

Development of a Road Safety Index for Metro Manila Based on a 10-year Retrospective Analysis

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ABSTRACT

Background. Global road traffic fatalities continue to rise, posing significant public health and economic burdens, with estimated productivity losses of \$12.69 billion, equivalent to 4.1% of GDP. Developing countries are disproportionately affected, highlighting persistent disparities in road traffic deaths. In the Philippines, Metro Manila has experienced increasing road traffic accidents and fatalities since 2005. Monitoring progress against global, national, regional, and local road safety goals is essential.

Objective. This study aimed to develop an overall Road Safety Index (RSI) and assess Metro Manila's road safety performance in alignment with the World Health Organization's (WHO) 5 Pillars of Road Safety.

Methods. Using WHO's 5 Pillars as a framework, we developed the RSI based on road safety data from 2009–2019 sourced from WHO, the Department of Health (DOH), the Department of Public Works and Highways (DPWH), the Metro Manila Development Authority (MMDA), and local hospitals. Data were scored and aggregated into indices using an equal-weighting method, and Metro Manila's overall RSI was calculated.

Results. Six major indices were generated: Road Safety Management, Safer Roads and Mobility, Safer Road Users, Safer Vehicles, and Post-Crash Response. Metro Manila performed best in Safer Roads and Mobility (78.9/100), followed by Safer Road Users (62.4/100) and Safer Vehicles (59.8/100). Road Safety Management (34.6/100) and Post-Crash Response (35.6/100) were identified as key areas needing improvement. Overall, Metro Manila's RSI increased from 46.0/100 in 2009 to 64.2/100 in 2020.

Conclusion. The Philippines-focused Road Safety Index provides a benchmark for Metro Manila's progress in road safety and highlights areas for targeted interventions. These findings can guide policymakers in prioritizing initiatives to improve road safety outcomes effectively and efficiently.

Keywords: road safety, road safety index, accidents, traffic, Philippines, benchmarking, safety management

INTRODUCTION

Lives claimed by road crashes have been increasing globally. In 2000, an estimated 1.15 million people died due to road traffic accidents, rising to 1.35 million in 2022, making road traffic accidents a major public health and economic problem, particularly in developing countries, which account for more than 93% of these fatalities.¹ Road traffic injuries were the 8th leading cause of death across all ages in 2016 and the leading cause of death among children and young adults aged 5 to 29 years old.¹ In the Philippines, approximately 12,690 road traffic deaths were estimated by the World Health Organization (WHO) in 2016. In addition, 190,350 people suffered injuries due to road accidents. The economic burden was estimated at \$12.69 billion, equivalent to 4.1% of GDP lost due to productivity losses in the same year.¹



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Metro Manila, the Philippines' National Capital Region (NCR), is composed of 16 cities and is the most economically progressive region, contributing 32.2% of the country's GDP.² It serves as the center of economic activity in Luzon, hosting eight of the country's central business districts (CBDs).³ Metro Manila is also the most densely populated region and the second most populated area in the country, with a total of 13,484,462 inhabitants.^{4,5} As a consequence of urbanization, the Metropolitan Manila Development Authority (MMDA) reported a steady increase in road traffic accidents, from 65,111 cases in 2005 to 121,771 cases in 2019.⁶ Fatal accidents also rose slightly, from 324 to 372 over the same period.^{6,7}

The increasing incidence of road traffic accidents, injuries, and deaths has prompted calls for a Decade of Action to stabilize and reduce global road traffic deaths through enhanced road safety measures at national, regional, and global levels.^{8,9} The Decade of Action for Road Safety (2011–2020) follows the WHO's 5 Pillars of Road Safety as a framework: road safety management, safer roads and mobility, safer vehicles, safer road users, and post-crash response.⁸ The Philippines adopted these pillars and committed to reducing road traffic fatalities by 50% by 2020.¹⁰

OBJECTIVE

This study aims to develop an overall Road Safety Index (RSI) based on the 5 Pillars, providing an overview of the road safety situation in the Philippines, particularly in Metro Manila. The Department of Health's Online National Electronic Injury Surveillance System (ONEISS), the only national injury surveillance system, offers the most comprehensive database for constructing the Road Safety Index. Member states of the WHO Road Safety Decade of Action, including the Philippines, are committed to reducing road crashes by 50% by the end of the Decade. The parameters used in this study for the Index are based on WHO-recommended strategies, enabling the government to track and guide progress in road safety interventions.

MATERIALS AND METHODS

With the need for a global guideline to reduce road crashes and promote road safety, the United Nations General Assembly launched the Decade of Action for Road Safety covering 2011–2020.¹ The framework emphasizes a multi-sectoral approach, in which road users, vehicles, road networks and environments, as well as health services, judicial systems, schools, and non-government organizations, all share responsibility in reducing road crashes.

The construction of the Road Safety Index (RSI) in this study was based on the WHO's Five Pillars of Road Safety: Road Safety Management, Safer Roads and Mobility, Safer Road Users, Safer Vehicles, and Post-Crash Response. The individual components of these indices, along with the databases used for each, are described below.

Index 1 – Road Safety Management

Data for Road Safety Management were obtained from the WHO's Global Status Report on Road Safety (WHO-GSRRS).¹ National Data Coordinators (NDCs), nominated by their governments and trained in WHO-GSRRS methodology, identified up to eight additional road safety experts from multiple sectors. These experts individually completed questionnaires and then convened in a consensus meeting to agree on a final set of data representing the country's situation (most recent data up to 2017). The finalized data were submitted to WHO for publication.

Index 2 – Safer Roads and Mobility

Multiple data sources were used for Safer Roads and Mobility. MMDA provided Annual Average Daily Traffic (AADT) data for major circumferential (C1–C5) and radial roads (R1–R10) in Metro Manila from 2012–2020. DPWH provided road condition data, which were assumed constant over the study period due to non-annual updates. DPWH categorized roads as Good, Fair, Poor, or Bad, reporting the distance (in km) of each condition. MMDA and DPWH data were synchronized by matching MMDA-measured roads with the DPWH database to obtain consistent surface type and condition information.

Index 3 – Safer Road Users

Data sources for Safer Road Users included:

- **DOH ONEISS** – Risky behaviors (alcohol use, sleep deprivation, smoking, mobile phone use) and safe behaviors (airbag use, helmet wearing, child restraint, seatbelt use) from 2010–2020. Metro Manila (33,824 samples), Region VII (36,530 samples), and Region XI (32,280 samples) were analyzed separately.
- **Hospital databases** – Risky behaviors (alcohol, drugs, fatigue) and safe behaviors (helmet wearing, seatbelt use) from 18,858 cases across Philippine General Hospital (PGH), POC, EAMC, and JRRMMC from 2009–2020.
- **MMDA MMARAS** – Risky behaviors categorized as Human Error (alcohol intoxication, inattentiveness, bad overtaking/turning, disobedience, other driver errors), Vehicle Defect, and Road Defect. Data spanned 2005–2020 with 1,354,189 observations.

Index 4 – Safer Vehicles

Data for Safer Vehicles included:

- **Hospital databases** – Vehicle types involved in crashes with drivers, passengers, or pedestrians.
- **MMDA MMARAS** – Vehicle involvement by crash severity.
- **PNP Davao Traffic Group** – Vehicle involvement by crash severity.
- **DOH ONEISS** – Vehicle type involvement by outcome for drivers and passengers.

Table 1. Participating Hospitals and Number of Road Crash Patient Data Gathered

Hospital name	Number of Patient Data Gathered	Percent
<i>Davao Regional Medical Center</i>	18,333	45.5
<i>East Avenue Medical Center</i>	6,790	16.9
<i>Jose R. Reyes Memorial Medical Center</i>	2,119	5.3
<i>Philippine General Hospital</i>	7,483	18.6

Index 5 – Post-Crash Response

Post-Crash Response included three components:

- **Outcome Score** – Proportion of patients with improved or recovered outcomes from hospital and ONEISS regional datasets, measuring hospital care performance.
- **Length of Stay Score** – Hospital stay duration, an indicator of care efficiency. Mean ranks per year were computed and normalized from 0 to 1.
- **Hospital Care Score** – Based on the Proposed Trauma Scoring System (PTSS). Cluster analysis divided PTSS scores into groups associated with recovery versus death. PTSS incorporates age, injured body parts, and Revised Trauma Score (RTS), providing a measure of hospital care efficiency (Table 1).

Data Sources

ONEISS Database

The DOH Online National Electronic Injury Surveillance System (ONEISS) captures injury data from health facilities and consolidates it centrally. From January 2010 to June 2019, ONEISS reported 894,989 cases, of which 296,760 (33.1%) were road crashes (“Transport/Vehicular Crash” or TVC). Table 2 shows the annual breakdown.

MMARAS Database

The MMDA Metro Manila Accident Recording and Analysis System (MMARAS) records road crashes in Metro Manila, maintained by the Road Safety Unit of MMDA-TDO-TEC in coordination with the PNP Traffic Enforcement Unit. Data from 2005–2020 totaled 1,354,189 crashes. The trend shows a 4.71% average annual increase from 2005–2019, with a drop in 2020 due to COVID-19 mobility restrictions (Table 3).

Summary

Table 4 summarizes the total number of road crash incidents, patients, roads, and other variables across the three regions analyzed.

RESULTS

Pillar 1: Road Safety Management

The Road Safety Management Index was constructed using summary data from the WHO Global Status Report on Road Safety.¹ The status of existing national road safety laws and policies in the Philippines was extracted from published reports for the years 2009, 2013, 2015, and 2018. Based on these data, a composite Road Safety Management Index was developed.

The computation of the Road Safety Management Index is as follows:

Road Safety Management Index Score

= 0.1667(Policies Score)
+ 0.1667(Speeding Index)
+ 0.1667(Drink Driving Index)
+ 0.1667(Helmet Wearing Index)
+ 0.1667(Seatbelt Index)
+ 1.667(Child Restraint Index)

Where:

Policies Index Score

= 0.2(Funding in National Budget)
+ 0.2(RSA for New Road Infra)
+ 0.2(RSA for existing infra)
+ 0.2(Policy promoting walking or cycling)
+ 0.2(Policy promoting public transport)

Speeding Index Score

= 0.25(National Speed Limit Policy)
+ 0.25(Local Speed Limit Policy)
+ 0.5(Speed Limit Enforcement Score)

Drink Driving Index Score

= 0.25(Drink Driving Law)
+ 0.25(Breath testing)
+ 0.5(Drink Driving Law Enforcement Score)

Helmet Wearing Index Score

= 0.5(Helmet wearing Law
+ Policy includes all riders + Helmet Standards)
+ 0.5(Helmet Wearing Law Enforcement Score)

Seatbelt Index Score

= 0.5(Seatbelt Law + Policy includes all occupants)
+ 0.5(Helmet Wearing Law Enforcement Score)

Child Restraint Index Score

= 0.5(Child Restraint Law)
+ 0.5(Child Restraint Law Enforcement)

All sub-scores and the overall Road Safety Management Index ranged from 0 to 1 and were later scaled to 0–100 for presentation.

