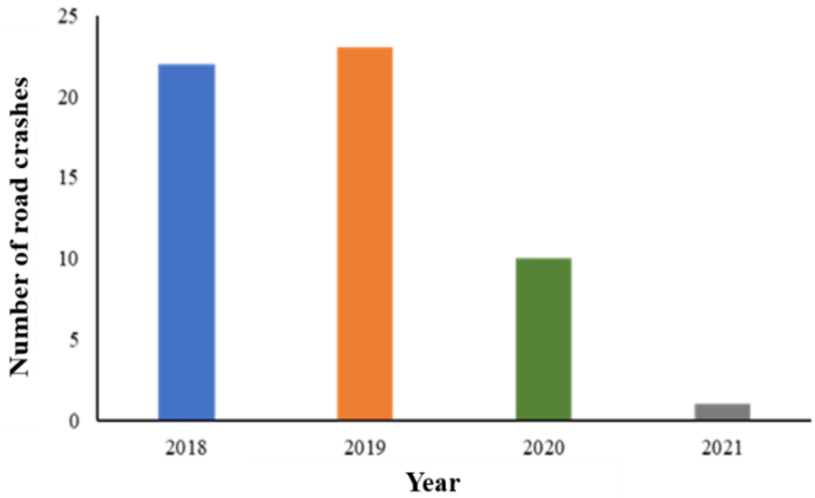
The road crash records indicate that accidents primarily occurred at specific locations within the campus road network, with 45% of crashes occurring along mid-block (straight road) sections, followed by 37% at intersections, 16% in parking areas, and 2% at roundabouts (Figure 3.8c). The high proportion of crashes in straight road segments suggests the presence of reckless or inattentive driving behaviours, such as speeding or a lack of concentration. With regard to collision types, 52% of crashes involved motorcycles, while 39% involved two-vehicle collisions, indicating that motorcyclists are the most vulnerable road users on campus. These patterns highlight unsafe riding and driving practices as key contributors to crash occurrences.

In the accident maps presented (Figure 3.8d), the severity of crashes was indicated by colour coding; locations with higher crash frequencies are shown in darker colours, while any fatal crashes would be marked in black to clearly highlight their severity level. In this study, the identification of blackspots and their annual frequency influenced the site selection for interventions by focusing on locations with recurrent crashes. The study underlines that crash blackspots predominantly occur along straight sections of the campus roads (middle of the roads) rather than intersections or parking areas. This information helps prioritise sites with high crash frequencies for targeted road safety measures. Thus, site selections for interventions and safety improvements were based on a spatial analysis of crash frequency and patterns over the years, highlighting areas with consistently high accident counts.

Behavioural factors play a significant role in these incidents, particularly poor compliance with traffic regulations, risky driving habits, and limited awareness of surrounding road users. Despite being within a university environment, many drivers and riders fail to adhere to basic road safety rules. Additionally, crash frequency was observed to increase during peak traffic periods, specifically between 9:00 am to 12:00 pm and 2:00 pm to 5:00 pm, when traffic volume is highest due to the movement of students, staff, and visitors. This combination of human factors and traffic congestion creates a higher-risk environment for crashes.

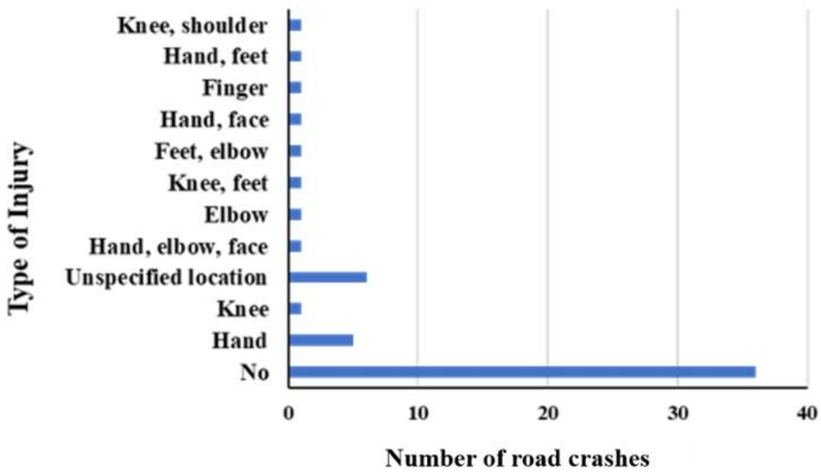
From an International Road Assessment Programme (iRAP) perspective, the property damage-only and slight-injury crashes suggest a relatively lower crash severity environment but do not necessarily indicate a low-risk road system. Instead, it reflects that while impact speeds may be low, the frequency of conflicts remains high, particularly at mid-block sections and intersections. This highlights the need for proactive safety improvements, as frequent, low-severity crashes can still indicate underlying road design and behaviour issues.

In summary, the injury data indicate that most campus road crashes are predominantly non-fatal and low in severity (damage-only and slight injury categories), with no severe or fatal cases reported. Nevertheless, the consistent involvement of motorcycles, the concentration of crashes at high-conflict locations, and the influence of unsafe driving and riding behaviours indicate that targeted interventions are necessary. These findings, corroborated by iRAP star ratings, informed targeted improvements in traffic enforcement, road user education, and engineering measures, particularly at intersections and along straight road sections to reduce crash frequency and enhance overall campus road safety.



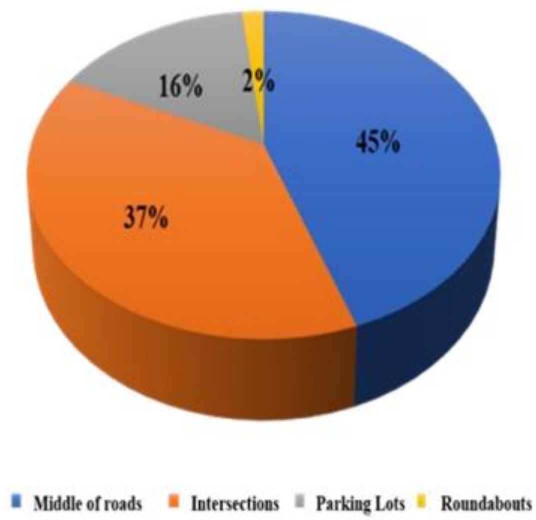
Number of road crashes
25
20
15
10
5
0
2018
2019
2020
2021
Year

(a)



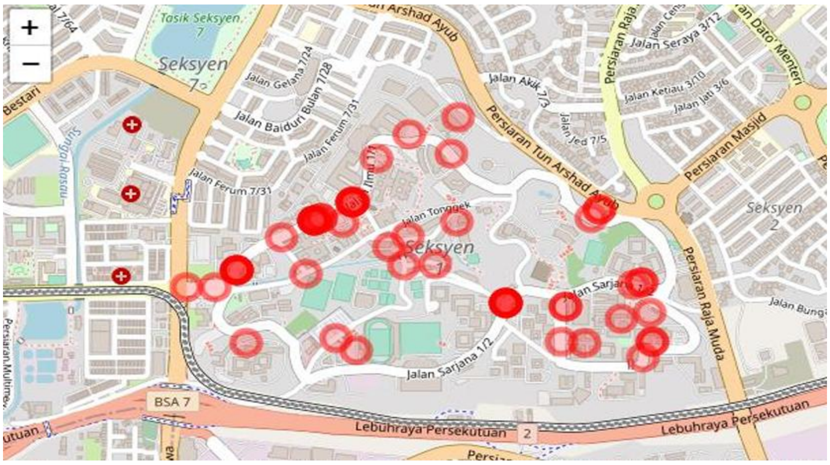
Type of Injury
Knee, shoulder
Hand, feet
Finger
Hand, face
Feet, elbow
Knee, feet
Elbow
Hand, elbow, face
Unspecified location
Knee
Hand
No
0
10
20
30
40
Number of road crashes

(b)



16%
2%
45%
37%
Middle of roads
Intersections
Parking Lots
Roundabouts

(c)



(d)

Figure 3.8 Road Crash Data on Campus: (a) Crashes by Year (b) Crashes by Injury Type (c) Crashes by Location, (d) Blackspots Location (Mohd Nusa et al., 2023)

3.3.1.6 Allocation of the Campus Budget

The transportation budget at UiTM's main campus experienced a notable upward trend over recent years (Table 3.2). In 2019, the allocation was approximately RM 2.54 million, reflecting a foundational investment in sustainable transportation initiatives. This amount increased significantly to RM 4.36 million in 2020, indicating a strengthened commitment to enhancing campus mobility and environmental sustainability. However, the 2021 budget appeared incomplete, with a figure of RM 5,413, which may have been due to budgetary adjustments resulting from the COVID-19 pandemic. These investments supported various critical projects, including enhancements to shuttle bus services, the promotion of zero-emission vehicles, strategic management of parking needs, and initiatives to reduce private vehicles on campus through the introduction of e-scooters, e-bikes, and public transportation options (UiTM Green Centre (UGC), 2022).

Table 3.2
The University Budgets Sustainability Initiatives for Transportation, 2019 to 2020

Year	2019	2020	2021
Malaysian Ringgit	2.54 mil	4.36 mil	5,413

(RM)

Source: (UiTM Green Centre (UGC), 2022)

Given the unavailability of recent budget data, the historical campus budget served as a benchmark for estimating and calculating the benefit-cost ratio, specifically focusing on the cost of countermeasures per kilometre.

3.3.2 Primary Data Collection

3.3.2.1 iRAP Road Survey

The road survey for this study began with a detailed review of the International Road Assessment Programme (iRAP) survey manual and its implementation requirements. Given the significant time and resource investment involved, strict adherence to iRAP protocols was essential to ensure that all collected data met the required standards and was accepted.

Effective planning led to the development of a comprehensive survey plan. This included a list of selected project roads, along with their names, GPS coordinates, and key landmarks defining the start and end points. The Malaysian Institute of Road Safety Research (MIROS) iRAP team coordinated the preparation of the instrumented survey vehicle, including the selection and setup of equipment and software. The survey vehicle was equipped with the Road Attributed Datalogger and Inspection System (RADIS) 2.0, a specialised system that integrates high-resolution video recording, GPS positioning, and distance measurement on a single platform (Figure 3.9). A 360-degree camera system was installed to capture continuous road environment imagery, while distance measuring instruments were used to accurately record segment lengths (Figure 3.10). The system also included data storage units and processing software to organise and synchronise spatial and visual data for subsequent analysis. Regular maintenance, including camera calibration and lens cleaning, was conducted to ensure high-quality data capture.

Figure 3.9 MIROS Team and the Survey Vehicle

In order to optimise data collection, surveys were scheduled outside peak traffic periods and in suitable weather conditions to ensure clear visibility and consistent recording quality. The survey vehicle was operated at an average speed of approximately 30–40 km/hr, within a controlled range of 20–50 km/hr depending on road conditions and traffic flow. This speed range aligns with iRAP recommendations, allowing for clear image capture while maintaining safe and stable driving conditions throughout the survey.

The road survey was conducted in October 2021 at 100 m intervals using RADIS 2.0. The system recorded essential information, including date, image references, start and end locations, total surveyed length, road name, latitude and longitude, and notable landmarks. Following data collection, all records underwent rigorous quality checks by the MIROS team to ensure compliance with iRAP standards. Survey points were also mapped to verify GPS accuracy and distance measurements (Figure 3.11).

Figure 3.10 The 360˚ Camera View on RADIS 2.0

The selection of survey locations was based on a combination of crash analysis and functional importance within the campus road network. Locations with consistently high crash frequencies, particularly mid-block sections and intersections identified as blackspots, were prioritised. Additional considerations included traffic volume levels, road hierarchy (for example, main access roads versus internal roads), and the presence of vulnerable road users such as motorcyclists and pedestrians. These criteria ensured that the selected sites represent high-risk and high-exposure areas, allowing for targeted safety assessment and effective intervention planning.

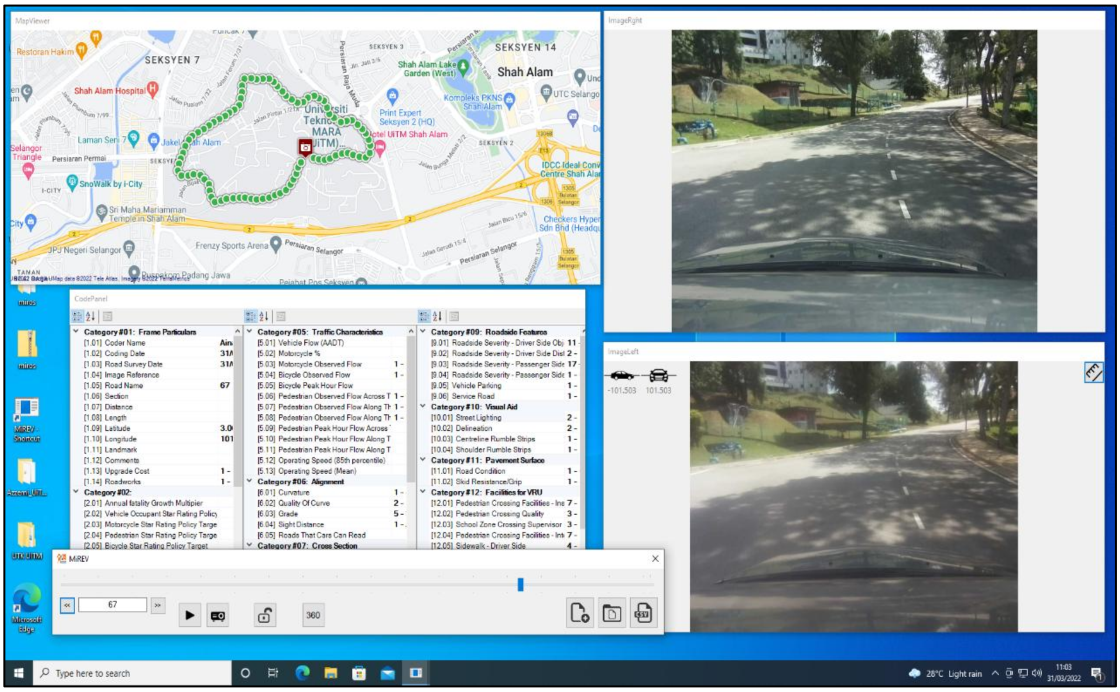


Figure 3.11 Georeferenced Survey Images

This structured methodology, supported by MIROS and guided by iRAP standards, ensures that the collected data are reliable and suitable for identifying road safety risks and recommending appropriate improvements.

3.3.2.2 Spot Speed Study

In December 2022, a spot speed study was conducted across nine selected locations, where data were collected from a sample of 100 vehicles on a weekday. The study used the speed radar meter method, and the apparatus (Figure 3.12) was provided by the School of Civil Engineering, UiTM Shah Alam. To ensure consistency in the data collection process, measurements were taken during off-peak hours, specifically between 10:00 AM and 11:00 AM or from 11:00 AM to 12:00 PM. During the data collection, the radar meter was strategically positioned and concealed to prevent the observation vehicle from being visible to the target vehicles, ensuring accurate speed measurements.

Figure 3.12 Radar Speed Gun

The spot speed study followed four essential steps. First, suitable locations were identified, and the radar meter was positioned appropriately (Figure 3.13). Next, an effective selection strategy was developed to collect data systematically. The observed vehicle speeds were then recorded on a radar meter spot speed study data form (Table 3.3), which included details such as date, location, posted speed limit, weather conditions, start time, end time, and direction of travel. Finally, the data were analysed by generating a frequency distribution table (Table 3.4) and calculating speed percentiles. In this study, the mean speed from the following Equation 3.1 and the 85th (design speed) percentiles of vehicle speeds from the cumulative frequency curve were determined for further analysis. This structured approach provided valuable insights into traffic patterns and vehicle speeds at the selected locations.

Figure 3.13 Spot Speed Study

Table 3.3
Spot Speed Study Data Collection Form

Location				Direction of travel			
Date				Start/End time			
Weather conditions				Posted speed			
Time (s)	Speed (km/hr)	Time (s)	Speed (km/hr)	Time (s)	Speed (km/hr)	Time (s)	Speed (km/hr)

Table 3.4
Frequency Distribution Table for Set of Speed Data

Speed group	Middle speed (v)	No. of observation (f)	% of the total observation	Cumulative %	fv	v^2	fv^2

To construct a cumulative frequency curve, a graph was plotted with speeds on the horizontal axis and cumulative percentages on the vertical axis. The data points were connected with a smooth curve to form the cumulative frequency curve. This curve visually represented traffic patterns and allowed for the identification of key speeds such as the median (50th percentile) and design speed (85th percentile).

$$\bar{x} = \sum fv / \sum f \tag{3.1}$$

Table 3.5 presents detailed locations where spot speed studies were conducted on the UiTM main campus, along with the accompanying figures. The selection of speed study locations along the main road of UiTM Shah Alam Main Campus was guided by a set of key criteria, including traffic volume, road geometry, safety considerations, and operational feasibility. The aim was to capture representative speed behaviours across different functional road environments, particularly locations with higher safety risks and traffic interactions.

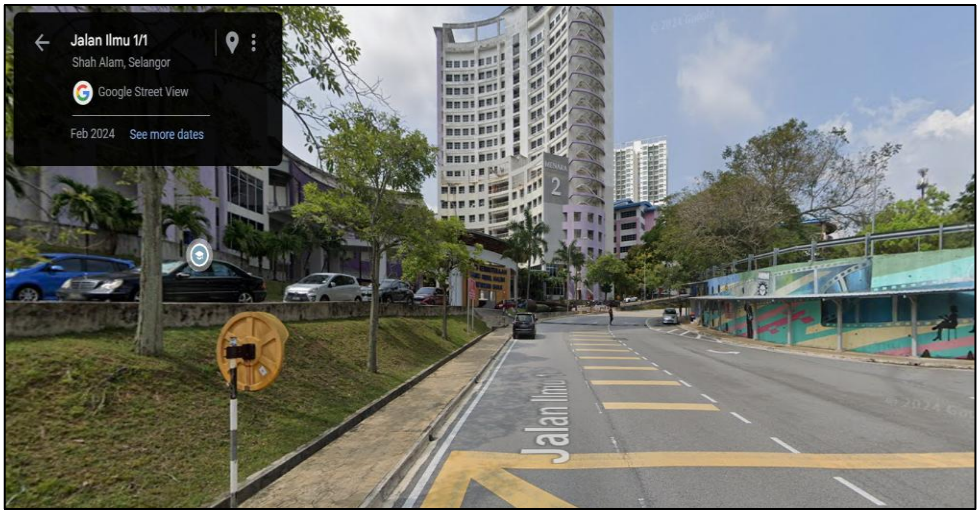
First, locations with high traffic volumes and flow control significance were prioritised. The UiTM Main Gate serves as the primary campus entry and exit point, where traffic density, merging movements, and speed variations are most prominent. Similarly, the Kolej Delima bus stop was selected due to its role as a public transport node, where frequent stopping buses and pedestrian crossings influence vehicle speed patterns.

Secondly, critical junctions and intersections were included due to their high conflict potential. The FSPU junction and DATC are key nodes where turning movements, crossing traffic, and pedestrian activity require careful monitoring of speed behaviours to assess compliance and safety risks.

Thirdly, the study incorporated varied road and geometric characteristics to reflect different driving conditions. Sections such as Bukit Tonggek and the Engineering College represent areas with gradients, curves, and varying road widths, all of which influence driver speed choice and vehicle control.

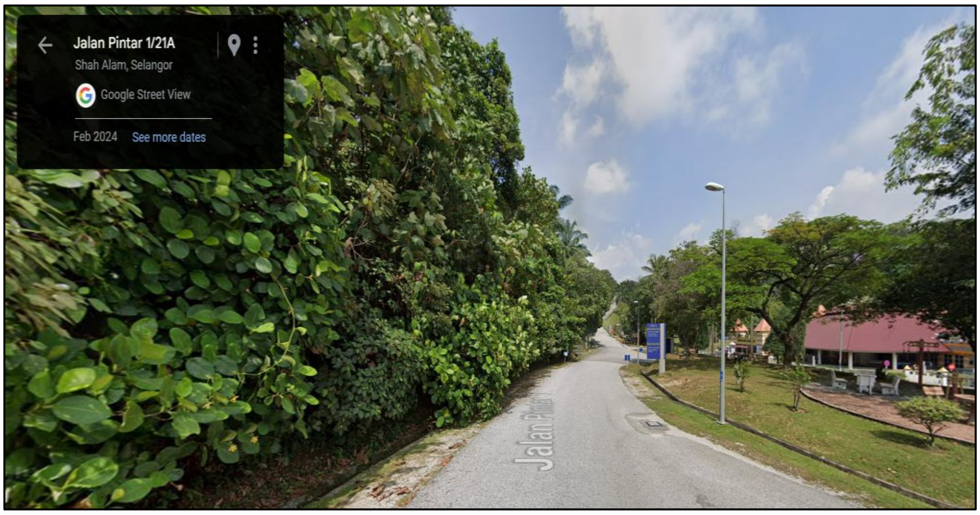
In addition, safety considerations involving vulnerable road users played a crucial role in site selection. Areas near academic buildings, administrative offices, and residential zones, including the Malaysia Institute of Transport, Facility Management Office, and Cempaka Complex, experience high pedestrian activity. These locations require speed assessment to evaluate compliance with safe speed limits and the need for traffic calming measures.

Table 3.5
Selected Locations for Spot Speed Studies

No.	Landmarks
1.	Engineering College 
2.	UiTM main gate 
3.	FSPU junction

4. Malaysia Institute of Transport

5. Bukit Tonggek



6.	Kolej Delima bus stop

7.	Facility Management Office

8.	Cempaka Complex

9. DATC

Furthermore, the selected locations provide strategic coverage along the main campus road, ensuring that different zones, ranging from entry points and academic areas to residential and service zones, are represented. This allows for a comprehensive analysis of speed profiles and supports the identification of high-risk segments for targeted interventions.

Finally, practical considerations for data collection were taken into account. All sites were chosen based on accessibility and suitability for safely installing speed monitoring equipment without disrupting traffic flow or compromising the safety of survey personnel, thereby ensuring reliable and consistent data collection.

In summary, the nine selected locations, UiTM Main Gate, Malaysia Institute of Transport, Bukit Tonggek, Engineering College, DATC, FSPU junction, Kolej Delima bus stop, Facility Management Office, and Cempaka Complex, represent a balanced combination of high-traffic zones, critical intersections, varied road geometries, and pedestrian-intensive areas. This systematic selection enables a comprehensive assessment of speed behaviour across the campus and supports the development of targeted road safety interventions aligned with the university's sustainability and safety objectives.

3.4 Data Coding

In this study, coding was conducted on existing roads, specifically focusing on a 7.4 km length of campus road. The process involved recording road attributes from geo-referenced images and compiling them into a Microsoft Excel file that adhered to the Upload File Specification provided by iRAP. Coding was performed for each 100 m segment of the road.

Certain types of data, known as supporting data, were sourced through additional methods, including essential information regarding vehicle operating speeds and vehicle flow, while for datasets with limited resources, logical judgements were made considering experts' advice (see Appendix 2). While iRAP does not specify particular coding systems, this study utilised a system supplied by the Malaysian Institute of Road Safety Research (MIROS) called MiREV (Figure 3.14). This system enables the conversion of stored coding data into a .csv file that complies with the Upload File Specification for processing by ViDA (Figure 3.15). In this structured format, each road attribute was assigned to a specific column, with inputs represented as numerical codes.

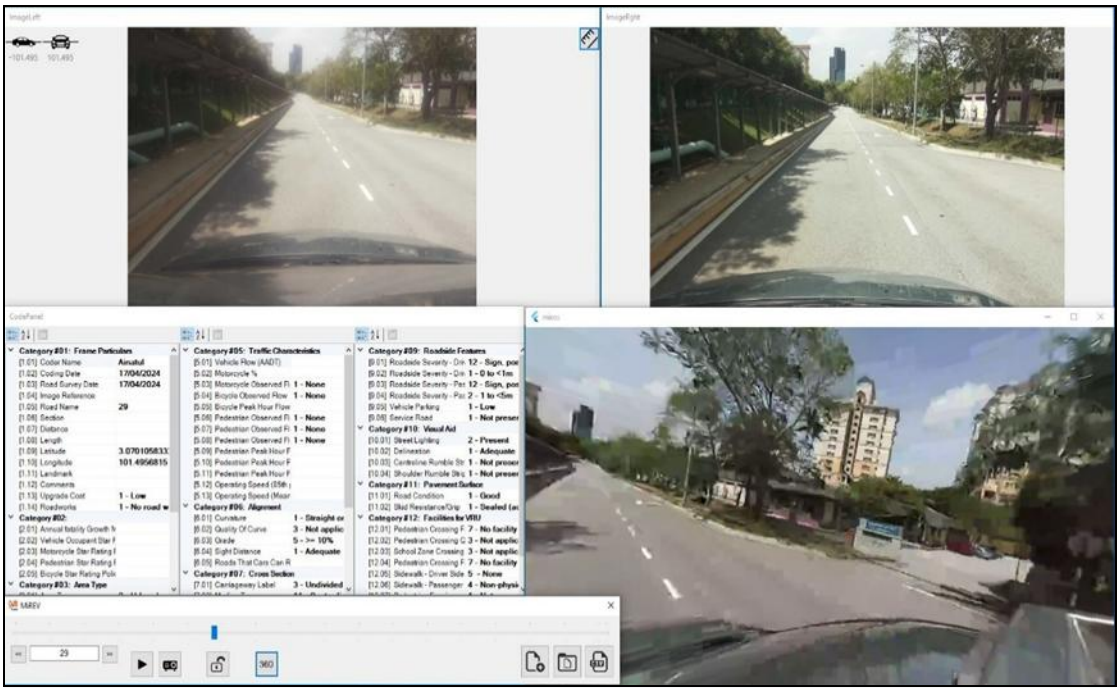


Figure 3.14 MiREV Coding System

The coding options for each attribute were organised from highest to lowest risk. Therefore, when an attribute varied within a single coding segment, the first option listed was recorded as the worst-case scenario for that attribute. To streamline this process, the worst-case category within each 100 m segment was coded. A table was used to help identify the worst-case coding options for each attribute (see Appendix 1).

During the coding task, a coding supervisor from MIROS managed the process and conducted quality checks before generating star ratings (Figure 3.16). This oversight ensured that no validation errors occurred during the upload to ViDA, and data that had not undergone quality review processes was not accepted. Thus, high standards of accuracy and reliability in the assessment results were maintained throughout the study.

