REAAA Technical Report

Vulnerable Road Users: Safety Status Among REAAA Countries

REAAA Road Safety Committee
Ir Ts Dr Muhammad Marizwan bin Hj. Abdul Manan,
Adjunct Professor, Malaysian Institute of Road Safety Research (MIROS)

REAAA Technical Report TC-14

REAAA Project: Vulnerable Road Users, with Particular Reference to Motorcyclists

Vulnerable Road Users: Safety Status Among REAAA Countries

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REAAA Project: Vulnerable Road Users

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Prepared by

Ir Ts Dr Muhammad Marizwan bin Hj. Abdul Manan,
Adjunct Professor, Malaysian Institute of Road Safety Research (MIROS)

Working Group: Vulnerable Road Users
on behalf of REAAA Road Safety Committee

Reviewed and Edited by

Kieran Sharp, Ex-Officio Chair of REAAA Technical Committee and REAAA Technical Editor

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The Road Engineering Association of Asia & Australasia
46B Jalan Bola Tampar 13/14, Section 13
40100 Shah Alam
Selangor, Malaysia
Phone: +603 5513 6380 / +603 5524 6380
E-mail: reaaa.technical@gmail.com
www.reaaa.net

VULNERABLE ROAD USERS: SAFETY STATUS AMONG REAAA COUNTRIES

REAAA 2025
Kuala Lumpur, Malaysia

REAAA Profile

The Road Engineering Association of Asia and Australasia (REAAA) promotes the science and practice of road engineering and related professions in the Asia-Pacific region through the development of professional and commercial links within, and between, countries in the region. REAAA Chapters have been set up in Australia, Brunei, Korea, Malaysia, New Zealand and the Philippines. REAAA is also active in Indonesia, Japan, Singapore, Taiwan and Thailand.

REAAA was established in June 1973 with a permanent secretariat in Malaysia. Currently there are more than 1,200 members in 23 countries. It holds regular events including two Governing Council meetings each year, business forums, a quadrennial international conference, technical visits and study tours, trade exhibitions, seminars, forums and workshops. It also published technical reports addressing issues of concern in the region and a Newsletters twice each year.

REAAA Technical Reports

This is the thirteenth in the series of Technical Reports since the first report was published in 2008. The following Technical Reports have been published to date:

TC-1 Guide to privatisation of expressways and highways

TC-2 Disaster risk management

TC-3 Efficient operation of the road network

TC-4 Road safety – make it happen

TC-5 Pavement durability

TC-6 Guide to the public-private partnership of road and highway projects

TC-7 Incorporating Japanese pavement design practice for a community road in Mongolia

TC-8 Pavement maintenance and rehabilitation practices

TC-9 Compendium on pavement recycling

TC-10 Report on FEHRL scanning tour to South Korea and Japan: infrastructure resilience

TC-11 Compendium on pavement structural design and rehabilitation methods

TC-12 Incorporating Japanese pavement design practice for a community/local road in Myanmar

TC-13 Compendium on pavement maintenance and rehabilitation practices.

TC-14 Vulnerable road users: safety status among REAAA countries

REAAA Technical Sub-Committee: Road Safety

The REAAA Road Safety Committee (RSC) is one of the three sub-committees reporting to the Technical Committee. It was established at the 108th Governing Council meeting in Brisbane, Australia, in May 2018. The first meeting focussed on the topics to be dealt with by the sub-committee. At the same time, cooperation with, and reference to, the PIARC Road Safety Committee has been maintained so that collaborative activities of mutual interest to both REAAA and PIARC are maintained. A similar strategy is being applied with the International Road Assessment Programme (iRAP).

Membership of REAAA Road Safety Committee (16th Council Term – 2021-2025)

Including Cooperation with PIARC Committee TC.3.1 – Road Safety and iRAP GTC – International Road Assessment Programme Global Technical Committee

Country	Member	Organisation
Chair	Ir Dr Muhammad Marizwan bin Abdul Manan	Director, Road Safety Engineering and Environment Research Centre, Malaysian Institute of Road Safety Research (MIROS)
Australia	Mr David Milling	National Transport Research Organisation
Brunei		
Indonesia	Dr Didik Rudjito	Ministry of Public Works & Housing
	Dr Yusuf Adinegoro	Ministry of Public Works & Housing
	Dr Alfa Adib	Director-General of Highways
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	Mr Min Soo Kim	Dasan Consultants Co. Ltd
	Dr Hyun Suk Lee	Korea Expressway Corporation
	Dr In Soo Kim	Korea Expressway Corporation
Malaysia	Dr Siti Zaharah Ishak[1]	Malaysia Institute of Transport (MITRANS) UiTM, Shah Alam
New Zealand	Mr Stephen Fletcher	GHD
	Ms Jessica Rattray	NZTA Waka Kotahi
Philippines	Mr Abdulfatak A Pandapatan	Department of Public Works & Highways
Singapore	Mr Tan Tee Nee	Land Transport Authority
Taiwan	Mr Chung-Chang Lee	Directorate General of Highways, MOTC
	Mr Pei-Yun Li	Directorate General of Highways, MOTC
	Prof. Jia-Ruey Chang	National Ilan University
Thailand[2]		
iRAP GTC	Mr Greg Smith	International Road Assessment Programme (iRAP)
Observer	Dr Blair Turner	World Bank, Washington DC
REAAA Secretariat	Ms Zalilahwati bt Latif (Ila)	REAAA
TC RS Secretariat	Ms Sharifah Allyana bt Syed Mohamad Rahim	Malaysian Institute of Road Safety Research (MIROS)
TC RS Secretariat	Ms Sharifah Allyana bt Syed Mohamad Rahim	Malaysian Institute of Road Safety Research (MIROS)
Observer	Mr Kieran Sharp	Ex-offico Chair of REAAA Technical Committee
Chair, REAAA Technical Committee	Dr James Grenfell	National Transport Research Organisation

1 Member of PIARC Committee TC.3.1.

2 Thailand contributed to the development of this compendium.

SUMMARY

The REAAA Road Safety Committee (RSC) is one of the three sub-committees reporting to the REAAA Technical Committee. It was established at the 108th Governing Council meeting in Brisbane, Australia, in May 2018. The first meeting focussed on the topics to be dealt with by the sub-committee. At the same time, cooperation with, and reference to, the PIARC Road Safety Committee was to be maintained so that collaborative activities of mutual interest to both REAAA and PIARC could be addressed. A similar strategy was adopted with the International Road Assessment Programme (iRAP).

The purpose of the project described in this report was to gain a better understanding of the current issues related to the safety of vulnerable road users (VRU), particularly users of powered-two-wheeled (PTW) vehicles. The strategy adopted was to determine the road infrastructure programs, or road safety measures, that are in place in REAAA member countries and to identify the problems pertaining to the drivers conflicting with VRUs, especially drivers of PTWs.

The work involved an investigation of existing strategies, or plans, in terms of providing the appropriate infrastructure or countermeasures to improve the safety of drivers of PTW's. Selected successful case studies are presented in this report as a means of referencing some of the best practices adopted by REAAA member countries.

The following comments are offered based on the information provided by each country, included case studies:

- Indonesia has the highest percentage of PTW (84%), followed by Thailand (52%) and Malaysia (46%).
- Malaysia and Indonesia have recorded the highest rate of fatalities (74% and 70% respectively) for all types of PTWs while the highest fatality rate for pedestrians is in Korea (35%) and Japan (31%).
- Korea has the highest fatality rate among the 30-60 years old group (78%). In terms of the young age group of 16-29 years age group, Singapore has the highest fatality rate of 37%
- High-income countries (HIC) with high VOSL have a lower fatality rate per 100,000 population compared to the low- and middle-income countries (LMIC).
- The main or similar crash causes among the participating countries were speeding and dangerous driving.

Based on the case studies presented by the participating countries, it can be concluded that only Malaysia has implemented dedicated countermeasures for motorcycles (i.e. NEMCL), while Thailand is more focussed on proactive measures such as road safety audits. To ensure a safer environment for pedestrian and cyclists, countries such as New Zealand and Korea presented dedicated countermeasures to curb speeding and promote segregation. Among all the participating countries, Australia has the most comprehensive countermeasures and programs for VRUs: it is the only country that has established guidelines for micromobility devices.

ACKNOWLEDGEMENTS

The input from the member countries who responded to the questionnaire is gratefully acknowledged.

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Acknowledgements

Special thanks to those who has contributed to the development of the report by providing input. The members of the Project Working Group were as follows:

Name	Post and Organization	Country
Dr Takeshi Ikeda	Head Road Safety Division, National Institute for Land and Infrastructure Management Ministry of Land, Infrastructure, Transport and Tourism	Japan
Dr Hyun Seok Lee	Research Fellow, Korea Expressway Corporation	Korea
Tong Kum Kong	Deputy Director, Commuter Infrastructure Construction 2 Land Transport Authority (LTA)	Singapore
Fabian Marsh	Senior Manager Road Safety, Waka Kotahi NZ Transport Agency	New Zealand
Alfa Adib Ash Shiddiqi	Director General Highways, Ministry of Public Works	Indonesia
David Milling Hooman Alenoori	Principal Professional Leader National Transport Research Organization National Transport Research Organization	Australia
Dr Chakree Bamrungwong Dr Suebpong Paisalwattana Dr Auckpath Sawangsuriya	Principal Advisor for Land Transport Economics, Ministry of Transport Director, Bureau of Highway Safety, Department of Highways Deputy Director, Bureau of Road Research and Development, Department of Highways	Thailand
Adonis Lu	Secretariat, China Road Federation	Taiwan
Ir Ts Dr Muhammad Marizwan bin Abdul Manan Ir Ts Sharifah Allyana bt Syed Mohamad Rahim	Director, Road Safety Engineering and Environmental Research Centre, REER, MIROS Senior Researcher, Road Safety Engineering and Environmental Research Centre, REER, MIROS	Malaysia

1. Introduction

The REAAA Road Safety Committee (RSC) is one of the three sub-committees reporting to the REAAA Technical Committee. It was established at the 108th Governing Council meeting in Brisbane, Australia, in May 2018. The first meeting focussed on the topics to be dealt with by the sub-committee. At the same time, cooperation with, and reference to, the PIARC Road Safety Committee was to be maintained so that collaborative activities of mutual interest to both REAAA and PIARC could be addressed. A similar strategy was adopted with the International Road Assessment Programme (iRAP).

The purpose of the project described in this report was to gain a better understanding of the current issues related to the safety of vulnerable road users (VRU), particularly users of powered-two-wheeled (PTW) vehicles. The work involved an investigation of existing strategies, or plans, in terms of providing the appropriate infrastructure or countermeasures to improve the road safety of drivers of PTW's. Selected successful case studies are presented in this report as a means of referencing some of the best practices adopted by REAAA member countries.

2. Method

A questionnaire addressing these issues was distributed to REAAA member countries in March 2022 and nine countries responded. The questionnaire consisted of the following three parts (Part A, B and C):

- Part A: General road safety information – Participants were required to provide accident statistics related to PTWs. This information was vital if the safety of PTW drivers was to be gauged and the data from each country compared. Participants were required to provide statistics based on the latest data available or data from three years back from 2022. Participants also needed to declare, or cite, the source of the data.
- Part B: Road infrastructure program, guidelines, or material related to VRUs – Participant were asked to provide details of issues and implemented countermeasures relevant to all types of VRUs which addressed road safety improvement.
- Part C: Case Studies – Participant were asked to provide at least one example related to Part B: the safety issues related to VRUs, details of implemented countermeasures, and the effectiveness of this implementation.