Because the WHO Global Status Report on Road Safety was published only in 2009, 2013, 2015, and 2018, index values were computed for those reporting years (Table 5).

Table 2. Distribution of ONEISS TVC reported from 2010 to 2019 (n = 296,760)

Year reported	Frequency
2010	11,306
2011	14,095
2012	17,379
2013	12,633
2014	19,535
2015	27,512
2016	46,321
2017	49,672
2018	56,115
2019	35,179

Table 3. Road Crash Incidents Recorded per Year from MMARAS Database

Year	Frequency	Percent
2005	65111	4.8081
2006	60964	4.5019
2007	63072	4.6575
2008	63606	4.6970
2009	67695	4.9989
2010	77946	5.7559
2011	77151	5.6972
2012	82758	6.1113
2013	86769	6.4075
2014	90257	6.6650
2015	95800	7.0743
2016	109324	8.0730
2017	110027	8.1249
2018	116906	8.6329
2019	121770	8.9921
2020	65032	4.8023
Missing	1	0.0001
Total	1354189	100

Table 4. Total Number of Road Crash Incidents and/or Road Crash Patients for Metro Manila

Region	Pillar	Database	Sample Size
Metro Manila	Safer Roads and Mobility	DPWH-Annual Average Daily Traffic	20 Roads
		DPWH-Road Condition Data	20 Roads
	Safer Road Users	ONEISS	33,824
		Hospitals (PGH, POC, EAMC, JRRMMC)	18,858
		MMARAS	1,354,189
	Safer Vehicles	Hospitals (PGH, POC, EAMC, JRRMMC)	18,858
		MMARAS	1,354,189
	Post-crash Response	Hospitals (PGH, POC, EAMC, JRRMMC)	18,858
		ONEISS	33,824

Historical Trends in Road Safety Management Components

Policies

In 2009, the Philippines received its lowest Policies Index score due to the absence of dedicated national funding for road safety and the lack of national policies promoting cycling and walking. In 2013, the absence of road safety audits for existing infrastructure further limited the score (Table 5).

Speeding

The year 2009 recorded the lowest performance in speed management. Enforcement was rated 3/10 in the WHO report, and no policy permitted local authorities to set speed limits. Although local authorities were allowed to set limits by 2013, enforcement remained low at 3/10 (Table 5).

Drink Driving

In 2009, the Philippines had no national law prohibiting drink driving, resulting in a score of 0. Republic Act No. 10586 (Anti-Drunk and Drugged Driving Act) was enacted in 2013. However, implementing rules and regulations were issued only on April 28, 2014. Enforcement from 2015 onward remained low, with random breath testing requiring probable cause. In fatal crashes, only selected drivers were tested for alcohol intoxication (Table 5).

Helmet Wearing

The Philippine Motorcycle Helmet Act was enacted on December 16, 2009, with implementing rules approved on December 26, 2011. Enforcement improved to moderate levels (5–6/10) from 2013 to 2018 (Table 5).

Seatbelt Use

Seatbelt enforcement was very low in 2009 (3/10). This increased significantly to 8/10 in 2013, accompanied by an increase in seatbelt wearing rates from 52% to 80%. However, enforcement declined in subsequent years, with ratings of 5/10 and 6/10 in 2015 and 2018, respectively (Table 5).

Child Restraints

From 2009 to 2018, the Philippines had no national law mandating child restraint systems, resulting in consistently low scores for this component (Table 5).

Overall Road Safety Management Index

Based on the component scores, the Road Safety Management Index was computed (Table 6).

The year 2009 recorded the lowest overall score at 20.83/100, primarily due to the absence of key legislation such as drink driving and helmet laws at the time, the lack of a child restraint law, and weak enforcement of existing regulations.

By 2018, the score improved to 59.22/100, reflecting legislative progress. However, performance remains sub-optimal due to inconsistent enforcement and the delayed adoption of child restraint legislation. These findings underscore the need for stronger enforcement mechanisms and comprehensive child passenger safety policies (Figure 1).

Pillar 2: Safer Roads and Mobility

The Safer Roads and Mobility Index was constructed using Annual Average Daily Traffic (AADT) data from the Metropolitan Manila Development Authority (MMDA) and

Table 5. Policies Index Scores of the Philippines from 2009 to 2018 Based on WHO Road Safety Management Indicators

Year	National Budget Funding for Road Safety	Road Safety Audit for new road construction	Road Safety Audit for existing infrastructure	National Policy to promote walking/ cycling	National policy to promote public transportation	Policies Score	
2009	0	1	1	0	1	0.6	
2013	1	1	0	1	1	0.8	
2015	1	1	1	1	1	1	
2018	1	1	1	1	1	1	
Speeding Index Score of the Philippines from 2009 to 2018							
Year	National Speed Limit	Local authorities can set Speed Limit		Speed Limit Enforcement (0-10)		Speed Limit Score	
2009	1	0		3		0.40	
2013	1	1		3		0.65	
2015	1	1		5		0.75	
2018	1	1		5		0.75	
Drink Driving Index Score of the Philippines from 2009 to 2018							
Year	Drink Driving Law	Random breath testing		Drink Driving Law Enforcement		Drink Driving Score	
2009	0	0		0		0	
2013	1	0		0		0.25	
2015	1	1		1		0.55	
2018	1	1		4		0.70	
Helmet Wearing Index Score of the Philippines from 2009 to 2018							
Year	Motorcycle Helmet Law	Applies to all riders	Helmet standard mandated	Driver Helmet wearing rate	All Riders Helmet wearing rate	Helmet Wearing Enforcement	Helmet Wearing score
2009	0	0	0	0.34		0	0
2013	1	1	1	0.87	0.51	5	0.625
2015	1	1	1	0.87	0.51	6	0.650
2018	1	1	1	0.87	0.51	6	0.650
Seat Belt Index Score of the Philippines from 2009 to 2018							
Year	Seat Belt Law	Applies to all occupants	Driver's Seat Belt Wearing Rate		Seat Belt Law enforcement		Seat Belt Score
2009	1	1	0.52		3		0.575
2013	1	1	0.80		8		0.700
2015	1	1	0.80		5		0.625
2018	1	1	0.80		6		0.650
Child Restraint Index Score of the Philippines from 2009 to 2018							
Year	Child Restraint Law		Child Restraint Law Enforcement			Child restraint score	
2009	0					0	
2013	0					0	
2015	0					0	
2018	0					0	

Table 6. Road Safety Management Index Scores of the Philippines from 2009 to 2018

Year	Policies Score	Speed Limit Score	Drink Driving Score	Helmet Wearing Score	Seatbelt Score	Child Restraint Score	Road Safety Management Index
2009	0.6	0.40	0	0	0.25	0	0.208333333
2013	0.8	0.65	0.25	0.625	0.378125	0	0.450520833
2015	1.0	0.75	0.55	0.650	0.453750	0	0.567291667
2018	1.0	0.75	0.70	0.650	0.453750	0	0.592291667

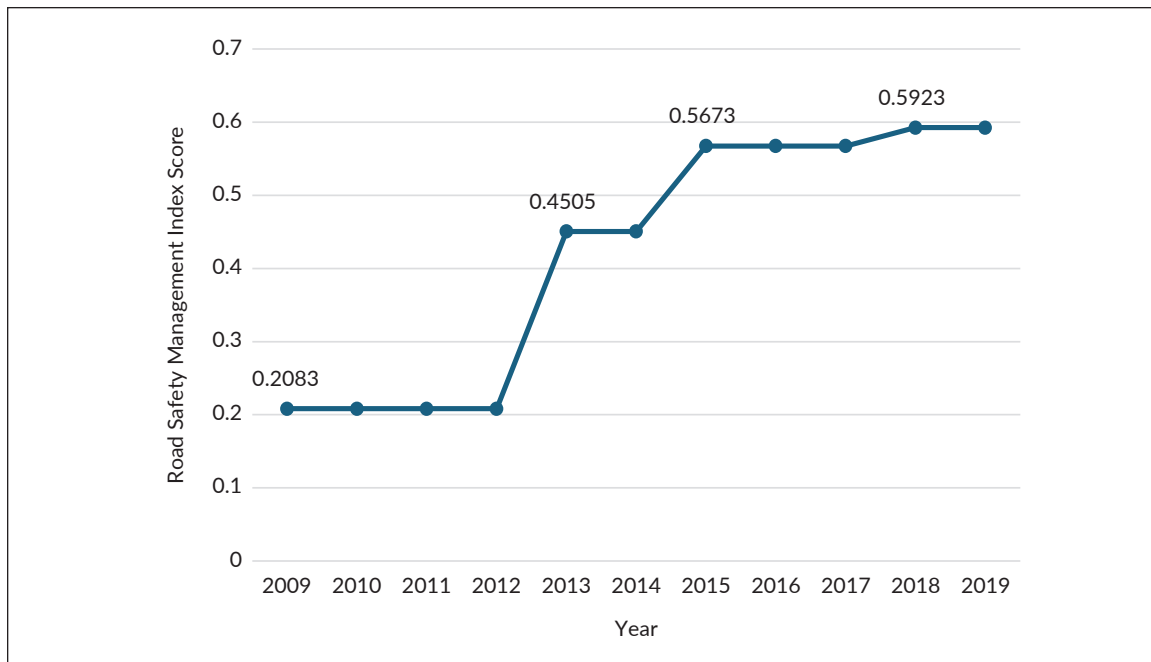


Figure 1. Road Safety Management Index Score from 2009-2019.

road condition data from the Department of Public Works and Highways (DPWH).

Annual Average Daily Traffic (AADT)

MMDA maintains AADT data for major roads in Metro Manila, including key segments of the Circumferential (C1–C5) and Radial (R1–R10) road networks. These roads serve as major transport arteries and provide a reasonable proxy for overall vehicular mobility in the NCR.