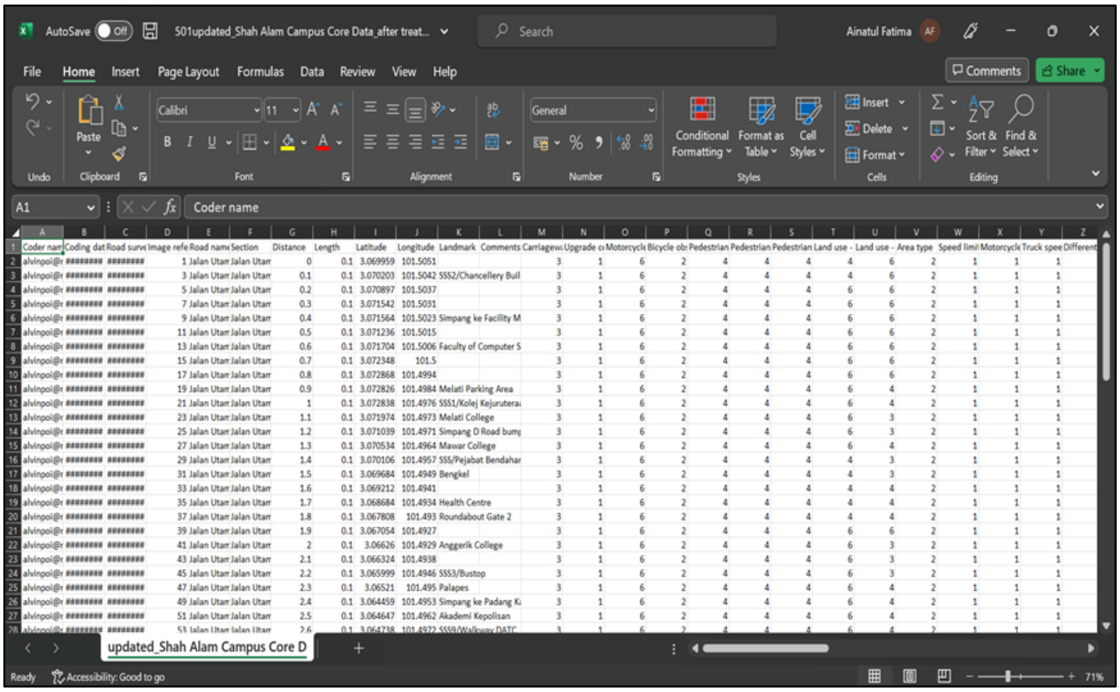


Figure 3.15 Screenshot of the Excel File

Figure 3.16 Coding Task

The study has reached a significant milestone with the coding of three Microsoft Excel files involving geo-referenced images and supporting data for further analysis. These files corresponded to three identified scenarios: the first two scenarios served as baselines representing the pre-condition, while the third scenario represented the optimised post-condition (Table 3.6).

Table 3.6
Classification of Star Rating Scenarios and Corresponding Outcomes

	Scenario	Explanation	Outcome
Baseline	1st: Based on adherence to posted speed limit	Reflects rating based on compliance with posted limits	Posted Speed Limit Star Rating
	2nd: Based on observed operating speed	Reflects actual operating conditions	Observed Operating Speed Star Rating
Optimised	3rd: Based on adjusted road attributes to increase rating	Reflects a hypothetical or planned improvement scenario where road features were modified to achieve better safety ratings	Optimised Star Rating

3.4.1 Baseline

3.4.1.1 Speed Limit

In the initial coding of the Excel file, the operating speed (columns 69-70/BQ-BR) was coded using the posted speed limit, defined as less than 30 km/hr. Table 3.7 shows the key categories coded in the file. The completed coding Excel file was subsequently processed using ViDA to check how safe campus roads are. The analysis aimed to figure out whether the current posted speed limit was appropriate for the campus and to examine patterns of road users' compliance with the speed limit. This speed limit applied uniformly to all vehicles, including motorcyclists, and both the 85th percentile and mean operating speeds were consistently recorded as below 30 km/hr across the entire length of 7.4 km of campus roads.

Table 3.7
Speed Settings in ViDA for Baseline Star Rating by Speed Limit

Speed limit	km
< 30 km/hr	7.4
Motorcyclist speed limit	km
< 30 km/hr	7.4
Operating speed (85th percentile)	km
< 30 km/hr	7.4
Operating speed (mean)	km
< 30 km/hr	7.4

3.4.1.2 Operating Speed

The study produced a second Excel file by copying the previous one. In this stage, the operating speed (columns 69-70/BQ-BR) was substituted with the operating speed data collected from the spot speed study to assess a scenario that reflects real conditions. This method provided a baseline star rating associated with operating speeds. Table 3.8 presents an overview of speed limits and operating speeds encoded in the file processed by ViDA. The posted speed limit for all vehicles, including motorcyclists, was set at less than 30 km/hr over 7.4 km, as set by the university. Furthermore, the table reveals a significant discrepancy between the posted speed limit and actual driving speeds, indicating that many vehicles exceeded the established limit. This second coding stage underscores that, despite the speed limit being 25 km/hr (Figure 3.17), many vehicles were travelling above this threshold, which raised safety concerns for road users on campus. Understanding this distribution is vital for comprehending typical road users' behaviours and identifying potential safety issues.

Figure 3.17 Campus Speed Limit (25 km/hr)

Table 3.8
Speed Settings in ViDA for Baseline Star Rating by Operating Speed

Speed limit	km
< 30 km/hr	7.4
Motorcyclist speed limit	km
< 30 km/hr	7.4
Operating speed (85th percentile)	km
45 km/hr	3.9
40 km/hr	1.8
35 km/hr	1.7
Operating speed (mean)	km
40 km/hr	3.9
35 km/hr	1.8
< 30 km/hr	1.7

Analyses derived from these attribute codes served a dual purpose in assessing road safety. First, it established a framework for generating star ratings, which evaluate road safety based on various criteria, including adherence to speed limits and typical operating speeds. Second, these ratings provided a measurable way to assess the risks associated with different road conditions, thereby guiding improvements in road design and enforcement strategies.

3.4.2 Optimised

The third Excel file, representing post-conditions, was created by duplicating the second Excel file and modifying specific road attributes to potentially enhance the campus road infrastructure. The posted speed limit and operating speeds were retained from the second file. This approach aimed to analyse the resulting star rating patterns and evaluate their impacts on campus safety standards.

3.5 Data Analysis

3.5.1 Visualising Road Safety

By overlaying the surveyed road data with injury records using Google Earth, the study pinpointed specific locations where road conditions were linked to accident occurrences. This process helped identify high-risk areas and supported the outcomes from star rating generation on the surveyed roads that required immediate attention. Visualising the injury data on a map revealed patterns and trends in incident locations, providing valuable insights for decision-making regarding safety measures, resource allocations, and potential interventions.

Furthermore, this study analysed raw accident data from the UiTM campus to identify potential road infrastructure factors contributing to traffic accidents. These results informed the selection of risk factors to address while enhancing the road star rating by changing relevant road attributes during the final coding phase (Section 3.4.2). This process involved simulating scenarios to predict how implementing improvements would impact road safety levels.

3.5.2 Star Ratings

The process of generating star ratings began with the preparation of road attribute coding data, which was organised in a .csv file that adhered to the ViDA Upload File Specification. Subsequently, ViDA, a suite of online tools designed for calculating, managing, analysing, and presenting star ratings, was employed to compute star rating scores based on these road attributes. This process produced the final star ratings separately for every road user group, involving car occupants, motorcyclists, pedestrians, and cyclists.

After uploading the data into ViDA, facilitated by the Malaysian Institute of Road Safety Research (MIROS), a range of analyses were conducted. These analyses were performed for every three Excel files prepared during the coding process. The analysis included detailed condition reports, which analysed and summarised the road data. Additionally, star ratings were presented through maps and summary tables tailored for different road user groups: car occupants, motorcyclists, pedestrians, and cyclists. These visual tools displayed both smoothed and raw star ratings across various locations, allowing stakeholders to understand the safety risks associated with each user group. Noted that raw star ratings were calculated for each 100 m road segment, offering a detailed view of risk levels influenced by specific crash types and road conditions. In contrast, smoothed star ratings aggregated the raw star ratings over longer distances, providing a clearer picture of overall road safety. This smoothing process helped eliminate extreme variations seen in raw ratings, allowing for better analysis and mapping of safety trends across larger sections of the road. This approach is beneficial for policymakers and planners who need to assess road safety at a network level rather than segment by segment. Meanwhile, the Detailed Condition Report provided a concise summary of the coded road attributes, offering a comprehensive overview of the findings.

The methodology for generating star ratings in this study was structured around three main sets (see Appendix 3) to provide a comprehensive assessment of road safety performance. The process began with the Baseline Star Rating, reflecting the existing conditions of the campus roads. This baseline was assessed differently for two scenarios, utilising both posted speed limits and observed operating speeds, respectively, calculated separately for car occupants, motorcyclists, pedestrians, and cyclists. For each user group, star ratings were presented in both smoothed (average) and raw to capture a nuanced view of safety conditions.

To further enhance the analysis, the observed operating speed set utilised actual speed data, offering insights into the real-world safety road infrastructure experienced by road users. The final set, the Optimised Star Rating, represented the after condition, where adjustments were made to relevant road attributes with the aim of improving safety outcomes. Again, ratings for all user groups were generated in both smoothed and raw forms.

By systematically comparing these three sets, this method enabled a clear evaluation of how targeted improvements could enhance road safety across different user groups within the campus environment.

3.5.2.1 High-Risk Locations

To identify the highest-risk locations within the surveyed network, the 'Core Data-Before' analysis, which referred to the second Excel file utilising the operating speed data, was downloaded. The 'sort' function in Excel was then employed to arrange

100 m segments in order of risk. For instance, by sorting the data by Vehicle SRS Total (column 86/CH) and ordering it from largest to smallest, the segments were listed according to vehicle occupant risk, with the highest-risk segments appearing first. The locations were identified using the road name (column 5/E), section name (column 6/F), and longitude and latitude (columns 9-10/I-J). Subsequently, the latitude and longitude values of each location were copied and pasted into Google Earth to visualise the specific locations. Meanwhile, to identify the highest-risk locations, the data was sorted by smoothed results; for example, Vehicle SRS Total Smoothed (column 87/CI) was used for this purpose. These were repeated for other road user groups: motorcyclist, pedestrian, and cyclist.

3.5.3 Benefit-Cost Ratio (BCR)

The effectiveness of relevant countermeasures in enhancing the star rating was assessed for cost efficiency through a benefit-cost ratio (BCR) analysis. To compute the BCR, six key data inputs were required. These inputs were processed using formulas embedded in a Microsoft Excel spreadsheet provided by the Malaysian Institute of Road Safety Research (MIROS), which adhered to the International Road Assessment Programme (iRAP) protocol. The BCR was calculated by dividing the total present value of benefits by the total present value of costs, a method commonly used to evaluate the economic viability of projects. This approach allowed for a systematic assessment of whether the benefits of road safety interventions outweighed their costs, thereby informing decision-making on resource allocation.

3.5.3.1 Baseline Injury Data

The baseline injury data in iRAP was typically calculated as the mean of data spanning at least three years. For this study, data from the UiTM police office between 2018 and 2021 were utilised as a benchmark. However, since no fatalities were reported during this period, the study hypothesised that one fatality occurred over the four-year period to facilitate the benefit-cost ratio analysis.

3.5.3.2 Values of Humans' Lives and Serious Injuries

The GDP per capita for Malaysia in the fourth quarter of 2024 was calculated using reliable data from the Department of Statistics Malaysia and Bank Negara Malaysia. Specifically, the real GDP per capita was derived from the GDP at constant prices, which was RM 430.7 billion, divided by the estimated population of 34.2 million (Department of Statistics Malaysia (DOSM), 2024). This calculation yielded a real GDP per capita of approximately RM 12,594. The use of real GDP ensures that the figure is adjusted for inflation, providing a more accurate measure of economic output per person over time. Notably, GDP serves as a key indicator of a population's economic level, influencing their willingness to pay for various goods and services, including safety measures.

$$\text{Value of Statistical Life (VOSL)} = 70 \times \text{GDP per capita} \tag{3.2}$$

$$\text{Value of Serious Injury (VOSI)} = 0.25 \times \text{VOSL} \tag{3.3}$$

Additionally, the constant value of 70 was used, as it falls between the minimum and maximum values of 60 and 80, respectively. This value was recommended by iRAP for all countries. Furthermore, VOSI accounted for one-quarter of VOSL. The computation of VOSL and VOSI followed the formulas outlined in Equations 3.2 and 3.3.

3.5.3.3 Discount Rate

In economic appraisal for BCR analyses, a discount rate is crucial because BCR calculations span multiple years. Typically, funding agencies or national banking institutions, such as Bank Negara Malaysia (BNM), determine the discount rate. However, the iRAP model used a default discount rate of 12% for Malaysia. This rate reflects broader economic considerations, including the cost of capital and the opportunity cost of funds, which often exceed the Overnight Policy Rate (OPR) set by BNM. The adoption of a 12% discount rate was justified by the need to account for project-specific risks and the cost of equity, ensuring that projects were evaluated under conservative assumptions. This approach enhanced the robustness of the BCR analysis by providing a more cautious assessment of project viability.

3.5.3.4 Cost of Countermeasures

A key contribution of this study is the adaptation of the Benefit–Cost Ratio (BCR) methodology to a campus-scale road network, where detailed economic valuation and crash cost data are often limited. The framework integrates historical crash data from 2018 to 2021 with standardised evaluation tools to estimate the expected reduction in crash frequency and severity resulting from selected countermeasures. This provides a practical and reliable basis for quantifying benefits within the BCR analysis.

The estimation of benefits follows a structured approach. Baseline crash data was first analysed to determine the average annual number of crashes per severity level. Expected reductions in crashes were then derived using established effectiveness factors, obtained from the Road Safety Toolkit and relevant literature. These reductions were subsequently converted into monetary terms using severity-based unit crash costs, representing the economic value of avoided crashes. The resulting annual benefits were aggregated over a 20-year treatment horizon and adjusted for shorter intervention lifespans where necessary, ensuring consistency in long-term benefit estimation. This approach ensures that benefit calculations are grounded in empirical data and supported by validated cost assumptions.

The 2020 campus transportation budget (RM 4.36 million), as in Section 3.3.1.4, *Allocation of the Campus Budget*, was used as a consistent baseline for cost estimates because the financial records for 2021 were incomplete. Budget allocations were distributed across low-cost (20%), medium-cost (50%), and high-cost (30%) interventions, in line with countermeasure classifications and cost structures derived from the Road Safety Toolkit and detailed road condition assessments. Costs per kilometre were calculated for each category and standardised over a 20-year treatment period. Adjustment factors were applied for shorter lifespans, where costs were doubled for 10-year treatments and quadrupled for 5-year treatments to ensure comparability across interventions (Table 3.9).

Table 3.9
Budget Allocation Across Different Upgrade Classes

Budget allocations for campus transportation			RM 4,362,111.41	
Upgrade class	Proportion	Upgrade cost	Upgrade length	Cost per km
Low	20%	RM 872,422.28	10 km	RM 87,242.23
Medium	50%	RM 2,181,055.70	5.3 km	RM 411,519.94
High	30%	RM 1,308,633.42	0 km	Not applicable

Note: The length of each countermeasure was determined using ViDA from the Detailed Condition Report following the generation of star ratings for baseline and optimised scenarios (Section 3.5.2), and this data was used to establish upgrade lengths based on their respective upgrade classes.

Table 3.10
Cost per km by Treatment Life for Low-Cost Upgrades

Upgrade class	Low-cost			
Cost per km	RM 87,242.23			
	Cost per km according to treatment life (RM)			
Treatment life	Year 0	Year 5	Year 10	Year 20
20 years (baseline)	RM 87,242.23			
10 years (x 2 times)			RM 174,484.46	
5 years (x 4 times)				RM 348,968.92

Table 3.11
Cost per km by Treatment Life for Medium-Cost Upgrades

Upgrade class	Medium-cost			
Cost per km	RM 411,519.94			
	Cost per km according to treatment life (RM)			
Treatment life	Year 0	Year 5	Year 10	Year 20

20 years (baseline)	RM 411,519.94			
10 years (x 2 times)			RM 823,039.88	
5 years (x 4 times)				RM 1,646,079.76

The allocation strategy reflects a balanced and evidence-based approach, enabling immediate improvements through low-cost measures (Table 3.10), broader risk reduction via medium-cost treatments (Table 3.11), and targeted solutions for more complex high-risk locations. This distribution aligns with international best practices, highlighted in studies by Byaruhanga & Evdorides (2022) and guidance from the Federal Highway Administration (Gross et al., 2021), which emphasise systemic and cost-effective safety improvements.

While the Road Safety Toolkit provides internationally recognised unit cost and efficacy data primarily sourced in the US context, direct cost calibration against US figures was not undertaken. Instead, this study anchored the cost estimation within actual Malaysian campus budget data from 2020 (RM 4.36 million), ensuring that final allocated costs per kilometre reflect local economic conditions, including labour and material expenses inherently embedded in this budget. The toolkit mainly informs the categorisation of countermeasures into low-, medium-, and high-cost categories, enabling systematic cost allocation within a Malaysian framework. This approach balances international best practices with realistic, locally meaningful financial inputs, enhancing the applicability and robustness of the BCR methodology for road safety investments on campus.

Overall, the proposed BCR framework demonstrates a practical and replicable method for prioritising road safety investments in a restricted campus environment. The integration of crash data, standardised cost assumptions, and established effectiveness factors provides a transparent and data-driven basis for optimising resource allocation and enhancing road safety on campus.

3.5.3.5 Effective of Countermeasures

The efficacy of each countermeasure varies, reflecting the diverse range of effectiveness observed in previous studies conducted worldwide. Consequently, to inform the analysis, the Road Safety Toolkit (Figure 3.18) was utilised, a comprehensive resource developed by iRAP in collaboration with other institutions. This toolkit provides a robust database of guidelines for various treatments and countermeasures, supporting informed decision-making in road safety planning.

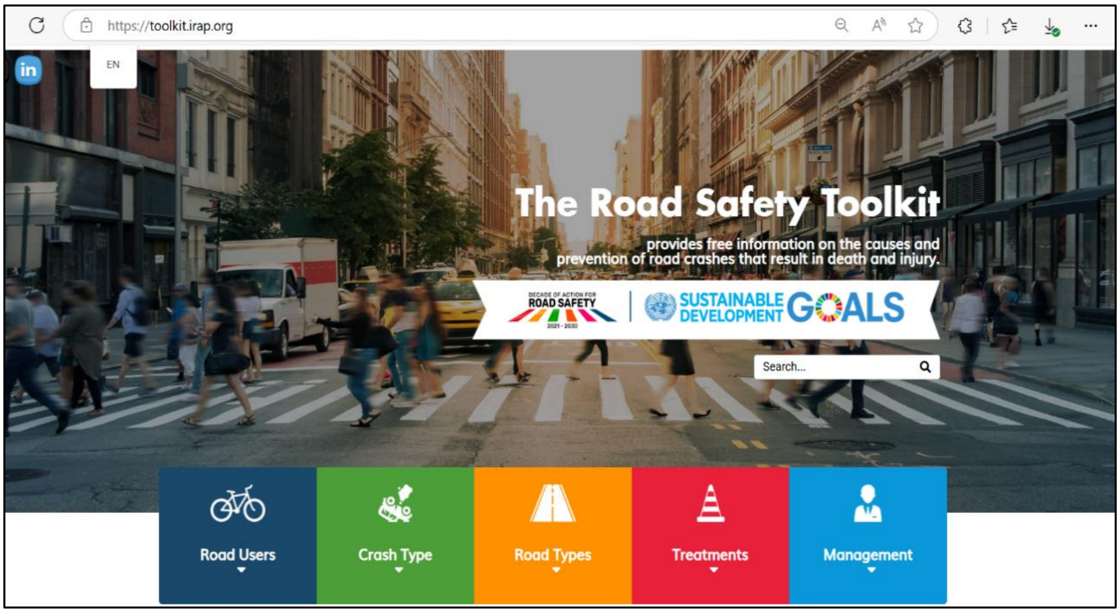


Figure 3.18 iRAP Road Safety Toolkit

Furthermore, when the treatment life ranged from 5 to 10 years, the longer duration of 10 years was adopted in this study. This decision was grounded in the principle of maximising the potential benefits of each countermeasure, thereby enhancing the overall effectiveness of safety interventions. Ultimately, by adopting the longer treatment life, the analysis captured the full potential of each countermeasure, aligning with best practices in road safety planning that emphasise the importance of sustained safety benefits over time.

3.5.3.6 Service Life

In conducting the BCR analysis, the service life of each countermeasure was considered, reflecting the duration during which a treatment provided safety benefits before requiring extensive rehabilitation or replacement. The service life was also determined by the Road Safety Toolkit, which provided a range of values. To account for potential variability and ensure a conservative estimate, the study adopted the lower end of the range. For instance, if the range is between 25% and 40%, the study employed a 25% reduction in service life as a worst-case scenario. This approach enhanced the robustness of the analysis by providing a buffer against unforeseen reductions in service life due to factors such as maintenance issues or environmental conditions.

Table 3.12
Summary of Road Safety Countermeasures

No.	Countermeasure	Upgrade cost range	Upgrade class	Effectiveness (%) range	Effectiveness (%)	Treatment life range	Treatment life	Upgrade cost (RM / mil)
1.	Roadside severity (both sides)	Low to medium	Medium	25-40	25	5-10	10	0.82
2.	Road condition	Medium	Medium	25-40	25	10-20	20	0.41
3.	Skid resistance/grip	Low to medium	Medium	25-40	25	5-10	10	0.82
4.	Delineation	Low	Low	10-25	10	1-5	5	0.35
5.	Street lighting	Medium	Medium	10-25	10	10-20	20	0.41
6.	Intersection quality	Low	Low	10-25	10	1-5	5	0.35
7.	Pedestrian crossing facilities – inspected road	Low	Low	25-40	25	1-5	5	0.35
8.	Pedestrian crossing quality	Low	Low	25-40	25	1-5	5	0.35
9.	Sidewalk (both sides)	Low to medium	Medium	40-60	40	10-20	20	0.41
10.	Speed management/traffic calming	Medium	Medium	25-40	25	5-10	10	0.82

Table 3.12 above summarises the details established in this study for computing the benefit-cost ratio, which determined the most cost-effective countermeasure. The analysis selected a medium upgrade cost, when costs ranged from low to medium, for balanced risk and benefit, offering more significant improvements than low-cost options while mitigating the uncertainties of higher-cost alternatives. Resources can be allocated effectively, by choosing a medium-cost option, ensuring substantial enhancements without excessive expenditure. This approach aligns with value engineering principles, prioritising necessary functions at a reasonable cost while

maintaining quality. Additionally, medium-cost upgrades can yield long-term cost benefits by reducing maintenance and operational expenses. Ultimately, this choice reflects a practical balance between cost efficiency and performance enhancement, aligning with broader engineering objectives.

The incorporation of the benefit-cost ratio into the final stages of iRAP research is essential for several compelling reasons. Firstly, it provides a robust economic rationale for implementing road safety measures by ensuring that the benefits they offer outweigh their costs. This ratio serves as a critical tool for prioritising interventions, as it helps identify which measures yield the greatest returns on investment. Decision-making processes are thereby informed, enabling the allocation of resources to projects that deliver substantial safety improvements at optimal cost. Furthermore, the benefit-cost ratio facilitates a standardised comparison across different projects, allowing for the evaluation of which interventions offer the best value for money. Ultimately, this approach enhances transparency and accountability by quantifying the expected outcomes of investments and ensuring that resources are used efficiently and effectively.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the study presents the findings of the road infrastructure assessment conducted at the Universiti Teknologi MARA (UiTM) Shah Alam main campus using the International Road Assessment Programme (iRAP) structured assessment framework. This assessment is carried out in line with the research's aim to systematically evaluate the existing road conditions on campus with the goal of enhancing road safety and infrastructure.

The findings are based on a comprehensive analysis of various attributes systematically inspected and rated according to iRAP's star rating system. This system provides an objective measure of road safety, translating complex data into a user-friendly 1-to-5-star rating that reflects the level of risk faced by different road users, including car occupants, motorcyclists, pedestrians, and cyclists.

Furthermore, this chapter discusses the implications of the assessment results for enhancing road safety within the campus environment. The findings offer invaluable insight into the specific risk factors present on campus roads, serving as a foundation for informed decision-making and the development of targeted safety improvement measures.

Through this discussion, the study also explores potential strategies for improving road safety based on the identified risks, emphasising the importance of proactive measures in mitigating accidents and enhancing overall campus mobility.

4.2 Operating Speed Distributions

The findings (Table 4.1) from the spot speed study (Appendix 4) conducted as a part of the International Road Assessment Programme's (iRAP) methodology revealed critical insights regarding operating speeds on various road sections within the campus. The data indicated that operating speeds, both at the 85^{th} percentile and mean levels, frequently exceeded the campus speed limit of 25 km/hr. For instance, at the Akademi Kepolisan, specifically at Padang Kawad to Kolej Mawar Exit Junction, the

85^{th} percentile speed reached 35 km/hr, while the mean speed was below 30 km/hr, highlighting a need for speed reduction measures. Similarly, at the Bukit Tonggek to Kolej Mawar Exit Junction, higher speeds were recorded, with the 85^{th} percentile at 35 km/hr for 33% of the distance and 40 km/hr for 67%, indicating that a significant portion of drivers exceeded safe operating speeds.

Table 4.1
Distributions of Operating Speeds Across the Surveyed Roads

Road section	Operating speed (85^{th} percentile)	Operating speed (mean)
Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction	35 km/hr (100% or 0.9 km)	< 30 km/hr (100% or 0.9 km)
Bukit Tonggek – Kolej Mawar Exit Junction	35 km/hr (33% or 0.2 km) 40 km/hr (67% or 0.4 km)	< 30 km/hr (33% or 0.2 km) 35 km/hr (67% or 0.4 km)
Jalan Utama UiTM	40 km/hr (9% or 0.4 km) 45 km/hr (91% or 3.9 km)	35 km/hr (9% or 0.4 km) 40 km/hr (91% or 3.9 km)
Kawasan Central UiTM	45 km/hr (91% or 3.9 km) 40 km/hr (100% or 1.0 km)	35 km/hr (100% or 1.0 km)
Kawasan Pembangunan UiTM	35 km/hr (100% or 0.6 km)	< 30 km/hr (100% or 0.6 km)

On Jalan Utama UiTM, most vehicles operated above the speed limit, with the 85^{th} percentile reaching 40 km/hr for 9% of the distance and 45 km/hr for 91%. The mean speeds were also concerning, as they registered at 35 km/hr and 40 km/hr, respectively. In the Kawasan Central UiTM, operating speeds further exceeded safety thresholds, with the 85^{th} percentile at 45 km/hr for 91% of the distance. Although the mean speed was recorded at 35 km/hr for the entire section, this still posed risks in areas with high pedestrian traffic. Lastly, in Kawasan Pembangunan UiTM, the mean speed fell below 30 km/hr, but the presence of vehicles travelling at higher speeds remained a concern.