Some notes and abbreviations used in the development of the questionnaire and the report are as follows.

REAAA – Road Engineering Association of Asia and Australasia.

iRAP – International Road Assessment Programme.

GTC – Global Technical Committee of World Health Organization.

VOS – Value of Statistical Life (i.e. 70 x GDP per capita of the country).

UNECE – United Nations Economic Commission for Europe.

VRU –Vulnerable Road users: a term applied to those most at risk in traffic. Vulnerable road users are mainly those unprotected by an outside shield, namely pedestrians, two-wheelers (e.g. bicycles) and powered-two-wheelers, as they sustain a greater risk of injury in any collision compared to a vehicle. They are therefore highly in need of protection against such collisions.

CMF – Crash modification factor (CMF): a factor used to compute the expected number of crashes after the implementation of a given countermeasure at a specific site. It is defined as the ratio of the expected crash frequency following an improvement and the expected crash frequency without an improvement.

DUI – Driving under the influence (DUI): the offense of driving, operating, or being in control of a vehicle while impaired by alcohol or drugs (including recreational drugs and those prescribed by physicians), to a level that renders the driver incapable of operating a motor vehicle safely.

PTW – Powered two-wheeler: based on the International Motorcycle Manufacturers Associations (IMMA), the term 'powered two- wheeler' (PTW) covers a wide diversity of vehicles. They are divided into different segments such as moped, scooter, street, classic, super-sport, touring, custom, Supermoto (aka superbike) and off-road motorcycles. In the international regulatory environment, and in particular UNECE, PTWs are referred to as 'vehicles of category L'. The categories are as follows:

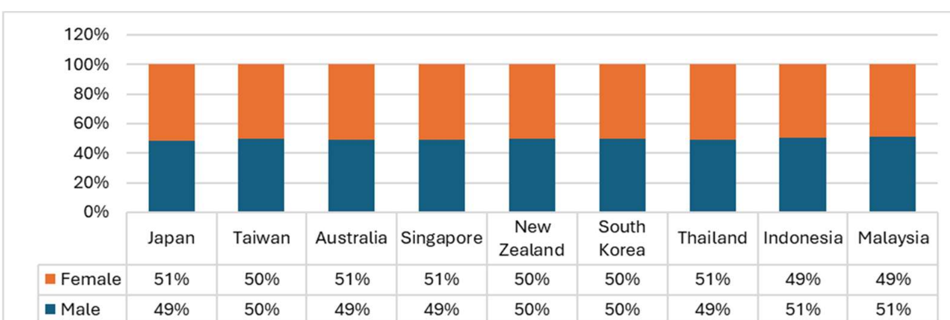
1. Category L1: A two-wheeled vehicle with a thermic engine cylinder capacity not exceeding 50 cm^3 (<50 cc) and, whatever the means of propulsion, a maximum design speed not exceeding 50 km/h (e.g. electric bicycle, moped, scooter).
2. Category L2: A three-wheeled vehicle of any wheel arrangement with a thermic engine cylinder capacity not exceeding 50 cm^3 (<50 cc) and, whatever the means of propulsion, a maximum design speed not exceeding 50 km/h (e.g. auto rickshaw).
3. Category L3: A two-wheeled vehicle with a thermic engine cylinder capacity exceeding 50 cm^3 (>50 cc) and, whatever the means of propulsion, a maximum design speed exceeding 50 km/h (e.g. motorcycle, maxi-scooter, classic, super-sport, touring, custom, superbike). However, in Asian countries such as Taiwan, Malaysia and Vietnam, by far the most common PTWs are those with engine capacities up to 150 cc; PTWs with engine capacities above 150 cc are considered large or high-capacity motorcycles (Hsu et al. 2003; Hussain et al. 2005; Abdul Manan and Várhelyi 2012). Despite the number of wheels or engine capacity assigned to these types of vehicles, they are commonly identified as 'motorcycles', and their riders have been categorized as vulnerable road users (Broughton *et al.* 2009; Haworth 2012; Van Elslande and Elvik 2012).
4. Category L4: A vehicle with three wheels asymmetrically arranged in relation to the longitudinal median plane with a thermic engine cylinder capacity exceeding 50 cm^3 (>50 cc) and, whatever the means of propulsion, a maximum design speed exceeding 50 km/h (e.g. motorcycle with sidecar).
5. Category L5: A vehicle with three wheels symmetrically arranged in relation to the longitudinal median plane with a thermic engine cylinder capacity exceeding 50 cm^3 (>50 cc) and, whatever the means of propulsion, a maximum design speed exceeding 50 km/h (e.g. motorized tricycle).

3. Results

This results are divided into two main sections: Part A: General findings (Section 3.1), and Part B: Case studies (Section 3.2). In the case study section, there are two tables which present: (1) materials, issues and implemented countermeasures for VRUs, and (2) case studies describing the county's best countermeasures for VRU.

3.1 Part A: General Findings

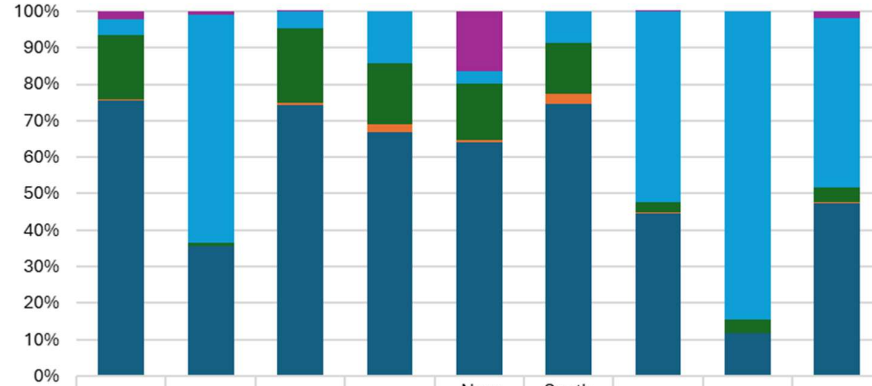
The population of the nine countries which participated in the survey are shown in Figure **1**. It can be seen that Indonesia has the highest population of the participating countries. Based on the gender population, all participating countries have an almost equally number of males and females.



Country and year of data	Japan 2020	Taiwan 2020	Australia 2021	Singapore 2021	New Zealand	Korea 2019	Thailand 2021	Indonesia 2019	Malaysia 2021
Total	126,146,099	23,560,000	25,422,789	5,450,000	5,127,200	51,829,136	66,300,002	272,681,000	32,700,000

Figure 1: Country population

The cumulative number of registered vehicles among the participating counties is shown in Figure **2**. Indonesia has the highest percentage of PTWs (84%), followed by Thailand (52%) and Malaysia (46%). The participating countries which have the lowest percentage of PTWs are Japan and New Zealand, with 4% each, whilst the figure for Australia is only 5%.

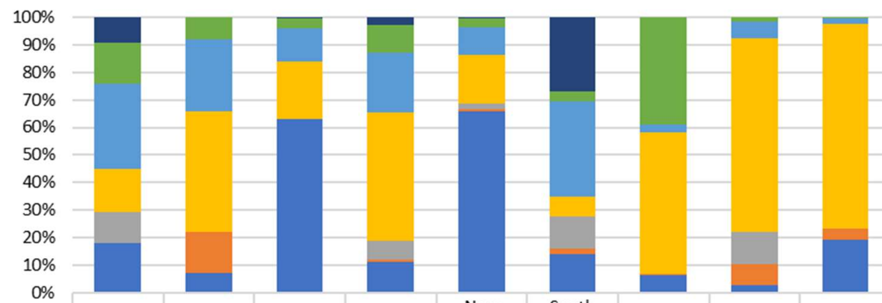


	Japan	Taiwan	Australia	Singapore	New Zealand	South Korea	Thailand	Indonesia	Malaysia
Others*	2%	1%	0.1%		16%		0.05%		2%
All type of PTW	4%	63%	5%	14%	4%	9%	52%	84%	46%
Heavy/goods vehicles	18%	1%	20%	17%	15%	14%	3%	4%	4%
Buses	0.3%	0.02%	0.4%	2%	1%	3%	0.3%	0.2%	0.2%
Passenger cars/light vehicles	76%	36%	74%	67%	64%	75%	44%	12%	47%

* Other – Includes vehicle such as moto-tricycles, rickshaws, animal carts, etc.

Figure 2: Cumulative number of registered vehicles

The percentage of road fatalities according to type of road user is compared in Figure **3**. Malaysia and Indonesia recorded the highest rate of fatalities (74% and 70%) for all types of PTWs. The highest fatality rate for pedestrians was in Korea (35%) and Japan (31%), while bicycles and rickshaws were the highest in Thailand, accounting for 39% of its total fatalities. In terms of for passenger vehicles or light vehicles, New Zealand had the highest rate, accounting for 65.9% of total fatalities.

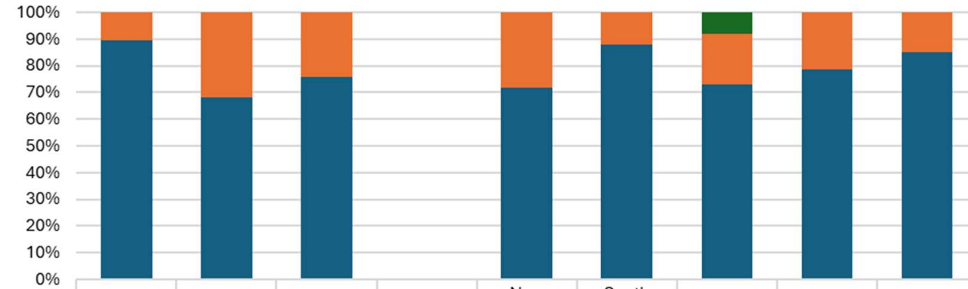


	Japan	Taiwan	Australia	Singapore	New Zealand	South Korea	Thailand	Indonesia	Malaysia
Others*	9.2%		0.5%	2.8%	0.3%	26.8%			
Bicycles/rickshaws	14.9%	8.1%	3.7%	10.3%	3.4%	3.8%	39.0%	1.5%	0.4%
Pedestrians	31.2%	26.0%	11.8%	21.5%	10.0%	34.7%	2.8%	6.1%	1.9%
All type of PTW	15.5%	43.8%	21.0%	46.7%	17.8%	6.9%	51.5%	70.5%	74.4%
Heavy/goods vehicles	11.3%			6.5%	1.9%	11.9%		11.3%	
Buses	0.1%	15.0%		0.9%	0.6%	1.9%	0.4%	7.7%	3.8%
Passenger cars/light vehicles	17.9%	7.1%	63.0%	11.2%	65.9%	14.0%	6.3%	2.8%	19.4%

* Other – Includes vehicle such as moto-tricycles, rickshaws, animal carts, etc.