Circumferential Roads

- C1: Recto Avenue
- C2: Alfonso Mendoza Street and President Quirino Avenue
- C3: Araneta Avenue
- C4: Epifanio de los Santos Avenue (EDSA)
- C5: Katipunan Avenue

Radial Roads

- R1: Roxas Boulevard
- R2: Taft Avenue
- R3: South Superhighway
- R4: Shaw Boulevard
- R5: Ortigas Avenue
- R6: Magsaysay Boulevard and Aurora Boulevard
- R7: Quezon Avenue and Commonwealth Avenue
- R8: Andres Bonifacio Avenue
- R9: Rizal Avenue
- R10: Del Pan Street, Marcos Highway, and MacArthur Highway

The total number of vehicles traversing these roads from 2012 to 2020 is shown in Table 7.

Normalization of AADT

To generate comparable scores across years, AADT values were normalized using min–max normalization:

$$z_i = [x_i - \min(x)] / [\max(x) - \min(x)]$$

This rescales values to the interval [0,1], where:

- 0 corresponds to the lowest recorded AADT for that road
- 1 corresponds to the highest recorded AADT

Because lower traffic volume is interpreted as better mobility, the normalized values were reversed:

$$\text{Annual Average Daily Traffic Score}_i = 1 - [x_i - \min(x)] / [\max(x) - \min(x)]$$

Thus:

- A score of 0 indicates the year with the highest traffic volume
- A score of 1 indicates the year with the lowest traffic volume

For most major roads, AADT was lowest in 2012 and increased steadily until 2019. Several roads—including EDSA, Katipunan Avenue, Roxas Boulevard, Shaw Boulevard, Ortigas Avenue, Magsaysay Boulevard, Commonwealth Avenue, and Rizal Avenue—recorded peak AADT in 2019. In 2020, mobility restrictions due to the COVID-19 pandemic resulted in significant declines in AADT for many roads.

However, some roads (e.g., Taft Avenue, Quezon Avenue, Recto Avenue, and R10) did not demonstrate propor-

Table 7. Annual Average Daily Traffic for Major Roads in Metro Manila from 2012 to 2020

Road	Road Name	Annual Average Daily Traffic								
		2012	2013	2014	2015	2016	2017	2018	2019	2020
C1	Recto	47782	63533	61831	70506	63362	64677	66814	66127	94622
C2	Mendoza	59674	82523	87069	91842	78551	84379	88644	91279	70475
	Pres. Quirino	138825	129893	124657	119824	117482	105118	108592	116767	55416
C3	Araneta Avenue	73090	105694	97360	89720	79202	80030	81219	92433	84967
C4	EDSA	326504	342612	360417	367675	364781	367728	383828	405882	328114
C5	Katipunan/CP Garcia	157987	175929	178429	194119	218155	218751	235744	236060	192418
R1	Roxas Boulevard	150242	141963	168963	173195	175185	191120	203487	203582	190626
R2	Taft Avenue	42276	77903	83463	91185	89848	90586	91766	100065	110916
R3	SSH	122460	131975	143610	126567	99923	103377	100909	130434	142755
R4	Shaw Boulevard	87217	88430	88057	95236	101307	101324	103077	104946	103609
R5	Ortigas	102446	106183	123277	121433	153425	153955	174480	180737	172490
R6	Magsaysay Boulevard	86058	92617	98753	99813	94779	102573	113727	119820	111540
	Aurora Boulevard	124770	122022	102554	93706	95595	98644	103463	120385	113196
R7	Quezon Avenue	143680	183609	183458	186321	187111	195335	204604	230099	237759
	Commonwealth Avenue	197809	237577	233101	259195	272255	272720	244916	317471	282137
R8	A. Bonifacio	88852	80570	90354	57897	58014	60790	64076	73286	81002
R9	Rizal Avenue	61978	71669	58951	70395	76295	81740	89473	95041	87544

Source: MMDA

tional reductions, indicating heterogeneous mobility patterns during lockdown periods.

Road Condition Index

The second component of the Safer Roads and Mobility Index is road condition. DPWH provides data on road surface condition in Metro Manila, categorized as:

- Good
- Fair
- Poor
- Bad

For each road, DPWH reports the length (in kilometers) corresponding to each category.

To integrate road condition into the index, a Road Condition Index (RCI) was computed as:

$$RCI = [3(\text{length of good road}) + 2(\text{length of fair road}) + 1(\text{length of poor road}) + 0(\text{length of bad road})] / [3(\text{sum of road lengths})]$$

The weighting scheme penalizes lower-quality road segments. Dividing by three times the total road length removes units and rescales the index to the interval [0,1].

- A score of 1 is achieved when all segments are classified as Good
- A score of 0 is achieved when all segments are classified as Bad

The lowest Road Condition Index scores were observed for Andres Bonifacio Avenue and President Quirino Avenue, both of which had minimal “Good” segments. Andres Bonifacio Avenue consisted predominantly of Poor segments,

while President Quirino Avenue was largely Fair. Overall, the condition of major roads in Metro Manila was generally classified as Good (Table 8).

Construction of the Safer Roads and Mobility Index

The two components were combined using equal weights:

$$\text{Safer Roads and Mobility Index} = 0.5(\text{Road Condition Index}) + 0.5(\text{Normalized Annual Average Daily Traffic})$$

Because DPWH road condition data were not available as a time series, the RCI was held constant across years. This represents a limitation of the study. However, given the long timelines required for major infrastructure rehabilitation, road condition was assumed relatively stable during the study period.

Trends in Safer Roads and Mobility

The Safer Roads and Mobility Index scores for major roads are presented in Table 9.

The overall trend shows a decline from 2012 to 2019. This is expected, as road condition remained constant while AADT increased steadily, reflecting worsening mobility. The year 2020 demonstrated modest improvement, corresponding to pandemic-related reductions in traffic volume.

President Quirino Avenue recorded the lowest average index score (43.3/100), largely driven by its poor road condition score. Del Pan Street recorded the highest average score (89.9/100) (Table 10).

Table 8. Road Condition Index Scores of Major Roads in Metro Manila from 2012 to 2020

Road	Road Name	Good Road Length	Fair Road Length	Poor Road Length	Bad Road Length	Road Condition Score	Road Condition Index
C1	Recto	2.36	0.43	0.41	0	8.35	0.8698
C2	Mendoza	1.28	0.45	0	0	4.74	0.9133
	Pres. Quirino	0.12	5.35	1.72	0.47	12.78	0.5561
C3	Araneta Avenue	2.72	2.2	0.19	0.2	12.75	0.8004
C4	EDSA	35.51	12.64	5.17	1.52	136.98	0.8326
C5	Katipunan/CP Garcia	3.17	0.3	0.67	0	10.78	0.8680
R1	Roxas Boulevard	20.78	0.72	0.28	0.21	64.06	0.9710
R2	Taft Avenue	7.07	3.45	2.13	0	30.24	0.7968
R3	SSH	30.48	4.19	0.06	0	99.88	0.9586
R4	Shaw Boulevard	7.08	0	0	0	21.24	1.0000
R5	Ortigas	9.47	1.58	0	0	31.57	0.9523
R6	Magsaysay Boulevard	2.66	2.17	0	0	12.32	0.8502
	Aurora Boulevard	16.45	4.55	3.86	1.52	62.31	0.7873
R7	Quezon Avenue	15.94	0.3	0	0	48.42	0.9938
	Commonwealth Avenue	14.34	1.36	0	0	45.74	0.9711
R8	A. Bonifacio	0.53	3.42	5.66	0	14.09	0.4887
R9	Rizal Avenue	7.17	1	0	0	23.51	0.9592
R10	Del Pan	0.74	0	0	0	2.22	1.0000
	Marcos Highway	2.83	0	0	0	8.49	1.0000
	McArthur Highway	7.43	1.77	0	0	25.83	0.9359

Table 9. Road Condition Index Scores of Major Roads in Metro Manila from 2012 to 2020

Road	Road Name	Good Road Length	Fair Road Length	Poor Road Length	Bad Road Length	Road Condition Score	Road Condition Index
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C2	Mendoza	1.28	0.45	0	0	4.74	0.9133
	Pres. Quirino	0.12	5.35	1.72	0.47	12.78	0.5561
C3	Araneta Avenue	2.72	2.2	0.19	0.2	12.75	0.8004
C4	EDSA	35.51	12.64	5.17	1.52	136.98	0.8326
C5	Katipunan/CP Garcia	3.17	0.3	0.67	0	10.78	0.8680
R1	Roxas Boulevard	20.78	0.72	0.28	0.21	64.06	0.9710
R2	Taft Avenue	7.07	3.45	2.13	0	30.24	0.7968
R3	SSH	30.48	4.19	0.06	0	99.88	0.9586
R4	Shaw Boulevard	7.08	0	0	0	21.24	1.0000
R5	Ortigas	9.47	1.58	0	0	31.57	0.9523
R6	Magsaysay Boulevard	2.66	2.17	0	0	12.32	0.8502
	Aurora Boulevard	16.45	4.55	3.86	1.52	62.31	0.7873
R7	Quezon Avenue	15.94	0.3	0	0	48.42	0.9938
	Commonwealth Avenue	14.34	1.36	0	0	45.74	0.9711
R8	A. Bonifacio	0.53	3.42	5.66	0	14.09	0.4887
R9	Rizal Avenue	7.17	1	0	0	23.51	0.9592
R10	Del Pan	0.74	0	0	0	2.22	1.0000
	Marcos Highway	2.83	0	0	0	8.49	1.0000
	McArthur Highway	7.43	1.77	0	0	25.83	0.9359