Overall, the analysis demonstrated that many road sections within the campus had operating speeds that exceeded the established limit. This discrepancy raised significant concerns regarding road safety and suggested a pressing need for effective speed management strategies. Potential interventions included implementing additional signage to remind road users of speed limits, introducing traffic calming measures such as speed bumps or road narrowing, and conducting awareness campaigns to educate road users about safe speeds in campus areas. Addressing these issues was crucial for enhancing overall road safety and reducing potential injuries on campus roads.

4.3 Road Inventory from Road Surveyed

The findings derived from the International Road Assessment Programme (iRAP) survey methodology are crucial for enhancing road safety. This methodology employs a systematic approach to gather detailed data on various road features, including geometric configurations, surface conditions, and safety installations, at regular intervals of 100 metres along surveyed routes. The systematic cataloguing of these attributes within the iRAP methodology enables researchers and practitioners to identify critical risk factors affecting road safety.

The assessment process in iRAP's methodology includes several key attributes essential for effective road evaluations: mid-block attributes, roadside attributes, vulnerable road user facilities, intersections, and speeds. In total, iRAP encompasses a comprehensive list of attributes recorded for effective assessments, covering dozens of specific factors related to road design, safety features, and environmental context.

4.3.1 Mid-Block Attributes

Table 4.2 presents a comprehensive inventory of road characteristics, offering valuable insights into the safety and operational aspects of the surveyed carriageway. The entire length of the road (7.4 km) is undivided, which raises safety concerns due to the lack of separation between opposing traffic flows. According to JKR Malaysia's standards for two-way carriageways, physical medians or barriers are generally recommended for two-lane, two-way roads where the average daily traffic exceeds 10,000 vehicles or where the risk of head-on collisions is high (Jabatan Kerja Raya Malaysia, 2015). However, for roads with lower traffic volumes or speeds, a centreline without a physical median may be acceptable if it is complemented by adequate delineation and other safety measures, such as reflective road markings and signage to guide drivers effectively.

In this assessment, the road features a centreline for only 51% of its length and is designated one-way for 36%, indicating partial traffic control measures. Moreover, there is minimal use of wide centrelines (9%) and physical medians (1%). The absence of physical medians on the two-way sections, although acceptable according to JKR standards for low-volume roads, presents potential safety hazards that could be alleviated through appropriate delineation or, when warranted by traffic volume or risk evaluation, physical separation.

Furthermore, the majority of the road consists of a single lane (93%), which can lead to increased congestion and heightened risk during high periods of heavy traffic. All lanes are classified as medium width, which is generally favourable for vehicle manoeuvrability. In terms of road alignment, a significant portion (61%) exhibits moderate curvature, while 38% is straight or gently curving; the presence of sharp curves is minimal, indicating a relatively safe alignment overall. Additionally, most sections have a grade between 0% and 7.5% (81%), which is manageable for vehicles but could pose risks in adverse weather conditions.

The condition of the road is predominantly rated as good (80%), positively contributing to overall safety. Furthermore, most sections demonstrate adequate skid resistance; however, 20% are rated as medium, indicating a potential risk for loss of traction under certain conditions. It is also important to note that delineation across the entire length of the road is poor, which could impair visibility and navigation, particularly at night. On a more positive note, street lighting is present in nearly all sections (99%), enhancing visibility for drivers and riders.

In terms of parking and accessibility, the absence of parking on one side of the road (65%) helps reduce congestion but may limit access for roadside services. Additionally, there are no service roads present within the campus area, which could negatively impact traffic flow and safety during emergencies. Fortunately, all sections provide adequate sight distance, which is crucial for drivers and riders awareness and reaction time.

Table 4.2
Mid-Block Attributes

Carriageway label	km	%
Undivided road	7.4	100
Median type	km	%
Centreline	3.8	51
One way	2.7	36
Wide centreline (0.3 m to 1.0 m)	0.7	9
Physical median width > = 1.0 m to < 5.0 m	0.1	1
Flexible posts	0.1	1
Centreline rumble stripes	km	%
Not present	7.4	100
Number of lanes	km	%
One	6.9	93
Two	0.5	7
Lane width	km	%
Medium (> = 2.75 m to < 3.25 m)	7.4	100

Curvature	km	%
Moderate	4.5	61
Straight or gently curving	2.8	38
Sharp	0.1	1
Quality of curve	km	%
Poor	4.6	62
Not applicable	2.8	38
Grade	km	%
> = 0% to < 7.5%	6.0	81
> = 7.5% to < 10%	1.3	18
> = 10%	0.1	1
Road condition	km	%
Good	5.9	80
Poor	1.5	20
Skid resistance/grip	km	%
Sealed – adequate	5.9	80
Sealed - medium	1.5	20
Delineation	km	%
Poor	7.4	100
Street lighting	km	%
Present	7.3	99
Not present	0.1	1
Vehicle parking	km	%
None	4.8	65
One side	2.3	31
Two sides	0.3	4
Service road	km	%
Not present	7.4	100
Sight distance	km	%
Adequate	7.4	100

In conclusion, while the road exhibits several positive attributes—including good road condition, adequate sight distance, and reasonable lane widths—there are notable concerns regarding its undivided nature, poor delineation, and limited safety features such as medians. These factors could contribute to higher accident rates, particularly in high-speed conditions or adverse weather. Therefore, to enhance safety on this roadway, it is recommended that stakeholders improve delineation to enhance visibility; introduce physical barriers where feasible to separate opposing traffic flows; consider additional safety features to protect vulnerable road users; and evaluate options for implementing service roads to improve traffic flow and access during emergencies. By addressing these concerns, stakeholders can significantly improve road safety and operational efficiency on this carriageway.

4.3.2 Roadside Attributes

The findings from the iRAP survey on roadside severity present critical insights into the safety conditions of the surveyed campus road. Table 4.3 reveals that a significant portion of the road, specifically 62% (4.6 km), has a driver side distance of less than 1.0 m from potential roadside hazards. This close proximity to objects poses a considerable risk, particularly since 32% of the roadside objects are trees with diameters greater than 10 cm, which can cause severe injuries in the event of a collision. Additionally, 24% of the roadside hazards include signs, posts, or poles of similar size, further emphasising the need for improved roadside safety measures.

On the passenger side, the situation is slightly better, with 53% (3.9 km) of the road also having less than 1.0 m from potential hazards. Here, signs, posts, or poles, and trees again, represent significant risks, accounting for 23% and 20%, respectively. The presence of unprotected safety barriers, slopes, and rigid structures adds to the potential dangers faced by both drivers and passengers (Figure 4.1).

Figure 4.1 Examples of Roadside Hazards, Such as Poles, Trees, and Roadside Distance Severity

Moreover, it is noteworthy that the surveyed road lacks shoulder rumble stripes entirely, which could help alert drivers and riders who veer too close to roadside hazards. The paved shoulders on both sides are classified as narrow (less than 1.0 m), which may not provide sufficient space for errant vehicles to recover safely.

Table 4.3
Roadside Attributes

Roadside severity – driver-side distance	km	%
0 to < 1.0 m	4.6	62
1.0 to < 5.0 m	2.8	38
Roadside severity – driver-side object	km	%
Tree > = 10 cm dia.	2.4	32
Sign, post or pole > = 10 cm dia.	1.8	24
Rigid structure/bridge or building	0.8	11
Upwards slope – rollover gradient	0.5	7
Large boulders > = 20 cm high	0.5	7
Upwards slope – no rollover gradient	0.4	5
None	0.4	5
Safety barrier – metal	0.2	3
Unprotected safety barrier end	0.2	3
Semi-rigid structure or building	0.1	1
Downwards slope	0.1	1
Roadside severity – passenger-side distance	km	%
0 to < 1.0 m	3.9	53
1.0 to < 5.0 m	3.5	47
Roadside severity – passenger-side object	km	%
Sign, post or pole > = 10 cm dia.	1.7	23
Tree > = 10 cm dia.	1.5	20
None	0.8	11
Unprotected safety barrier end	0.7	9
Safety barrier – metal	0.6	8
Rigid structure/bridge or building	0.5	7
Upwards slope – rollover gradient	0.4	5
Upwards slope – no rollover gradient	0.3	4
Large boulders > = 20 cm high	0.3	4
Semi-rigid structure or building	0.2	3
Deep drainage ditch	0.2	3
Downwards slope	0.2	3
Shoulder rumble stripes	km	%
Not present	7.4	100
Paved shoulder – driver-side	km	%
Narrow (> = 0 m to < 1.0 m)	7.4	100
Paved shoulder – passenger-side	km	%
Narrow (> = 0 m to < 1.0 m)	7.4	100

Overall, these findings underscore a concerning level of roadside severity on the campus road. The proximity of hazardous objects combined with inadequate shoulder width and lack of protective measures significantly heightens the risk of serious accidents. In order to mitigate these risks, it is essential to implement effective safety measures, such as increasing the distance between the roadway and hazardous objects and enhancing roadside delineation. Furthermore, introducing physical barriers or redesigning certain areas to improve safety can play a vital role in reducing collision severity and enhancing overall road safety for all users.

4.3.3 Intersections

The findings on intersection attributes on the campus road reveal significant safety concerns and highlight opportunities for improvement. Notably, a substantial portion of the roadway, specifically 85% (6.3 km), lacks any formal intersections, which can lead to high-speed travel without the necessary traffic control measures (Table 4.4). Among the few intersections that do exist, the majority are three-legged and not signalled, with only minimal provisions for protected turn lanes. This situation raises the potential for conflicts, particularly at these three-leg intersections where turning vehicles may not have adequate protection.

Figure 4.2 Intersection Conflict Points Near Dataran Cendekiawan

Furthermore, intersection channelisation is notably absent in 92% (6.8 km) of the surveyed road, which can exacerbate confusion and increase the likelihood of accidents at points where vehicles converge (Figure 4.2). The intersecting road volume is also concerning; 85% of the surveyed length has no intersecting traffic, while only a small fraction accommodates light traffic (1 to 100 vehicles). This lack of traffic control and channelisation can create unsafe conditions for both drivers and pedestrians alike.

Table 4.4
Intersections

Intersection type	km	%
None	6.3	85
3-leg (not signalled) with no protected turn lane	0.4	5
3-leg (not signalled) with protected turn lane	0.3	4
Roundabout	0.2	3
4-leg (not signalled) with no protected turn lane	0.1	1
Median crossing point – formal	0.1	1
Intersection channelisation	km	%
Not present	6.8	92
Present	0.6	8
Intersecting road volume	km	%
None	6.3	85
1 to 100 vehicles	1.1	15
Intersection quality	km	%
Not applicable	6.3	85
Poor	1.0	14
Adequate	0.1	1
Property access point	km	%
Commercial access	6.4	86
Residential access	1.0	14

In terms of intersection quality, 14% of the surveyed length is rated as poor, suggesting that these areas may not provide adequate visibility or safety features necessary for safe navigation. The presence of commercial access points (86%) further complicates the situation, as they introduce more conflict points where vehicles enter and exit the roadway.

Overall, these findings emphasise key areas for intervention to enhance safety at intersections on the campus road. Implementing measures such as improved intersection design, including signalling where appropriate and channelling to direct traffic flow more effectively, could significantly reduce collision risk. Additionally, enhancing visibility through better signage and lighting is essential. Considering the introduction of roundabouts or other traffic-calming measures may further improve safety by reducing vehicle speeds and minimising conflict points. Addressing these issues proactively, stakeholders can create a safer environment for all road users on campus, ultimately fostering a community that prioritises safety and accessibility for everyone.

4.3.4 Vulnerable Road User (VRU) Features

The findings towards vulnerable road user (VRU) facilities on the inspected campus road highlight significant deficiencies that pose safety risks for pedestrians and other non-motorised users (Table 4.5). Notably, a substantial 81% of the surveyed road (6.0 km) lacks any pedestrian crossing facilities, which can lead to unsafe conditions as pedestrians may attempt to cross without designated areas. Among the limited crossings available, 19% are not signalled and lack refuges, while 16% of the crossings are rated as poor in quality, indicating inadequate safety features for pedestrians.

Furthermore, the data reveals that all intersecting roads (7.4 km) also lack pedestrian crossing facilities, further exacerbating the challenges faced by pedestrians navigating the campus. Additionally, pedestrian fencing is absent in 97% of the surveyed area, which could otherwise help guide pedestrians safely and prevent them from straying into traffic.

Table 4.5
Vulnerable Road User (VRU) Features

Pedestrian crossing facilities – inspected road	km	%
No facility	6.0	81
Not signalled marked crossing without a refuge	1.4	19
Pedestrian crossing quality	km	%
Not applicable	6.0	81
Poor	1.2	16
Adequate	0.2	3
Pedestrian crossing facilities – intersecting road	km	%
No facility	7.4	100
Pedestrian fencing	km	%
Not present	7.2	97
Present	0.2	3
Sidewalk – driver-side	km	%
Non-physical separation 0 m to < 1.0 m	3.8	51
None	3.5	47
Non-physical separation 1.0 m to < 3.0 m	0.1	1
Sidewalk – passenger-side	km	%
None	4.2	57
Non-physical separation 0 m to < 1.0 m	3.0	41
Informal path 0 m to < 1.0 m	0.2	3
Facilities for motorised two-wheelers	km	%
None	7.4	100
Facilities for bicycles	km	%
None	7.4	100

The findings on sidewalks indicate that nearly half (51%) of the driver-side sidewalks have non-physical separation of less than 1.0 m from traffic, while 47% have no sidewalk at all. On the passenger side, a significant 57% of the road lacks any sidewalk, and even those with non-physical separation do not provide adequate protection for users. Moreover, there are no facilities for motorised two-wheelers or bicycles along the entire length of the surveyed road.

The identified deficiencies suggest an increased level of risk for pedestrians. However, higher-order facilities such as signalised crossings or pedestrian refuges should be implemented selectively, focusing on locations with clear pedestrian demand to ensure their effectiveness and efficient use of resources. In situations where detailed pedestrian volume data is unavailable, a practical first step is to introduce basic, cost-effective measures. These include marked unsignalised crossings, improved sidewalk continuity and surface quality, and simple traffic-calming interventions. Such measures can substantially reduce risk in areas where pedestrian activity is already present or can be reasonably expected based on campus land use.

At the same time, regular monitoring of pedestrian volumes is important to guide future upgrades. A data-driven approach allows for more targeted investment in advanced facilities as demand becomes clearer, ensuring that improvements remain responsive to actual usage patterns. Overall, the absence of safe crossing points, inconsistent sidewalk provision, and limited protective infrastructure highlights the need for stronger support for vulnerable road users on the campus road. Addressing these issues through a phased approach starting with essential improvements and progressing towards more comprehensive facilities can significantly enhance both safety and accessibility. This approach aligns with Safe System principles and supports the development of a safer and more inclusive campus environment.

4.3.5 Speeds

The findings regarding speed limits and speed management on the surveyed campus road reveal important insights into traffic control measures and their implications for safety (Table 4.6). Notably, the speed limit for both general traffic and motorcyclists is set at less than 30 km/hr across the entire line of the road (7.4 km). This low-speed limit is beneficial for enhancing safety, particularly in areas with high pedestrian activity, as it allows for reduced stopping distances and greater reaction time for drivers.

However, the data also indicates that speed management and traffic calming measures are not uniformly implemented along the road. Specifically, 54% (4.0 km) of the surveyed area lacks any speed management features, which may lead to inconsistent adherence to the speed limit and potentially unsafe driving behaviour. In contrast, 46% (3.4 km) of the roadway does incorporate some form of speed management or traffic calming measures, which can effectively encourage compliance with the posted speed limit and enhance overall safety.

The presence of traffic calming measures, such as speed bumps, chicanes, or raised crosswalks, is crucial in areas where vulnerable road users are prevalent. These measures can help reduce vehicle speeds and create a safer environment for pedestrians and cyclists. However, the significant portion of the road without such features raises concerns about the potential for speeding and related accidents.

In conclusion, while the implementation of a low-speed limit is a positive aspect of the campus road's design, the lack of comprehensive speed management measures in over half of its length presents a significant opportunity for improvement. To enhance safety further, it is recommended that stakeholders prioritise the introduction of effective traffic calming strategies throughout the entire roadway. By doing so, they can promote safer driving behaviours, reduce vehicle speeds, and ultimately create a more secure environment for all road users on campus.

Table 4.6
Speeds

Speed limit	km	%
< 30 km/hr	7.4	100
Motorcyclist speed limit	km	%
< 30 km/hr	7.4	100
Speed management/traffic calming	km	%
Not present	4.0	54
Present	3.4	46

The data collected through this rigorous methodology is vital for analysis, leading to the generation of star ratings that indicate the safety level of each road segment. These ratings range from 1-star (high risk) to 5-star (low risk). The star rating system provides an objective measure of road safety levels for various users, including car occupants, motorcyclists, pedestrians, and cyclists. A 1-star rating signifies a very unsafe road condition, while a 5-star rating indicates a highly safe environment.

Furthermore, this robust methodology facilitates further analysis that leads to the creation of recommendation plans prioritising interventions based on road accidents data. By utilising the insights gained from the assessments, stakeholders can implement targeted measures to improve road safety effectively.

4.4 iRAP Star Ratings

4.4.1 Baseline

4.4.1.1 Speed Limit

The smoothed star rating table for various road users on the campus road indicates a uniformly high level of safety (Table 4.7), with all categories, car occupants, motorcyclists, pedestrians, and cyclists, receiving a 5-star rating across the entire surveyed length (7.4 km). This 5-star rating signifies that, under conditions where all road users comply with the posted speed limit of 25 km/hr, the road is considered to provide a low risk of accidents for all types of users.

The fact that every user group is rated equally at 5 stars suggests that the road design and associated features effectively support safe travel for everyone. This includes not only motor vehicle occupants but also vulnerable road users such as pedestrians and cyclists. The high star rating reflects several positive attributes of the roadway, including appropriate speed limits, adequate visibility, and likely the presence of essential safety features such as crosswalks and traffic calming measures.

Table 4.7
Baseline (Speed Limit): Smoothed Star Ratings

	Car occupant		Motorcyclist		Pedestrian		Cyclist	
Star ratings	Length (km)	%	Length (km)	%	Length (km)	%	Length (km)	%
5-star	7.4	100	7.4	100	7.4	100	7.4	100
4-star								
3-star								
2-star								
1-star								
Total	7.4	100	7.4	100	7.4	100	7.4	100

However, it is essential to acknowledge that these ideal conditions are contingent upon compliance with the speed limit. If drivers exceed this limit, the safety ratings could potentially decrease significantly due to increased stopping distances and reduced reaction times. Therefore, while the current ratings are promising, they underscore the importance of ongoing education and enforcement efforts to ensure that all road users adhere to the speed limit.

The findings also highlight an encouraging scenario where compliance with speed limits results in optimal safety ratings for all road users on campus. To maintain these high standards of safety, it is crucial for stakeholders to implement continuous monitoring and promote awareness campaigns that emphasise the importance of adhering to speed limits. Additionally, further enhancements to infrastructure, such as improved signage and traffic-calming measures, can help sustain these favourable conditions and ensure a safe environment for all campus road users.

Contradictory, the raw star rating table for various road users on the campus road provides a detailed assessment of safety levels when all users comply with the posted speed limit of 25 km/hr (Table 4.8). The data reveals that a substantial portion of the roadway is rated as 5 stars across all user categories, indicating a low risk of accidents under these conditions. Specifically, car occupants receive a 5-star rating over 6.9 km (93.2%), motorcyclists over 6.5 km (87.8%), pedestrians over 7.0 km (94.6%), and cyclists over 7.3 km (98.7%). This high percentage of 5-star ratings suggests that the road is generally well designed to accommodate safe travel for all types of users.

However, there are notable percentages of lower star ratings in the raw data, particularly in the 4-star category, where car occupants account for 6.8% (0.5 km), motorcyclists for 10.8% (0.8 km), pedestrians for 5.4% (0.4 km), and cyclists for only 1.4% (0.1 km). Additionally, a small portion of the roadway is rated as 3-star for motorcyclists (1.4%). These lower ratings indicate that while the majority of the road performs well under ideal conditions, there are specific segments that may require attention to improve safety further.

Table 4.8
Baseline (Speed Limit): Raw Star Ratings

	Car occupant		Motorcyclist		Pedestrian		Cyclist	
Star ratings	Length (km)	%	Length (km)	%	Length (km)	%	Length (km)	%
5-star	6.9	93.2	6.5	87.8	7.0	94.6	7.3	98.7
4-star	0.5	6.8	0.8	10.8	0.4	5.4	0.1	1.4
3-star			0.1	1.4				
2-star								
1-star								
Total	7.4	100	7.4	100	7.4	100	7.4	100

When comparing these raw star ratings with the previously discussed smoothed star ratings, where all user groups received a uniform 5-star rating, the differences highlight the impact of compliance and road conditions on safety perceptions. The smoothed ratings assume optimal conditions across the entire length of the road, suggesting that when users adhere strictly to speed limits, safety risks are minimised effectively.

In contrast, the raw ratings reveal that there are still road segments where improvements can be made to enhance safety for all users, particularly in areas where lower star ratings are observed. For instance, addressing factors contributing to the 4-star and 3-star ratings, such as improving signage, enhancing visibility, or implementing additional traffic calming measures, could help elevate these segments to a full 5-star rating.

To simplify, while both the smoothed and raw star ratings indicate that compliance with speed limits results in favourable safety conditions on campus roads, the raw ratings reveal specific areas that required targeted interventions to ensure consistent safety across all segments. By focusing on improving those sections with lower star ratings, stakeholders can work towards achieving an overall safer environment for all road users, thereby maintaining high standards of safety and encouraging adherence to speed limits throughout the campus area.

The following figure presents a visual representation of the 3-star road rating for motorcyclists at Jalan Pintar 1/21A, UiTM Shah Alam, specifically at the location known as Bukit Tonggek (Figure 4.3).

Figure 4.3 3-Star Rated Road for Motorcyclist at Jalan Pintar 1/21A

For better illustration, the accompanying figure presents a comparative analysis of smoothed and raw star ratings for various road users, car occupants, motorcyclists, pedestrians, and cyclists, on the campus road (Figure 4.4).

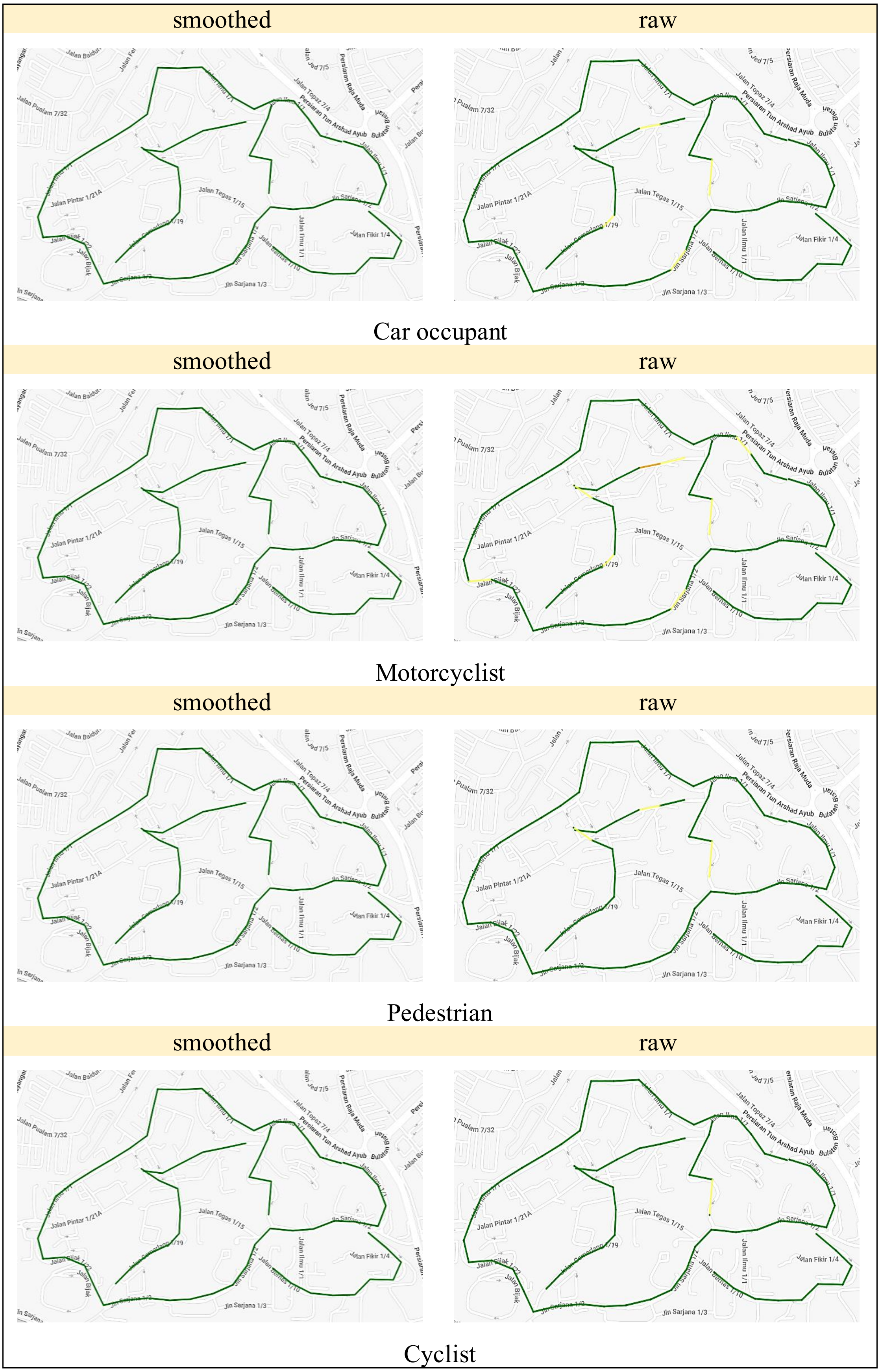


Figure 4.4 Star Rating Maps by Road User Type

The study now broadens its findings to identify key areas that require attention based on the distribution of smoothed and raw star ratings by road section and user type. The analysis of smoothed star ratings indicates a consistent level of safety across various segments of the campus road. Notably, all assessed sections, including Akademi Kepolisan (Padang Kawad) to Kolej Mawar Exit Junction, Bukit Tonggek to Kolej Mawar Exit Junction, Jalan Utama UiTM, Kawasan Central UiTM, and Kawasan Pembangunan UiTM, achieved a 100% rating in the 5-star category for all road users, indicating optimal safety conditions (Table 4.9).