Figure 3: Percentage of road fatalities by type of road user

The percentage of road fatalities according to gender are shown in Figure **4**. As expected, the majority share of the fatalities in all countries are males, with Japan having the highest fatality rate for males (89% of its total road fatalities). Taiwan has the highest fatality rate among female road users, with 32% of the total fatalities.

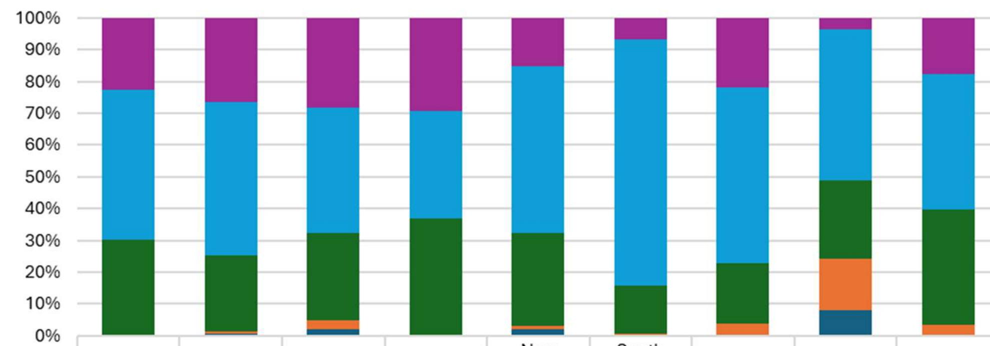


	Japan	Taiwan	Australia	Singapore*	New Zealand	South Korea	Thailand	Indonesia	Malaysia
Unknown							8%		
Female	11%	32%	24%		28%	12%	19%	21%	15%
Male	89%	68%	76%		72%	88%	73%	79%	85%

* Singapore – No data.

Figure 4: Percentage of road fatalities by gender and per 100,000 population

Due to variance in the categories of age range among participating countries, the category ranges had to be revised to suit all country age ranges and the results (see Figure **5**). It can be seen that the majority of the countries had the highest fatality rate in the 30-60 years old group, with Korea having the highest fatality rate (78%) among the participating countries. In terms of the young age group of 16-29 years, Singapore had the highest fatality rate of 37%.



	Japan	Taiwan	Australia	Singapore*	New Zealand	South Korea	Thailand**	Indonesia	Malaysia
60+ years	23%	27%	28%	29%	15%	7%	22%	4%	17%
30-60 years	47%	48%	39%	34%	52%	78%	55%	48%	43%
16-29 years	30%	24%	28%	37%	29%	15%	19%	25%	37%
6-15 years	0%	1%	3%		1%	1%	4%	16%	3%
0-5 years	0%	1%	2%		2%			8%	0.3%

* Singapore – Data range starts from 0-29 years old. **Thailand – Data range starts from 0-14 years old.

Figure 5: Percentage of road fatalities by age group

A comparison of the Value of Statistical Life (VOSL), in million USD and fatalities per 100,000 population, among the participating countries is shown in Figure **6**. There is an obvious pattern, in that high-income countries (HIC) with high VOSL such Singapore, New Zealand, Japan and Korea had a lower fatality rate per 100,000 population compared the low- and middle-income countries (LMIC) such as Malaysia, Thailand and Indonesia. However, Taiwan shows a slightly different perspective, by which it has a high VOSL (2.3 million) but also high fatality per 100,000 population (15.64 fatalities per 100,000 population).

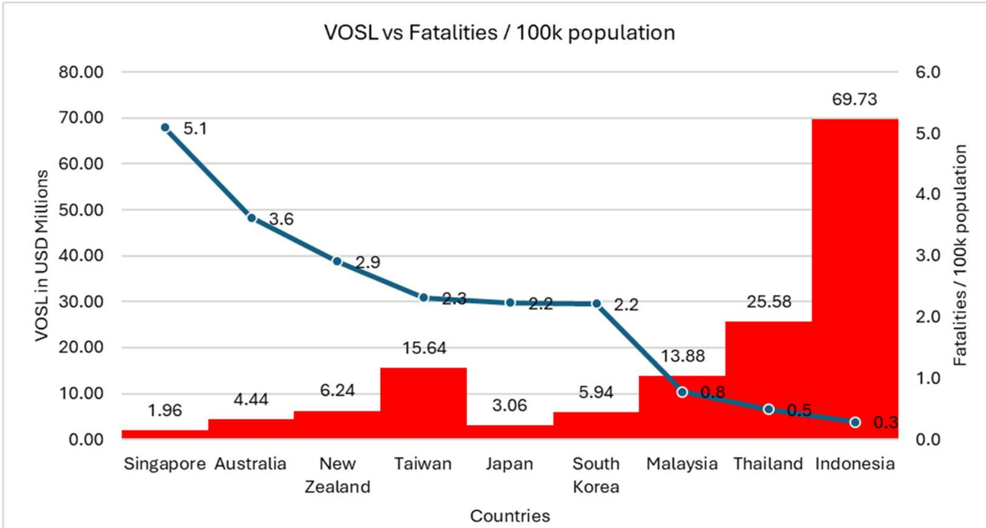


Figure 6: Value of statistical life (VOSL) in million USD and fatalities per 100,000 population (2022)

The fatal causes or fatal risk factors reported by each participating country were matched and the results are shown in Table 1. It can be seen that the factor of 'speeding', appeared to be a common causality for Australia, New Zealand, Thailand, Indonesia, and Malaysia, while 'dangerous driving' (e.g. abrupt overtaking, tailgating, etc). appears to be a similar causality for Japan, Australia, Malaysia, and Thailand.

Table 1: Top five crash causality for each participating country

Japan	Singapore	Taiwan*	Australia	New Zealand	South Korea	Thailand	Indonesia	Malaysia
Poor handling	Poor handling	Driving under influence of alcohol	Speeding	Driving under influence of alcohol	Distraction	Speeding	Poor hazard perception	Dangerous driving
Dangerous driving	Poor hazard perception		Distraction	Speeding	Red-Light Running	Driving fatigue	Failed to keep a safe distance	Speeding
Red-light running	Driving under influence of alcohol		Dangerous driving	Poor handling	Failed to keep a safe distance	Road Defects	Failed to overtake	Visibility
Unconfirmed safety	Failing to give way to traffic with right of way		Driving under influence of alcohol	Poor hazard perception	Intersection Driving Violation	Driving under influence of alcohol	Speeding	Road Defects
	Turning without due care		Driving fatigue	Position on Road	Median Encroachment	Dangerous driving	Vehicle brakes not working	Driving fatigue

* Taiwan – Only one crash causality given.

3.2 Case Studies

3.2.1 Japan – Reduction of shoulder width

Materials, issues & implemented countermeasures for VRU

Vulnerable road user	Program/guidelines/material available within member country	Safety issue/ risk factor	Implemented countermeasure
Pedestrians, cyclists	• Zone 30 plus	• Accidents in residential areas • Vehicles passing through residential areas unnecessarily • Excess vehicle speed	• Measures that appropriately combine traffic regulations such as speed restrictions with physical devices such as speed humps in selected areas.
	• Safe school road program	• School children	• Measures such as implementing walking space, based on joint inspections of school routes by road administrators, Police, school officials, and residents.
Pedestrians	• Guidelines for facilitation of road travel, etc.	• Disabled people	• Barrier-free sidewalks/footpaths implemented on designated roads which prioritise areas such as around railway stations.
Cyclists	• Bicycle use promotion plan • Guidelines for creating a safe and comfortable environment for cyclists	• Insufficient road space to separate pedestrians and bicycles • Bicycle-to-pedestrian accidents	• Based on the guidelines, the bicycle roads, bicycle lanes, or mixed roadways with arrow-shaped road markings are maintained according to traffic volume and speed.
Pedestrians, cyclists, and motorcyclists	• Safety measures at hazardous locations	• Section of arterial road with the highest accident rate	• Road administrators and the Police work together to implement safety measures.

Vulnerable road user	Motorcyclists
Countermeasure	Reduction of shoulder width

Safety issues related to vulnerable road users

There are sections of the arterial road with high accident rates. Among them, there are cases where an accident occurs in which a car turning right or left and a pedestrian, bicycle, or motorcycle collide at an intersection. Measures have been implemented according to the accident occurrence situation at each location and the road traffic environment.

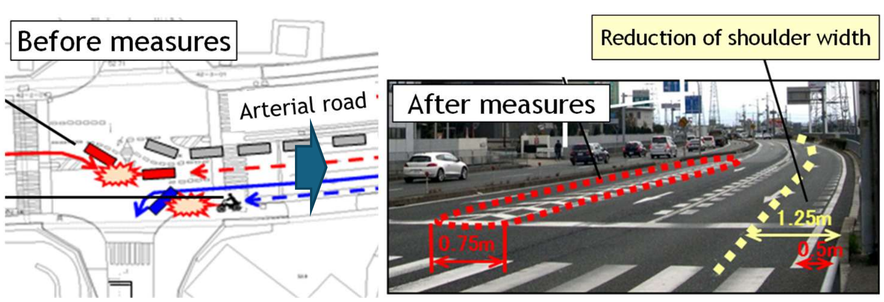
This is an example of countermeasures for accidents in which two-wheeled vehicles and left-turning vehicles collide.

Details of implemented countermeasure

A 1.25 m wide shoulder is installed on the main road, and two-wheeled vehicles cannot pass on the shoulder legally.

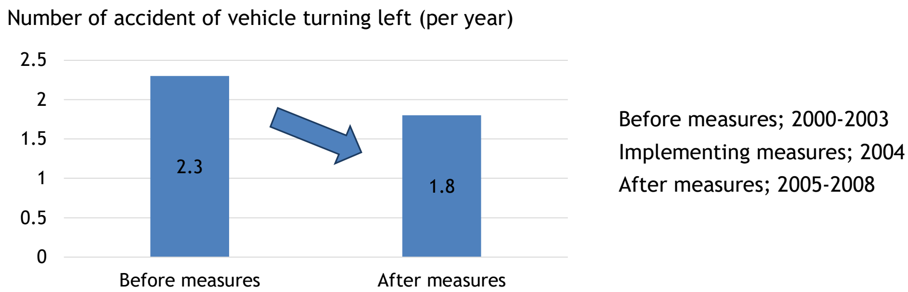
For this reason, there are many accidents where a vehicle turning left collides with a two-wheeled vehicle travelling straight on the shoulder.

The shoulder width was reduced from 1.25 m to 0.5 m to reduce the situations where motorcycles travel on the shoulder.



Result/effectiveness of implementation

Accidents decreased after measures compared to before.



3.2.2 Malaysia – Provision of shoulders

Materials, issues & implemented countermeasures for VRU

Vulnerable road user	Guidelines available within member country	Safety issues/risk factor	Implemented countermeasure
Pedestrians	• JKR Nota Teknik (Jalan) 18/97: *Basic guidelines on pedestrian facilities*	• School children • Disabled people • Underutilized pedestrian bridge • Poor connectivity of pedestrian walkway & channelization • Misuse of pedestrian crossing • Jaywalking	• Traffic warden at school. • Universal design of pedestrian facilities.
Cyclists	• Design of cycle tracks	• High risk in mixed traffic • Low usage of bicycle lane due to hot climate & misuse by motorcyclists • Poor connectivity & substandard design of bicycle facility	• Segregated on-road bicycle lane.
Motorcyclists	• *Guidelines on two wheelers facilities*	• High risk in mixed traffic • High-speed road • Unsafe barrier for motorcyclist, e.g. guardrail • Underutilized NEMCL due to security issues • Low maintenance • Misuse of emergency lane	• Motorcycle lanes: exclusive & non-exclusive.