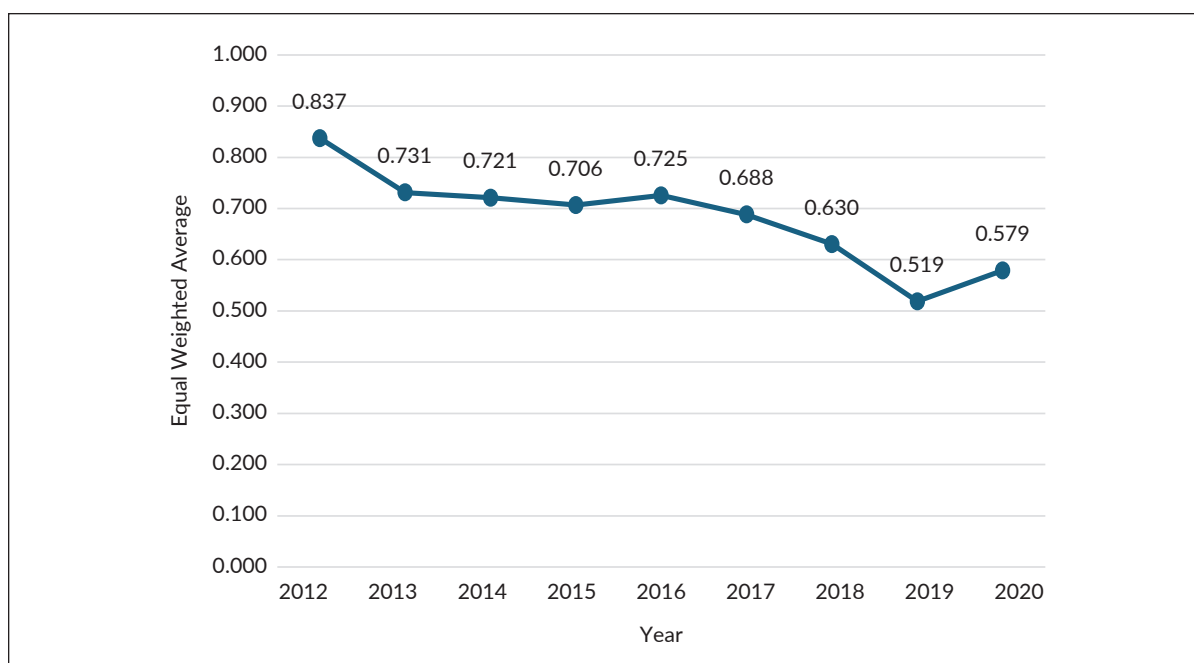


Figure 2. Equal weighted average safer roads and mobility scores of major roads in Metro Manila from 2012 to 2020.

Table 10. Average Safer Roads and Mobility Scores of Major Roads in Metro Manila from 2012 to 2020

Road	Road Name	Average Safer Roads and Mobility Score
C1	Recto	0.734
C2	Mendoza	0.616
	Pres. Quirino	0.433
C3	Araneta Avenue	0.686
C4	EDSA	0.700
C5	Katipunan/CP Garcia	0.660
R1	Roxas Boulevard	0.696
R2	Taft Avenue	0.577
R3	SSH	0.722
R4	Shaw Boulevard	0.723
R5	Ortigas	0.716
R6	Magsaysay Boulevard	0.686
	Aurora Boulevard	0.659
R7	Quezon Avenue	0.726
	Commonwealth Avenue	0.736
R8	A. Bonifacio	0.515
R9	Rizal Avenue	0.729
R10	Del Pan	0.899
	Marcos Highway	0.759
	McArthur Highway	0.798

The equal-weighted annual average across all roads declined from 83.7/100 in 2012 to 51.9/100 in 2019. A partial rebound was observed in 2020 (57.9/100), highlighting the impact of reduced vehicular volume on mobility (Figure 2).

Pillar 3: Safer Road Users

Three (3) databases were used to create an index for Safer Road Users: the Department of Health's Online National Electronic Injury Surveillance System (ONEISS), selected hospital databases, and the Metro Manila Development Authority's Metro Manila Accident Reporting and Analysis System (MMARAS).

The ONEISS database covers the period 2010–2020 and includes information on risky road user behaviors such as alcohol use, sleep deprivation, smoking, and mobile phone use, as well as protective behaviors including airbag deployment, helmet wearing, child restraint use, and seatbelt use. Only cases from Metro Manila were included in the analysis. The hospital database, covering 2009–2020, includes data from Philippine General Hospital–ISIS, Philippine Orthopedic Center, East Avenue Medical Center, and Jose R. Reyes Memorial Medical Center. Similar variables were extracted from hospital records, including alcohol use, drug use, fatigue, helmet wearing, and seatbelt use. The MMARAS database, spanning 2005–2020, provided information on crash causation factors, which were ultimately grouped into Human Error, Vehicle Defect, and Road Defect. Human Error included alcohol intoxication, inattentiveness, improper overtaking or turning, disobedience of traffic rules, avoidance maneuvers, and other driver-related errors. Mechanical and vehicular issues were classified under Vehicle

Defect, while environmental and infrastructure-related contributors such as slippery roads, obstructions, and road surface irregularities were categorized as Road Defect.

The Safer Road Users Index was computed as follows:

$$\text{Safer Road Users Index} = 0.333(\text{Behaviors leading to Damage to Property}) + 0.333(\text{Behaviors leading to Damage to Injury}) + 0.333(\text{Behaviors leading to Fatality})$$

ONEISS Database

To compute the safer road user component from ONEISS, frequency tables were generated for patient outcomes categorized as died, improved, or unimproved. For each outcome group, the frequency of individuals who committed risky road behaviors was counted, as well as the frequency of individuals who did not use safety measures.

To adjust for differences in annual sample size, these frequencies were divided by their respective row totals to obtain proportions. The resulting proportions were then subtracted from one so that higher values would correspond to fewer fatalities or injuries associated with risky behaviors.

However, using these adjusted proportions alone would produce relatively stable averages across years and would not sufficiently capture variation over time. Therefore, the values were normalized using the min-max normalization formula:

$$z_i = [x_i - \min(x)] / [\max(x) - \min(x)]$$

If $\max(x) = \min(x)$, z_i is set to be 0.5. But if $\max(x) = \min(x) = 0$, z_i is set to be 1 for all years, since the goal is to have the minimum number of fatalities/injuries. This adjustment was particularly relevant for smoking- and sleep-related fatalities, which recorded zero fatalities across all years. Assigning a value of 0.5 in such cases would underestimate optimal safety performance.

Under this scoring system, a value of 0 represents the year with the highest proportion of fatalities or injuries, while a value of 1 represents the year with the lowest proportion. The resulting index scores from ONEISS are summarized in Table 11.

Hospital Database

The methodology applied to the hospital database was similar to that used for ONEISS. Frequency tables were generated for patient outcomes categorized as died, improved, or unimproved. Within each outcome group, the frequency of risky behaviors and the frequency of non-use of protective measures were counted.

To adjust for varying sample sizes across years, frequencies were divided by their respective row totals. The resulting proportions were subtracted from one so that higher values corresponded to fewer fatalities or injuries. These adjusted values were then normalized using the same min-max normalization formula:

$$z_i = [x_i - \min(x)] / [\max(x) - \min(x)]$$

Table 11. Average Scores of Died, Improved, or Unimproved Road Users from 2010 to 2020

ONEISS Database		
Year	Died	Improved/ Unimproved
2010	0.578	0.550
2011	0.617	0.543
2012	0.618	0.670
2013	0.838	0.687
2014	0.572	0.707
2015	0.554	0.703
2016	0.554	0.703
2017	0.607	0.710
2018	0.628	0.544
2019	0.554	0.672
2020	0.554	0.709
Hospital Database		
Year	Died	Improved/ Unimproved
2009	0.769	0.719
2010	0.800	0.800
2011	0.503	0.730
2012	0.710	1.000
2013	0.554	0.747
2014	0.714	0.683
2015	0.731	0.723
2016	0.639	0.335
2017	0.706	0.700
2018	0.600	0.471
2019	0.736	0.549
2020	0.800	0.673

If $\max(x) = \min(x)$, z_i is set to be 0.5. But if $\max(x) = \min(x) = 0$, z_i is set to be 1 for all years, since the goal is to have the minimum number of fatalities/injuries.

This ensured that years with zero fatalities or injuries associated with a specific risk factor received the maximum score. The resulting hospital-based index scores are likewise presented in Table 11.

MMARAS Database

For the MMARAS database, frequency tables were generated for fatal crashes, non-fatal (injurious) crashes, and damage-to-property crashes. Crash causation variables were consolidated into three categories: Human Error, Vehicle Defect, and Road Defect. This grouping was performed to align with updated MMARAS classifications and to ensure consistency in analysis. All human-related contributing factors were classified under Human Error, mechanical issues under Vehicle Defect, and environmental or infrastructure-related contributors under Road Defect.

As with the ONEISS and hospital databases, frequencies were divided by their respective row totals to account for annual variations in total crash counts. The resulting proportions were subtracted from one so that higher scores indicated safer outcomes. The normalized values were computed using the same min-max normalization procedure and special case adjustment for zero values.

$$z_i = [x_i - \min(x)] / [\max(x) - \min(x)]$$

If $\max(x) = \min(x)$, z_i is set to be 0.5. But if $\max(x) = \min(x) = 0$, z_i is set to be 1 for all years, since the goal is to have the minimum number of fatalities/injuries/damages to property crashes.

Under this system, a score of 0 represents the year with the highest proportion of fatalities, injuries, or damage-to-property crashes attributed to a given factor, while a score of 1 represents the lowest proportion. The resulting MMARAS-based scores are presented in Table 12.

Safer Road Users Index

For the final Safer Road Users Index, fatality-related scores were averaged across the relevant databases, injury-related scores were averaged, and the damage-to-property component derived from MMARAS was incorporated directly. The equal-weighted average of these three components produced the annual Safer Road Users Index, shown in Table 12.

The Safer Road Users Index exhibited fluctuations over time. The lowest score was recorded in 2018 (0.503/100), followed by an improvement to 0.672/100 in 2020. The highest

Table 12. Safer Road User Index of Metro Manila from 2005 to 2020

Year	Road User Killed Score	Road User Injured Score	Road User DTP Score	Safer Road User Index
2005	0.579	0.662	0.667	0.636
2006	0.552	0.660	0.667	0.626
2007	0.586	0.665	0.667	0.639
2008	0.667	0.667	0.666	0.667
2009	0.718	0.692	0.659	0.690
2010	0.682	0.670	0.666	0.672
2011	0.532	0.628	0.642	0.601
2012	0.546	0.772	0.616	0.645
2013	0.686	0.677	0.636	0.666
2014	0.552	0.623	0.473	0.549
2015	0.546	0.687	0.644	0.626
2016	0.620	0.560	0.637	0.606
2017	0.660	0.687	0.640	0.662
2018	0.632	0.546	0.333	0.503
2019	0.652	0.548	0.384	0.528
2020	0.785	0.607	0.624	0.672

safer road user score was achieved in 2009. These trends are illustrated in Figure 3.