However, the distribution of raw star ratings reveals important insights into specific safety conditions across these segments (Table 4.10). For instance, in the Akademi Kepolisan (Padang Kawad) to Kolej Mawar Exit Junction section, car occupants, motorcyclists, and pedestrians received ratings ranging from 4 to 5 stars, indicating a generally high level of safety; notably, only cyclists achieved a perfect 5-star rating in this segment. This disparity suggests that while the road conditions are favourable for most users, there remain opportunities for improvement specifically aimed at enhancing safety for car occupants, motorcyclists, and pedestrians. Meanwhile, at Bukit Tonggek to Kolej Mawar Exit Junction, car occupants and pedestrians also received ratings ranging from 4 to 5 stars; however, motorcyclists received a 16.7% rating in the 3-star category while the remainder achieved 4 to 5 stars. This indicates a moderate level of safety but highlights the need for targeted improvement for motorcyclists. Similarly, only cyclists achieved a perfect 5-star rating in this road section.

In the Jalan Utama UiTM section, both car occupants and motorcyclists received ratings ranging from 4 to 5 stars, while pedestrians and cyclists achieved perfect 5-star ratings. This indicates a generally high level of safety for most road users; however, there is still room for improvement for car occupants and motorcyclists. In contrast, the Kawasan Central UiTM section stands out as all user categories achieved 5-star ratings, reflecting optimal safety conditions across the board. Meanwhile, the Kawasan Pembangunan UiTM section presents a mix of 4-to-5-star ratings for all road users, suggesting that while safety is generally good, there are specific areas that could benefit from enhancements to further improve user safety.

Table 4.9
Baseline (Speed Limit): Distribution of Smoothed Star Ratings by Road Section and Road User Type

		Car occupant			Motorcyclist			Pedestrian			Cyclist		
		Proportion in each star rating											
Road section	Length (km)	3-star (%)	4-star (%)	5-star (%)	3-star (%)	4-star (%)	5-star (%)	3-star (%)	4-star (%)	5-star (%)	3-star (%)	4-star (%)	5-star (%)
Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction	0.9			100			100			100			100
Bukit Tonggek – Kolej Mawar Exit Junction	0.6			100			100			100			100
Jalan Utama UiTM	4.3			100			100			100			100
Kawasan Central UiTM	1.0			100			100			100			100
Kawasan Pembangunan UiTM	0.6			100			100			100			100

Table 4.10

Baseline (Speed Limit): Distribution of Raw Star Ratings by Road Section and Road User Type

		Car occupant			Motorcyclist			Pedestrian			Cyclist		
		Proportion in each star rating											
Road section	Length (km)	3-star (%)	4-star (%)	5-star (%)	3-star (%)	4-star (%)	5-star (%)	3-star (%)	4-star (%)	5-star (%)	3-star (%)	4-star (%)	5-star (%)
Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction	0.9		11.1	88.9		22.2	77.8		11.1	88.9			100
Bukit Tonggek – Kolej Mawar Exit Junction	0.6		16.7	83.3	16.7	16.7	66.7		16.7	83.3			100
Jalan Utama UiTM	4.3		2.3	97.7		7	93			100			100
Kawasan Central UiTM	1.0			100			100			100			100
Kawasan Pembangunan UiTM	0.6		33.3	66.7		33.3	66.7		33.3	66.7		16.7	83.3

4.4.1.2 Operating Speed

Table 4.11 is the smoothed star rating table that comprehensively assesses road safety levels for various user categories by presenting star rating bands. For car occupants, most roads received a 4-star rating (74.3%), with only 25.7% achieving a 5-star rating, indicating that while conditions are generally safe, there remains room for improvement. In contrast, motorcyclists faced a more concerning situation, as no roads were rated as 5-star and nearly half (44.6%) were rated as 3-star, suggesting higher risk levels due to less optimal road conditions. Pedestrians also experienced vulnerabilities, with only 13.5% of roads rated as 5-star and the majority at 4-star, highlighting the need for better infrastructure to enhance pedestrian safety. Cyclists shared similar challenges, facing low percentages of 5-star roads (12.2%) and a significant portion rated as 3-star (31.1%). The data underscores the importance of addressing safety for these vulnerable user groups, which pose exacerbated risks if not managed effectively.

Table 4.11
Baseline (Operating Speed): Smoothed Star Ratings

	Car occupant		Motorcyclist		Pedestrian		Cyclist	
Star ratings	Length (km)	%	Length (km)	%	Length (km)	%	Length (km)	%
5-star	1.9	25.7			1.0	13.5	0.9	12.2
4-star	5.5	74.3	4.1	55.4	6.4	86.5	4.2	56.8
3-star			3.3	44.6			2.3	31.1
2-star								
1-star								
Total	7.4	100	7.4	100	7.4	100	7.4	100

Table 4.12 presents a detailed assessment of road safety across four user categories. For car occupants, 35.1% of the roads were rated as 5-star, indicating a relatively safe environment, while 48.7% received a 4-star rating. However, the presence of 16.2% of 7.4 km rated as 3-star suggests that some areas still pose risks. Motorcyclists faced more challenging conditions, with only 21.6% of roads rated as 5-star, 31.1% rated as 4-star, and a significant 44.6% rated as 3-star, indicating a higher likelihood of accidents due to less favourable road conditions. The small percentage (2.7%) of 7.4 km rated as 2-star further highlights the urgent need for improvements in motorcyclist infrastructure.

Table 4.12
Baseline (Operating Speed): Raw Star Ratings

	Car occupant		Motorcyclist		Pedestrian		Cyclist	
Star ratings	Length (km)	%	Length (km)	%	Length (km)	%	Length (km)	%
5-star	2.6	35.1	1.6	21.6	1.4	18.9	2.8	37.8
4-star	3.6	48.7	2.3	31.1	4.5	60.8	2.1	28.4
3-star	1.2	16.2	3.3	44.6	1.5	20.3	2.5	33.8
2-star			0.2	2.7				
1-star								
Total	7.4	100	7.4	100	7.4	100	7.4	100

Pedestrians also encountered vulnerabilities, with only 18.9% of roads rated as 5-star and the majority (60.8%) rated as 4-star. Cyclists fared slightly better, with the highest percentage of roads rated as 5-star (37.8%) and a substantial portion (33.8%) rated as 3-star.

Overall, the data revealed varying levels of safety experienced by different road users, particularly concerning operating speeds. Higher speeds on lower-rated roads exacerbate risks for all categories. However, given the significant proportion of motorcyclists on roads rated as 2-star and the high percentage of those rated as 3-star, it is evident that motorcyclists' safety requires attention, as well as pedestrians and cyclists; the notably low ratings suggest an urgent need to enhance road designs and infrastructure for these vulnerable groups. For a better illustration of Tables 4.11 and 4.12, the accompanying figures present a comparative analysis of the smoothed and raw star ratings for various road users (Figures 4.5 to 4.8).

1) Car occupant

smoothed raw

Figure 4.5 Baseline (Operating Speed): Star Rating Maps for Car Occupant

The study expanded its findings to highlight critical areas that necessitate attention, focusing on distributing smoothed and raw star ratings by road section for car occupants. According to Table 4.13, the road segment of Akademi Kepolisan (Padang Kawad) to Kolej Mawar Exit Junction, which spans 0.9 km, received a 5-star rating, indicating excellent conditions. Similarly, the segment from Kawasan Central UiTM, at 1.0 km, also achieved a 5-star rating. In contrast, the segment from Bukit Tonggek to Kolej Mawar Exit Junction, which spans 0.6 km, was rated 4 stars, as were both the Jalan Utama UiTM and Kawasan Pembangunan UiTM segments, measuring 4.3 km and 0.6 km, respectively.

Table 4.13
Baseline (Operating Speed): Distribution of Smoothed Star Ratings by Road Section for Car Occupant

Road section	Length (km)	Proportion in each star rating				
		1-star (%)	2-star (%)	3-star (%)	4-star (%)	5-star (%)
Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction	0.9					100
Bukit Tonggek – Kolej Mawar Exit Junction	0.6				100	
Jalan Utama UiTM	4.3				100	
Kawasan Central UiTM	1.0					100
Kawasan Pembangunan UiTM	0.6				100	

In total, there were three road sections rated with 4 stars and two road sections rated with 5 stars. This resulted in a proportion of approximately 26% for the 5-star ratings and 74% for the 4-star ratings across all assessed segments. The findings indicated that while a significant portion of the road sections met high-quality standards, there is still room for improvement in some areas to enhance overall road safety and performance.

Table 4.14 presents the distribution of raw star ratings. It offers valuable insights through a more detailed analysis, as the star ratings were generated from a scoring system calculated for each 100 m segment of the road. These ratings serve as essential indicators of safety and quality for car occupants, providing information to authorities investigating appropriate initiatives for road improvement. The road section connecting Akademi Kepolisan (Padang Kawad) to Kolej Mawar Exit Junction, spanning 0.9 km, was distinguished by a remarkable 5-star rating (77.8%) reflecting the road's excellent conditions every 100 m, ensuring a safe and comfortable experience. In contrast, the segment from Bukit Tonggek to Kolej Mawar Exit Junction, measuring 0.6 km, displayed a more diverse distribution of ratings: 50% rated as 5-star, 16.7% as 4-star, and 33.3% as 3-star. This variation suggests that while a considerable portion of this road segment is in good condition, certain areas require enhancements to improve overall safety.

Table 4.14
Baseline (Operating Speed): Distribution of Raw Star Ratings by Road Section for Car Occupant

Road section	Length (km)	Proportion in each star rating				
		1-star (%)	2-star (%)	3-star (%)	4-star (%)	5-star (%)
Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction	0.9				22.2	77.8
Bukit Tonggek – Kolej Mawar Exit Junction	0.6			33.3	16.7	50
Jalan Utama UiTM	4.3			23.3	55.8	20.9
Kawasan Central UiTM	1.0				60	40
Kawasan Pembangunan UiTM	0.6				50	50

The Jalan Utama UiTM segment, which extends over 4.3 km, shows a different profile, with only 20.9% achieving a 5-star rating. Most of this segment was rated as 4-star at 55.8%, with the remaining 23.3% rated as 3-star. This distribution indicates that, although the road is generally acceptable, there are significant concerns regarding its safety features that need addressing. Conversely, both the segment from Kawasan Central UiTM, at 1.0 km, and the segment from Kawasan Pembangunan UiTM, measuring 0.6 km, exhibited a more balanced distribution of ratings. The former shows a rating of 60% as a 4-star and 40% as a 5-star, while the latter reflects an equal split of 50% for both ratings.

Overall, the analysis highlighted that while several road segments achieved high ratings, indicative of good safety conditions, others revealed specific areas that necessitate attention to enhance overall road safety for car occupants. This comprehensive assessment underscores the importance of ongoing evaluations and improvements in road infrastructure to ensure user safety and comfort on the roads.

Table 4.15 provides a detailed illustration of 3-star rated roads for car occupants, shedding light on their typical characteristics and conditions. These roads are primarily undivided and accommodate operating speeds ranging from 40 to 45 km/hr, despite being subject to a speed limit of 25 km/hr. This discrepancy highlights a potential safety concern, as the actual driving conditions encourage higher speeds than recommended. The delineation on these roads is often inadequate, which complicates navigation and increases the risk of accidents.

Moreover, the overall condition of these roads is generally subpar, with inadequate skid resistance identified as a significant hazard, particularly during wet weather conditions. This evaluation of skid resistance utilised visual coding according to iRAP categories, grounded in RADIS and ViDA video footage, which methodically assessed surface texture and grip as essential safety features. The roads' geometry features moderate curves; however, their quality is often poor, causing difficulties in manoeuvrability for road users. Certain segments, such as those at Bukit Tonggek, include steep rises that further challenge vehicle handling. Although a centreline is present, its effectiveness in enhancing safety is limited without accompanying traffic calming measures. Additionally, vehicle parking along roadsides, specifically from Bukit Tonggek to Kolej Mawar Exit Junction, obstructs traffic flow and reduces visibility, further compromising road safety. This comprehensive evaluation, including skid resistance, directly informs the recommendations for targeted interventions under the iRAP framework.

Table 4.15
3-Star Rated Roads for Car Occupant

Road name / road section	Location	Typical characteristics
Jalan Pintar 1/21A Bukit Tonggek – Kolej Mawar Exit Junction		• Undivided road • Operating speed 40 to 45 km/hr • Speed limit 25 km/hr • Poor delineation • Poor road condition • Poor skid resistance • Moderate curvature • Poor curve quality
Jalan Ilmu 1/1 Jalan Utama UiTM		

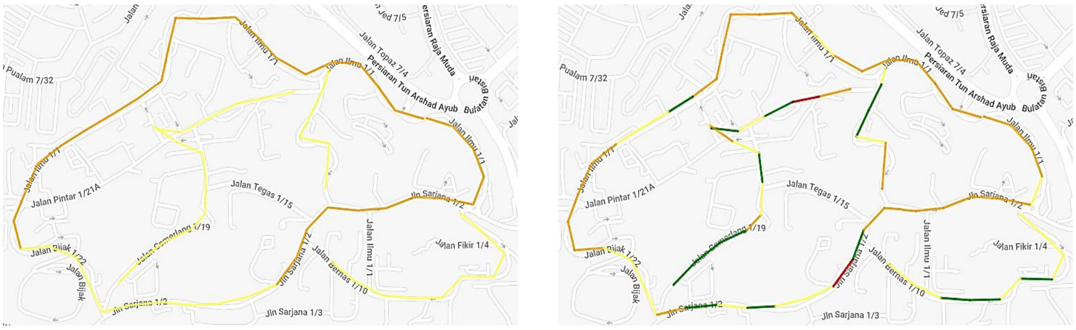
- Steep rise
- Centreline
- No traffic calming
- Vehicle parking along the side of the road
- Property access points
- Objects with distances of less than 1.0 m from the edge line
- Poor intersection quality
- No street lighting

Jalan Sarjana 1/2

Jalan Utama UiTM

To add more, access points to properties disrupt the smooth flow of traffic, and objects located less than 1.0 m from the edge line create further hazards for drivers. The quality of intersections on these roads is generally poor, contributing to confusion and potential accidents. Lastly, the absence of street lighting on Jalan Utama UiTM, specifically near Dewan Agong Tuanku Censelor (DATC) road, exacerbates safety concerns, particularly during nighttime driving. Collectively, these characteristics underline the urgent need for improvements to enhance safety and usability for car occupants navigating these 3-star-rated roads.

2) Motorcyclist



smoothed raw

Figure 4.6 Baseline (Operating Speed): Star Rating Maps for Motorcyclist

For a better illustration of Tables 4.16 and 4.17, Figure 4.6 presents a comparative analysis of smoothed and raw star rating maps for motorcyclists on the campus road. The analysis of road sections relevant to motorcyclists on campus revealed important insights into their star ratings and safety conditions (Table 4.16). The segment from Akademi Kepolisan (Padang Kawad) to Kolej Mawar Exit Junction, measuring 0.9 km, received a 4-star rating, indicating a high level of safety and quality. Similarly, the segment from Bukit Tonggek to Kolej Mawar Exit Junction, spanning 0.6 km, also achieved a 4-star rating. In contrast, the Jalan Utama UiTM segment, which extends over 4.3 km, presented a mixed profile with 76.7% rated as 3-star and only 23.3% rated as 4-star. This suggests that while parts of this road are acceptable, significant areas pose risks for motorcyclists.

Table 4.16
Baseline (Operating Speed): Distribution of Smoothed Star Ratings by Road Section for Motorcyclist

Road section	Length (km)	Proportion in each star rating				
		1-star (%)	2-star (%)	3-star (%)	4-star (%)	5-star (%)
Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction	0.9				100	
Bukit Tonggek – Kolej Mawar Exit Junction	0.6				100	
Jalan Utama UiTM	4.3			76.7	23.3	
Kawasan Central UiTM	1.0				100	
Kawasan Pembangunan UiTM	0.6				100	

Furthermore, both the Kawasan Central UiTM and Kawasan Pembangunan UiTM segments, measuring 1.0 km and 0.6 km, respectively, were rated entirely at 4-star, reflecting good conditions for motorcyclists. Overall, the distribution of star ratings across these road sections highlights that while several routes provided safe travel for motorcyclists, the presence of lower-rated segments indicated specific areas requiring improvement to enhance overall safety and usability on campus roads.

Table 4.17 shows the distribution of raw star ratings for various road sections relevant to motorcyclists on campus and offers significant insight into their safety and usability. The segment from Akademi Kepolisan (Padang Kawad) to Kolej Mawar Exit Junction, which spans 0.9 km, exhibited a commendable distribution with 44.4% rated as 5-star, 33.3% as 4-star, and 22.2% as 3-star. This indicates that the majority of this road is in excellent condition, offering a safe environment for motorcyclists. Similarly, the segment from Bukit Tonggek to Kolej Mawar Exit Junction, measuring 0.6 km, also showed a strong performance with 50% rated as 5-star and a balanced distribution among the lower ratings, suggesting overall good conditions.

Table 4.17
Baseline (Operating Speed): Distribution of Raw Star Ratings by Road Section for Motorcyclist

Road section	Length (km)	Proportion in each star rating				
		1-star (%)	2-star (%)	3-star (%)	4-star (%)	5-star (%)
Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction	0.9			22.2	33.3	44.4
Bukit Tonggek – Kolej Mawar Exit Junction	0.6		16.7	16.7	16.7	50
Jalan Utama UiTM	4.3		2.3	65.1	23.3	9.3
Kawasan Central UiTM	1.0				70	30
Kawasan Pembangunan UiTM	0.6			33.3	33.3	33.3

In contrast, the Jalan Utama UiTM segment, extending over 4.3 km, presents a more concerning profile with only 9.3% rated as 5-star, while the majority, at 65.1%, was rated 3-star and a small percentage at 2.3% as 2-star. This significant proportion of lower ratings highlighted potential safety issues that could affect motorcyclists navigating this route. Meanwhile, the segments from Kawasan Central UiTM and Kawasan Pembangunan UiTM, measuring 1.0 km and 0.6 km, respectively, demonstrated a favourable rating distribution, with the former achieving a rating of 70% as a 4-star and the latter showing an equal split among all three ratings, at 33.3% each for 3-star, 4-star, and 5-star. Overall, the analysis revealed that while many road sections provided safe conditions for motorcyclists, particularly those rated higher, there were notable areas, especially along Jalan Utama UiTM, that required attention to improve safety and usability for all users on campus roads.

Table 4.18 provides a comprehensive overview of the 2-star rated roads for motorcyclists, emphasising their typical characteristics and conditions. These roads are primarily undivided and allow for an operating speed of 40 km/hr, although they are governed by a much lower speed limit of 25 km/hr, highlighting a significant disparity between actual driving conditions and regulatory standards. The poor delineation on these roads complicates navigation, thereby increasing safety risks for riders. Furthermore, the overall condition of these roads is inadequate, with insufficient skid resistance posing hazards, especially during wet weather.

The roadway geometry typically features moderate curvature; however, the quality of these curves is often inadequate, which leads to difficulties in manoeuvrability for motorcycle riders. Certain segments, such as those at Bukit Tonggek, present steep rises that further challenge riders. Although a centreline is present, it contributes little to safety due to the lack of traffic calming measures. Additionally, vehicle parking along the sides of these roads obstructs traffic flow and visibility, particularly along the segment from Bukit Tonggek to Kolej Mawar Exit Junction.

Table 4.18
2-Star Rated Roads for Motorcyclist

Road name / road section	Location	Typical characteristics
Jalan Pintar 1/21A Bukit Tonggek – Kolej Mawar Exit Junction		• Undivided road • Operating speed 40 km/hr • Speed limit 25 km/hr • Poor delineation • Poor road condition • Poor skid resistance • Moderate curvature • Poor curve quality • Steep rise • Centreline
Jalan Sarjana 1/2 Jalan Utama UiTM		

	• No traffic calming • Vehicle parking along the side of the road • Property access points • Objects with distances of less than 1.0 m from the edge line • No street lighting • No specific provisions for motorised two-wheelers

Access points to properties frequently disrupt the smooth traffic flow, while objects positioned less than 1.0 m from the edge line create additional hazards for motorcyclists. The lack of street lighting on Jalan Utama UiTM, specifically near Dewan Agong Tuanku Censelor (DATC) road exacerbates safety concerns, particularly during nighttime riding. Moreover, there are no specific provisions for motorised two-wheelers, which further compromises the safety and usability of these roads for motorcyclists. Collectively, these characteristics underscore the urgent need for improvements to enhance safety and create a more accommodating environment for motorcyclists navigating these 2-star rated roads.

3) Pedestrian

smoothed raw

Figure 4.7 Baseline (Operating Speed): Star Rating Maps for Pedestrian

For a better illustration of Tables 4.19 and 4.20, Figure 4.7 presents a comparative analysis of smoothed and raw star rating maps for pedestrians on the campus road. The analysis of road sections relevant to pedestrians on campus revealed important insights into their star ratings and safety conditions (Table 4.19). The segment from Akademi Kepolisan (Padang Kawad) to Kolej Mawar Exit Junction, which measures 0.9 km, received a 4-star rating, indicating a high level of safety and comfort for pedestrians. Similarly, the segment from Bukit Tonggek to Kolej Mawar Exit Junction, spanning 0.6 km, also achieved a 4-star rating. The Jalan Utama UiTM segment, extending over 4.3 km, maintained a consistent quality with a full 4-star rating, suggesting that this route was well-suited for pedestrian use.

Table 4.19
Baseline (Operating Speed): Distribution of Smoothed Star Ratings by Road Section for Pedestrian

Road section	Length (km)	Proportion in each star rating				
		1-star (%)	2-star (%)	3-star (%)	4-star (%)	5-star (%)
Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction	0.9				100	
Bukit Tonggek – Kolej Mawar Exit Junction	0.6				100	
Jalan Utama UiTM	4.3				100	
Kawasan Central UiTM	1.0					100
Kawasan Pembangunan UiTM	0.6				100	

In contrast, the segment from Kawasan Central UiTM, measuring 1.0 km, stood out with an exceptional 5-star rating, indicating superior conditions for pedestrians in this area. The segment from Kawasan Pembangunan UiTM, at 0.6 km, was rated as 4-star, reflecting good conditions but slightly lower than that of the best-rated segment. Overall, the distribution of star ratings across these road sections highlighted a predominantly positive environment for pedestrians on campus, with the notable exception of one segment that provided outstanding conditions, thereby underscoring the importance of continued investment in pedestrian infrastructure to enhance safety and accessibility throughout the campus.

Table 4.20 shows the distribution of raw star ratings by road section for pedestrians on campus and reveals various conditions that significantly influenced safety and usability. The segment from Akademi Kepolisan (Padang Kawad) to Kolej Mawar Exit Junction, measuring 0.9 km, exhibits strong performance with 55.6% rated as 5-star and 44.4% as 4-star, indicating that this route provided a high level of safety and comfort for pedestrians. Similarly, the segment from Bukit Tonggek to Kolej Mawar Exit Junction, spanning 0.6 km, demonstrates an equal distribution among ratings, with 33.3% assigned to each of the 3-star, 4-star, and 5-star categories, suggesting a mixed quality that requires targeted improvements in certain areas.

Table 4.20
Baseline (Operating Speed): Distribution of Raw Star Ratings by Road Section for Pedestrian

Road section	Length (km)	Proportion in each star rating				
		1-star (%)	2-star (%)	3-star (%)	4-star (%)	5-star (%)
Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction	0.9				44.4	55.6
Bukit Tonggek – Kolej Mawar Exit Junction	0.6			33.3	33.3	33.3
Jalan Utama UiTM	4.3			27.9	72.1	
Kawasan Central UiTM	1.0				50	50
Kawasan Pembangunan UiTM	0.6			16.7	50	33.3

In contrast, the Jalan Utama UiTM segment, which extends over 4.3 km, was predominantly rated as 4-star at 72.1%, with a smaller percentage rated as 3-star at 27.9%, indicating generally acceptable conditions for pedestrian use but highlighting specific areas that need attention. The segment from Kawasan Central UiTM, measuring 1.0 km, achieved a balanced rating of 50% for both 4-star and 5-star categories, showcasing excellent conditions for pedestrians in this area. Lastly, the 0.6 km segment from Kawasan Pembangunan UiTM had a wide range of ratings: 16.7% rated as 3-star, 50% as 4-star, and 33.3% as 5-star, reflecting a need for ongoing monitoring and potential enhancements.

Overall, this analysis highlighted that while many road sections provided safe and comfortable environments for pedestrians, there are also areas needing improvements to ensure consistent safety and accessibility across the campus. These findings emphasise the importance of ongoing assessments and infrastructure enhancements to effectively support pedestrian safety and usability.

Table 4.21, detailing sidewalk facilities by road section, provides a comprehensive overview of the pedestrian infrastructure along specific routes on campus. For the segment from Bukit Tonggek to Kolej Mawar Exit Junction, which spans 0.6 km, the data reveals that 50% of the driver-side sidewalks feature non-physical separation within a distance of 0 m to less than 1.0 m (0.3 km), while the remaining 50% lack any sidewalk provision. On the passenger side, only 17% of the sidewalk is characterised by non-physical separation, with a significant 83% having no sidewalk at all.

In the Jalan Utama UiTM segment, extending over 4.3 km, the driver-side sidewalks present a more complex situation: just 2% have non-physical separation within the range of 1.0 m to less than 3.0 m, while a substantial 51% fall within the 0 m to less than 1.0 m category, and 47% have no sidewalk. The passenger-side sidewalks indicate that 58% are characterised by non-physical separation within 0 m to less than 1.0 m, while 37% lack sidewalks entirely, and an informal path accounts for 5%.

Lastly, in the segment from Kawasan Pembangunan UiTM, measuring 0.6 km, both driver-side and passenger-side sidewalks exhibit similar conditions, with 83% having no sidewalk and only 17% featuring non-physical separation within the 0 m to less than 1.0 m range.

Overall, this table underscores significant deficiencies in pedestrian infrastructure across these road sections, particularly regarding the presence and quality of sidewalks. The lack of adequate pedestrian infrastructures, especially in high-traffic areas, highlights the urgent need for improvements to enhance safety and accessibility for pedestrians on campus. Addressing these gaps contributes to fostering a more pedestrian-friendly environment that supports safe navigation throughout the campus.