3.2.3 Malaysia – Non-exclusive motorcycle lane (NEMCL)

Materials, issues & implemented countermeasures for VRU

Vulnerable road user	Motorcyclist
Countermeasure	Non-exclusive motorcycle lane (NEMCL)

Safety issues related to vulnerable road users

Crash statistics from 2005 to 2015 released by the Royal Malaysian Police revealed that, on average, motorcyclists (including pillion riders) and pedestrians accounted for 62% of the total road deaths, with more than half of the deaths occurring on rural roads. The most common types of crash that caused deaths among motorcyclists were head-on, intersection, and run-off-road crashes. Youths aged 16 to 30 constituted half of the total number of deaths among motorcyclists. Many of those who died were young working adults, and perhaps the only breadwinner for the family. Their contribution to the nation's socio-economic progress was cut short prematurely, costing the country in lost earnings.

A model developed by the International Road Assessment Programme (iRAP) estimated that the cost of fatal and serious road traffic crashes could be as large as 5% of Gross Domestic Product (GDP) for a middle-income country such as Malaysia.

Details of implemented countermeasure

Costs: 'medium' would be more helpful if a cost per-km was available.

Lane width: 1.5 m – 2.0 m

Separator width: 0.7 m

Service life: minimum 10 years

Result/effectiveness of implementation

Cross-sectional method: Crash Modification Factor (CMF): 0.17 – 0.88

Odds ratio method: Crash Modification factor (CMF) : 0.84

As far as this study was concerned, NEMCL provided the highest benefit when the average daily traffic (ADT) was about 15,000 per lane and the percentage of motorcycle was 20%. Case-control design also indicated an overall positive effect of NEMCL in reducing motorcycle crash risk. The relative risk for sections with NEMCL was found to be lower but it was not statistically significant owing to the low number of cases and controls used.

A recent study showed that, with the Bayesian network, single- or dual-carriageway roads with NEMCL, and equipped with adequate width of paved shoulder, had a very low probability of fatal crash cases, ranging from 0.2% to 1.7%. In analyzing the typical urban and rural road settings, there was a predicted higher probability of fatal crashes if urban and rural roads were not equipped with NEMCL (up to 18.4% chance of fatal crash cases). In addition, as the number of lanes increased from two-lane single carriageway to four-lane single carriageway for a typical rural road, then the probability of fatal crashes was more than 20 times the risk if it was not equipped with NEMCL.

3.2.4 Korea – Elderly drivers, cyclists, motorcyclists, commercial vehicle drivers, drunk drivers, pedestrians

Materials, issues & implemented countermeasures for VRU

Vulnerable road user	Program/guidelines/material available within member country	Safety issue/ risk factor	Implemented countermeasure
Elderly drivers	• *Guidelines for designing roadways for the aging population* (Ministry of Land, Infrastructure, and Transport, MLIT). • *Traffic safety and road design for aging society* (Korea Road Traffic Authority, KoROAD).	• Decreased physical function. • Decreased recognition response. • Decreased information processing & attention ability. • Increase in traffic accidents in congested traffic conditions.	• Period reduction of driver's license aptitude test and voluntary return of driver's license over the age of 75. • Development of online education and promotion of expert instruction for the aging population. • Outreach customized education for the elderly. • Production and distribution of standard elderly drivers' silver mark and provision of safety equipment. • Designing roadways for the aging population.
Cyclists	• *Cycling design standards* (Ministry of the Interior and Safety, MOIS). • *Safety education and guidelines for personal mobility* (Korea Road Traffic Authority).	• Risk of conflict with nearby vehicles when changing lane. • Avoid wearing bike helmets. • Cycling under the influence. • Disconnection of bikeway and poor infrastructure management.	• Establishment of penalties for cyclists riding under the influence. • Promotional video for safe driving in multi-use facilities.
Commercial vehicle drivers	• Driver's license aptitude tests (Korea Transportation Safety Authority). • Examination guidelines for traffic safety management system (Ministry of Land, Infrastructure, and Transport, MLIT).	• Inadequate adherence to rest times. • Increased fatigue and risky driving behaviour when driving for a long time.	• Vitalization of experience education for qualification acquisition of trucks and buses. • Expansion of service areas and public garages for trucks.

			• Expansion of supply of advanced safety devices for trucks. • Strengthening of administrative measures in terms of ineligible transit workers and commercial transport companies.
Drunk drivers & traffic law violators	• Indicator for disposal of traffic enforcement (National Police Agency)	• Inveterate drunk driving. • Inadequacy of pedestrian environment. • Inadequacy of management of high-risk driver groups. • Risk of collision with pedestrians when turning right at an intersection.	• Reinforcement of drunk driving penalties and punishment of abetters. • Obligation to complete special traffic safety education for habitual traffic law violators. • Criminal punishment for high-speed drivers. • Expansion of installation of automatic pedestrian-detecting signal system. • Resident report system for illegal parking.
Children & pedestrians	• *Integration guidelines for protected areas* (Ministry of Public Safety and Security, MPSS) • *Guidelines for pedestrian priority streets* (Ministry of Land, Infrastructure, and Transport, MLIT)	• Increased usage of smartphones while crossing a crosswalk. • Danger of children crossing between illegally parked vehicles. • Difficulty in using transportation facilities for the disabled. • Interruption of walking, and walking along the edge of a local road.	• Taxi car seat service. • Supply of car seats for children. • Expansion of school zones and inspection of hazards around elementary schools. • Clarification of the speed limit of 30 km/h for roads in pedestrian areas (local roads, etc.). • Expansion of applying speed limit 5030 in urban areas. • Installation of sidewalks/footpaths on local roads.
Motorcyclists	• *Safety guidelines for the protection of two-wheeled food delivery workers* (Ministry of Employment and Labor, MOEL) • *Traffic safety public interest organization* (Korea Transportation Safety Authority, TS)	• Traffic violations: two-wheeled vehicles. • Driving two-wheeled vehicles over the sidewalk/footpath. • Difficulty in cracking down on drivers of two-wheeled vehicles.	• Strengthening crackdown by public interest organization. • Supplying safety helmets and safety equipment for two-wheeled vehicles. • Development of traffic safety experience education for two-wheeled vehicle drivers.

3.2.5 Korea – Road safety facilities to support jaywalking ban

Materials, issues & implemented countermeasures for VRU

Vulnerable road user	Pedestrians
Countermeasure	Road safety facilities for jaywalking ban
Safety issues related to vulnerable road users The number of traffic accident deaths due to jaywalking accounts for about 35% of all pedestrian deaths in Korea. The ratio of jaywalking fatalities has been gradually increasing over the past three years (2017~2019). In addition, according to the pedestrian behavior evaluation index of the 'Transportation Culture Index' (2021), conducted annually, the frequency of jaywalking on roads other than crosswalks was 35.27%, an increase of 3.07% compared to 32.20% in 2020. In the case of Korea, in order to prevent pedestrian accidents related to trespassers (e.g. jaywalkers), the provision of facilities that prohibit trespassing within the median zone of urban roads has been continuously increasing. Facilities prohibiting trespassing are installed to prevent traffic accidents caused by trespassing pedestrians and vehicles undertaking illegal U-turns, and also to attract drivers' attention at night and during bad weather. In 2012, the Ministry of Land, Infrastructure and Transport (MLIT) stipulated facilities prohibiting trespassing as regular facilities be included in their *Road safety facilities and management guidelines*. As a result, there was a 30.4% decrease in accidents at locations where facilities prohibiting trespassing in the urban areas were provided.	
Details of implemented countermeasure Cost: 'medium' would be more helpful if a cost per km was provided. Width of facility: 0.25 meters. Installation standard: Facilities should be installed within median strips that satisfies the width criterion of a marginal strip of at least 0.25 meters. Service Life: at least 5 years.	

Result/effectiveness of implementation

Accident Reduction Factor(ARF): 9.6~78.3%

- Commercial areas: 78.3%
- Areas with schools: 61.4%
- Residential and commercial areas: 36.5%
- Areas without an apartment and schools that are not included in other clusters: 30.7%
- Residential areas with high road rating and low population density: 9.6%.

According to the road characteristics, there is a difference in the accident reduction factor resulting from the installation of facilities that prohibit trespassing. In commercial areas with large floating populations, the effect of the installation of the facility can be maximized. In particular, since the effect of the installation of the facility is the second largest in an area where schools exist, it should be given priority when installing facilities that prohibit trespassing. However, in residential areas, the effect of facility installation does not appear to be significant, so it should be considered as the lowest priority when installing facilities.

3.2.6 Korea – Number of traffic accidents and traffic violations

Materials, issues & implemented countermeasures for VRU

Vulnerable road user	Commercial Drivers
Countermeasure	Number of traffic accidents and traffic violations

Safety issues related to vulnerable road users

An average of 6,000 truck accidents and 220 fatalities occur annually in Korea. This is about 13% and 28% respectfully of the total number of traffic accidents and fatalities annually in Korea. This continually raises the problem of traffic safety for trucks. There are also significant social concerns due to the increase in the volume of freight vehicles, truck traffic and distance travelled. The Ministry of Land, Infrastructure, and Transport (Korean government affiliated institution) has legally mandated the installation of Digital Tachograph(DTG) for trucks in stages from 1 January 2011, with continuing education and consultation for high-risk drivers and transportation companies through the analysis of DTG driving records (11 dangerous driving behaviours). After selecting high-risk drivers using DTG data related to dangerous driving behaviour (speeding, overtaking, sudden stopping, etc.) and conducting traffic safety education programs, the number of traffic accidents and traffic violations, and the frequency of median encroachment, decreased by 78.8%, 52.4%, and 58.6% each by high-risk drivers.

Details of implemented countermeasure

DTG Installation Cost: ₩120,000 per unit.

Integration of DTG Information by Driving Information Management System of Korea Transportation Safety Authority.

Installation Object: commercial trucks and buses exceeding 1 ton (compulsory installation).

Result/effectiveness of implementation

Improvement effects by comparing before and after the execution of customized education according to DTG analysis (6 months each):

- Traffic accidents by high-risk drivers: The number of traffic accidents and fatalities decreased by 78.8% and 75.0% respectively.
- Traffic violations by high-risk drivers: The number of red-light violations, median encroachments, and distraction decreased by 52.4%, 62.3%, and 42.6% respectively.

Compared to other vehicles' traffic accidents, the risk of traffic accidents, and the fatality rates, in freight vehicle accidents in Korea are high. Driver fatigue, overloading, and speeding are the main causes of accidents involving freight vehicles. Driver behavior and customized education through the analysis of DTG data were found to be effective. Along with crackdowns, there is a significant need to actively promote traffic safety measures based on scientific techniques such as education to change driver behavior and big data analysis.