The improvement observed in 2020 may partly reflect reduced mobility and behavioral exposure during pandemic-related restrictions. Nevertheless, the variability in scores across years indicates that behavioral risk factors and human

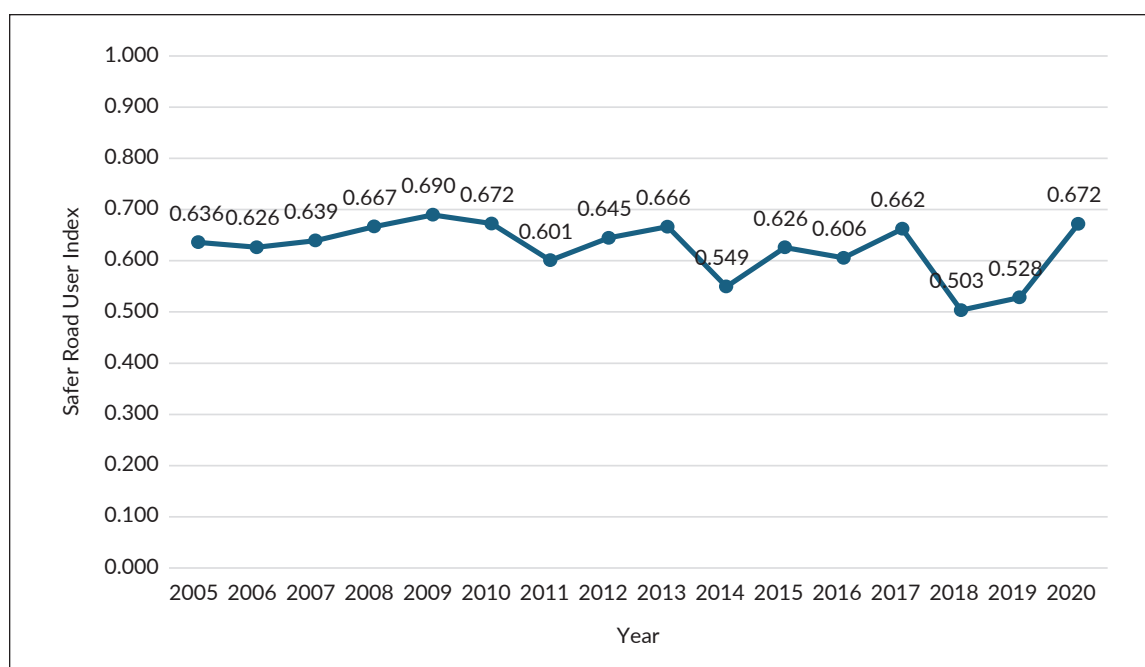


Figure 3. Safer road user index of Metro Manila from 2005 to 2020.

error remain significant and inconsistent determinants of road safety outcomes in Metro Manila.

Pillar 4: Safer Vehicles

Two (2) databases were used to create the Safer Vehicles Index: the hospital database and the Metro Manila Development Authority's Metro Manila Accident Reporting and Analysis System (MMARAS). The hospital database provided information on vehicle types involved in crashes affecting drivers or passengers, as well as pedestrians. The MMARAS database provided data on vehicle involvement according to crash severity.

In constructing the Safer Vehicles Index, MMARAS data were used to compute the "Vehicles per Crash Severity" component, while hospital data were used to compute the "Vehicles per Road User Type" component.

The Safer Vehicles Index was computed as follows:

$$\text{Safer Vehicles Index} = 0.5(\text{Vehicles per Crash Severity}) + 0.5 (\text{Vehicles per Road User Type})$$

The Vehicles per Crash Severity component was computed as:

$$\text{Vehicles per Crash Severity} = 0.5(\text{Vehicle involvement in Fatal Crashes}) + 0.333(\text{Vehicle involvement in Injurious Crashes}) + 0.1667(\text{Vehicle involvement in DTP Crashes})$$

The Vehicles per Road User component was computed as:

$$\text{Vehicles per Road User} = 0.5(\text{Vehicle involvement for Drivers/Passengers}) + 0.5(\text{Vehicle involvement for Pedestrians})$$

Vehicles per Crash Severity (MMARAS)

To compute the Vehicles per Crash Severity component from the MMARAS database, frequency tables of vehicle types were generated for each crash severity category: fatal crashes, injurious crashes, and damage-to-property (DTP) crashes.

The raw frequencies were normalized using the formula:

$$z_i = 1 - [x_i - \min(x)] / [\max(x) - \min(x)]$$

This transformation rescales the frequencies to values between 0 and 1, where the lowest frequency for a given vehicle type across years is assigned a value of 1, and the highest frequency is assigned a value of 0. The reversal ensures that lower vehicle involvement corresponds to a higher safety score.

After obtaining the normalized scores for each vehicle type, row averages were computed for each year and crash severity category. These yearly normalized row averages served as the component scores:

- The normalized row average for fatal crashes represents the Vehicle Involvement in Fatal Crashes score.

Table 13. Vehicle Crash per Severity Scores in Metro Manila from 2005 to 2020 based on MMARAS Database

Year	Vehicle involvement in Fatal Crashes	Vehicle involvement in Injurious Crashes	Vehicle involvement in DTP Crashes	Vehicles per Crash Severity
2005	0.631	0.652	0.695	0.649
2006	0.454	0.700	0.738	0.583
2007	0.518	0.735	0.736	0.627
2008	0.815	0.666	0.692	0.745
2009	0.823	0.715	0.662	0.760
2010	0.461	0.452	0.597	0.480
2011	0.528	0.423	0.607	0.506
2012	0.435	0.398	0.539	0.440
2013	0.452	0.387	0.487	0.436
2014	0.417	0.399	0.451	0.417
2015	0.124	0.335	0.452	0.249
2016	0.440	0.385	0.277	0.394
2017	0.460	0.498	0.282	0.443
2018	0.545	0.356	0.211	0.426
2019	0.561	0.246	0.155	0.388
2020	0.633	0.649	0.748	0.657

- The normalized row average for injurious crashes represents the Vehicle Involvement in Injurious Crashes score.
- The normalized row average for DTP crashes represents the Vehicle Involvement in DTP Crashes score.

To obtain the Vehicles per Crash Severity score, these three components were weighted according to crash severity. Fatal crashes were assigned a weight of 3/6 (0.5), injurious crashes a weight of 2/6 (0.333), and damage-to-property crashes a weight of 1/6 (0.1667). This weighting scheme reflects the greater societal burden associated with more severe crash outcomes. The resulting scores are presented in Table 13.

Vehicles per Road User (Hospital Database)

To compute the Vehicles per Road User component from the hospital database, frequency tables of vehicle types were generated for crashes involving drivers or passengers and for crashes involving pedestrians.

Because annual hospital case counts differed across years, frequencies were first divided by their respective row totals to adjust for sample size variation. The resulting proportions were then normalized using the formula:

$$z_i = 1 - [x_i - \min(x)] / [\max(x) - \min(x)]$$

This transformation rescales the proportion values to the interval [0,1], such that the lowest vehicle involvement for a given type across years is assigned a value of 1, and the highest involvement is assigned a value of 0.

After obtaining the normalized values for each vehicle type, yearly row averages were computed. These row averages served as the component scores:

- The normalized row average for crashes involving drivers or passengers represents the Vehicle Involvement for Drivers/Passengers score.
- The normalized row average for crashes involving pedestrians represents the Vehicle Involvement for Pedestrians score.

The resulting scores are presented in Table 14.

Safer Vehicles Index

As defined, the Safer Vehicles Index is composed of the equally weighted average of the Vehicles per Crash Severity and Vehicles per Road User components.

Similar to the other pillars, a marked improvement in the Safer Vehicles Index was observed in 2020. Prior to 2020, the overall trend indicated worsening performance, declining from its peak of 76.4/100 in 2009 to 43.6/100 in 2019. The improvement in 2020 is illustrated in Figure 4 and may be partly attributable to reduced traffic exposure during pandemic-related mobility restrictions.

Overall, the downward trend prior to 2020 suggests increasing involvement of certain vehicle types in severe crashes over time, highlighting the need for stronger vehicle

Table 14. Vehicle per Road User Scores in Metro Manila from 2009 to 2020 based on Hospital Database

Year	Vehicle involvement for Drivers/Passengers	Vehicle involvement for Pedestrians	Vehicles per Road User
2009	0.53	1.00	0.77
2010	0.62	1.00	0.81
2011	0.79	1.00	0.90
2012	0.68	1.00	0.84
2013	0.62	1.00	0.81
2014	0.53	1.00	0.77
2015	0.81	0.70	0.75
2016	0.52	0.41	0.46
2017	0.59	0.57	0.58
2018	0.51	0.49	0.50
2019	0.50	0.47	0.48
2020	0.75	0.58	0.67

safety standards, enforcement of roadworthiness regulations, and improved pedestrian protection measures.

Pillar 5: Post-Crash Response

The Hospital Database and the ONEISS dataset were used in constructing the Post-Crash Response Index.

From the Hospital Database, the proportion of recoveries, length of hospitalization, and the Proposed Trauma Scoring System (PTSS) scores of patients were obtained. The Hospital Database includes data from Philippine General Hospital

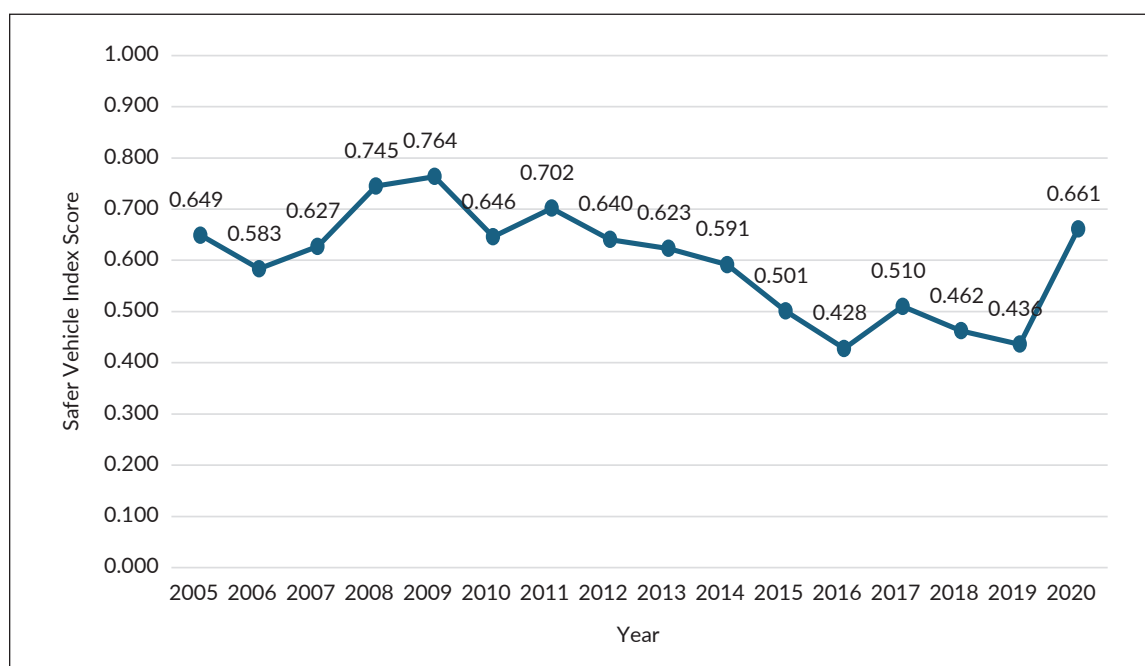


Figure 4. Safer vehicle index scores of Metro Manila from 2005 to 2020.