Table 4.21
Sidewalk Facilities by Road Section Rated 3-Star

Road section	Bukit Tonggek – Kolej Mawar Exit Junction (0.6 km)	
Sidewalk – driver-side	km	%
Non-physical separation 0 m to < 1.0 m	0.3	50
None	0.3	50
Sidewalk – passenger-side	km	%
Non-physical separation 0 m to < 1.0 m	0.1	17
None	0.5	83
Road section	Jalan Utama UiTM (4.3 km)	
Sidewalk – driver-side	km	%
Non-physical separation 1.0 m to < 3.0 m	0.1	2
Non-physical separation 0 m to < 1.0 m	2.2	51
None	2.0	47
Sidewalk – passenger-side	km	%
Non-physical separation 0 m to < 1.0 m	2.5	58

None	1.6	37
Informal path 0 m to < 1.0 m	0.2	5
Road section	Kawasan Pembangunan UiTM (0.6 km)	
Sidewalk – driver-side	km	%
Non-physical separation 0 m to < 1.0 m	0.1	17
None	0.5	83
Sidewalk – passenger-side	km	%
Non-physical separation 0 m to < 1.0 m	0.1	17
None	0.5	83

The overview of roads rated 3-star for pedestrians, presented in Table 4.22, highlights their typical characteristics and conditions. These roads are generally undivided and feature a single lane, with operating speeds ranging from 40 to 45 km/hr, despite a significantly lower speed limit of 25 km/hr. This discrepancy raises safety concerns for pedestrians. Typically, these roads exhibit poor delineation and overall substandard conditions, including inadequate skid resistance, which poses hazards, particularly during adverse weather. The geometry of these roads features moderate curvature, but the quality of the curves is often lacking, with steep rises that complicate navigation. Although a centreline is present, it does little to enhance safety due to the absence of traffic calming measures. Vehicle parking along the sides obstructs visibility and traffic flow, while insufficient street lighting further worsens safety issues at night. Additionally, the lack of designated pedestrian crossings, informal sidewalks, and pedestrian fencing, combined with generally poor intersection quality, contributes to an unsafe environment for pedestrians. These factors collectively highlight the urgent need for improvements to enhance safety and accessibility on these 3-star roads.

Table 4.22
3-Star Rated Roads for Pedestrian

Road name / road section	Location	Typical characteristics

<table>
<tr>
<td>Jalan Pintar 1/21A

Bukit Tonggek – Kolej Mawar Exit Junction</td>
<td></td>
<td rowspan="2">

Undivided road
Operating speed 40 to 45 km/hr
Speed limit 25 km/hr
Poor delineation
Poor road condition
Poor skid resistance
Moderate curvature
Poor curve quality
Steep rise
Centreline
No traffic calming
Vehicle parking along the side of the road
No street lighting
Informal sidewalk
One lane
No provision for pedestrians crossing
Pedestrian fencing does not present
Poor intersection quality

</td>
</tr>
<tr>
<td>Jalan Ilmu 1/1

Jalan Utama UiTM</td>
<td>



</td>
</tr>
</table>

	
Jalan Sarjana 1/2 Jalan Utama UiTM	
Jalan Cendekiawan 1/15 Kawasan Pembangunan UiTM	  

4) Cyclist

smoothed raw

Figure 4.8 Baseline (Operating Speed): Star Rating Maps for Cyclist

For a clearer illustration of Tables 4.23 and 4.24, Figure 4.8 presents a comparative analysis of smoothed and raw star rating maps for cyclists on the campus road. Furthermore, an assessment of road sections relevant to cyclists on campus has revealed significant insights into their star ratings and safety conditions as detailed in Table 4.23. The segment from Akademi Kepolisan (Padang Kawad) to the Kolej Mawar Exit Junction, which measures 0.9 km, received a perfect 5-star rating, showing a high level of safety and comfort for pedestrians. In contrast, three other road sections, namely, Bukit Tonggek to the Kolej Mawar Exit Junction (spanning 0.6 km), Kawasan Central UiTM, and Kawasan Pembangunan UiTM (measuring 1.0 km and 0.6 km, respectively), achieved a 4-star rating. Moreover, the Jalan Utama UiTM segment, which extends over 4.3 km, shows that more than half of the road (53.5%) rated 3-star, while the remaining rated 4-star. This analysis underscores the varying levels of pedestrian safety across different segments of the campus roads, highlighting areas where improvements are needed to enhance pedestrian safety.

Table 4.23
Baseline (Operating Speed): Distribution of Smoothed Star Ratings by Road Section for Cyclist

Road section	Length (km)	Proportion in each star rating				
		1-star (%)	2-star (%)	3-star (%)	4-star (%)	5-star (%)
Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction	0.9					100
Bukit Tonggek – Kolej Mawar Exit Junction	0.6				100	
Jalan Utama UiTM	4.3			53.5	46.5	
Kawasan Central UiTM	1.0				100	
Kawasan Pembangunan UiTM	0.6				100	

The distribution of raw star ratings across the analysed road sections in Table 4.24 reveals varying degrees of safety for cyclists. The segment from Akademi Kepolisan (Padang Kawad) to Kolej Mawar Exit Junction, spanning 0.9 km, was predominantly rated 5-star (77.8%), with smaller portions receiving 3-star (11.1%) and 4-star (11.1%) ratings. This suggests a generally high level of safety for cyclists, although localised areas could benefit from targeted improvements. Similarly, the Bukit Tonggek to Kolej Mawar Exit Junction segment, at 0.6 km, presented a mix of ratings: 50% 5-star, 33.3% 3-star, and 16.7% 4-star, revealing variable safety conditions that require more consistent safety measures. The Jalan Utama UiTM segment, expanding 4.3 km, exhibits a more balanced distribution, with 46.5% 3-star, 32.6% 4-star, and 20.9% 5-star, highlighting the need for comprehensive safety enhancements to improve cyclist safety along this corridor.

Table 4.24
Baseline (Operating Speed): Distribution of Raw Star Ratings by Road Section for Cyclist

Road section	Length (km)	Proportion in each star rating				
		1-star (%)	2-star (%)	3-star (%)	4-star (%)	5-star (%)
Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction	0.9			11.1	11.1	77.8
Bukit Tonggek – Kolej Mawar Exit Junction	0.6			33.3	16.7	50
Jalan Utama UiTM	4.3			46.5	32.6	20.9
Kawasan Central UiTM	1.0				50	50
Kawasan Pembangunan UiTM	0.6			33.3		66.7

The Kawasan Central UiTM, spanning a 1.0 km segment, has an even split between 4-star and 5-star ratings (50% each), reflecting generally good safety conditions for cyclists. Finally, the Kawasan Pembangunan UiTM segment, which measures 0.6 km, was rated 66.7% 5-star and 33.3% 3-star, suggesting that while a majority of the segment is safe, some portions require attention to mitigate potential risks. Overall, the distribution of star ratings indicates a variable landscape of road safety for cyclists across the campus. While certain segments prove high safety levels, others require targeted improvements to ensure a consistently safe environment for cyclists, aligning with the iRAP goal of promoting safer road infrastructure. The iRAP star ratings, ranging from 1-star (highest risk) to 5-star (lowest risk), are based on road attributes that influence the risk for different road users. Addressing the deficiencies found in the lower-rated segments could significantly enhance cyclist safety across the campus.

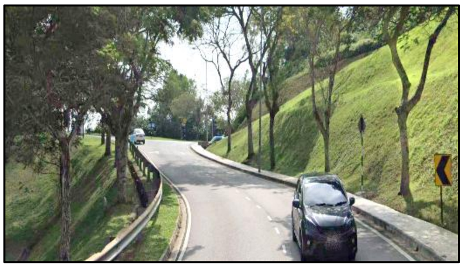
Table 4.25
Bicycle Facilities

Facilities for bicycle	km	%
None	7.4	100

The data presented in Table 4.25 indicates that there are no dedicated facilities for bicycles along a total distance of 7.4 km, accounting for 100% of the surveyed area. This absence of bicycle infrastructure suggests a significant gap in the provision of safe and accessible cycling options for users, which discourages cycling as a mode of transportation. Although the study reveals that most roads are rated generally acceptable, the lack of designated bike lanes or facilities not only compromises the safety of cyclists but also contributes to increased traffic congestion and reliance on motor vehicles. Hence, it is essential to prioritise the development of bicycle-friendly infrastructure to promote sustainable transportation, enhance cyclist safety, and encourage healthier commute habits within the community.

Table 4.26
3-Star Rated Roads for Cyclist

Road name / road section	Location	Typical characteristics
Jalan Pintar 1/21A Bukit Tonggek – Kolej Mawar Exit Junction		• Undivided road • Operating speed 40 to 45 km/hr • Speed limit 25 km/hr • Poor delineation • Poor road condition • Poor skid resistance • Moderate curvature • Poor curve quality
Jalan Pintar 1/21A Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction		

Jalan Ilmu 1/1 Jalan Utama UiTM	     	• Steep rise • No traffic calming • Vehicle parking along the side of the road • No street lighting • Poor intersection quality • Objects with distances of less than 1.0 m from the edge line • No bicycle facility • Property access points

	 
Jalan Sarjana 1/2 Jalan Utama UiTM	 
Jalan Cendekiawan 1/15 Kawasan Pembangunan UiTM	

Table 4.26 presents a detailed overview of 3-star rated roads for cyclists, emphasising characteristics affecting their safety. These undivided roads often experience operating speeds of 40 to 45 km/hr, despite a lower speed limit of 25 km/hr, posing risks to cyclists. Common issues include poor delineation, substandard road conditions, and inadequate skid resistance, which are especially concerning given the

speeds involved. The roads typically feature moderate curvature with low-quality curves and steep rises, challenging cyclists at locations such as Bukit Tonggek. A lack of traffic calming measures on most of these roads and frequent vehicle parking along the roadside, such as in Kawasan Pembangunan UiTM, further compromises cyclist safety. Poor lighting on Jalan Utama UiTM, specifically near DATC, and the presence of objects close to the road edge increase risks, especially at night. Furthermore, the absence of dedicated bicycle facilities, the intersection of roads with property access points, such as along the route from Akademi Kepolisan to Kolej Mawar Exit Junction, and poor intersection quality contribute to a hazardous environment. Cumulatively, these factors highlight the need for substantial improvements to enhance cyclist safety on these 3-star rated roads. Improving roads to a minimum 3-star rating is a global initiative to reduce road deaths and injuries.

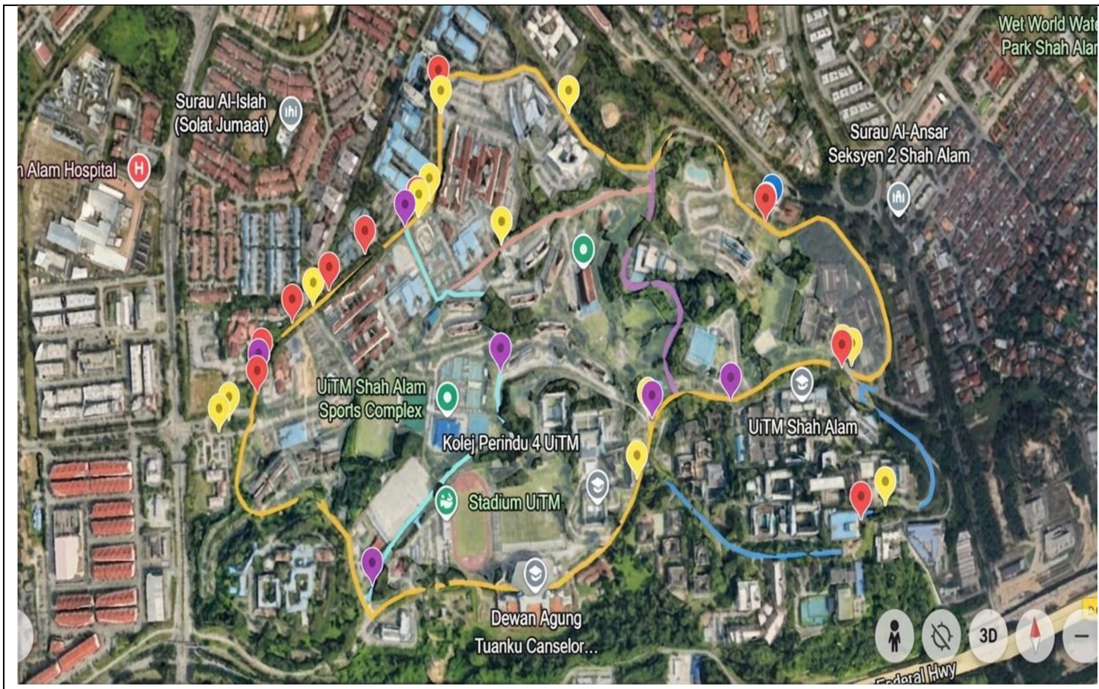
4.4.2 Optimised

4.4.2.1 Visualising Accident Hotspots

The spatial distribution of accident hotspots within the Universiti Teknologi MARA (UiTM) Shah Alam campus was analysed to identify locations with a high frequency of road injuries and to support targeted road safety interventions. Accident data were obtained from official institutional records, as mentioned in Section 3.3.1.5. The dataset included key variables such as accident location, date, and severity, ensuring sufficient detail for spatial analysis.

To facilitate accurate mapping, accident locations were geocoded based on recorded descriptions and verified against the UiTM campus road network. The processed data was then visualised using Google Earth, which served as the primary tool for spatial analysis. Through its satellite imagery and georeferencing capabilities, each accident point was precisely plotted onto the campus map. This process enabled the identification of spatial clustering patterns, particularly around major roads, intersections, and activity centres.

The analysis revealed several prominent hotspots (Figure 4.9), including Jalan Utama UiTM near the main gate area and chancellery building, roads adjacent to the Faculty of Computer Science and Mathematics, and the Engineering College, and multiple residential college zones such as Kolej Melati, Kolej Mawar, Kolej Perindu, and Kolej Seroja. High-risk intersections were also observed at Dataran Cendekia, Pejabat Bendahari UiTM, Bengkel UiTM, Pusat Kesihatan UiTM, and the roundabout at UiTM Gate 2. Additional critical segments included the routes near PTAR 1, Seri Budiman Hall, Bukit Tonggek, Akademi Kepolisan, and the UiTM mosque area. These locations exhibited recurring accident patterns, indicating concentrated risk zones within the campus.



Legend:

Road name	Road section	Legend
Jalan Cemerlang 1/19 & Jalan Dataran Cendekiawan 2	Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction	
Jalan Pintar 1/21A & Jalan Dataran Cendekiawan 2	Bukit Tonggek – Kolej Mawar Exit Junction	
Jalan Ilmu 1/1, Jalan Bijak 1/22, & Jalan Sarjana 1/2	Jalan Utama UiTM	
Jalan Ilmu 1/1 & Jalan Bernas 1/10	Kawasan Central UiTM	
Jalan Cendekiawan 1/15	Kawasan Pembangunan UiTM	
	Road accident in 2018	
	Road accident in 2019	
	Road accident in 2020	
	Road accident in 2021	

Figure 4.9 Accident Hotspots on a Uitm Campus Road

The analysis of road accidents on the UiTM campus revealed several critical infrastructure issues that contributed to the high incidence of collisions (Table 4.27). Narrow lanes and poor road curvature were identified as significant factors, as they limited drivers’ visibility and reaction time, leading to accidents at intersections like Kolej Perindu. Additionally, inadequate sight distances at intersections, such as the

Bendahari Perolehan junction, resulted in sudden collisions due to obstructions or improper grading. This was exemplified by an incident where a car struck a motorcycle exiting a three-way intersection.

Other notable factors included uneven pavement and potholes, which compromised vehicle control, particularly for motorcycles. This was evident in a motorcycle collision that occurred due to poor road conditions. Furthermore, the absence of clear directional signs contributed to navigation error, although specific examples were not documented. Inadequate lighting at night also posed risks, especially for motorcycles. Roadside hazards, such as unmanaged zones with obstacles like trees or utility poles, increased the severity of accidents involving vehicles leaving the road. Uncontrolled intersections without traffic signals or roundabouts were hotspots for angle collisions, reflecting inadequate traffic management. Lastly, the lack of dedicated pedestrian infrastructure forced pedestrians to share roads with vehicles, heightening their risk of being involved in accidents, as seen in an incident where a car struck a police officer.

Table 4.27
Contributing Factors of Road Infrastructure Issue

No.	Type	Description	Example
1.	Narrow lanes and poor curvature	Roads with insufficient widths or sharp curves reduce manoeuvrability and increase collision risks. 	Accidents at intersections like Kolej Perindu often stemmed from poor road geometry limiting visibility and reaction time.

2.	Inadequate sight distance	Poor visibility at intersections like the junction of Bendahari Perolehan due to obstructions or improper grading led to abrupt collisions. 	A car struck a motorcycle exiting a three-way intersection, reflecting this issue.
3.	Uneven pavement and potholes	Degraded surfaces reduce vehicle control, especially for motorcycles. 	A motorcycle collision related to instability caused by poor pavement.
4.	Missing or faded signs	Lack of clear directional signs, such as at the DC or Mawar exit junction, contributes to wrong-way driving and U-turn errors. 	The collision involving a car exiting an intersection without checking mirrors highlighted this gap.
5.	Inadequate lighting	Poor lighting at night exacerbates risks, particularly for motorcycles. 	

6.	Roadside hazards	Trees, utility poles, or unguarded shoulders such as those found in the Padang Kawad area increase injury severity in run-off road crashes. 	A car collided with another parked car, underscoring the danger of unmanaged roadside zones.
7.	Uncontrolled junctions	Intersections without traffic signals or roundabouts, such as Bulatan Lingua, are hotspots for angle collisions. 	The car's collision reflected inadequate traffic calming measures.
8.	Lack of pedestrian infrastructure	Pedestrians forced to share roads with vehicles face higher risks. 	A car struck a police officer member.

These findings highlight the need for targeted road safety improvements, as poor road design and inadequate maintenance were identified as key contributors to accidents. To address these issues, measures such as traffic-calming devices, improved lighting, and the provision of dedicated pedestrian infrastructure are recommended. Effective implementation requires collaboration among relevant stakeholders to enhance awareness and ensure coordinated safety interventions. The identification of accident hotspots plays a critical role in prioritising these improvements. The visualisation approach adopted in this study provided a clear representation of high-risk locations, supporting evidence-based decision-making. These insights were used to guide interventions aimed at enhancing road conditions and achieving a minimum 3-star safety rating following the International Road Assessment Programme (iRAP) standards.

4.4.2.2 Optimised Attributes

The analysis of smoothed star ratings, following modifications to relevant road attribute categories during coding, shows a positive shift towards improved safety levels for all road user types across the analysed road network as in Table 4.28. Specifically, for car occupants and cyclists, 55.4% (4.1 km) of the road segments now achieve a 5-star rating, with the remaining 44.6% (3.3 km) rated 4-star. Motorcyclists and pedestrians exhibit a similar, albeit slightly less pronounced, trend; 41.9% (3.1 km) of the road campus is rated 5-star, while the majority, 58.1% (4.3 km), is rated 4-star. The absence of road segments with ratings of 3-star or lower post-modification suggests a successful overall enhancement of the road network's inherent safety. These improvements reflect a proactive approach to road safety management and align with global initiatives aimed at reducing road traffic fatalities and serious injuries through evidence-based interventions. Furthermore, the results underscore the potential for targeted modifications to yield significant, measurable improvements in road safety outcomes for diverse user groups. The iRAP star ratings, employed in this analysis, serve as a valuable tool for benchmarking road safety performance towards achieving defined road safety targets.

Table 4.28
Optimised: Smoothed Star Ratings

	Car occupant		Motorcyclist		Pedestrian		Cyclist	
Star ratings	Length (km)	%	Length (km)	%	Length (km)	%	Length (km)	%
5-star	4.1	55.4	3.1	41.9	3.1	41.9	4.1	55.4
4-star	3.3	44.6	4.3	58.1	4.3	58.1	3.3	44.6
3-star								
2-star								
1-star								
Total	7.4	100	7.4	100	7.4	100	7.4	100

Table 4.29 shows the analysis of raw star rating distributions following the implemented modifications reveals differentiated safety outcomes across road user groups, though the campus road network generally achieved commendable ratings of 4

to 5-star. Car occupants and cyclists exhibited a higher proportion of road segments attaining a 5-star rating, at 58.1% (4.3 km) and 62.2% (4.6 km), respectively, with the remaining segments rated 4-star. Conversely, motorcyclists and pedestrians demonstrated a comparatively lower proportion of 5-star rated segments, with 48.7% (3.6 km) and 32.4% (2.4 km), respectively, and a correspondingly larger proportion of 4-star rated segments. These findings suggest that while the modifications enhanced safety across the network, the impact was not uniform. Car occupants and cyclists appear to have experienced a more pronounced improvement in road safety, as evidenced by the greater prevalence of 5-star ratings. Nevertheless, the absence of road segments rated below 4-star indicates a broad enhancement of the road network's safety baseline. This also highlights potential areas for targeted interventions to further improve safety for motorcyclists and pedestrians, ensuring a more equitable distribution of safety benefits across all user groups. The iRAP raw star ratings, grounded in road attributes influencing crash risk and injury severity, indicate that higher ratings reflect the presence of safer road infrastructure.

Table 4.29
Optimised: Raw Star Ratings

	Car occupant		Motorcyclist		Pedestrian		Cyclist	
Star ratings	Length (km)	%	Length (km)	%	Length (km)	%	Length (km)	%
5-star	4.3	58.1	3.6	48.7	2.4	32.4	4.6	62.2
4-star	3.1	41.9	3.8	51.4	5.0	67.6	2.8	37.8
3-star								
2-star								
1-star								
Total	7.4	100	7.4	100	7.4	100	7.4	100

Table 4.30 provides a comparative analysis of smoothed star ratings before and after the road attribute modifications, segmented by road user type across five distinct road sections. Employing star ratings ranging from 1 (indicating the highest risk) to 5 (denoting the lowest risk), the table offers an objective framework for evaluating the efficacy of the modifications in enhancing road safety. The data facilitates an assessment of how targeted measures impact safety levels for car occupants, motorcyclists, pedestrians, and cyclists across the specified locations. Comparing the pre- and post-intervention star rating distributions, the table allows for a quantitative evaluation of the success of the suggested interventions in improving road safety

outcomes. The iRAP star ratings are based on road attributes that influence the risk of a crash occurring and the likely severity of injury.

The data reveals varying baseline safety levels and the impact of modification across different road sections and user types, as measured by the iRAP star rating system. Prior to intervention, the Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction exhibited high safety levels, with car occupants and cyclists already at 100% 5-star ratings, while motorcyclists and pedestrians were at 100% 4-star. Following the intervention, all road user categories achieved a perfect 100% 5-star rating. In contrast, Bukit Tonggek – Kolej Mawar Exit Junction and Kawasan Pembangunan UiTM present a different scenario, where all road user groups initially had 100% 4-star ratings. Post-intervention, these sections achieved a uniform improvement to 100% 5-star ratings across all user groups.

The Jalan Utama UiTM section, the longest at 4.3 km, displays a more complex safety profile. Initially, only car occupants and pedestrians had 100% 4-star ratings. Motorcyclists experienced predominantly 3-star ratings (76.7%), with the rest portion at 4-star. Cyclists also primarily faced 3-star ratings (53.5%), and the remaining received 4-star. After interventions, motorcyclists and pedestrians only achieved 100% rated 4-star. However, car occupants' and cyclists' ratings improved, with 76.7% of the road now rated 4-star and the remaining 23.3% achieving a 5-star rating. These results suggest that while the interventions enhanced safety for car occupants and cyclists, they did not elevate the safety levels for motorcyclists and pedestrians beyond a 4-star rating.

Table 4.30
Optimised: Percentage of Smoothed Star Rating by Road User Type

Location	Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction							
Total length (km)	0.9							
	Car occupant		Motorcyclist		Pedestrian		Cyclist	
Star ratings	Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention
5-star	100%	100%		100%		100%	100%	100%
4-star			100%		100%			
3-star								
2-star								
1-star								
Total	100%	100%	100%	100%	100%	100%	100%	100%
Location	Bukit Tonggek – Kolej Mawar Exit Junction							

Total length (km)	0.6							
Star ratings	Car occupant		Motorcyclist		Pedestrian		Cyclist	
	Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention
5-star		100%		100%		100%		100%
4-star	100%		100%		100%		100%	
3-star								
2-star								
1-star								
Total	100%	100%	100%	100%	100%	100%	100%	100%
Location	Jalan Utama UiTM							
Total length (km)	4.3							
Star ratings	Car occupant		Motorcyclist		Pedestrian		Cyclist	
	Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention
5-star		23.3% (1.0 km)						23.3% (1.0 km)
4-star	100%	76.7% (3.3 km)	23.3% (1.0 km)	100%	100%	100%	46.5% (2.0 km)	76.7% (3.3 km)
3-star			76.7% (3.3 km)				53.5% (2.3 km)	
2-star								
1-star								
Total	100%	100%	100%	100%	100%	100%	100%	100%
Location	Kawasan Central UiTM							
Total length (km)	1.0							
Star ratings	Car occupant		Motorcyclist		Pedestrian		Cyclist	
	Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention
5-star	100%	100%		100%	100%	100%		100%
4-star			100%				100%	
3-star								
2-star								
1-star								
Total	100%	100%	100%	100%	100%	100%	100%	100%
Location	Kawasan Pembangunan UiTM							
Total length (km)	0.6							
Star ratings	Car occupant		Motorcyclist		Pedestrian		Cyclist	
	Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention
5-star		100%		100%		100%		100%

4-star	100%		100%		100%		100%	
3-star								
2-star								
1-star								
Total	100%	100%	100%	100%	100%	100%	100%	100%

Kawasan Central UiTM demonstrates minimal change. Before the intervention, only motorcyclists and cyclists were at 100% 4-star, achieving 100% 5-star after the intervention. Car occupants and pedestrians kept a consistent 100% 5-star rating both before and after the intervention. Overall, the modifications demonstrated effectiveness in improving star ratings across the specified locations, aligning with global road safety enhancement efforts. The most prominent improvements were the attainment of 5-star ratings, signifying a substantial reduction in road user risk. This is crucial as roads with higher star ratings correlate with lower fatal and serious injury rates.

1) Car occupant

Figure 4.10 Optimised: Star Rating Maps for Car Occupant

Figure 4.10 provides a comparative analysis of smoothed and raw star rating maps for car occupants on the campus road, illustrating Tables 4.28 and 4.29. The data from Table 4.31 indicates that readily implementable modifications hold significant promise for enhancing road safety for car occupants across specific segments. Applying these modifications to the Bukit Tonggek – Kolej Mawar Exit Junction and Kawasan Pembangunan UiTM sections has the potential to elevate 100% of their lengths (0.6 km each) from 4 to 5-star rating, suggesting a notable improvement in safety. Similarly, implementing immediate remedial measures on Jalan Utama UiTM could enhance 23.3% of its length (1.0 km) from a 3-star to a 5-star rating. Cumulatively, these modifications could positively affect 2.2 km of roadways, improving star ratings for car occupants and, consequently, enhancing overall road safety in these segments. The emphasis on immediate implementation reflects a focus on readily achievable strategies that offer immediate and tangible safety benefits. Such strategies align with the principles of Vision Zero and the Safe System approach, which aim to reduce fatalities and serious injuries through multi-faceted interventions. Table 4.36 gives examples of enhancements relevant to car occupants, such as providing a safe distance from roadside objects, enhancing delineation, road condition, skid resistance, adequate street lighting, better speed management, and intersection quality.