3.2.7 New Zealand – Pedestrians, cyclists and motorcyclists

Materials, issues & implemented countermeasures for VRU

Vulnerableroad user	Program/guidelines/material available within member country	Safety issue/risk factor	Implemented countermeasure
Pedestrians, cyclists motorcyclists	• Speed and Infrastructure Programme (SIP): https://www.nzta.govt.nz/safety/partners/speed-and-infrastructure/ • Walking and Cycling Programme https://www.nzta.govt.nz/planning-and-investment/national-land- transport-programme/2021-24- nltp/activity-classes/walking-and- cycling/ • *Innovating Streets for People Programme* https://www.nzta.govt.nz/roads-and-rail/streets-for-people/ • *Austroads Guide to Road Design* – various design guides: https://austroads.com.au/safety-and-design/road-design/guide-to-road-design • *Standard Safety Intervention Toolkit:* https://www.nzta.govt.nz/resources/standard-safety-intervention-toolkit/ • SIP design framework: https://www.nzta.govt.nz/assets/resources/road-to-zero-speed-and- infrastructure-programme-design- framework/Road-to-Zero-Speed-and-Infrastructure-Programme-Design-Framework-draft.pdf	• Pedestrian crashes. • Cyclist crashes. • Motorcyclist crashes. • School children.	• Universal design and implementation of pedestrian, cyclist and motorcyclist facilities. • Raised safety platforms (intersections and pedestrian crossings). • Segregated on-road bicycle lanes. • Motorcycle under-run barriers. • Kerb and footpath design techniques for less-abled pedestrians (e.g. tactile surfaces).

Case Study – Te Ara Mua Future Streets

Vulnerable road user	Pedestrians and cyclists
Countermeasure	Te Ara Mua Future Streets

Safety issues related to vulnerable road users

Selection of speed and infrastructure case studies
https://www.nzta.govt.nz/safety/partners/road-to-zero-resources/safe-system-case-studies/

Selection of innovating streets for people case studies
https://www.nzta.govt.nz/roads-and-rail/streets-for-people/case-studies-2/

Te Ara Mua Future Streets

https://www.nzta.govt.nz/walking-cycling-and-public-transport/cycling/cycling-standards-and- guidance/cycling-network-guidance/case-studies/auckland-te-ara-mua-future-streets/

The study area lacked safe walking and cycling facilities and had poor accessibility.

Details of implemented countermeasures

Installation of a series of countermeasures aimed at improving safety for people walking and cycling in an Auckland suburb. Included separated cycle lanes, wider footpaths, safe crossing facilities, safer routes to schools and shops, traffic calming measures, improved accessibility and removal of roadside parking.

Result/effectiveness of implementation

A reduction in traffic volumes and mean speeds in the study area.

3.2.8 Thailand – Pedestrians, Cyclists and Motorcyclists

Materials, issues & implemented countermeasures for VRU

Vulnerable road user	Program/guidelines/material available within member country	Safety issue/ risk factor	Implemented countermeasure
Motorcyclists, cyclists, and pedestrians	• Rural road management system (RM)	• Road infrastructure, e.g. road signs, road markings, bridges, light poles. • Road geometry, e.g. horizontal and vertical curves, intersections.	• Assessed road safety issues by visual inspection via the internet . Conducted an in-office road safety audit. • Monitored and analyzed the risk locations and conducted road safety audits (RSA) in order to provide road safety improvements before accidents occur.
	• Road safety audit system (RSAS) (additional module in RM system)	• Road infrastructure, e.g. road signs, road markings, bridges, light poles. • Road geometry, e.g. horizontal and vertical curves, intersections.	• Automatically analyzed and identified risk locations in line with the International Road Assessment Programme (iRAP) which was recommend by the United Nations, World Health Organization, FIA foundation and other leading institutions. • Automatically suggested road improvement countermeasures fitted to the characteristics of the problem in both the short term and long term.
	• Development of road safety manuals, e.g. manuals for inspectors, auditors and senior auditors	• Road safety audit at design stage, construction stage, and also an audit of the existing road (proactive measure). • Road accident investigation and road safety improvement strategy, short-term and long-term (reactive measure).	• Three road safety manuals implemented as training courses, separated into three levels according to the experience of the staff. • The contents covered a wide range of road safety topics in Thailand. The safe system approach for vulnerable road users was included in the guidelines of road design.
	• DRR road safety improvement project evaluation system (Department of Rural Roads RAI dashboard)	• Accidents occurred on rural roads and were usually related to motorcyclists.	• Road safety measures taken after the accident based on the guidelines. The aim of the project was to evaluate the status of the implemented road safety improvement and its performance.
	• Supplementary safety measures at intersections	• Accident at an intersection due to overshooting (driver did not stop or slow down when approaching the intersection).	• Widen the road median before entering the intersection by installing flexible poles so that drivers would feel 'narrow' and slow down or stop at the intersection.
Motorcyclists and cyclists	• Clearing road hazards	• Severe impact with a hazardous object such as a large-diameter tree, a concrete guide post, and other rigid structures as a result of motorcyclists or cyclists running off the road.	• Replace concrete guide post with flexible post. • Reposition or clear the large-diameter tree. • Protect a permanent structure by installing a concrete barrier.

Case Study – Proactive Measures from RSA of Existing Roads

Vulnerable road user	Motorcyclists, cyclists, and pedestrians (and all of the road users)
Countermeasure	Proactive measures from road safety audit of the existing roads in DRR's responsibility

Safety issues related to vulnerable road users

- Locations that have a high risk of accidents were identified using the Road Safety Audit System (RSAS) adopting the concept of iRAP (International Road Assessment Program).
- Desktop auditing was conducted using the Rural Road Network Management System (RM).

Details of implemented countermeasures

- Site auditing and complete road safety audit report.
- Launch of safety improvement project.
- Monitoring and evaluation projects.

Result/effectiveness of implementation

The road safety improvement program has involved 1,309 projects in DRR's route since 2018 – 2019. The number of fatalities decreased by 74.68% and 57.94% of the accidents did not occur at the same location. This indicated successful road safety strategies and measures. The benefit/cost (B/C) ratio of the project was 6.20.

Case Study – Reactive measures on DRR accident site

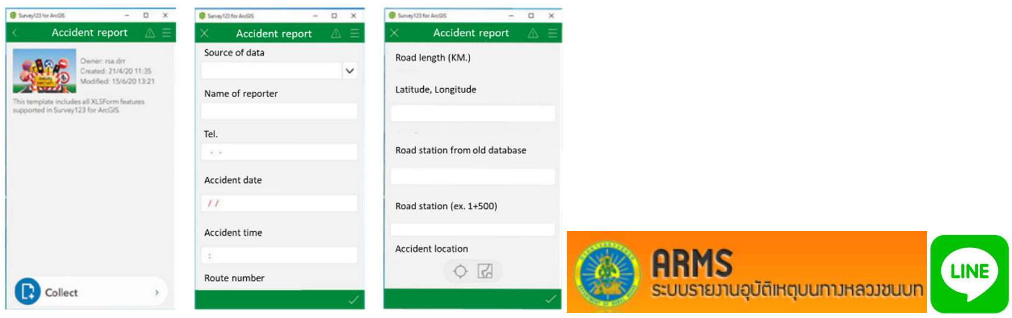
Vulnerable road user	Motorcyclists, cyclists, and pedestrians (and all of the road users)
Countermeasure	Reactive measure on DRR accident site

Safety issues related to vulnerable road users

- Non-self-explaining roads (lack of signs, road markings, etc.)
- Unforgiving road (roadside hazards)

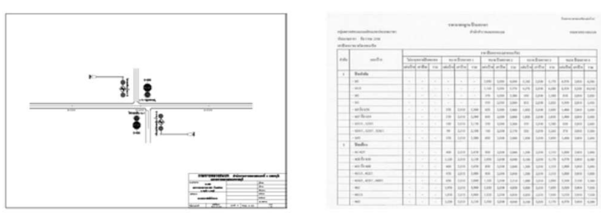
Details of implemented countermeasures

1. Accidents on DRR road network reported from Accident Report Management System (ARMS) and police reports (via Line application).
2. Office of Road Safety audit verified accident occurrence and reported via DRR Road Safety Improvement Project Evaluation System.



3. Office audit from RM and site investigation to complete the road accident investigation report.

4. Regional bureau design road safety improvement as well as cost estimation.



5. Bureau of traffic safety supports financial resources.
6. Road safety improvement and report status on DRR Road Safety Improvement Project Evaluation System.

7. Office of road safety audit evaluated its effectiveness.

Result/effectiveness of implementation

- There were 346 accidents before the road safety improvement was implemented, but only 31 accidents after the improvement, a reduction in accidents of 91.04%.
- There were 369 fatalities before the road safety improvement was implemented, but only 36 fatalities after the improvement, a reduction in fatalities of 90.24%.

3.2.9 Indonesia – Pedestrians, cyclists and motorcyclists

Materials, issues & implemented countermeasures for VRU

Vulnerable road user	Program/guidelines/material available within member country	Safety issue/ risk factor	Implemented countermeasure
Pedestrians	• *Pedoman Fasilitas Pejalan Kaki 2018* • *Pedestrian Facility Guideline*	• Inadequate pedestrian facilities. • High density of pedestrians in urban areas.	• Providing and improving pedestrian sidewalks/footpaths according to the guideline.
	• Safe School Program (ZOSS) Peraturan Direktur Jenderal Perhubungan Darat Nomor SK.3582/AJ.403/DRJD/2018	• School children.	• Implementing ZoSS (safe school zone).
Cyclists	• *Pedoman Fasilitas Pesepeda 2021* • *Cyclist Facility Guideline 2021*	• Inadequate facilities for cyclists.	• Providing safer cycling lanes in line with the guideline.

Case Study – Evaluating and improving the escape lane quality

Vulnerable road user	Pedestrian
Countermeasure	Evaluating and improving escape lane quality

Safety issues related to vulnerable road users

An escape lane is one of the safety countermeasures provided for vehicles that lose control and/or have brake failure. In Indonesia, escape lanes are mainly provided on toll roads and roads with an extreme declining grade. However, in early 2022, there was an accident in an escape lane resulting in one death and one serious injury. The truck lost control and entered the escape lane; however, the arrester bed material in the escape lane had hardened and, as a result, the truck suffered serious damage.

Vulnerable road user: pedestrian.

Countermeasure: enhance the pedestrian crossing.

Crashes that involve pedestrians are the 4th highest crash type in Indonesia. Some of the accidents occur while pedestrians are crossing the road, even when they are using the pedestrian crossing.

Details of implemented countermeasure

To prevent the same accident happening again, the National Toll Road Authority evaluated 19 escape lanes on several toll roads. As a result, the toll road company was instructed to reconstruct the arrester bed according to the guideline and remove the mounding (photo on left). The National Toll Road Authority also demanded that the maintenance and operational procedures be improved to ensure that the quality and condition of the arrester bed was always up to the standard.

Some pedestrian crossings are not equipped with proper street lighting so other road users are not aware of the crossing. To improve the safety of the pedestrian crossing, pedestrian crossing signs and rumble strips were installed before the crossing. Streetlamps were also installed near the crossing.