(PGH), East Avenue Medical Center (EAMC), Philippine Orthopedic Center (POC), and Jose R. Reyes Memorial Medical Center (JRRMMC). The Metro Manila subset of the ONEISS database was likewise utilized to supplement outcome data.

The Post-Crash Response Index was computed as follows:

$$\text{Post-Crash Response Index} = 0.333(\text{Outcome Score}) + 0.333(\text{Hospital Care Score}) + 0.333(\text{Length of Stay Score})$$

Outcome Score

The Outcome Score represents the proportion of patients with improved or recovered outcomes in the Hospital Database (PGH, EAMC, POC, and JRRMMC) and in the Metro Manila subset of ONEISS. This score is intended to measure the overall performance of hospital care provided to road crash patients.

The Outcome Score demonstrates an overall improving trend, increasing from 21/100 in 2010 to 87.82/100 in 2020. Fluctuations are observed across years, largely driven by variations in the proportion of recoveries recorded in the Hospital Database. In certain years, recovery proportions were considerably lower, which temporarily reduced the overall score.

Length of Stay Score

Length of hospital stay is an important indicator of hospital management efficiency and quality of patient care. Shorter hospitalization reduces the risk of hospital-acquired infections and medication-related complications, lowers medical costs, increases bed turnover rates, and reduces overall societal burden. This subcomponent captures the efficiency dimension of post-crash response.

The Length of Stay Score was computed by ranking the length of hospital stay for each patient and calculating the mean rank per year. The yearly mean ranks were then normalized to the interval [0,1] using the formula:

$$z_i = 1 - [x_i - \min(x)] / [\max(x) - \min(x)]$$

Because longer hospital stays are less desirable, the normalization was structured so that shorter average lengths of stay correspond to higher scores.

A score of 0 was assigned to the theoretical highest mean rank (15,450), representing the longest hospitalization, while a score of 1 was assigned to the theoretical lowest mean rank (1), representing the shortest hospitalization. The shortest average length of stay for road crash patients in Metro Manila occurred in 2019, which resulted in the highest Length of Stay Score for that year. Although Length of Stay Scores are generally lower compared to other subcomponents, a gradual improvement is observed over time, indicating shorter hospitalizations in more recent years. The yearly values are presented in Table 15.

Table 15. Length of Hospital Stay Scores of Road Crash Victims in Metro Manila from 2009 to 2020 based on ONEISS and Hospital Databases

Year	Mean Rank	Length of Stay Score
2009	9841.856	0.363
2010	11878.190	0.231
2011	11893.194	0.230
2012	11658.195	0.245
2013	11326.530	0.267
2014	11447.272	0.259
2015	10474.487	0.322
2016	10934.849	0.292
2017	9222.422	0.403
2018	6489.597	0.580
2019	5086.807	0.671
2020	7159.987	0.537

Hospital Care Score

The Hospital Care Score was derived from the Proposed Trauma Scoring System (PTSS). Cluster analysis was performed on PTSS values to determine score thresholds associated with patient mortality. This procedure divided PTSS values into two groups: scores associated with deaths and adverse outcomes, and scores associated with recovery or improved outcomes.

The PTSS incorporates patient age, injured body regions, and Revised Trauma Score (RTS), all of which are predictors of injury severity. By evaluating recovery rates within PTSS-defined severity groups, the analysis provides a measure of hospital care effectiveness, adjusted for injury severity. High recovery rates among severely injured patients indicate better hospital performance.

The Hospital Care Score demonstrates an overall increasing trend, from 44.3/100 in 2009 to 72/100 in 2019. The highest score was recorded in 2018 (85/100), largely driven by a 90% recovery rate in the high-PTSS group and a 79.3% recovery rate in the low-PTSS group. In 2012, the score was 0 due to the absence of available cases, representing a data limitation. The yearly values are shown in Table 16.

Post-Crash Response Index

The Post-Crash Response Index was computed as the mean of the three subcomponents: Outcome Score, Hospital Care Score, and Length of Stay Score.

Overall, the Post-Crash Response Index shows an increasing trend, rising from its lowest value of 17.4/100 in 2011 to 70.8/100 in 2020. The upward trajectory reflects improvements in recovery rates, shorter hospital stays, and enhanced hospital care performance in more recent years. These trends are illustrated in Figure 5.

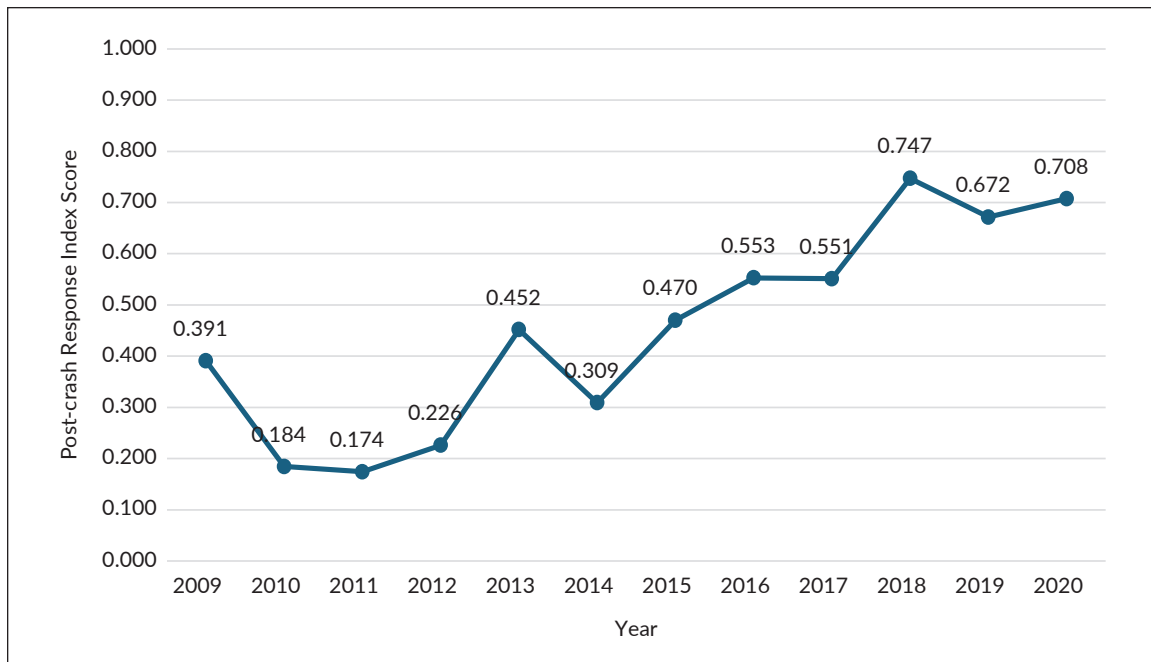


Figure 5. Post-crash response index scores of Metro Manila from 2009 to 2020.

Table 16. Hospital Care Scores of Road Crash Victims in Metro Manila from 2009 to 2020 based on Hospital Database

Year	Low PTSS Score Group	High PTSS Score Group	Critical Care Score
2009	0.407	0.478	0.443
2010	0.121	0.103	0.112
2011	0.067	0.000	0.033
2012	0.000	0.000	0.000
2013	0.344	0.536	0.440
2014	0.048	0.231	0.139
2015	0.286	0.800	0.543
2016	0.327	0.906	0.616
2017	0.360	0.941	0.650
2018	0.793	0.907	0.850
2019	0.748	0.692	0.720

Road Safety Index

The overall Road Safety Index (RSI) was computed as the equal-weighted average of the five pillar indices:

$$\text{Road Safety Index} = 0.2(\text{Road Safety Management Index}) + 0.2(\text{Safer Vehicles and Mobility Index}) + 0.2(\text{Safer Road Users Index}) + 0.2(\text{Safer Vehicles Index}) + 0.2(\text{Post-Crash Response Index})$$

Several component indices contained missing values in certain years (Table 17). To address this issue, regression imputation was applied using year as the independent variable and the index value as the dependent variable. A linear

regression model was fitted to the non-missing observations, and predicted values were imputed for missing years.

Because predicted values may exceed the theoretical bounds of the index, values greater than 1 were truncated to 1, and values less than 0 were truncated to 0, thereby preserving the 0–1 scale. A potential limitation of this approach is that imputed values depend on the available data and assume a linear trend over time. Moreover, structural changes in infrastructure and policy may occur gradually, making year-to-year changes relatively small.

The Road Safety Index for Metro Manila fluctuated within the range of 45/100 to 65/100 between 2005 and 2020. A modest upward trend is observed, with the index peaking at 64.20/100 in 2020. The 2020 value was influenced by pandemic-related mobility reductions, suggesting that decreased vehicular exposure may contribute to improved road safety outcomes. However, this interpretation must be treated cautiously due to projected values and potential imputation bias. Substantial room for improvement remains, particularly through enhanced data quality and policy implementation. These trends are illustrated in Figure 6.