Table 4.31
Quick-Fix Lengths for Car Occupant

Road section	3 to 4-star	3 to 5-star	4 to 5-star	Total (km)
Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction				
Bukit Tonggek – Kolej Mawar Exit Junction			100% (0.6)	0.6
Jalan Utama UiTM			23.3% (1.0)	1.0
Kawasan Central UiTM				
Kawasan Pembangunan UiTM			100% (0.6)	0.6
Total (km)			2.2	2.2

2) Motorcyclist

smoothed raw

Figure 4.11 Optimised: Star Rating Maps for Motorcyclist

Figure 4.11 compares smoothed and raw star rating maps for motorcyclists on the campus road to provide a better understanding of Tables 4.28 and 4.29. Table 4.32 presents the potential for effective measures to improve road safety for motorcyclists, as indicated by enhancements in star ratings across various road sections. Notably, the most significant gains are projected in the 4 to 5-star category, with several segments including Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction (0.9 km), Bukit Tonggek – Kolej Mawar Exit Junction (0.6 km), Kawasan Central UiTM (1.0 km), and Kawasan Pembangunan UiTM (0.6 km), potentially achieving a 100% upgrade. For Jalan Utama UiTM, the implementation of effective measures could elevate 76.7% (3.3 km) of its length from a 3-star to a 4-star rating. Cumulatively, these improvements could positively affect 6.4 km of roadway, suggesting a substantial enhancement in safety for motorcyclists through readily achievable interventions. The prevalence of upgrades from 4-star to 5-star ratings, affecting a total of 3.1 km of roads, underscores the potential for targeted modifications to yield significant safety benefits. Examples of enhancements relevant to motorcyclists are shown in Table 4.36. These include providing a safe distance from roadside objects, enhancing delineation, road condition, skid resistance, adequate street lighting, better speed management, and intersection quality.

Table 4.32
Quick-Fix Lengths for Motorcyclist

Road section	3 to 4-star	3 to 5-star	4 to 5-star	Total (km)
Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction			100% (0.9)	0.9
Bukit Tonggek – Kolej Mawar Exit Junction			100% (0.6)	0.6
Jalan Utama UiTM	76.7% (3.3)			3.3
Kawasan Central UiTM			100% (1.0)	1.0
Kawasan Pembangunan UiTM			100% (0.6)	0.6
Total (km)	3.3		3.1	6.4

3) Pedestrian

smoothed raw

Figure 4.12 Optimised: Star Rating Maps for Pedestrian

Figure 4.12 compares smoothed and raw star rating maps for pedestrians on the campus road to better illustrate Tables 4.28 and 4.29. Table 4.33 presents the potential for readily achievable modifications to enhance pedestrian safety, as reflected by improved star ratings on specific road segments. According to the data, implementing the modifications detailed in Table 4.36 on the Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction (0.9 km), Bukit Tonggek – Kolej Mawar Exit Junction (0.6 km), and Kawasan Pembangunan UiTM (0.6 km) road sections could elevate 100% of their lengths from their current rating from 4 to 5-star rating. Cumulatively, these interventions could improve pedestrian safety across 2.1 km of roadway. This targeted approach suggests a strategic prioritisation of readily implementable improvements, such as enhancing road conditions, skid resistance, better delineation, sufficient street lighting, enhancing intersection quality, pedestrian crossing facilities, and sidewalk quality, as well as implementing speed management measures to maximise pedestrian safety in key locations. These modifications reflect a focus on creating more pedestrian-friendly environments. Such interventions align with the principles of the Safe System approach, which focuses on proactive measures to minimise crash risk and severity for all road users.

Table 4.33
Quick-Fix Lengths for Pedestrian

Road section	3 to 4-star	3 to 5-star	4 to 5-star	Total (km)
Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction			100% (0.9)	0.9
Bukit Tonggek – Kolej Mawar Exit Junction			100% (0.6)	0.6
Jalan Utama UiTM				
Kawasan Central UiTM				
Kawasan Pembangunan UiTM			100% (0.6)	0.6
Total (km)			2.1	2.1

4) Cyclist

smoothed raw

Figure 4.13 Optimised: Star Rating Maps for Cyclist

For a better understanding of Tables 4.28 and 4.29, Figure 4.13 presents a comparative analysis of the smoothed and raw star rating maps associated with cyclists on the campus road. Table 4.34 outlines the potential for enhancing cyclist safety through the implementation of cost-effective measures, as reflected in improvements to road section star ratings. As detailed in Table 4.36, applying these modifications to Bukit Tonggek – Kolej Mawar Exit Junction (0.6 km), Kawasan Central UiTM (1.0 km), and Kawasan Pembangunan UiTM (0.6 km) could elevate 100% of their lengths from their current rating from 4 to 5-star rating. On Jalan Utama UiTM, 23.3% (1.0 km) of the road could see improvements from a 3-star to a 5-star rating. Cumulatively, these targeted interventions have the potential to positively affect 3.2 km of roadways, indicating a significant opportunity to enhance cyclist safety through relatively simple and readily implementable changes. These modifications could encompass a range of strategies, including improvements to road conditions and skid resistance, enhancing delineation, adequate street lighting, improving intersection quality, better roadside severity through increased side distances, and proactive speed management. Such measures align with a proactive approach to cyclist safety, emphasising the importance of infrastructure improvements and traffic management strategies to minimise risks and promote a safer cycling environment.

Table 4.34
Quick-Fix Lengths for Cyclist

Road section	3 to 4-star	3 to 5-star	4 to 5-star	Total (km)
Akademi Kepolisan (Padang Kawad) – Kolej Mawar Exit Junction				
Bukit Tonggek – Kolej Mawar Exit Junction			100% (0.6)	0.6
Jalan Utama UiTM		23.3% (1.0)		1.0
Kawasan Central UiTM			100% (1.0)	1.0
Kawasan Pembangunan UiTM			100% (0.6)	0.6
Total (km)		1.0	2.2	3.2

4.5 Proposed Treatments

The countermeasures proposed in this study are developed based on the International Road Assessment Programme (iRAP) framework, which provides a systematic and evidence-based methodology for evaluating road safety. Through a star rating system and detailed road attribute assessments, this study, using iRAP, enables the identification of infrastructure-related risk factors affecting different categories of road users. This study utilised the framework to evaluate the UiTM Shah Alam campus road network, facilitating the identification of significant deficiencies and their corresponding safety risks.

Based on this assessment, a range of targeted countermeasures was developed to address critical infrastructure issues. These include improving roadside clearance, enhancing pavement condition and skid resistance, improving road delineation, providing sufficient street lighting coverage, and upgrading intersection design. Such interventions are widely recognised by the iRAP methodology as effective measures for reducing crash likelihood and injury severity. Their application ensures that the proposed improvements are both practical and aligned with internationally accepted road safety standards.

Table 4.35 presents a comparative analysis of key road attributes before and after the implementation of these interventions. Prior to improvement, several deficiencies were identified. Road condition and skid resistance were below optimal levels due to pavement degradation, while poor delineation reduced driver guidance. Street lighting coverage was insufficient, increasing risk during night-time conditions. Intersection quality was particularly inadequate, with only 1% of locations meeting acceptable safety standards. In addition, roadside hazards were prevalent, with 62% of road segments having objects located within one metre of the carriageway, significantly increasing the risk of severe run-off crashes.

Table 4.35
Road Attributes Category Improvement

Section	Item		Category	
			Before	After
Roadside attributes	Roadside severity – driver-side distance		0 to < 1 m	0 to < 1 m
		Risk factor	1.0	1.0
		Percentage / km	(62%) / 4.6 km	(61%) / 4.5 km
	Roadside severity – passenger-side distance		0 to < 1 m	0 to < 1 m
		Risk factor	1.0	1.0
		Percentage / km	(53%) / 3.9 km	(51%) / 3.8 km
Mid-block attributes	Road condition		Good	Good
		Risk factor	1.0	1.0
		Percentage / km	(80%) / 5.9 km	(100%) / 7.4 km
	Skid resistance/grip		Sealed – adequate	Sealed – adequate
		Risk factor	1.0	1.0
		Percentage / km	(80%) / 5.9 km	(100%) / 7.4 km
	Delineation		Poor	Adequate
		Risk factor	1.2	1.0
		Percentage / km	(100%) / 7.4 km	(100%) / 7.4 km
	Street lighting		Present	Present
		Risk factor	1.0	1.0
		Percentage / km	(99%) / 7.3 km	(100%) / 7.4 km
Intersections	Intersection quality		Adequate	Adequate
		Risk factor	1.0	1.0
		Percentage / km	(1%) / 0.1 km	(15%) / 1.1 km

Vulnerable road user (VRU) features	Pedestrian crossing facilities – inspected road		Not signalled marked crossing without a refuge	Not signalled marked crossing without a refuge
		Risk factor	4.80	4.80
		Percentage / km	(19%) / 1.4 km	(22%) / 1.6 km
	Pedestrian crossing quality		Adequate	Adequate
		Risk factor	1.0	1.0
		Percentage / km	(3%) / 0.2 km	(22%) / 1.6 km
	Sidewalk – driver-side		Non-physical separation 0 m to < 1.0 m	Non-physical separation 0 m to < 1.0 m
		Risk factor	0.09	0.09
		Percentage / km	(51%) / 3.8 km	(53%) / 3.9 km
	Sidewalk – passenger-side		Non-physical separation 0 m to < 1.0 m	Non-physical separation 0 m to < 1.0 m
		Risk factor	0.09	0.09
		Percentage / km	(41%) / 3.0 km	(45%) / 3.3 km
Speeds	Speed management/traffic calming		Present	Present
		Risk factor	1.00	1.00
		Percentage / km	(46%) / 3.4 km	(68%) / 5.0 km

Following the implementation of the proposed measures, substantial improvements were observed. Road condition and skid resistance reached uniformly good levels, effectively eliminating surface-related hazards. Delineation improved to an adequate standard, enhancing driver visibility and navigation. Street lighting coverage increased to nearly 100%, reducing risks under low-visibility conditions. Intersection adequacy improved from 1% to 15%, indicating better traffic control and safer movement through conflict points. Although roadside hazards remained a concern, there was a slight reduction in high-risk segments, reflecting incremental progress in improving roadside safety.

Additional improvements were observed in pedestrian-related infrastructure. Pedestrian crossing facilities were upgraded from having no formal provision to marked crossings without refuge, reducing the associated risk factor. Crossing quality improved from 3% to 22%. Sidewalk availability also increased on both sides of the road, replacing informal paths or absent facilities with defined walking spaces featuring minimal separation from traffic. Speed management measures showed notable progress, increasing from 46% to 68%, indicating greater implementation of traffic calming strategies.

It should be noted that this analysis focuses on changes in physical road attributes rather than crash data, as post-intervention accident trends require longer-term monitoring. Nevertheless, the integration of iRAP assessment results with supporting road surveys and local accident mapping strengthens the reliability of the findings by combining infrastructure evaluation with contextual safety insights.

Overall, the comparison proves clear improvements in key safety attributes across the campus road network. While targeted interventions have been effective in addressing several high-risk areas, further enhancements, particularly in roadside hazard mitigation and comprehensive pedestrian protection, are necessary to maximise safety outcomes. A more holistic approach is essential to achieve higher safety performance and meet the minimum target of a three-star road standard.

Table 4.36
Effective Countermeasures for Increasing Star Ratings

No.	Countermeasure description and justification
1.	**Effective distance treatment:** The proximity of roadside objects such as poles, trees, and walls to the road edge drastically increases the severity of run-off-road crashes and reduces recovery space for drivers and motorcyclists. Treating these hazards by increasing lateral clearance or installing protective barriers mitigates the risk of collisions with roadside obstacles and enhances safety, particularly in segments rated 2 to 3 stars.
2.	**Road defect management:** Road defects like potholes, surface deformities, and edge degradation negatively affect vehicle control, causing instability, especially for motorcyclists and cyclists. Regular maintenance to repair these defects reduces crash risks due to vehicle loss of control or sudden manoeuvres, resulting in smoother, safer journeys across the campus.
3.	**Surface texture restoration:** Low skid resistance was noted as a contributing factor to crashes, especially in curves and high operating speed areas where braking performance is critical. Restoring surface texture to an adequately sealed surface improves tyre grip, reduces skidding and helps prevent loss-of-control collisions, an important factor in enhancing safety for all vehicle types.
4.	**Adequate delineation:** The study highlighted poor delineation throughout campus roads, limiting visibility and navigation for all users. Installing clear centrelines, lane markings, guideposts, and hazard markers improves driver guidance, reducing confusion and collision risks.
5.	**Sufficient illumination:** Several high-risk locations, including Jalan Utama UiTM near Dewan Agong Tuanku Canselor, lacked adequate street lighting, elevating night-time accident risks. Improved lighting infrastructure enhances visibility of roads, pedestrians, cyclists, and hazards at night, thus preventing collisions and improving the overall sense of safety.
6.	**Intersection quality improvement:** Many intersections presented poor design and lack of adequate traffic control measures, becoming hotspots for angle collisions and conflicting movements. Upgrading intersection quality through signage, markings, and facilities for vulnerable users improves traffic flow and greatly reduces crash risks at these critical points.
7.	**Pedestrian crossing facilities:** The significant lack of pedestrian crossings, with 81% of the surveyed length having no crossing facilities, exposes pedestrians to severe risks. Installing marked and signalled pedestrian crossings enables safe road crossing for the most vulnerable

	users, directly reducing pedestrian-vehicle conflicts and improving compliance.
8.	**Enhanced pedestrian crossing quality:** Beyond provision, the quality of pedestrian crossings, like visibility, signage, and anticipation by drivers, was often poor. Improving these factors ensures crossings effectively capture driver attention, increasing compliance and further protecting pedestrians.
9.	**Official sidewalk provision:** Many road sections lacked formal sidewalks or had insufficient separation from carriageways, forcing pedestrians to share roads with vehicles or use informal paths. Constructing official sidewalks with adequate clearance offers safe pedestrian routes apart from traffic, minimising pedestrian risks and enhancing comfort and accessibility.
10.	**Speed management/traffic calming measures:** Despite a campus speed limit of 25 km/hr, operating speeds frequently exceeded this limit, undermining safety benefits. Implementing physical traffic calming devices such as speed humps and raised crossings changes driver behaviour, reducing speeds and crash severity, particularly protecting vulnerable road users.

Table 4.36 outlines the proposed countermeasures in a structured manner, focusing on critical areas that influence crash risk and injury severity. These include reducing roadside hazards, maintaining high-quality road surfaces, improving visibility through delineation and lighting, enhancing intersection and pedestrian crossing design, providing formal sidewalks in high-demand areas, and implementing effective speed management strategies. Collectively, these measures form a comprehensive approach to improving road safety and support the development of a safer campus environment for all users.

4.5.1 Data Sources and Methodology for Cost-Effectiveness Analysis

Table 4.37 presents a cost-effective analysis of selected road safety countermeasures for the campus road network at Universiti Teknologi MARA (UiTM) Shah Alam. The analysis is based on data obtained through the International Road Assessment Programme (iRAP) methodology, supported by accident records and internationally validated research on safety interventions. The primary dataset was derived from a detailed road survey covering 7.4 km of campus roads. This survey captured key road attributes, including geometry, surface condition, pedestrian infrastructure, street lighting, roadside hazards, and traffic calming features. These attributes informed the iRAP star rating evaluations, which provide objective measures of risk levels facing various road users such as pedestrians, cyclists, motorcyclists, and vehicle occupants. To strengthen the analysis, accident data were spatially examined to identify high-risk locations within the campus. This allowed the selection of countermeasures to be aligned with areas where safety improvements are most needed, ensuring that the proposed interventions are both relevant and targeted.

The effectiveness values adopted in this analysis were obtained from the iRAP Toolkit. They are based on internationally established crash reduction estimates developed by the International Road Assessment Programme through extensive empirical studies. These values, commonly expressed as percentage reductions in fatalities and serious injuries, reflect the typical safety impact of individual countermeasures under a range of conditions. Within the iRAP Toolkit, these standardised effectiveness estimates are applied to model the expected safety improvements associated with proposed interventions. Although derived from international studies, these effectiveness values are considered sufficiently representative for application in similar road environments, including campus settings.

For example, sidewalks on both sides of the road are associated with an estimated 40% reduction in serious pedestrian injuries, while pedestrian crossing facilities and improved street lighting contribute approximately 25% and 10% reductions, respectively. Cost estimates include both initial implementation and ongoing maintenance per kilometre. These were calculated in Malaysian Ringgit (RM) and adjusted to reflect realistic construction and maintenance conditions within the campus environment.

4.5.1.1 Effectiveness and Benefit-Cost Ratio Computation

The effectiveness metric in Table 4.37 represents the expected reduction in fatalities and serious injuries with each countermeasure. These values are derived from established international evidence and provide a practical basis for estimating the safety benefits of infrastructure improvements and traffic management measures. The benefit-cost ratio (BCR) is used to assess the economic efficiency of each intervention by comparing the monetary value of expected safety benefits. It incorporates direct costs, such as medical expenses, as well as indirect and societal impacts, including productivity losses and the broader consequences of injury and fatality, in line with approaches recommended by the World Health Organization (WHO) and other international road safety bodies.

A higher BCR indicates a more economically efficient intervention. For example, a BCR of 21 for pedestrian crossing facilities implies that every RM 1 invested is expected to generate RM 21 in benefits through the reduction of injuries and fatalities. Similarly, sidewalks and street lighting demonstrate strong economic performance, each with a BCR of 14, highlighting their importance as priority safety measures.

Overall, the analysis identifies interventions that deliver the greatest safety benefits relative to cost, providing a clear basis for prioritising investment that improves road safety while ensuring efficient use of available resources.

4.5.2 Cost-Effective Countermeasures

Evaluating the cost-effectiveness of road safety countermeasures is crucial for optimising resource allocation and maximising the impact of safety initiatives. A comprehensive analysis, as seen in Table 4.37, highlights the importance of benefit-cost ratios (BCRs) in assessing these measures. The top three cost-effective countermeasures identified are pedestrian crossing facilities with a BCR of 21 and street lighting and sidewalks on both passenger and driver sides, each with a BCR of 14. These measures stand out due to their substantial benefits relative to costs, particularly in enhancing safety for pedestrians and reducing serious injuries and fatalities.

When considering the effectiveness and lives saved per measure, sidewalks stand out as particularly effective for pedestrians, boasting a high effectiveness of 40% and preventing 20 serious injuries and 2 deaths per implementation. However, speed control and traffic calming are widely seen as important ways to lower deaths on the world's roads (Global Road Safety Partnership & International Federation of Red Cross and Red Crescent Societies, 2023; International Road Assessment Programme (iRAP), 2022f, 2023c; Vecino-Ortiz et al., 2022). Speeding is a major risk factor for road deaths, and implementing these measures, in conjunction with improved infrastructure and enforcement, can be highly effective in saving lives worldwide.

Table 4.37
Cost-Effectiveness of Road Safety Countermeasures

No.	Countermeasure	Target user	Cost (RM)/km	Effectiveness (%)	Serious injuries prevented	Deaths prevented	BCR
1.	Pedestrian crossing facilities – inspected road	iii, iv	0.35 mil	25	13	1	21

2.	Street lighting	i, ii, iii, iv	0.41 mil	10	5	1	14
3.	Sidewalk (both sides)	iii	0.41 mil	40	20	2	14
4.	Roadside severity distance (both sides)	i, ii, iv	0.82 mil	25	13	1	9
5.	Pedestrian crossing quality	iii	0.35 mil	25	13	1	3
6.	Road condition	i, ii, iii, iv	0.41 mil	25	13	1	2
7.	Intersection quality	i, ii, iii, iv	0.35 mil	10	5	1	2
8.	Skid resistance/grip	i, ii, iii, iv	0.82 mil	25	13	1	1
9.	Speed management/traffic calming	i, ii, iii, iv	0.82 mil	25	13	1	1
10.	Delineation	i, ii, iii, iv	0.35 mil	10	5	1	0

Note: (i) car occupant, (ii) motorcyclist, (iii) pedestrian, and (iv) cyclist

In terms of minimising costs while enhancing road safety, pedestrian crossing facilities, pedestrian crossing quality, intersection quality, and delineation are the most affordable options, each costing RM 0.35 million per kilometre. These measures are not only the least expensive but also relatively quick to implement, as they typically involve straightforward installations or improvements that do not require extensive construction or infrastructure changes. Among these, pedestrian crossing facilities and pedestrian crossing quality have a higher effectiveness of 25%, making them slightly more impactful than intersection quality and delineation, which have an effectiveness of 10%. However, all these measures are practical choices for rapid implementation and cost savings. If speed of implementation is a priority, measures like delineation might be among the fastest to deploy, as they often involve simple installations of signs or markings, which can be done quickly with minimal disruption to traffic.

This chapter presents the comprehensive findings of the road infrastructure and safety assessment conducted at Universiti Teknologi MARA (UiTM) Shah Alam using the International Road Assessment Programme (iRAP) framework. The study identified critical issues related to operating speeds that frequently exceed the campus speed limit of 25 km/hr, signalling a need for enhanced speed management and traffic-calming interventions to improve compliance and reduce risk. Infrastructure deficiencies are apparent, notably the high proportion of road sections lacking formal intersections and channelisation, inadequate pedestrian crossing facilities, and the absence of dedicated infrastructure for vulnerable users such as motorcyclists and cyclists, which cumulatively elevate safety risks.

The iRAP star rating analysis revealed generally high safety ratings for car occupants and pedestrians but highlighted specific segments where motorcyclists and cyclists experience moderate to lower safety conditions, particularly on major campus roads like Jalan Utama UiTM. Detailed spatial analysis of accident hotspots further corroborated these findings, identifying key areas around academic buildings, residential colleges, and major intersections requiring focused attention. The chapter underscores the urgent need for targeted infrastructure improvements, including roadside hazard mitigation, improved delineation, surface condition enhancements, better lighting, and enhanced intersection and pedestrian crossing quality. Additionally, the implementation of comprehensive traffic calming measures is essential to moderate vehicle speeds and protect vulnerable users. These evidence-based recommendations aim to elevate the overall road safety star ratings across the campus network, fostering a safer, more inclusive environment aligned with Safe System principles and the iRAP methodology, ultimately supporting the university's goal of reducing road injuries and fatalities within its precincts. The findings provide a robust foundation for informed decision-making and the prioritisation of interventions that promise substantial safety benefits for all campus road users.

CHAPTER 5
CONCLUSION

5.1 Introduction

This study addresses three main research questions: firstly, to identifying and documenting the road inventories within the UiTM Shah Alam campus using iRAP surveys. This objective was systematically addressed through an extensive road survey encompassing 7.4 kilometres of the campus road network. The survey collected detailed data on geometric road characteristics, such as lane widths, shoulder presence, and horizontal and vertical alignments, in addition to safety infrastructure elements including guardrails, pedestrian crossings, traffic calming devices, and street lighting. Furthermore, operational factors were examined, specifically vehicle operating speeds relative to the posted 25 km/hr limit. The comprehensive compilation of these attributes provided an empirical foundation for assessing the current road environment, revealing deficiencies such as incomplete centreline markings, limited physical medians, inadequate pedestrian facilities, inadequate lighting in certain areas, and the proximity of roadside hazards. This baseline inventory facilitated a nuanced understanding of the infrastructural and operational context relevant to road safety assessment.

Secondly, to establishing iRAP star ratings for the campus roads. The collected road attribute dataset was subsequently processed using iRAP's proprietary analytical framework to generate star ratings on a scale from 1-star (indicating highest risk) to 5-star (indicating lowest risk). Both raw and smoothed star rating analyses were conducted at segment and network levels, enabling identification of specific road sections exhibiting elevated crash risk. Findings indicated a predominance of 4- and 5-star ratings across most road segments under current operating conditions, with certain areas demonstrating lower ratings, particularly for motorcyclists and pedestrians. The disparity in ratings underscored existing vulnerabilities, particularly where operational speeds exceeded the speed limit and where infrastructure did not adequately protect non-motorised users. These results emphasised the heterogeneity of safety performance across user groups and spatial locations, thus guiding the prioritisation of safety interventions.

Finally, to recommending targeted improvement plans to enhance road safety and usability. Informed by the star rating outcomes and the identified risk factors, this study proposed a suite of evidence-based countermeasures focusing on key road infrastructure attributes: enhancement of speed management controls, improved road delineation and signage, restoration of adequate skid resistance, upgrading of intersection design standards, augmentation of pedestrian crossing facilities, and mitigation of roadside hazards. Simulation of these interventions within the iRAP framework projected an elevation in star ratings, with a significant proportion of road segments attaining 5-star status post-intervention for all user categories. Furthermore, the economic viability and anticipated safety benefits of the proposed treatments were substantiated through cost-effectiveness analyses employing internationally recognised benefit-cost ratio methodologies, consonant with iRAP's Safe System approach. These findings corroborate the efficacy of the recommended improvements in reducing crash risk and enhancing overall road safety and mobility on campus.

5.2 Research Process and Findings

The research process involved extensive road surveys, speed studies, and structured coding validated through iRAP's ViDA platform. Key findings indicated that adherence to posted speed limits yields an average 5-star safety rating; however, observed operating speeds reduced ratings to between 3- and 5-star. Strategic adjustments to pedestrian crossings and roadside severity distances significantly, for instance, improved average ratings to 4- to 5-star across all user groups.

5.3 Limitations

Despite these successes, several challenges emerged during the study. The absence of a tailored iRAP model for university campuses hindered targeted interventions due to a lack of specialised organisational structures and expertise. Financial constraints posed significant obstacles, as universities often operate under tight budgets that limit the implementation of recommended improvements. Additionally, the infrequent occurrence of road deaths on campus complicated data collection efforts, while bureaucratic processes in collaboration with governmental entities introduced delays. Methodological limitations necessitated reliance on benefit-cost ratio analysis to identify cost-effective safety measures.

5.4 Recommendations for Future Research

To overcome the challenges identified and expand the scope of this research, future studies should focus on developing customised iRAP models specifically designed for campus environments. This involves clearly outlining each step of the process: beginning with a thorough analysis of road safety factors unique to campuses, followed by adapting the existing iRAP framework to incorporate these factors, and then validating the modified model through pilot studies within campus settings. The integration of emerging technologies such as artificial intelligence (AI) and the Internet of Things (IoT) can enhance data collection and analysis. For instance, by using AI to identify risk patterns and IoT devices to monitor real-time conditions. Additionally, exploring alternative data collection methods, such as drones, mobile sensors, or community reporting, will improve the reliability and comprehensiveness of safety assessments in academic environments.

Based on these improvements, it is recommended that the modified iRAP model, along with the enhanced procedures, be applied to other campuses. This should follow a systematic approach: first, adjusting the model to fit each campus's unique characteristics; second, implementing the improved data collection techniques; third, conducting detailed safety assessments; and finally, reviewing the results to further refine the model. This structured process will help ensure that road safety evaluations are accurate and meaningful across diverse campus settings.