3.2.10 Australia – Pedestrians, cyclists and motorcyclists

Materials, issues & implemented countermeasures for VRU

Vulnerable road user	Program/guidelines/material available within member country	Safety issue/ risk factor	Implemented countermeasure
General	Pedestrian-cyclist conflict minimisation on shared paths and footpaths	• Increasing the number of people walking or cycling. • Conflicts on shared facilities. • Degree of separation of a cycle facility from motorised traffic. • Inappropriate path user behaviour. • Poor path design. • Poor path location. • Poor path maintenance.	• Segregating cyclists from road traffic. • Improving path. • Changing behaviour.
General	Pedestrian and cyclist safety- recent development	• Under-reporting pedestrian and bicyclist injuries. • Intoxicated pedestrians. • Poor visibility/ conspicuity. • Environmental factors. • Disabled pedestrians.	• Pelican crossings. • Pedestrian-operated signals (POS). • Puffin crossings. • Toucan crossings. • Refuges and medians. • Kerb extension. • Raised pedestrian platform. • Bicycle lighting. • Safe route to school. • Pedestrian safety audit. • Speed limit. • Reduction in signal time. • Width of pedestrian walk. • Bicycle crossing facilities.

			• Upgrade street lighting. • Grade-separated facilities. • Pedestrian fencing. • Wombat crossing.
General	Evaluation Report of Ride or Walk to School Program (ACT Heath)	• School children • Obesity and overweight • Population health - Distance of homes to school • Local pathway and infrastructure • Parental engagement • Weather	• Teacher professional development. • Student learning. • Provision of bikes and helmets. • Self-defence to enhance student safety.
General	Best Practices for Urban intersections and other active travel infrastructure (ACT)	• Shared path. • Give way. • Priority of pedestrians to bikes and PMDs. • Privately-owned PMDs. • Inconsistency in design.	• Safe System framework. • Movement and place framework. • User-centred designs. • Forgiving road environment. • Equality in speed between modes and users in shared areas. • Eliminate path-side hazards • Quick-build separator treatments. • Separation or integration of cycle and motor traffic. • Self-explaining streets and paths. • Designs for context. • Compact Intersections. • Kerb radii. • Raised platforms. • Kerb extensions. • Continuous footpath.. • Raised Intersection entries • Countdown pedestrian displays.
General	Toward Zero (NT)	• Indigenous road users. • Alcohol. • Speed-related accidents. • Failure to wear a seatbelt. • Unlicensed, cancelled or disqualified driver.	• Improved road treatments and design. • Licensing education program. • Regional and remote school road safety education program.
General	Pedestrian and cyclist safety — investigation of accidents in different road environments	• Young, older and intoxicated pedestrians. • inner metropolitan region. • pedestrian near side hit from right. • pedestrian far side hit from left. • pedestrian hit emerging behind the vehicle. • rate of accident at CBD. • Second Vehicle. • High density commercial development. • Poor road surfaces. • Adverse vertical road alignment. • Poor compliance of pedestrian signal. • Inadequate kerb side lane	• Lower 40 km/h speed limit for the CBD area. • Reduction in the traffic signal cycle times. • Traffic management strategies. • Convert minor streets or laneways within the CBD to shared with vehicle zone or to pedestrian malls. • Increase the width of pedestrian walk lines at signalised crossings. • Widen tram safety zones and install shelters. • Create traffic free zones. • Maximise the width of the kerb side parking. • Install bicycle crossing facilities at signalised intersections. • Improve the skid resistant of road surfaces.

		width. • poor visibility/conspicuity of cyclists.	• Upgrade street lighting. • Erect pedestrian barriers. • Regular maintenance of markings.
Pedestrian	Pedestrian crashes at pedestrian facilities	• Increasing traffic flow. • Crash at pedestrian-operated signals (POS). • In intersections, crash at the entry or departure zone of crossing. • Turning drivers. • Disobedience of red signal by pedestrians and drivers. • Stopping ability.	• Younger yellow or all red times. • Pedestrian signal display. • Auditory messages. • Double-cycled pelican crossing. • Improve skid resistance. • Education and publicity of drivers and pedestrians.
Pedestrian	Pedestrian safety	• High-speed roads. • Time of the day. • Alcohol. • Give way. • Overtaking or passing vehicles that are stopping or slowing down at crossings.	• Pedestrian signals. • Pedestrian countdown timer. • Zebra crossings. • Children crossings. • School crossing supervisors. • Pedestrian refuge islands. • Shared path. • Motorised wheelchair. • High pedestrian activity area. • Shared zones.
Pedestrian	Safety of pedestrians and cyclists	• Child pedestrians. • Senior pedestrians. • Pedestrians with prams. • Impaired pedestrians. • Limited walking ability. • Intoxicated pedestrians. • Lack of protection. • Vehicle speed. • Lack of pedestrian facilities. • Visibility of pedestrians/vehicles.	• Autonomous Emergency Braking (AEB). • Full auto brake and pedestrian and cyclist detection. • Pedestrian airbag. • Self-explaining roads. • Enforcement. • Shared path. • Countdown timer. • Longer confusing walk and clearance phases. • Puffin crossings • Provision of auditory signals. • Raised crosswalks
Cyclist	Investigation of cyclist safety at intersections	• Bicycle facilities. • Urban areas. • Conspicuity. • Presence of signage or roadside furniture. • Signal clearance time. • Intersection complexity. • Sight lines.	• Exclusive kerb-side turning lanes. • Advanced top-lines. • Use of continuity lines or road markings. • Hook turns. • Extended signal clearance time.
Cyclist	Bicycle safety at roundabouts	• Geometric design components. • Circulating lane near the entry of an approach road. - Right-adjacent type crashes. • Entry geometry of the roundabouts. • Sight distance for a approaching vehicle from the right side. • Speed zone of 60 km/h.	• Roundabout with a radial type of alignment. • Reducing the speed to ≤ 30 km/h. • Restricting the sight distance on the approach to a roundabout reduces the approach speed of vehicles. • Increasing entry path curvature. • Decreasing entry curve radius on local roads.

		• Entry curve radii. • Travel path curvature at the entry.	
Cyclist	The safety of people walking and riding cyclists	• Interaction with fast moving traffic. • Lack of protection. • Cycle lanes parallel parking bays exposing cyclists to opening door injuries. • Painted bike boxes. - t intersections. • High road speed. • Road surface. • Visibility of obstacles. • Road course. • Width of bicycle paths and lanes. • Blind spot in mirrors.	• Infrastructure upgrades. • Physically separates cyclists from motorised vehicles. • Lower speeds as sharing of roads. • Helmets. • Dedicated cycling routes. • Speed limit reduction. • Traffic calming measures. • Awareness campaigns. • Vehicle design safety features (reversing collision avoidance, Autonomous Emergency Braking (AEB), blind spot monitoring, pedestrian airbags, intersection collision warning, head airbag). • Self-explaining roads (installing roadside street art, landscaping the surrounding area, installing furniture to create pinch points, laying different road surfaces, widening pathways, and introducing cycle lanes). • Bike boulevards. • Education schemes. • Intelligent Infrastructure.
Cyclist	Evaluation of the ACT Government's safer cycling reforms	• Minimum passing distance • Crossing at pedestrian crossings.	• Cross, straddle or drive on centre lines and painted islands when overtaking cyclists. • Educational campaign. • Wider pedestrian crossings. • Speed platform along the roadway. • 1~1.5 m gap. • Ride across pedestrian crossings that are equipped with dedicated bicycle traffic lights (NSW, WA). • Ride across pedestrian crossings as long as they obey traffic lights and signals. • Advisory signs. • Enforcement of minimum passing distance.
Cyclist	Bike lanes design guidelines	• Limited available road width. • Kerb-side car parking. • Cyclist at intersections.	• Kerb-side physically separate. • Double chevron. • Single chevron on the parking side of the bike lane. • Single chevron on the traffic side of the bike lane. • Simple bike lane. • Shared traffic bike lane. • Intersection treatment (covering physically separated bike lanes/ separation through traffic signal phasing/ roundabouts).
Motor cyclists	Motorcycle in-depth crash study	• Sport motorcycles. • Age groups. • Riders who rode the crash location daily had seven times	• Protective clothing for motorcycle use. • Full-face helmet. • Enhanced motorcycle technologies.

		the odds of being in the crash sample than the control sample. • Route unfamiliarity. • Increased severity for older users. • Nature of trip. • Motorcycle fuel tank. • Conspicuity. • Human factor. • Environmental factor. • Experience with the motorcycle.	• Intelligent transport technologies.
Motorcyclists	Motorcycle Safety Research Project: • Part 1 - Investigate and develop a pre-learner motorcycle licensing package • Part 2 - Review of the consistent assessment process (cap) • Part 3 - Training and licensing interventions for risk taking and hazard perception for motorcyclists. • Summary report – motorcycle rider safety project	• Learner rider safety. • Supervision of learner rider. • Role of training on crash risk. • Riding pattern of young riders. • Carrying pillions. • Drunk riding. • Non-usage of helmets. • Non-usage of protective clothing. • Unlicensed riding.	• Licensing and training system. • Pre-learner package. • Compulsory training • Hazard perception training. • Safe off-road training. • Q-Ride CAP program. • Q-Safe program. • Zero BAC. • Minimum learner period. • Consistent assessment process.
Motorcyclists	Motorcycling safety	• Young riders. • Crash barriers. • Polished/slippery surface. • Steel manhole covers. • Intersection design. • Light pole location. • Wire rope barriers.	• Protective gear. • Helmet. • Flexible fabric mesh. • Under-run protection (for w-beam barriers). • Motorcycle blackspot program. • Barrier protection. • Loss of control treatment. • Safety campaigns. • Pre-license training course. • Antilock braking system (ABS). • Traction control. • Motorcycle airbags.
Scooters	Mobility scooter usage and safety survey report	• Environmental factors. • Changing nature of mobility • Higher incidence in regional/rural/remote areas. • Cars backing out of driveways. • Damaged roads and footpath. • Confusion at intersections with other modes.	• Additional safety features and safety items (helmet, flags, reflectors, bright clothing). • Raise awareness of all road users. • Safety training.
Scooters	Review of shared micromobility	• Enforcement of privately-owned micromobility devices. • Data limitation. • Safe, efficient paths and roads. • Wearing helmet. • Influence of alcohol or drugs. • Number of users. • Over-speeding. • Children. • Safety education.	• Footpath decal. • No-go zones. • Rules of operation • Reduce motor vehicle traffic in e-scooter zones. • Separation of traffic. • Parking infrastructure. • Speed limit. • Appropriate data collection framework.

		• Parked devices.	
Scooters	Fact Sheet of the Centre for Accident Research & Road Safety – Queensland (CARRS-Q)	• Non-use of helmets. • Excessive riding speeds. • Drink-riding. • Pedestrians. • Scooter parked on footpath. • Carrying passengers. • Use a mobile device. • Using a road path or footpath. • Under-age riders.	• Low-speed roads. • Comprehensive insurance. • Technological constraints on parking locations. • Penalties for operators. • Provision of dedicated parking (virtual docks).