Across the five pillars, the best-performing component over time was the Safer Roads and Mobility Index, with an average score of 78.9/100. This was followed by the Safer Road Users Index and the Safer Vehicles Index. The lowest-performing pillar was the Road Safety Management Index, which was negatively affected by the absence or delayed implementation of key protective legislation, including child restraint laws. While several road safety laws exist in the Philippines, international evaluations suggest that enforcement levels remain low to moderate. The Post-Crash

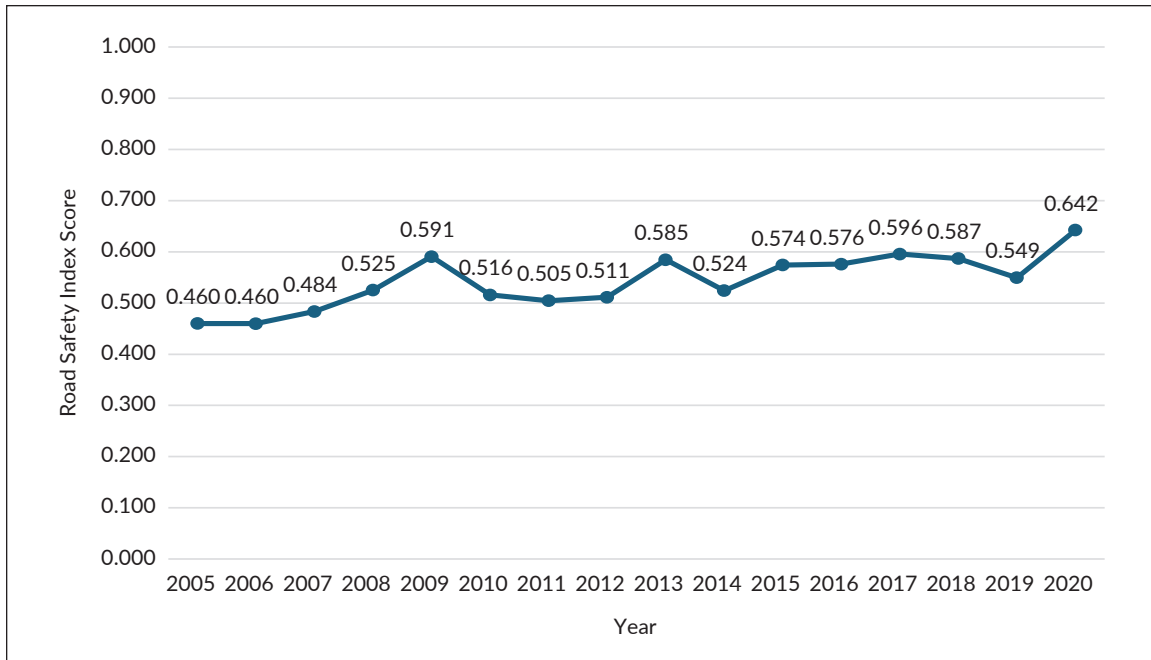


Figure 6. Road safety index scores of Metro Manila from 2005 to 2020.

Table 17. Road Safety Index Components Scores of Metro Manila from 2005 to 2020

Year	Road Safety Management Index	Safer Roads and Mobility Index	Safer Road User Index	Safer Vehicles Index	Post-crash Response Index
2005			0.636	0.649	
2006			0.626	0.583	
2007			0.639	0.627	
2008			0.667	0.745	
2009	0.2083		0.69	0.764	0.391
2010			0.672	0.646	0.184
2011			0.601	0.702	0.174
2012		0.837	0.645	0.640	0.226
2013	0.4505	0.731	0.666	0.623	0.452
2014		0.721	0.549	0.591	0.309
2015	0.5673	0.706	0.626	0.501	0.470
2016		0.725	0.606	0.428	0.553
2017		0.688	0.662	0.510	0.551
2018	0.5923	0.63	0.503	0.462	0.747
2019		0.519	0.528	0.436	0.672
2020		0.579	0.672	0.661	0.708

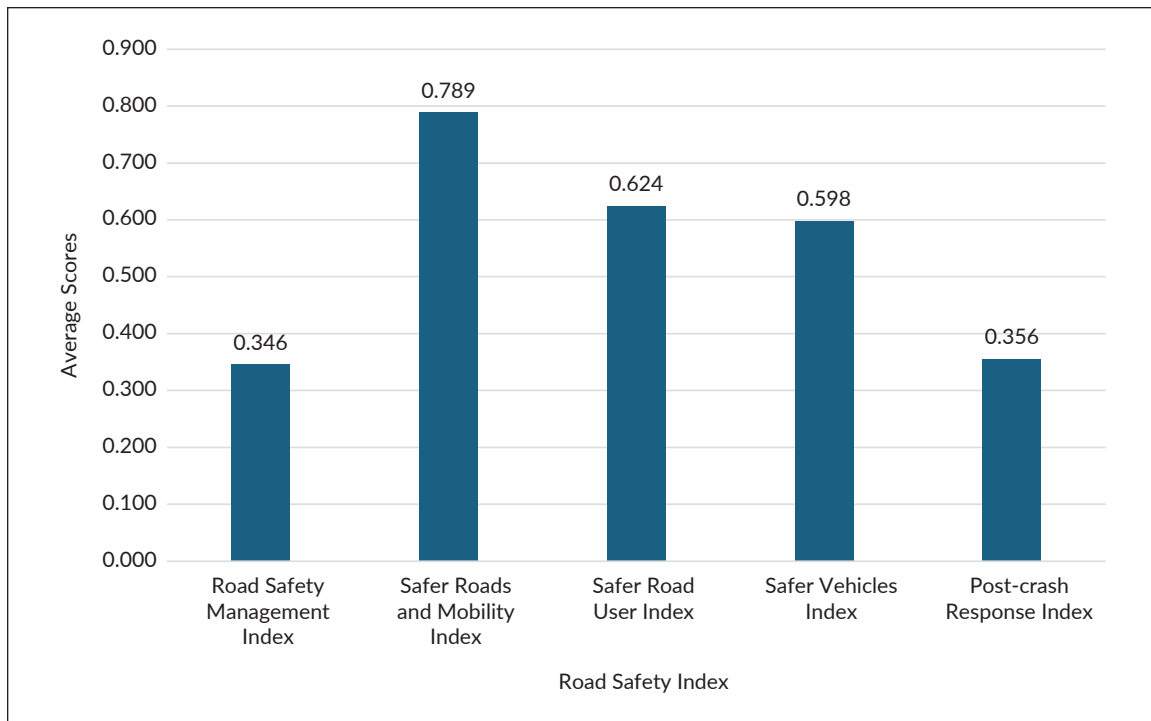


Figure 7. Comparison of the average scores of Metro Manila according to the components of road safety index.

Response Index also recorded relatively low average scores, although its upward trend reflects improvements in recovery rates and hospital efficiency in recent years. These comparative trends are shown in Figure 7.

DISCUSSION

The study showed the development of a road safety index. This can be used to assess the state of Metro Manila's overall road safety performance in line with the WHO's 5 Pillars of Road Safety. The indicators utilized in this study differed significantly from the traditional road safety evaluation by incorporating key elements in making roadways safe, such as legislation, infrastructure, road user behavior, vehicle safety, and trauma care.

Road Safety Management

Safer roadways require strong institutional capacity. Such capacity is characterized by an established and adequately financed lead agency to oversee and direct the national road safety plan and related activities, as well as spearheading multi-sectoral collaboration, monitoring, and evaluating the progress of the national directive.¹ The WHO reported that out of 175 countries, 132 have a national road safety strategy laid out.¹ However, only 109 have targets set for reducing road traffic fatalities. The Philippines is one of these 132 and 109 countries.

Along with the continuous efforts in the national road safety strategy are the continuous passing of laws aimed at

the risk factors on the roadways. This study in the country's NCR showed that the Road Safety Management score has been increasing from 20.83/100 in 2009 to 59.20/100 in 2019, with 2009 having the lowest score among all the years covered. This is because of the lack of significant legislation in addressing the risks causing road crashes. For instance, prior to 2009, only the Land Transportation and Traffic Code (RA 4136) and the Seat Belt Use Act of 1999 (RA 8750) were in effect. The former is a law that sanctions reckless drivers for violating the maximum allowable speed.¹¹ On the other hand, RA 8750 requires drivers and front passengers of private or public vehicles to use seatbelts. The same law also prohibits children under 6 years of age from being seated in the front seat.¹² At that time, that was the only law addressing child safety.

Relevant road safety laws such as RA 10054, known as the Motorcycle Helmet Act of 2009, RA 10586, known as the Anti-Drunk and Drugged Driving Act of 2016, RA 10913, known as the Road Speed Limiter Act of 2016), and RA 11229, known as the Child Safety in Motor Vehicles Act of 2019) were only passed in 2010, 2016, and 2019, respectively.¹³⁻¹⁶ The low score in road safety management in Metro Manila could be attributed to the lack of a child safety law, as well as the lax enforcement of related road legislation.

While it is true that the Philippines' road safety management is improving over the years, there are still gaps in the overall road safety strategy of the country. The poor conditions of the roads, weak institutional capacities of agencies leading to inadequate maintenance of roadways,

poor implementation and enforcement of legislation, as well as the lack of quality transportation systems, especially in the urban areas.¹⁷

Safer Roads and Mobility

Vehicle registration in Metro Manila is increasing. The total number of registered motor vehicles in Metro Manila was 1,904,395 in 2010, and increased to 4,083,622 in 2019.¹⁸ The number of cars registered in Metro Manila also increased from 415,566 in 2009 to 452,959 in 2013 as opposed to the number of buses which is at 12,319 in 2009 and 13,989 in 2013.^{19,20}

Urban areas, such as in the case of Metro Manila, have higher traffic volumes as it serves as the center of economic activity in Luzon. In fact, Metro Manila is the biggest contributor to the Philippine economy. The region contributed 36.6% to the Philippine GDP in 2015 and 32.2% in 2019.^{2,21} In addition, Metro Manila is the most densely populated region in the Philippines and the second most populated area with 13,484,462 population in the latest 2020 population census of the Philippine Statistics Authority.^{4,5} Higher daytime population in the metropolis is seen due to workers from neighboring regions working during the day in the area.²² Along with the rise in vehicular registrations, hotspots for road accidents are also found to be located in downtowns or central business districts with high population density.²³

While the road conditions in this study were shown to be in good to fair conditions in general, the Safer Roads and Mobility Index in Metro Manila decreased from 78.2 to 50.7 in 2019. This is because road infrastructure did not keep up with the increasing population, as well as the increasing vehicle registration over the years. For instance, EDSA is forced to accommodate vehicles almost twice its allotted vehicular capacity of 160,000 vehicles daily.²⁴ In 2018, more cars (251,628) passed by EDSA than buses (13,356), making Metro Manila the most congested city among developing Asian countries, and the second most congested city in the world.²⁵⁻²⁷ Adding also to the burden is the inefficient use of road space from the erratic behavior of public transport drivers.