5.5 Contribution and Conclusion

This research makes a significant contribution to the body of knowledge in road safety assessment and campus traffic management by developing a rigorous, data-driven methodology specifically adapted to the complex traffic environment of a university campus. Leveraging the International Road Assessment Programme (iRAP) framework, the study goes beyond traditional star rating applications by integrating a comprehensive road inventory survey with detailed spatial accident analysis, enabling a multifaceted evaluation of road infrastructure and safety performance across diverse road user groups, including car occupants, motorcyclists, pedestrians, and cyclists.

The findings provide empirical evidence of how systematic assessment of road attributes, such as geometrics, surface conditions, roadside hazards, intersection quality, and pedestrian facilities, directly influence safety risk levels, as quantified through the iRAP star rating system. The research adeptly demonstrates the tangible impact of targeted improvements on elevating star ratings, confirming the effectiveness of specific interventions like enhancing road delineation, upgrading intersection design, expanding pedestrian infrastructure, and implementing speed management strategies. The contrast between baseline and optimised road conditions elucidates the critical role of infrastructure quality in mitigating crash risks, particularly for vulnerable road users, while also highlighting areas where safety remains suboptimal and requires further attention.

Importantly, the integration of road survey data with accident occurrence mapping allows for a prioritisation of countermeasures that are cost-effective and contextually relevant, ensuring resource allocation aligns with the highest safety needs on campus. This methodological advancement supports proactive infrastructure management rather than reactive approaches based solely on historical crash data, thus facilitating preventive safety strategies tailored to the nuances of campus traffic dynamics.

Moreover, the study enriches existing paradigms by providing a replicable framework for conducting nuanced road safety analyses in controlled settings characterised by mixed user types, diverse road features, and fluctuating traffic volumes. This specificity addresses a notable gap in literature pertaining to road safety within educational environments, where conventional urban road safety models may not fully capture operational realities. The research enhances theoretical comprehension and practical abilities in campus traffic governance by providing a comprehensive, evidence-based framework for prioritising interventions, evaluation, and monitoring.

In sum, this work elevates the discourse on road safety assessment by demonstrating how an adapted iRAP methodology, informed by granular infrastructure data and integrated with spatial risk analysis, can drive meaningful enhancements in safety performance and user protection within university settings. It offers valuable methodological insights and pragmatic solutions that can be adopted by practitioners and policymakers aiming to optimise road safety outcomes in similar institutional contexts globally.

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APPENDICES

APPENDIX 1

iRAP Road Attributes

Attribute	Item	Category ID	Category
1	Coder name	N/A	N/A
2	Coding date	N/A	N/A
3	Road survey date	N/A	N/A
4	Image reference	N/A	N/A
5	Road name	N/A	N/A
6	Section	N/A	N/A
7	Distance	N/A	N/A
8	Length	N/A	N/A
9	Latitude	N/A	N/A
10	Longitude	N/A	N/A
11	Landmark	N/A	N/A
12	Comments	N/A	N/A
13	Carriageway	1	Carriageway A of a divided road
		2	Carriageway B of a divided road
		3	Undivided road
		4	Carriageway A of a motorcycle facility
		5	Carriageway B of a motorcycle facility
14	Upgrade cost	3	High
		2	Medium
		1	Low
15	Motorcycle observed flow	6	8+ motorcycles
		5	6 to 7 motorcycles
		4	4 to 5 motorcycles
		3	2 to 3 motorcycles
		2	1 motorcycle
		1	None
16	Bicycle observed flow	6	8+ bicycles
		5	6 to 7 bicycles
		4	4 to 5 bicycles
		3	2 to 3 bicycles
		2	1 bicycle
		1	None
17	Pedestrian observed flow	6	8+ pedestrians

	across the road	5	6 to 7 pedestrians
		4	4 to 5 pedestrians
		3	2 to 3 pedestrians
		2	1 pedestrian
		1	None
18	Pedestrian observed flow along the driver-side	6	8+ pedestrians
		5	6 to 7 pedestrians
		4	4 to 5 pedestrians
		3	2 to 3 pedestrians
		2	1 pedestrian
		1	None
19	Pedestrian observed flow along the passenger-side	6	8+ pedestrians
		5	6 to 7 pedestrians
		4	4 to 5 pedestrians
		3	2 to 3 pedestrians
		2	1 pedestrian
		1	None
20	Land use – driver-side	6	Educational
		4	Commercial
		7	Industrial and manufacturing
		3	Residential
		2	Farming and agricultural
		1	Undeveloped areas
		5	Not recorded
21	Land use – passenger-side	6	Educational
		4	Commercial
		7	Industrial and manufacturing
		3	Residential
		2	Farming and agricultural
		1	Undeveloped areas
		5	Not recorded
22	Area type	2	Urban
		1	Rural
23	Speed limit	25	≥ 150 km/hr
		23	140 km/hr
		21	130 km/hr
		19	120 km/hr
		17	110 km/hr
		15	100 km/hr

		13	90 km/hr
		11	80 km/hr
		9	70 km/hr
		7	60 km/hr
		5	50 km/hr
		3	40 km/hr
		1	< 30 km/hr
		45	≥ 90 mph
		43	80 mph
		41	70 mph
		39	60 mph
		37	50 mph
		35	40 mph
		33	30 mph
		31	< 20 mph
24	Motorcycle speed limit	25	≥ 150 km/hr
		23	140 km/hr
		21	130 km/hr
		19	120 km/hr
		17	110 km/hr
		15	100 km/hr
		13	90 km/hr
		11	80 km/hr
		9	70 km/hr
		7	60 km/hr
		5	50 km/hr
		3	40 km/hr
		1	< 30 km/hr
		45	≥ 90 mph
		43	80 mph
		41	70 mph
		39	60 mph
		37	50 mph
		35	40 mph
		33	30 mph
		31	< 20 mph
25	Truck speed limit	25	≥ 150 km/hr
		23	140 km/hr
		21	130 km/hr

		19	120 km/hr
		17	110 km/hr
		15	100 km/hr
		13	90 km/hr
		11	80 km/hr
		9	70 km/hr
		7	60 km/hr
		5	50 km/hr
		3	40 km/hr
		1	< 30 km/hr
		45	≥ 90 mph
		43	80 mph
		41	70 mph
		39	60 mph
		37	50 mph
		35	40 mph
		33	30 mph
		31	< 20 mph
26	Differential speeds	2	Present
		1	Not present
27	Median type	11	Centreline
		14	Wide centreline 0.3 m to 1 m
		10	Central hatching > 1 m
		8	Continuous central turning lane
		9	Flexible posts
		7	Physical median width 0 to < 1 m
		6	Physical median width 1 to < 5 m
		5	Physical median width 5 to < 10 m
		2	Safety barrier - concrete
		1	Safety barrier - metal
		12	Safety barrier - motorcycle friendly
		15	Safety barrier - wire rope
		4	Physical median width 10 to < 20 m
		3	Physical median width ≥ 20 m
		13	One way
28	Centreline rumble strips	1	Not present
		2	Present
29	Roadside severity –driver-side distance	1	0 to < 1 m
		2	1 to < 5 m

		3	5 to < 10 m
		4	≥ 10 m
30	Roadside severity – driver-side object	10	Cliff
		11	Tree ≥ 10 cm
		12	Rigid sign, post or pole ≥ 10 cm
		15	Unprotected safety barrier end
		5	Aggressive vertical face
		6	Upwards slope – rollover
		8	Deep drainage ditch
		9	Downwards slope
		16	Low rigid object ≥ 20 cm high
		13	Rigid structure or building
		7	Upwards slope – no rollover
		14	Semi-rigid structure or building
		2	Safety barrier – concrete
		1	Safety barrier – metal
		4	Safety barrier – wire rope
		3	Safety barrier – motorcycle friendly
		17	No object
31	Roadside severity – passenger-side distance	1	0 to < 1 m
		2	1 to < 5 m
		3	5 to < 10 m
		4	≥ 10 m
32	Roadside severity – passenger-side object	10	Cliff
		11	Tree ≥ 10 cm
		12	Rigid sign, post or pole ≥ 10 cm
		15	Unprotected safety barrier end
		5	Aggressive vertical face
		6	Upwards slope – rollover
		8	Deep drainage ditch
		9	Downwards slope
		16	Low rigid object ≥ 20 cm high
		13	Rigid structure or building
		7	Upwards slope – no rollover
		14	Semi-rigid structure or building
		2	Safety barrier – concrete
		1	Safety barrier – metal
		4	Safety barrier – wire rope
		3	Safety barrier – motorcycle friendly

		17	No object
33	Shoulder rumble strips	1	Not present
		2	Present
34	Paved shoulder – driver-side	4	None
		3	Narrow 0 m to < 1 m
		2	Medium 1 m to < 2.4 m
		1	Wide ≥ 2.4 m
35	Paved shoulder – passenger-side	4	None
		3	Narrow 0 m to < 1 m
		2	Medium 1 m to < 2.4 m
		1	Wide ≥ 2.4 m
36	Intersection type	8	4-leg
		7	4-leg with protected turn lane
		10	4-leg signalised
		4	3-leg
		3	3-leg with protected turn lane
		17	Mini roundabout
		6	3-leg signalised
		9	4-leg signalised with protected turn lane
		5	3-leg signalised with protected turn lane
		2	Roundabout
		13	Railway crossing – passive
		1	Merge lane
		14	Railway crossing – active
		15	Median crossing point – informal
		16	Median crossing point – formal
		12	None
37	Intersection channelisation	2	Present
		1	Not present
38	Intersecting road volume	1	≥ 15,000 vehicles
		2	10,000 to 15,000 vehicles
		3	5,000 to 10,000 vehicles
		4	1,000 to 5,000 vehicles
		5	100 to 1,000 vehicles
		6	1 to 100 vehicles
		7	Not applicable
39	Intersection quality	2	Poor
		1	Adequate
		3	Not applicable

40	Property access points	1	Commercial access ≥ 1
		2	Residential access ≥ 3
		3	Residential access < 3
		4	None
41	Number of lanes	4	Four or more
		3	Three
		6	Three and two
		2	Two
		5	Two and one
		1	One
42	Lane width	3	Narrow 0 m to < 2.75 m
		2	Medium 2.75 m to < 3.25 m
		1	Wide ≥ 3.25 m
43	Curvature	4	Very sharp
		3	Sharp
		2	Moderate
		1	Straight or gently curving
44	Quality of curve	2	Poor
		3	Not applicable
		1	Adequate
45	Grade	5	≥ 10%
		4	7.5% to < 10%
		1	0% to < 7.5%
46	Road condition	3	Poor
		2	Medium
		1	Good
47	Skid resistance	5	Unsealed - poor
		4	Unsealed - adequate
		3	Sealed - poor
		2	Sealed - medium
		1	Sealed - adequate
48	Delineation	2	Poor
		1	Adequate
49	Street lighting	1	Not present
		2	Present
50	Pedestrian crossing facilities – inspected road	7	No facility
		6	Refuge only
		5	Marked crossing only
		17	Raised unmarked crossing

		4	Marked crossing with refuge
		16	Raised unmarked crossing with refuge
		15	Raised marked crossing
		14	Raised marked crossing with refuge
		3	Signalised crossing
		2	Signalised crossing with refuge
		1	Grade separated facility
51	Pedestrian crossing facilities quality	2	Poor
		1	Adequate
		3	Not applicable
52	Pedestrian crossing facilities – side road	7	No facility
		6	Refuge only
		5	Marked crossing only
		17	Raised unmarked crossing
		4	Marked crossing with refuge
		16	Raised unmarked crossing with refuge
		15	Raised marked crossing
		14	Raised marked crossing with refuge
		3	Signalised crossing
		2	Signalised crossing with refuge
		1	Grade separated facility
53	Pedestrian fencing	1	Not present
		2	Present
54	Speed management	1	Not present
		2	Present
55	Vehicle parking	3	Two sides
		2	One side
		1	None
56	Sidewalk – driver-side	5	None
		7	Informal path 0 m to < 1 m
		6	Informal path ≥ 1 m
		4	Sidewalk 0 m to < 1 m from road
		3	Sidewalk 1 m to < 3 m from road
		2	Sidewalk ≥ 3 m from road
		1	Sidewalk with barrier
57	Sidewalk – passenger-side	5	None
		7	Informal path 0 m to < 1 m
		6	Informal path ≥ 1 m
		4	Sidewalk 0 m to < 1 m from road

		3	Sidewalk 1 m to < 3 m from road
		2	Sidewalk ≥ 3 m from road
		1	Sidewalk with barrier
58	Service road	1	Not present
		2	Present
59	Facilities for motorcycles	6	None
		5	Motorcycle lane on roadway
		2	Motorcycle path – one way
		4	Motorcycle path – two ways
		3	Motorcycle path – one way with barrier
		1	Motorcycle path – two ways with barrier
60	Facilities for bicycles	4	None
		6	Signed shared roadway
		5	Extra wide outside ≥ 4.2 m
		3	Dedicated bicycle lane on roadway
		7	Shared use path
		2	Segregated bicycle path
		1	Segregated bicycle path with barrier
61	Roadworks	3	Major road works
		2	Minor road works
		1	No road works
62	Sight distance	2	Poor
		1	Adequate
63	Vehicle flow (AADT)	NA	NA
64	Motorcycle %	10	100%
		9	81% - 99%
		8	61% - 80%
		7	41% - 60%
		6	21% - 40%
		5	11% - 20%
		4	6% - 10%
		3	1% - 5%
		2	0%
		1	Not recorded
65	Pedestrian peak hour flow across the road	11	900+
		10	501 to 900
		9	401 to 500
		8	301 to 401
		7	201 to 300

		6	101 to 200
		5	51 to 100
		4	26 to 50
		3	6 to 25
		2	1 to 5
		1	0
66	Pedestrian peak hour flow along the road driver-side	11	900+
		10	501 to 900
		9	401 to 500
		8	301 to 401
		7	201 to 300
		6	101 to 200
		5	51 to 100
		4	26 to 50
		3	6 to 25
		2	1 to 5
		1	0
67	Pedestrian peak hour flow along the road passenger-side	11	900+
		10	501 to 900
		9	401 to 500
		8	301 to 401
		7	201 to 300
		6	101 to 200
		5	51 to 100
		4	26 to 50
		3	6 to 25
		2	1 to 5
		1	0
68	Bicycle peak hourly flow	11	900+
		10	501 to 900
		9	401 to 500
		8	301 to 401
		7	201 to 300
		6	101 to 200
		5	51 to 100
		4	26 to 50
		3	6 to 25
		2	1 to 5
		1	0

69	Operating speed (85th percentile)	25	≥ 150 km/hr
		24	145 km/hr
		23	140 km/hr
		22	135 km/hr
		21	130 km/hr
		20	125 km/hr
		19	120 km/hr
		18	115 km/hr
		17	110 km/hr
		16	105 km/hr
		15	100 km/hr
		14	95 km/hr
		13	90 km/hr
		12	85 km/hr
		11	80 km/hr
		10	75 km/hr
		9	70 km/hr
		8	65 km/hr
		7	60 km/hr
		6	55 km/hr
		5	50 km/hr
		4	45 km/hr
		3	40 km/hr
		2	35 km/hr
		1	< 30 km/hr
		45	≥ 90 mph
		44	85 mph
		43	80 mph
		42	75 mph
		41	70 mph
		40	65 mph
		39	60 mph
		38	55 mph
		37	50 mph
		36	45 mph
		35	40 mph
		34	35 mph
		33	30 mph
		32	25 mph

		31	< 20 mph
70	Operating speed (mean)	25	≥ 150 km/hr
		24	145 km/hr
		23	140 km/hr
		22	135 km/hr
		21	130 km/hr
		20	125 km/hr
		19	120 km/hr
		18	115 km/hr
		17	110 km/hr
		16	105 km/hr
		15	100 km/hr
		14	95 km/hr
		13	90 km/hr
		12	85 km/hr
		11	80 km/hr
		10	75 km/hr
		9	70 km/hr
		8	65 km/hr
		7	60 km/hr
		6	55 km/hr
		5	50 km/hr
		4	45 km/hr
		3	40 km/hr
		2	35 km/hr
		1	< 30 km/hr
		45	≥ 90 mph
		44	85 mph
		43	80 mph
		42	75 mph
		41	70 mph
		40	65 mph
		39	60 mph
		38	55 mph
		37	50 mph
		36	45 mph
		35	40 mph
		34	35 mph
		33	30 mph

		32	25 mph
		31	< 20 mph
71	Roads that cars can read	2	Does not meet specification
		1	Meets specification
72	Vehicle occupant star rating policy target	1	1-star
		2	2-star
		3	3-star
		4	4-star
		5	5-star
		6	Not applicable
73	Motorcyclist star rating policy target	1	1-star
		2	2-star
		3	3-star
		4	4-star
		5	5-star
		6	Not applicable
74	Pedestrian star rating policy target	1	1-star
		2	2-star
		3	3-star
		4	4-star
		5	5-star
		6	Not applicable
75	Bicyclist star rating policy target	1	1-star
		2	2-star
		3	3-star
		4	4-star
		5	5-star
		6	Not applicable
76	Annual fatality growth	N/A	N/A
77	School zone warning	3	No school zone warning (school present)
		2	School zone static signs or road markings
		1	School zone flashing beacons
		4	Not applicable (no school at the location)
78	School zone crossing supervisor	2	School zone crossing supervisor not present
		1	School zone crossing supervisor present at school start and finish times
		3	Not applicable (no school at the location)

Source: (International Road Assessment Programme (iRAP), 2015b)

APPENDIX 2

Supporting Details

Section	Item	Col. No	Type	Category ID	Category
Road details and context	Road name	5	text	N/A	N/A
	Section	6	text	N/A	N/A
	Landmark	11	text	N/A	N/A
	Comments	12	text	N/A	N/A
Road user flows	Vehicle flow (AADT)	63	number	N/A	N/A
	Motorcycle %	64	code	10	100%
				9	81% - 99%
				8	61% - 80%
				7	41% - 60%
				6	21% - 40%
				5	11% - 20%
				4	6% - 10%
				3	1% - 5%
				2	0%
				1	Not recorded
	Pedestrian peak hour flow across the road	65	code	11	900+
				10	501 to 900
				9	401 to 500
				8	301 to 401
				7	201 to 300
				6	101 to 200
				5	51 to 100
				4	26 to 50
				3	6 to 25
				2	1 to 5
				1	0
	Pedestrian peak hour flow along the road driver-side	66	code	11	900+
				10	501 to 900
				9	401 to 500
				8	301 to 401
				7	201 to 300
				6	101 to 200
				5	51 to 100

				4	26 to 50
				3	6 to 25
				2	1 to 5
				1	0
	Pedestrian peak hour flow along the road passenger-side	67	code	11	900+
				10	501 to 900
				9	401 to 500
				8	301 to 401
				7	201 to 300
				6	101 to 200
				5	51 to 100
				4	26 to 50
				3	6 to 25
				2	1 to 5
				1	0
	Bicycle peak hour flow	68	code	11	900+
				10	501 to 900
				9	401 to 500
				8	301 to 401
				7	201 to 300
				6	101 to 200
				5	51 to 100
				4	26 to 50
				3	6 to 25
				2	1 to 5
				1	0
Operating speeds	Operating speed – 85th percentile	69	code	25	≥ 150 km/hr
				24	145 km/hr
				23	140 km/hr
				22	135 km/hr
				21	130 km/hr
				20	125 km/hr
				19	120 km/hr
				18	115 km/hr
				17	110 km/hr
				16	105 km/hr
				15	100 km/hr
				14	95 km/hr
				13	90 km/hr

				12	85 km/hr
				11	80 km/hr
				10	75 km/hr
				9	70 km/hr
				8	65 km/hr
				7	60 km/hr
				6	55 km/hr
				5	50 km/hr
				4	45 km/hr
				3	40 km/hr
				2	35 km/hr
				1	< 30 km/hr
				45	≥ 90 mph
				44	85 mph
				43	80 mph
				42	75 mph
				41	70 mph
				40	65 mph
				39	60 mph
				38	55 mph
				37	50 mph
				36	45 mph
				35	40 mph
				34	35 mph
				33	30 mph
				32	25 mph
				31	< 20 mph
	Operating speed - mean	70	code	25	≥ 150 km/hr
				24	145 km/hr
				23	140 km/hr
				22	135 km/hr
				21	130 km/hr
				20	125 km/hr
				19	120 km/hr
				18	115 km/hr
				17	110 km/hr
				16	105 km/hr
				15	100 km/hr
				14	95 km/hr

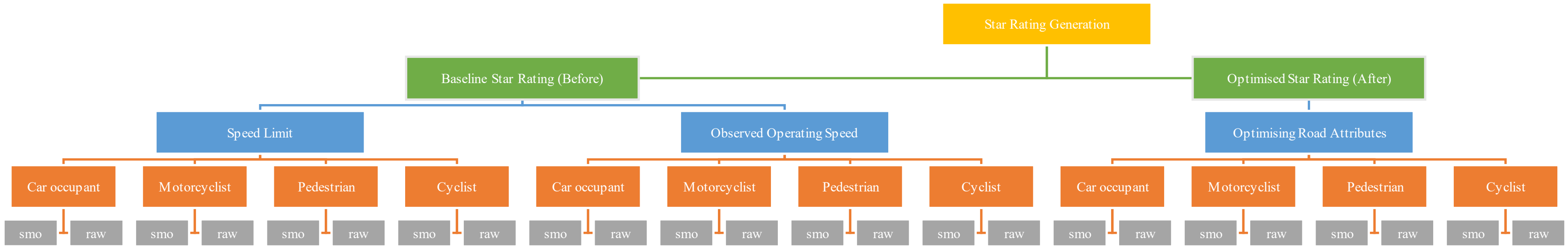
				13	90 km/hr
				12	85 km/hr
				11	80 km/hr
				10	75 km/hr
				9	70 km/hr
				8	65 km/hr
				7	60 km/hr
				6	55 km/hr
				5	50 km/hr
				4	45 km/hr
				3	40 km/hr
				2	35 km/hr
				1	< 30 km/hr
				45	≥ 90 mph
				44	85 mph
				43	80 mph
				42	75 mph
				41	70 mph
				40	65 mph
				39	60 mph
				38	55 mph
				37	50 mph
				36	45 mph
				35	40 mph
				34	35 mph
				33	30 mph
				32	25 mph
				31	< 20 mph
Other	Roads that cars can read	71	code	2	Does not meet specification
				1	Meets specification
	Vehicle occupant star rating policy target	72	code	1	1-star
				2	2-star
				3	3-star
				4	4-star
				5	5-star
				6	Not applicable
	Motorcyclist star rating policy target	73	code	1	1-star
				2	2-star
				3	3-star

			4	4-star
			5	5-star
			6	Not applicable
Pedestrian star rating policy target	74	code	1	1-star
			2	2-star
			3	3-star
			4	4-star
			5	5-star
			6	Not applicable
Bicyclist star rating policy target	75	code	1	1-star
			2	2-star
			3	3-star
			4	4-star
			5	5-star
			6	Not applicable
Annual fatality growth	76	number	N/A	N/A

Source: (International Road Assessment Programme (iRAP), 2024b)

APPENDIX 3

Structure of Star Rating Generation for Campus Road Safety



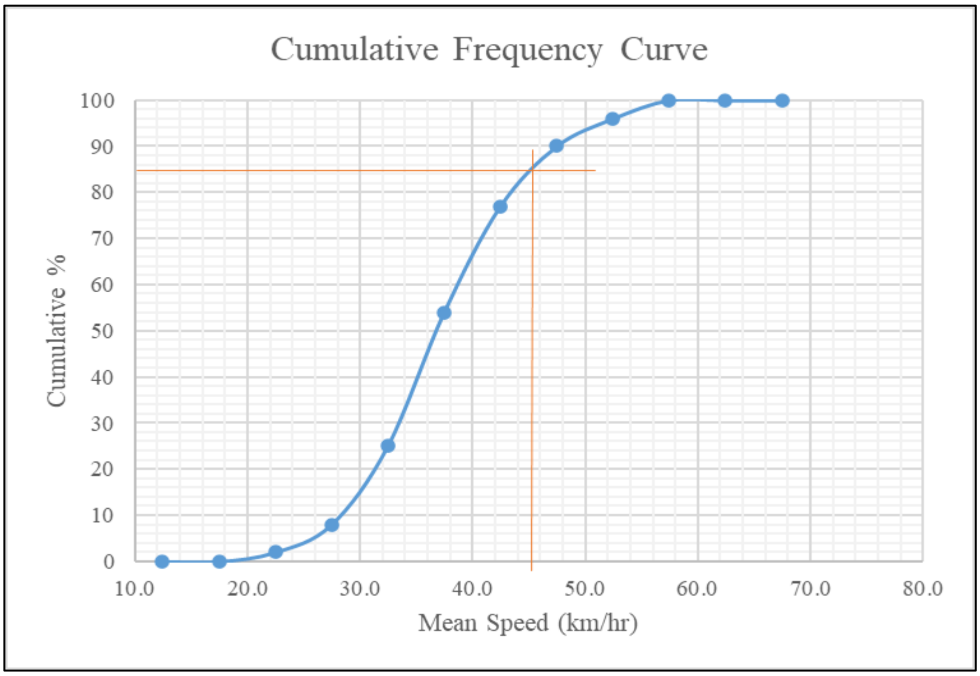
APPENDIX 4

Speed Data: Location 1

Time / Day	10:00-11:00 am / Monday
Location	Depan Kolej Kejuruteraan dan Kolej Melati

Speed Group	Middle Speed, v	No of observations, f	% of the total observation	Cumulative %	fv	v^2	fv^2
10-14.9	12.5	0	0	0	0	155.0025	0.0
15-19.9	17.5	0	0	0	0	304.5025	0.0
20-24.9	22.5	2	2	2	44.9	504.0	22629.7
25-29.9	27.5	6	6	8	164.7	753.5	124101.9
30-34.9	32.5	17	17	25	551.65	1053.0	580888.8
35-39.9	37.5	29	29	54	1086.05	1402.5	1523187.8
40-44.9	42.5	23	23	77	976.35	1802.0	1759385.1
45-49.9	47.5	13	13	90	616.85	2251.5	1388839.3
50-54.9	52.5	6	6	96	314.7	2751.0	865740.5
55-59.9	57.5	4	4	100	229.8	3300.5	758455.5
60-64.9	62.5	0	0	100	0	3900.0	0.0
65-69.9	67.5	0	0	100	0	4549.5	0.0
		100	100	652	3985	22727.03	7023228.663