Case Study – Evaluation of the Motorcycle Blackspot Program

Vulnerable road user	Motorcyclist
Countermeasure	Evaluation of the motorcycle blackspot program

Detail of safety issues related to vulnerable road users

Motorcycle crashes pose a serious threat to the Australian community. According to a report by Austroads, the fatality and serious injury rate for motorcyclists is approximately 30 times higher than that of car drivers. The report highlighted the potential consequences of the increasing number of people opting for motorcycles as their preferred mode of transport. Even a small percentage of car drivers switching to motorcycles could have catastrophic consequences, potentially derailing casualty targets in national and state road safety strategies.

Detail of implemented countermeasure

The Motorcycle Blackspot Program (MBP) aims to enhance motorcycle safety at specific locations that have a history of motorcycle accidents. The MBP implements safety measures at locations with a history of motorcycle crashes. Since the number of motorcycle crashes is relatively low, the criteria for this program differ from the general blackspot program. Various projects include:

- Blackspot projects, which focus on individual locations with adverse motorcycle crash histories, e.g. individual curves or intersections.
- Black-length projects, which are also based on adverse motorcycle crash histories. They extend beyond a single location but are of limited extent.
- Long-route projects, which are proactive projects intended to improve the consistency of road conditions, guidance and delineation along routes carrying a large numbers of motorcycles.

Result/effectiveness of implementation

1. The program has been successful in reducing motorcycle casualty crashes (by 27%) and fatal and serious injury (FSI) crashes (by 31%); both reductions are statistically highly significant.
2. The program also showed good economic returns.
3. The barrier protection program has been particularly effective in reducing FSI crashes (by 74%). It also shows the best economic returns.
4. The long-route and loss-of-control treatments have both successfully reduced crashes and the economic returns are good. In both cases, a sufficient numbers of sites have received the treatments to allow confidence in the results.
5. The intersection treatments also showed good reductions in motorcycle crashes, but the number of sites is small. Trials at more sites are needed before full confidence can be placed in the outcome.

Case Study – Motorcycle Road Safety Audit: Adelaide Metro Region

Vulnerable road user	Motorcyclist
Countermeasure	Motorcycle road safety audit – Adelaide Metro region

Detail of safety issues related to vulnerable road users

The road safety audit identified several safety issues across the audit sites that contribute to the cause and severity of motorcycle crashes. Often, a road safety issue identified on a road is not identified in isolation, but rather is combined with other safety issues. These issues may arise due to poor road design – such as road alignment, road formation, drainage, sight lines, and clear zones – or poor maintenance, such as poor surface texture, pavement deficiencies, and foreign matter on the road surface. The audit found that the safety deficiencies that most affected motorcyclists on rural roads were those on curves, especially sharp, reverse, and compound curves. Based on the audit, it was found that the most problematic curves were those on rural roads and, of those curves, those that posed the most significant risk to motorcyclists were those that were sharp, reverse, and compound. Seventy per cent had a hazard on the outside of the curve which was the most likely impact area for an errant motorcycle.

In addition:

- 11% had water on the surface as a result of no formal roadside drainage or poor drainage on the road surface
- 46% had travel lane surface hazards such as poor surface texture, pavement deficiencies and foreign matter
- 22% had shoulder surface hazards such as edge drops, including a drop from a sealed surface to an unsealed shoulder
- 45% had no shoulder, an unsealed shoulder, or a sealed shoulder of 0–0.5 m wide
- 12% had poor curve delineation, including missing, poorly-mounted, or inconspicuous Chevron alignment markers

- 10% had no horizontal sight distance, and approximately 50% had limited horizontal sight distance.

A combination of these deficiencies on a curve creates a high-risk road environment for a motorcycle.

Detail of implemented countermeasure

To minimize the chances of a crash, it is essential to have a hazard-free surface, good surface friction, and adequate signage to identify road alignment and hazards. In case of a crash, it is crucial to remove or substitute roadside hazards. For example, providing signs with motorcycle-friendly posts or guardrails can be helpful, as can providing protection against them, such as guardrails on cliffs. Improving curve signage and delineation, revising intervention levels and criteria for maintenance programs, and enhancing the road surface condition by providing sealed shoulders, drainage, improving sightlines at intersections, and reducing the severity of roadside hazards are some of the steps that can be taken to prevent crashes. Signage can supplement poor road alignment and restricted sightlines because it helps to identify changes in alignment and hazards on the road. After auditing 18 locations and reviewing crash summaries and safety issues, general audit findings and detailed recommendations were presented for each location. One of the specific recommendations was to install different motorcycle signage (crash zone, look for bikes, road condition) as shown below.

A

B (Existing TMR sign)

Figure 5.1: Crash Zone motorcycle warning signage

Figure 5.3: Intersection– motorcycle warning signage

A

A

Case Study – Infrastructure Improvements to Reduce Motorcycle Casualties

Vulnerable road user	Motorcyclist
Countermeasure	Infrastructure Improvements to Reduce Motorcycle Casualties

Detail of safety issues related to vulnerable road users

Motorcycle accidents are a major cause of fatalities and serious injuries on Australian roads. Despite representing only 1% of total traffic volume, motorcycle riders accounted for 16% of all fatalities, and 22% of serious injury casualties, in 2012. The rate of motorcyclist deaths per registered motorcycles is five times higher than that of occupant deaths per registered 4-wheeled vehicles. In recent years, there has been an upward trend in motorcycle crashes in both Australia and New Zealand. The aim of this study was to examine the relationship between motorcycle accidents and road infrastructure elements such as road design, road surface condition, skid resistance, roadside hazards, and maintenance condition, with a view to showing how road infrastructure can influence both the likelihood of a crash occurring and the potential to reduce the incidence and severity of accidents.

The desired outcome of the project was the provision of guidance for practitioners by recommending updates to existing road design, traffic management, road safety, and asset management guidelines. It was hoped that the project would contribute to the objectives of the Australian National Road Safety Strategy, which include improving safety on popular motorcycle routes (a specific action for the first three years of the strategy). Additionally, the project aimed to provide advice before the introduction of motorcycle blackspot/black-length programs in all jurisdictions.

Detail of implemented countermeasure

A report was prepared which presented the findings of a two-year study aimed at pinpointing infrastructure upgrades that could lower the risk and severity of motorcycle accidents. It delved into the connection between motorcycle collisions and road infrastructure and, particularly, how road infrastructure affects the probability of an accident happening or the extent of damage caused by an accident. The study involved a literature review, identifying knowledge gaps, and conducting a crash analysis to demonstrate the relationship between motorcycle crashes, travel period, vehicle configuration, road geometry, road layout, and crash types. The report explained how road infrastructure elements can influence motorcycle accident risk and severity based on their design and condition. It also provided a combination of treatments that could be used to justify engineering decisions for managing these elements, even outside of existing design warrants, asset management, and maintenance practices. The report recommended that a proactive approach be taken in the assessment of the safety of motorcycle-specific networks and in the conduct of safety audits on roads. It also suggested that road design parameters for roads that have a significant number of motorcyclists be revised. These parameters included horizontal geometry, superelevation, skid resistance, sight lines, lane and shoulder width, intersection type, intersection quality, roadside hazards, and controls. The AusRAP model demonstrated that the risk of a crash significantly increases when several factors that contribute to the likelihood or severity of an accident are present together. The report provided a comprehensive list of solutions and a detailed explanation, allowing engineering decisions to manage these factors to be justified, even if they fall outside existing design parameters. Additionally, the report provided insights into asset management and maintenance practices.

Result/effectiveness of implementation

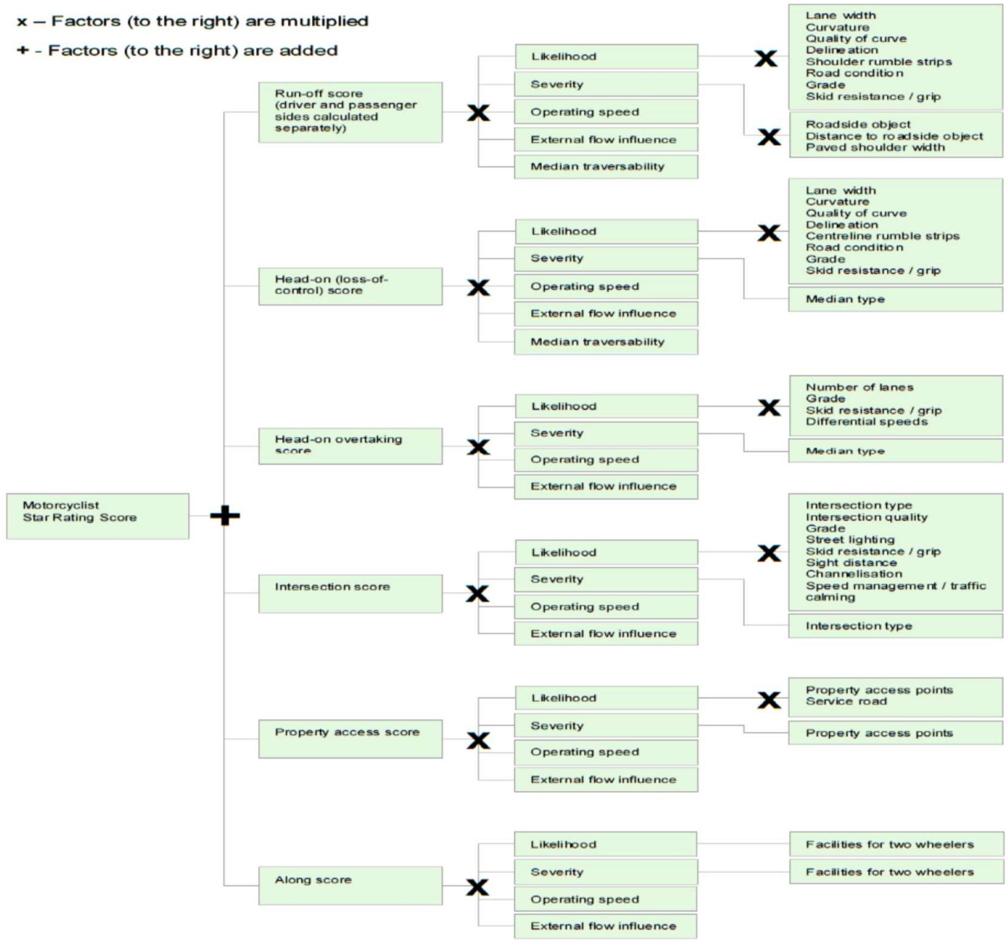
Proactive Road Assessment Programs (RAPs) such as ANRAM, AusRAP, and iRAP can be highly useful in identifying motorcycle crash risks on specific routes or networks. To identify high-risk locations for priority action, a motorcycle-specific road safety audit can be conducted using the methodology developed by ARRB Group. The resulting recommendations for motorcycle-specific treatments followed an industry-recognized hierarchy of controls, which prioritizes measures based on their ability to reduce the likelihood or severity of crashes. This approach aligns with the Safe System approach and ensures that treatments are effective in enhancing road safety for motorcyclists.

Appendix A AusRAP Star Rating Score (SRS) Risk Factors and Equation

A.1 Motorcycle Star Rating Score Equation

Figure A 1: Motorcycle star rating score equation

Motorcyclist SRS are calculated using equations in the following form.