Safer Road Users

Road user behavior contributes to the occurrence and outcomes of traffic accidents on the road, which is why the majority of the identified road traffic accident risk factors of the World Health Organization were behavioral in nature.²⁸ This is supported by various studies focused on the contribution of behaviors in road safety. Kadilar in 2016 found that driving while being intoxicated by alcohol, and at the same time, being under the influence of harmful substances increases the risk for accident by 2.062.²⁹ Present evidence suggests that intoxicating substances have an adverse impact on the driving performance because it directly affects the cognition, vigilance, attention, judgement, and reaction of

the user.³⁰ Driving over the maximum allowable speeds also increases the risk for deadly road accidents, while severe brain traumatic injuries could be the outcome of the non-usage of helmets and seatbelts among drivers and passengers.³¹⁻³⁵

In the Philippines, the usage of protective gear is low. This is evidenced by the report of the DOH in the 4th quarter of 2009 that out of the 1,802 transport/vehicular accidents recorded, only 7.3% and 6.9% used helmets and seatbelts, respectively. While another 13.2% drunk-drove.³⁶ During the 4th quarter of 2019, 10,525 TVC cases were documented. Of these, 3.7% used helmets, and none used seatbelts. On the other hand, 3.5% consumed alcohol prior to the accidents.³⁷ Other exhibited behaviors by road users in Metro Manila, driving while intoxicated, and fatigued riding as reported by the MMDA.³⁸ Another study also showed that non-usage of helmets in Metro Manila is due to drivers finding wearing a helmet uncomfortable, hot, and heavy, given that the Philippines is a tropical country.³⁹ The relatively low use of safety gadgets over the years can also be observed in this study; however, this could also be due to the under-reporting of data.

Contributing also to the worsening trend of road user behavior could be the lax enforcement of the existing road laws. There is a lack of available enforcement equipment, such as speed guns, for use, and/or the inability of LGUs to set local speed limits in the country.⁴⁰ Penalties imposed only lay out a short-term solution to the behavior, and the existence of legislation alone cannot entirely prevent unfavorable road user behavior. Drivers could be aware of road policies and legislation; however, their knowledge and practices can remain poor.⁴¹ In the Philippines, the knowledge, attitudes, and practices of road users remain low.⁴² The non-usage of pertinent protective systems on the road is due to the lack of awareness of road users. Therefore, road safety education targeted at behavior change is necessary.⁴³

While the Philippine government offers and conducts road safety education and promotion, the gap lies in the unstandardized curriculum of the various agencies. LTO and LTFRB conduct road safety education for those penalized for traffic violations. The insufficient mass publication of road safety as well as the lack of monitoring and evaluation tools on the effectiveness of the offered education services, remain as some of the challenges to be tackled by the national government.⁴⁴

Safer Vehicles

The third pillar of the WHO's 5 Pillars of road safety focuses on the encouragement of the provision of safer vehicle norms and technologies because the condition of the vehicle is an important determinant of patient outcomes.^{1,45}

The increase in the number of vehicle registrations in Metro Manila is proportional to the increase in the number of motorcycles in the region. The number of motorcycles and tricycles increased from 608,839 in 2009 to 1,468,474 in 2019, with 87.2% classified as motorcycles without side

cars in 2019.^{19,46} In fact, more Filipinos own motorcycles than cars, as the former is seen as a more efficient mode of mobility.⁴⁷

In this study, motorcycles are the vehicle type observed to be the most common cause of accidents resulting in fatal and non-fatal accidents among drivers, passengers, and pedestrians. This is consistent with the results of a study in Metro Manila and other studies in developing countries.⁴⁷⁻⁵⁰ The favor in motorcycles in developing countries could be attributed to heavy vehicular traffic in an area, such as in the case of Metro Manila. Motorcycles are also generally cheaper than four-wheel vehicles.⁵¹ However, motorcycles offer limited safety protection and lack the structural support of enclosed vehicles, thereby putting drivers and passengers at risk for deadly road accidents.⁵² In the Philippines, motorcycle drivers ply pedestrian lanes in bouts of heavy vehicular traffic, which makes the most vulnerable road user – pedestrians – at risk of road accidents.⁴⁷

Post-Crash Response

Post-crash response is an important aspect of road safety as it focuses on the prevention of death and disabilities, as well as decreasing the severity of injuries sustained by the victims.⁵³ Therefore, elements of post-crash response, such as average response time, hospital density, emergency hotline availability, and emergency training for healthcare workers, are incorporated in this study in the construction of a road safety index.⁵⁴⁻⁵⁶

Post-crash response also influences the length of hospital stay, which is an indicator of the effectiveness and efficiency of hospital management.^{57,58} Shorter hospital stays are favorable because excessive unnecessary stays contribute to the development of complications, infections, medication side effects, and increased hospital bills to the side of the victim.⁵⁸

The Philippines' post-crash response index, as well as its components, is in an increasing trend. This may be due to legislation focused on the improvements in the healthcare delivery of the Philippines, in general. Pre-hospital care services legislation is set and continuously being improved.⁵⁹ For instance, the National Policy on Violence and Injury Prevention was first legislated in 2007 but revised in 2014 and 2017. This program aims to reduce mortalities in 5 key areas, which include road traffic injuries by spearheading multi-sectoral collaboration, engaging communities and building healthcare workers' capacities, promoting evidence-based research, developing and training for an electronic surveillance system, enhance service delivery.⁶⁰

In Metro Manila, the MMDA and PNP-HPG are also mandated to respond to crash emergencies by having trained emergency medical technicians (EMT). LGUs have set up their own emergency response units, such as Marikina and Makati.^{44,61} Since 2016, emergency medical services in the country as a whole have been made more available to the public through the establishment of a national emergency

hotline for EMS.⁶² Another study in Metro Manila also showed that there are sufficient emergency ambulances to accommodate victims whenever accidents happen.⁶³

All the developments in the health services in the Philippines may have contributed to the increasing overall post-crash response index scores of Metro Manila from a low score of 39.1/100 in 2009 to 70.8/100 in 2020. The improvements shown to positively impact the components of the index, citing the general increasing trend of the outcome, critical care, and length of hospital stays due to the more prompt and competent health service delivery of the allied medical healthcare workers. Oviedo-Trespalacios and Haworth benchmarked 10 ASEAN countries in terms of road safety maturity.⁵⁶ The Philippines ranked the second/third highest in the post-crash response index developed by the authors in this study.

Despite the improving trend in post-crash response as seen in this study. There is a need to address the gaps in the post-crash response in the country, such as standardizing the training for EMTs, and addressing problems including unregularized ambulance systems, lack of proper facilities for hospital care, and overcrowded hospitals.⁶²

The Metro Manila Road Safety Index

Over the last 15 years, the overall road safety index of Metro Manila has improved. From a score of 46.0/100 in 2005 to 64.2/100 in 2020. However, there are still areas for improvement in the road safety program, not only in Metro Manila but also in the whole of the Philippines.

On the comparison of the 5 Pillars of Road Safety indices developed, Safer Roads and Mobility Index has the highest average score of 78.9/100. This is due to the generally good conditions of the roads examined in the study. What brought the score down was the drastic increase in traffic on almost all major roads in Metro Manila. This led to a monotonic decrease in mobility. A pandemic-stricken Metro Manila revealed improvements in safer roads and mobility score. To recreate or continue this trend post-pandemic, where people start to meet face-to-face again, is the challenge for policymakers.

Generally, an increase in the annual daily traffic was observed due to the increase in private vehicles and motorcycles in Metro Manila. Therefore, there is a need to improve the mass transportation system in Metro Manila by providing more systematic bus regulations and an increase in the number of railway lines to shift the public from solely using roads as a form of transportation.

For Road Safety Management, which scored the lowest with an average score of 34.6/100, there should be huge improvements in the enforcement of laws and ordinances. Law enforcement of traffic-related violations is generally low in the Philippines, according to WHO's Global Status Report on Road Safety. There is also a need to legislate more laws that will protect road users, especially children. Child restraint law in the Philippines has only recently been passed,

but the implementing rules and regulations are still being discussed by concerned agencies.

For Safer Vehicles, it can be noted that the scores for motorcycles, pedicabs, taxis, trucks, and trains are at their lowest these past years. Even the pandemic in 2020 did not do anything to decrease the number of fatalities for motorcycles. There is a need to address the safety protocols and driver behaviors of people driving these vehicles in order to decrease injurious and fatal crashes involving these vehicles.

For Safer Road Users, there is a need to engage the public more aggressively in terms of road safety. Behavior change should be the focus of road user education. There is also observed underreporting of data in this index; thereby calls for a more standardized data collection of the national injury surveillance systems available.

CONCLUSION

Indicators are used to determine the progress of a phenomenon. When indicators are aggregated into one group, an index is formed. In the context of road safety, indices are important for benchmarking road safety performance. This study focused on the construction of a road safety index in the context of the Philippines' NCR, which is the second most congested city in the world. The study used the WHO's 5 Pillars of Road Safety (road safety management, safer roads and mobility, safer vehicles, safer road users, and post-crash response) to construct 6 road safety indices. The 5 Pillars of Road Safety are the framework of road safety programs in the Philippines.

An increasing trend in the road safety index of Metro Manila was observed from 2005 (46.0/100) to 2020 (64.2/100). Safer Roads and Mobility had the highest average component score of (78.9/100), followed by Safer Road Users (62.4/100) and Safer Vehicles Index (59.8/100). Improvements for the two weak aspects of the Metro Manila Road Safety Index, which are Road Safety Management (34.6/100) and Post-Crash Response (35.6/100), are highlighted.

There is a need for stricter commitment and compliance with the strategies set out by the World Health Organization based on the Five Pillars in order to realize its goals for reduction in road crashes over the years through a specific legislative framework on road safety, stricter implementation of laws on road safety, and creation of interoperable systems across agencies for more comprehensive databases on road and vehicular crashes.

Statement of Authorship

The author certified fulfillment of ICMJE authorship criteria.

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