Mean Speed	40 km/hr
85th Percentile	45 km/hr

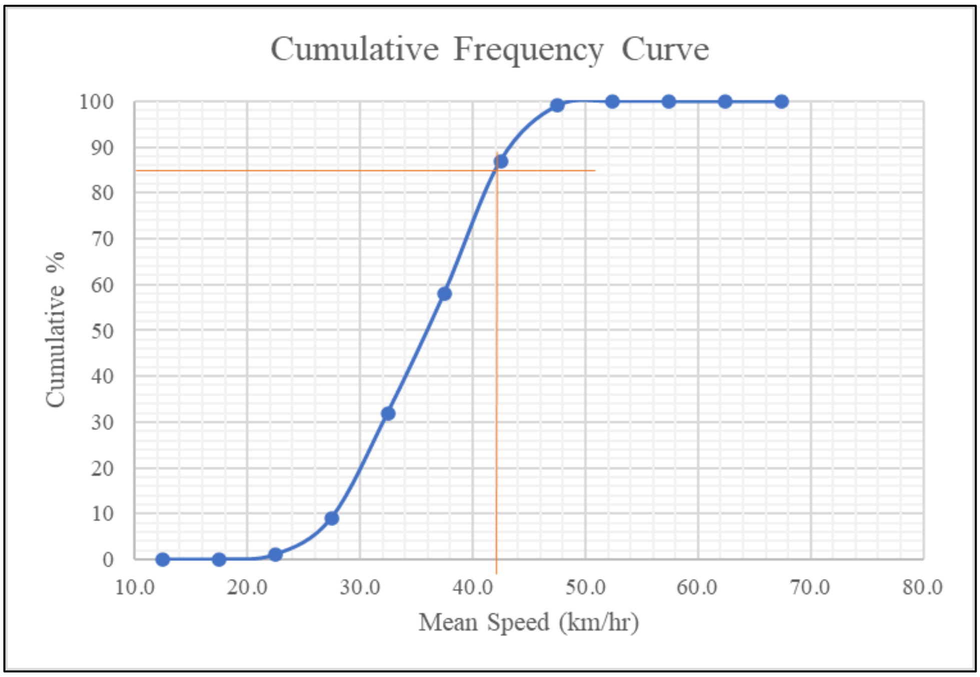


Speed Data: Location 2

Time / Day	10:00-11:00 am / Tuesday
Location	Chancellory Building Intersection

Speed Group	Middle Speed, v	No of observations, f	% of the total observation	Cumulative %	fv	v^2	fv^2
10-14.9	12.5	0	0	0	0	155.0025	0.0
15-19.9	17.5	0	0	0	0	304.5025	0.0
20-24.9	22.5	1	1	1	22.45	504.0	11314.9
25-29.9	27.5	8	8	9	219.6	753.5	165469.1
30-34.9	32.5	23	23	32	746.35	1053.0	785908.4
35-39.9	37.5	26	26	58	973.7	1402.5	1365616.7
40-44.9	42.5	29	29	87	1231.05	1802.0	2218355.2
45-49.9	47.5	12	12	99	569.4	2251.5	1282005.5
50-54.9	52.5	1	1	100	52.45	2751.0	144290.1
55-59.9	57.5	0	0	100	0	3300.5	0.0
60-64.9	62.5	0	0	100	0	3900.0	0.0
65-69.9	67.5	0	0	100	0	4549.5	0.0
		100	100	686	3815	22727.03	5972959.888

Mean Speed	38 km/hr
85th Percentile	42 km/hr

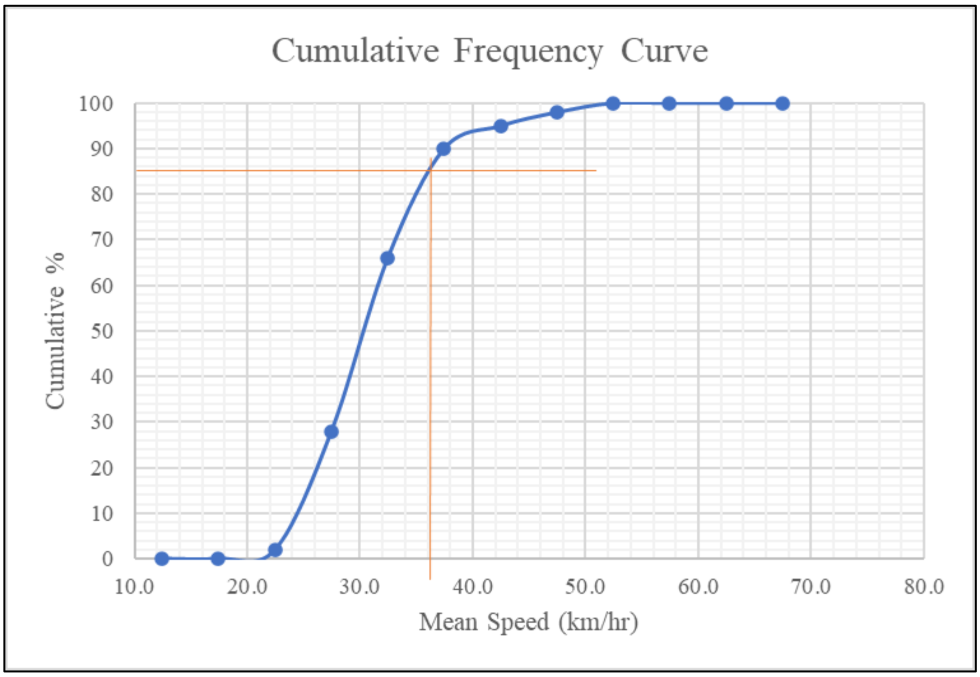


Speed Data: Location 3

Time / Day	10:00-11:00 am / Friday
Location	FSPU Intersection

Speed Group	Middle Speed, v	No of observations, f	% of the total observation	Cumulative %	fv	v^2	fv^2
10-14.9	12.5	0	0	0	0	155.0025	0.0
15-19.9	17.5	0	0	0	0	304.5025	0.0
20-24.9	22.5	2	2	2	44.9	504.0	22629.7
25-29.9	27.5	26	26	28	713.7	753.5	537774.7
30-34.9	32.5	38	38	66	1233.1	1053.0	1298457.4
35-39.9	37.5	24	24	90	898.8	1402.5	1260569.2
40-44.9	42.5	5	5	95	212.25	1802.0	382475.0
45-49.9	47.5	3	3	98	142.35	2251.5	320501.4
50-54.9	52.5	2	2	100	104.9	2751.0	288580.2
55-59.9	57.5	0	0	100	0	3300.5	0.0
60-64.9	62.5	0	0	100	0	3900.0	0.0
65-69.9	67.5	0	0	100	0	4549.5	0.0
		100	100	779	3350	22727.03	4110987.65

Mean Speed	34 km/hr
85th Percentile	36 km/ hr

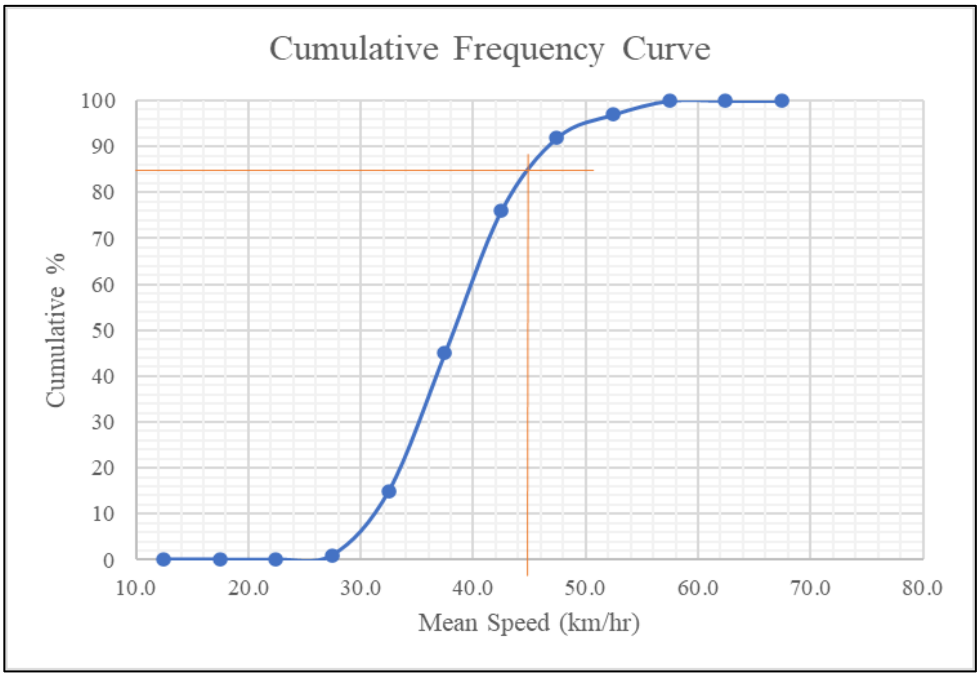


Speed Data: Location 4

Time / Day	11:00-12:00 pm / Tuesday
Location	MITRANS Intersection

Speed Group	Middle Speed, v	No of observations, f	% of the total observation	Cumulative %	fv	v^2	fv^2
10-14.9	12.5	0	0	0	0	155.0025	0.0
15-19.9	17.5	0	0	0	0	304.5025	0.0
20-24.9	22.5	0	0	0	0	504.0	0.0
25-29.9	27.5	1	1	1	27.45	753.5	20683.6
30-34.9	32.5	14	14	15	454.3	1053.0	478379.0
35-39.9	37.5	30	30	45	1123.5	1402.5	1575711.6
40-44.9	42.5	31	31	76	1315.95	1802.0	2371345.2
45-49.9	47.5	16	16	92	759.2	2251.5	1709340.7
50-54.9	52.5	5	5	97	262.25	2751.0	721450.4
55-59.9	57.5	3	3	100	172.35	3300.5	568841.6
60-64.9	62.5	0	0	100	0	3900.0	0.0
65-69.9	67.5	0	0	100	0	4549.5	0.0
		100	100	626	4115	22727.03	7445752.138

Mean Speed	41 km/hr
85th Percentile	44.5 km/hr

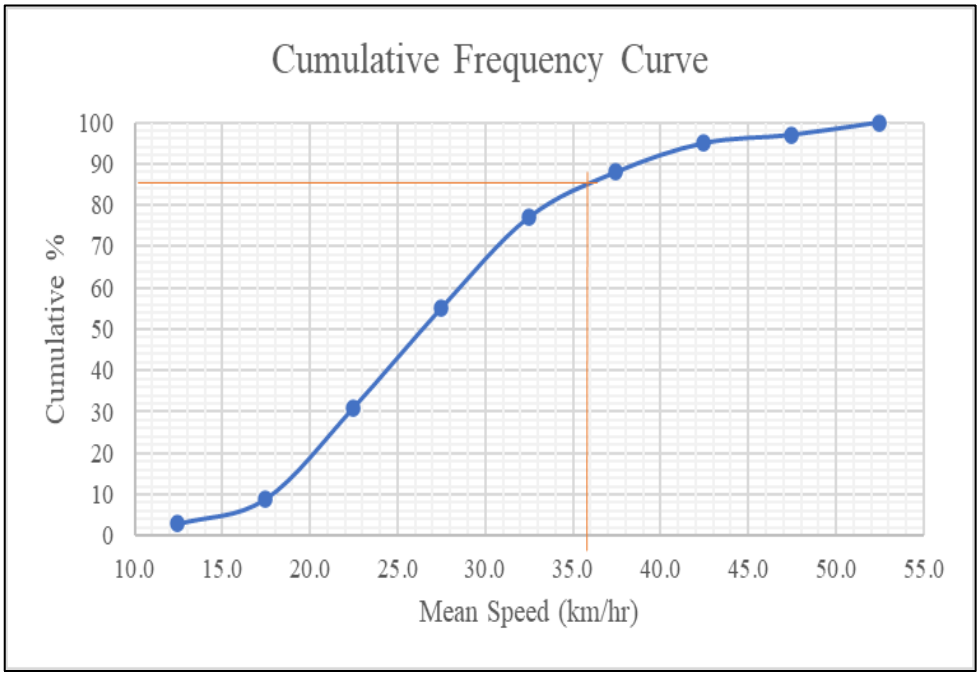


Speed Data: Location 5

Time / Day	10:00-11:00 am / Thursday
Location	Nursery Intersection from Pejabat Polis Bantuan UiTM Shah Alam

Speed Group	Middle Speed, v	No of observations, f	% of the total observation	Cumulative %	fv	v^2	fv^2
10-14.9	12.5	3	3	3	37.35	155.0025	5789.3
15-19.9	17.5	6	6	9	104.7	304.5025	31881.4
20-24.9	22.5	22	22	31	493.9	504.0	248926.8
25-29.9	27.5	24	24	55	658.8	753.5	496407.4
30-34.9	32.5	22	22	77	713.9	1053.0	751738.5
35-39.9	37.5	11	11	88	411.95	1402.5	577760.9
40-44.9	42.5	7	7	95	297.15	1802.0	535465.0
45-49.9	47.5	2	2	97	94.9	2251.5	213667.6
50-54.9	52.5	3	3	100	157.35	2751.0	432870.2
		100	100		2970		3294507.3

Mean Speed	30 km/hr
85th Percentile	35.5 km/hr

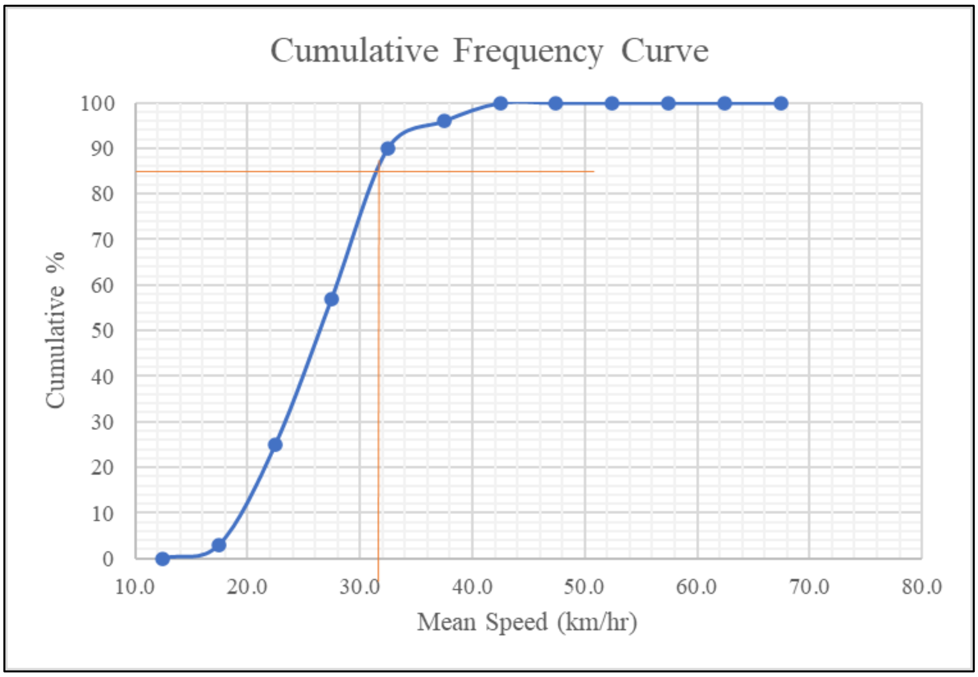


Speed Data: Location 6

Time / Day	11:00-12:00 pm / Tuesday
Location	Along Bustop Kolej Delima

Speed Group	Middle Speed, v	No of observations, f	% of the total observation	Cumulative %	fv	v^2	fv^2
10-14.9	12.5	0	0	0	0	155.0025	0.0
15-19.9	17.5	3	3	3	52.35	304.5025	15940.7
20-24.9	22.5	22	22	25	493.9	504.0	248926.8
25-29.9	27.5	32	32	57	878.4	753.5	661876.6
30-34.9	32.5	33	33	90	1070.85	1053.0	1127607.7
35-39.9	37.5	6	6	96	224.7	1402.5	315142.3
40-44.9	42.5	4	4	100	169.8	1802.0	305980.0
45-49.9	47.5	0	0	100	0	2251.5	0.0
50-54.9	52.5	0	0	100	0	2751.0	0.0
55-59.9	57.5	0	0	100	0	3300.5	0.0
60-64.9	62.5	0	0	100	0	3900.0	0.0
65-69.9	67.5	0	0	100	0	4549.5	0.0
		100	100	871	2890	22727.03	2675474.2

Mean Speed	29 km/hr
85th Percentile	31.5 km/hr

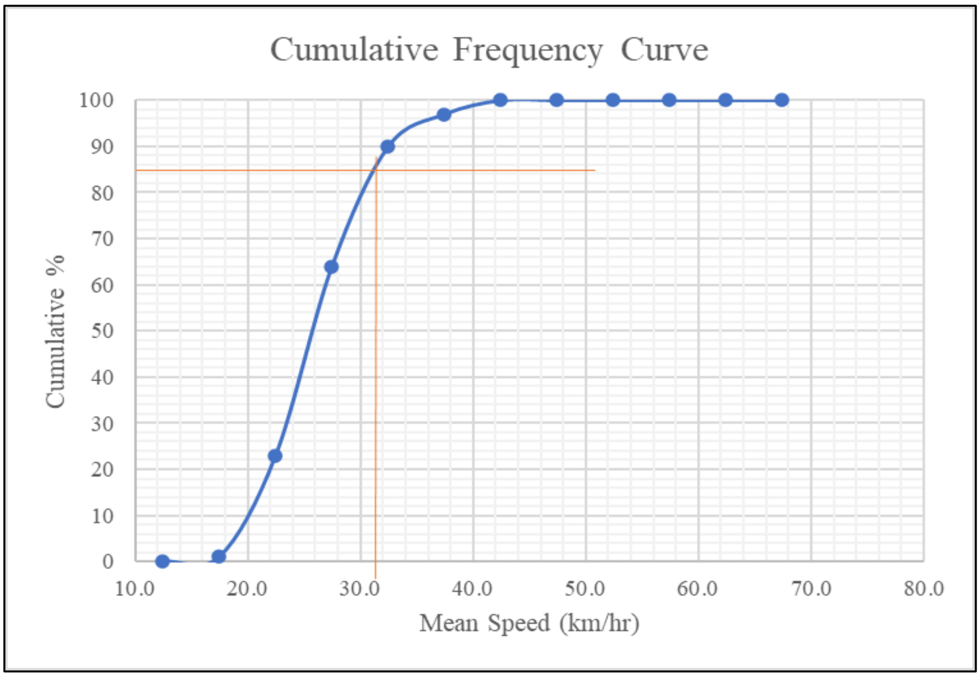


Speed Data: Location 7

Time / Day	10:00-11:00 am / Tuesday
Location	Along Facility Management Office

Speed Group	Middle Speed, v	No of observations, f	% of the total observation	Cumulative %	fv	v^2	fv^2
10-14.9	12.5	0	0	0	0	155.0025	0.0
15-19.9	17.5	1	1	1	17.45	304.5025	5313.6
20-24.9	22.5	22	22	23	493.9	504.0	248926.8
25-29.9	27.5	41	41	64	1125.45	753.5	848029.4
30-34.9	32.5	26	26	90	843.7	1053.0	888418.2
35-39.9	37.5	7	7	97	262.15	1402.5	367666.0
40-44.9	42.5	3	3	100	127.35	1802.0	229485.0
45-49.9	47.5	0	0	100	0	2251.5	0.0
50-54.9	52.5	0	0	100	0	2751.0	0.0
55-59.9	57.5	0	0	100	0	3300.5	0.0
60-64.9	62.5	0	0	100	0	3900.0	0.0
65-69.9	67.5	0	0	100	0	4549.5	0.0
		100	100	875	2870	22727.03	2587839.05

Mean Speed	29 km/hr
85th Percentile	31 km/hr

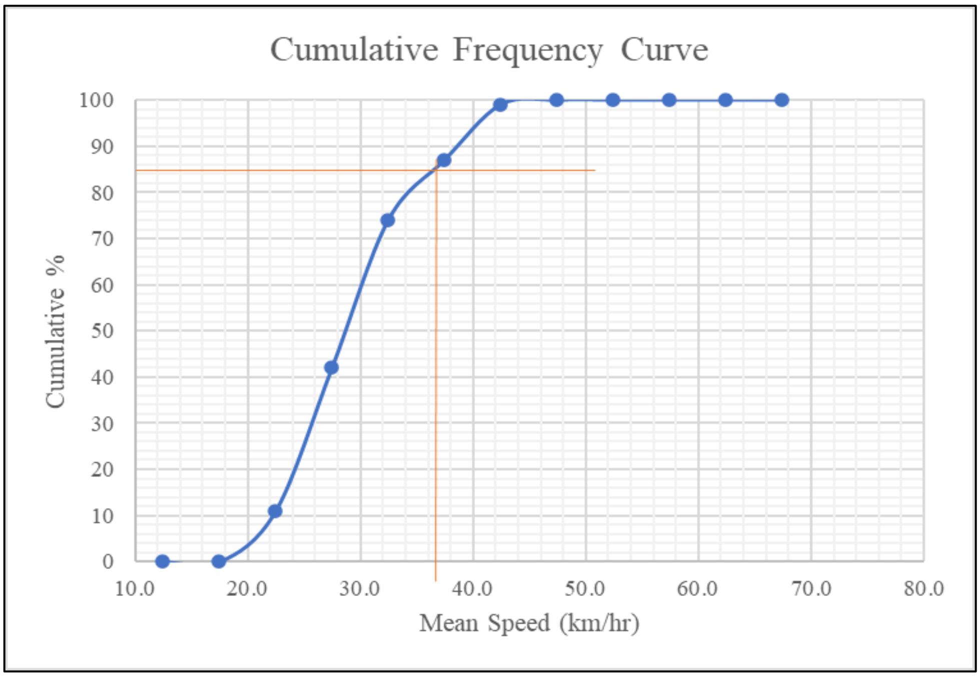


Speed Data: Location 8

Time / Day	11:00-12:00 pm / Friday
Location	Along Kenanga Complex Intersection

Speed Group	Middle Speed, v	No of observations, f	% of the total observation	Cumulative %	fv	v^2	fv^2
10-14.9	12.5	0	0	0	0	155.0025	0.0
15-19.9	17.5	0	0	0	0	304.5025	0.0
20-24.9	22.5	11	11	11	246.95	504.0	124463.4
25-29.9	27.5	31	31	42	850.95	753.5	641193.0
30-34.9	32.5	32	32	74	1038.4	1053.0	1093437.8
35-39.9	37.5	13	13	87	486.85	1402.5	682808.3
40-44.9	42.5	12	12	99	509.4	1802.0	917940.1
45-49.9	47.5	1	1	100	47.45	2251.5	106833.8
50-54.9	52.5	0	0	100	0	2751.0	0.0
55-59.9	57.5	0	0	100	0	3300.5	0.0
60-64.9	62.5	0	0	100	0	3900.0	0.0
65-69.9	67.5	0	0	100	0	4549.5	0.0
		100	100	813	3180	22727.03	3566676.375

Mean Speed	32 km/hr
85th Percentile	36.5 km/hr

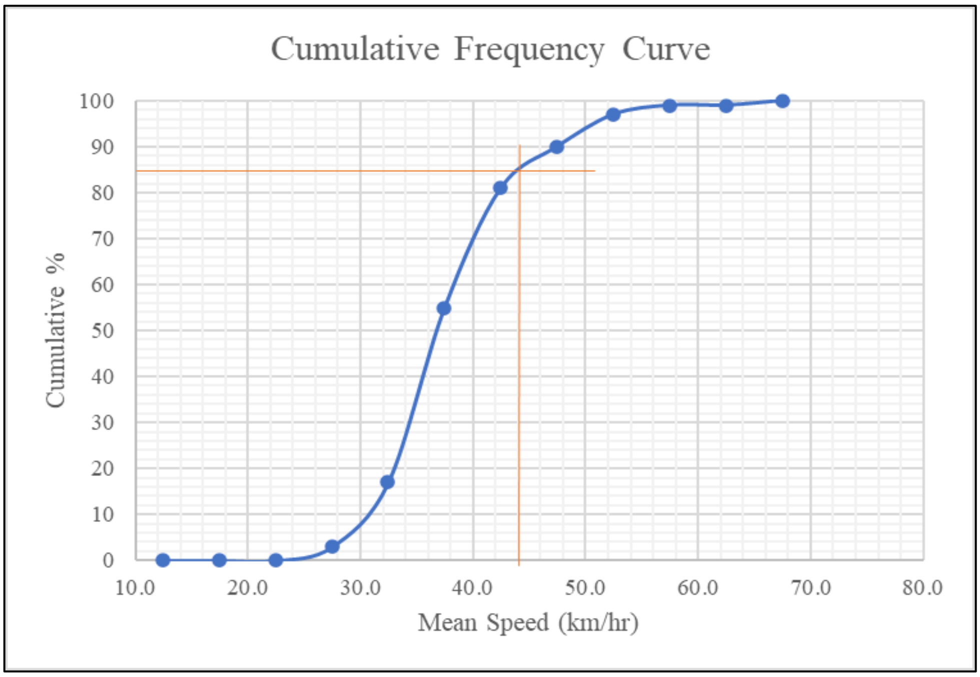


Speed Data: Location 9

Time / Day	10:00-11:00 am / Friday
Location	Walkway to DATC

Speed Group	Middle Speed, v	No of observations, f	% of the total observation	Cumulative %	fv	v^2	fv^2
10-14.9	12.5	0	0	0	0	155.0025	0.0
15-19.9	17.5	0	0	0	0	304.5025	0.0
20-24.9	22.5	0	0	0	0	504.0	0.0
25-29.9	27.5	3	3	3	82.35	753.5	62050.9
30-34.9	32.5	14	14	17	454.3	1053.0	478379.0
35-39.9	37.5	38	38	55	1423.1	1402.5	1995901.3
40-44.9	42.5	26	26	81	1103.7	1802.0	1988870.2
45-49.9	47.5	9	9	90	427.05	2251.5	961504.1
50-54.9	52.5	7	7	97	367.15	2751.0	1010030.6
55-59.9	57.5	2	2	99	114.9	3300.5	379227.7
60-64.9	62.5	0	0	99	0	3900.0	0.0
65-69.9	67.5	1	1	100	67.45	4549.5	306863.9
		100	100	641	4040	22727.03	7182827.825

Mean Speed	40 km/hr
85th Percentile	44 km/hr



AUTHOR'S PROFILE

Ainatul-Fatima binti Md Murozi earned a Diploma in Civil Engineering from Universiti Teknologi MARA (UiTM) Pulau Pinang, Malaysia, in 2018 and a Bachelor of Engineering (Hons) in Civil Engineering from Universiti Teknologi MARA (UiTM) Shah Alam, Malaysia, in 2021. She is currently pursuing a Master of Science in Transport and Logistics at the Malaysia Institute of Transport (MITRANS), Universiti Teknologi MARA (UiTM) Shah Alam, Malaysia. Her master's thesis focuses on assessing road infrastructure within the campus environment utilising the International Road Assessment Programme (iRAP). This approach is recognised for its efforts to enhance road safety globally by evaluating and improving infrastructure to reduce casualties and injuries among road users, particularly vulnerable groups such as pedestrians and cyclists.

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