Case Study – Motorcycle Rider Perceptual Countermeasures

Vulnerable road user	Motorcyclist
Countermeasure	Motorcycle rider perceptual countermeasures

Detail of safety issues related to vulnerable road users

Single-vehicle motorcycle accidents usually occur on curved parts of the road. To reduce the likelihood of motorcycles failing to maintain lane position on curves, running off the road, or colliding head-on with other vehicles, one countermeasure is to enhance the delineation of the curve. Excessive speed is a common factor among serious motorcycle crashes. Therefore, reducing travel speed is also likely to be an effective way to address motorcycle crash risks on curves.

Detail of implemented countermeasure

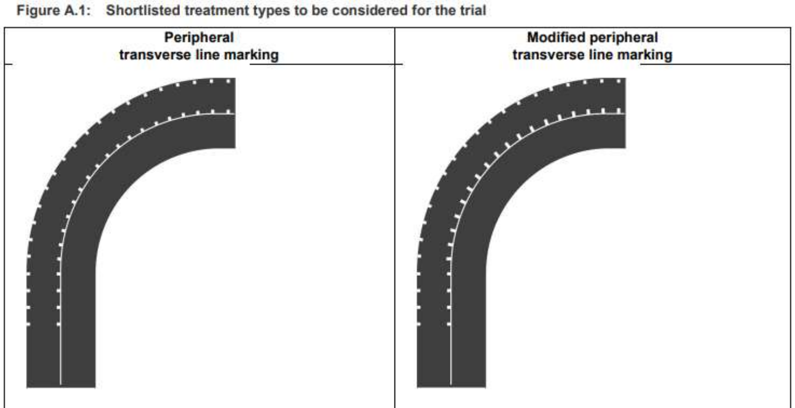
This project was concerned with using road-based treatments as a countermeasure to influence a motorcyclist's perceptions of speed and lane width to incentivize a safe approach when negotiating critical curves on regional and rural roads. A suitable design for a 'motorcyclist perceptual countermeasure' (PCM) was identified through an initial search of perceptual treatments in the literature and discussion with stakeholders. The PCM design selected for the trial was a modified version of a peripheral transverse line-marking treatment with incrementally wider painted blocks through the apex of the curve. The PCM was trialled at two curves characterized by high and low curvature, respectively. Additionally, two other curves matched to each of the treated curves were used as control locations during the trial. Since the trialled PCM design specifically aims to reduce intentional crossing of the centerline due to cutting through the curve chord, only the travel lane where the curve is bending to the right-hand side was treated and evaluated. Travel speed at the apex of the curve and motorcycle lane position at the entry and the apex of each trial curve were measured. Only vehicle detections that matched the following criteria were considered in the analysis: dry road surface, free speed, and no oncoming traffic.

The proposed PCM design appears to have a high potential to enhance motorcyclist safety at critical curves in regional and rural areas. Its design can be quickly installed on existing roads with minimal work. It would be compatible with practically any of the existing road infrastructure that may be present on regional and rural roads, such as vehicle restraint systems, line-marking or signage. It is an appropriate low-cost and low-maintenance secondary treatment that can be used to improve and complement existing primary treatments such as standard line-marking and signage. In addition, the treatment is compatible with three pillars of the Safe System approach to road safety: safe road users, safe speeds, and safe roads. Future trials are required to confirm the long-term duration of the behavioural changes observed in this short-term trial as well as to investigate potential side effects such as inducing drivers to drift along treated shallow curves or the creation of visual clutter due to overlapping with existing road visual treatments such as signs or curve aligned markers (CAMs). In particular, it is critical to ensure that PCMs do not have unintended consequences for other road users, including cyclists, or interfere with vehicle safety technologies that rely on line marking. The trialled PCM is expected to be used for treating curves that are deemed to be dangerous in the case motorcyclists voluntarily crossing the centreline. Given the specific focus of the PCM on motorcyclists, the application of this treatment should be limited to motorcycle routes in regional and rural areas. Under this suggested application scenario, it is expected that motorcyclists would associate this PCM with curves at risk of head-on crashes on popular motorcyclist routes. Therefore, the installation of the PCM should be avoided on curves where the risk of head-on crashes is limited. An otherwise indiscriminate extension of this PCM to non-critical curves may induce motorcyclists to lose confidence in this treatment. The adoption of consistent warrants/criteria to identify critical curves that require this type of treatment is essential if appropriate expectations among motorcyclists regarding the level of risks associated with those treated curves are to be created. A consistent and targeted implementation of this PCM is expected to help achieve a good level of compliance with this treatment, thanks to a perception by road users that the treatment is applied only when required.

Result/effectiveness of implementation

The proportion of motorcyclists riding in the monitored lane segment closest to the centerline after the installation of the treatment decreased from 55.3% to 4.5% at the apex of the tight curve and from 29.1% to 6.2% at the apex of the shallow curve. After accounting for the change at the paired control site, the before/after variation was –43.1 percentage points for the tight curve and –17.2 percentage points for the shallow curve. Additionally, the trialled PCM treatment induced motorcyclists to conservatively position themselves within the lane with an additional safety margin, as indicated by the considerable post-treatment increase in the proportion of motorcyclists riding within the leftmost 2/3 of the lane while they were negotiating through the apex of the treated curves (from 6.8% to 46.6% at the tight curve, and from 27.5% to 51.3% at the shallow curve). After adjusting for the change at the paired control site, the post-treatment increases in those proportions were 40% at the tight curve and 23.8% at the shallow curve.

Figure A.1: Shortlisted treatment types to be considered for the trial



Block Specifications					
	Edge Line	**Centre Line**		**Edge Line**	**Centre Line**
Spacing (mm)	3,500	3,500	**Spacing (mm)**	3,500	3,500
Width (mm)	300	450	**Width (mm)**	300	450 (entry/exit) to 600 (apex)
Length (mm)	500	500	**Length (mm)**	500	500

Generally, both the mean and 85th percentile travel speeds at the curve apex tended to decrease at each of the two treated curves, with a much more marginal reduction occurring at their paired control curves. After accounting for the variation at the control sites, the mean speed reduced by 1.8 km/h at the tight curve and 3.8 km/h at the shallow curve. Similarly, the 85th percentile speed at the tight and shallow curves was reduced by 1.2 km/h and 3.5 km/h, respectively. This trend was also observed for all the broad motorcycle categories considered in this analysis except for sport motorcycles, the travel speeds of which increased at the treated tight curve after the installation of the PCM. Moderate reductions in the mean travel speed were also found for light and heavy vehicles after the installation of the PCM, as indicated by post-treatment reductions in the controlled mean travel speed, varying between 0.3 km/h and 2.9 km/h (depending on the vehicle type and specific site). However, after the PCM installation, a slight increase in the controlled 85th percentile speed was observed for heavy vehicles travelling at the apex of the shallow curves. The observed speed-related effect on light vehicles was partially expected. Indeed, the peripheral blocks used for this PCM may likely induce in drivers a lateral friction effect similar to other perceptual line markings used for traffic calming purposes, such as the dragon's teeth. However, it should also be noted that this PCM was trialled in a different environment compared to the dragon's teeth (i.e. curves along a rural route as opposed to urban roads with high pedestrian activity). Most importantly, after the installation of the PCM, there was a general increase in the proportion of motorcyclists who were riding through the apex of the treated curves at or below a speed threshold equal to 10 km/h below the posted speed limit (i.e. 50 km/h at the tight curve and 90 km/h at the shallow curve). The post-treatment increase in the proportion of motorcyclists riding at or below this threshold was 13.6 percentage points at the tight curve and 14.5 percentage points at the shallow curve.

Additionally, the control-adjusted proportion of motorcyclists who travelled through the apex of the treated curves over the posted speed limit reduced by 3 percentage points at the tight curve (posted speed limit of 60 km/h) and by 6.5 percentage points at the shallow curve (posted speed limit of 100 km/h). Based on the analysis of the trial results, the proposed PCM treatment appears to deliver both safety effects for which it was designed. The major and most desired effect is that of inducing most motorcyclists to maintain a safe distance from the centerline when travelling through the apex of a right-hand curve. The second but more marginal effect of the PCM treatment is to mitigate the travel speed of motorcyclists as well as that of other road users at the apex of the treated curves. Both of these effects have been observed at the tight curves as well as the shallow trial curves.

4. Conclusions

The purpose of the project described in this report was to gain a better understanding of the current issues related to the safety of vulnerable road users (VRU), particularly users of powered-two-wheeled (PTW) vehicles. The strategy adopted was to determine the road infrastructure programs, or road safety measures, that are in place in REAAA member countries and to identify the problems pertaining to the drivers conflicting with VRUs, especially drivers of PTWs.

The work involved an investigation of existing strategies or plans in terms of providing the appropriate infrastructure or countermeasures to improve the safety of drivers of PTW's. Selected successful case studies are presented in this report as a means of referencing some of the best practices adopted by REAAA member countries.

The following comments are offered based on the information provided by each country, included case studies:

- Indonesia has the highest percentage of PTW (84%), followed by Thailand (52%) and Malaysia (46%).
- Malaysia and Indonesia have recorded the highest rate of fatalities (74% and 70% respectively) for all types of PTWs while the highest fatality rate for pedestrians is in Korea (35%) and Japan (31%).
- Korea has the highest fatality rate among the 30-60 years old group (78%). In terms of the young age group of 16-29 years age group, Singapore has the highest fatality rate of 37%
- High-income countries (HIC) with high VOSL have a lower fatality rate per 100,000 population compared to the low- and middle-income countries (LMIC).
- The main or similar crash causes among the participating countries were speeding and dangerous driving.

Based on the case studies presented by the participating countries, it can be concluded that only Malaysia has implemented dedicated countermeasures for motorcycles (i.e. NEMCL), while Thailand is more focussed on proactive measures such as road safety audits. To ensure a safer environment for pedestrian and cyclists, countries such as New Zealand and Korea presented dedicated countermeasures to curb speeding and promote segregation. Among all the participating countries, Australia has the most comprehensive countermeasures and programs for VRUs: it is the only country that has established guidelines for micromobility devices.

References

Abdul Manan, MM & Várhelyi, A 2012, Motorcycle fatalities in Malaysia, *IATSS Research*, vol. 36, no. 1, pp. 30-39.

Broughton, PS, Fuller, R, Stradling, S, Gormley, M, Kinnear, N, O'Dolan, C & Hannigan, B 2009, Conditions for speeding behaviour: a comparison of car drivers and powered two-wheeled riders, *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 12, no. 5, pp. 417-27.

Haworth, N 2012, Powered two wheelers in a changing world, challenges and opportunities, *Accident Analysis & Prevention*, vol. 44, no. 1, pp. 12-18.

Hsu, T-P. Ahmad Farhan, MS & Nguyen, XD, 2003, A comparative study on motorcycle traffic development in Taiwan, Malaysia and Vietnam, *Journal of Eastern Asia Society for Transportation Studies* vol. 5, pp. 179-93.

Hussain, H, Radin Umar, RS, Ahmad Farhan, MS & Dadang, MM, 2005, Key components of a motorcycle-traffic system – a study along the motorcycle path in Malaysia, *IATSS Research* vol. 29, no. 1, pp. 50-56.

Van Elslande, P & Elvik, R 2012, Powered two-wheelers within the traffic system, *Accident Analysis & Prevention* vol. 49, no. 0, pp. 1-4.