



**A NEEDS-BASED INVESTIGATION TO MANAGE THE SAFETY OF
PUBLIC TRANSPORT INFRASTRUCTURE
USING JAMAICA AS A CASE STUDY**

by

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Abstract

The global concerns for road safety have risen over the past decades based on the number of road fatalities and serious injuries that have occurred. Nonetheless, there have been significant gains in reducing the number road crashes that occur in developed countries. However, road crashes still remain a challenge for developing countries, where road safety is not included as a key aspect of road design. This is as a result of road crashes being viewed as a consequence of road transport and not a preventable occurrence in most developing countries, (WHO, 2005).

This research begins with introducing the global problem of mass population movement into urban areas and the impact on road users, public transport facilities and urban road design features. It explains the background for the basis of the research project by looking at the existing situation in Jamaica. And at the same time presents a literature review, which looks at research in the areas of road safety, road safety models and public transport facilities. The methodology that follows, demonstrates the development of a new crash allocation star rating model for public transport pedestrian users at public transport facilities. This by adopting the model development principles of the iRAP methodology.

In addition, a needs-based approach was developed to assess the safety needs of public transport pedestrian users at public transport facilities. This was as a result of public transport pedestrian users and public transport facilities not included as a road user type or road attribute in iRAP. Nonetheless, data collection was done using the iRAP methodology. In particular, the data was collected at different IQL levels according to the iRAP road survey methodology. The data considered road attributes, transport facilities such as bus shelters and transport centres and road crash fatalities. Moreover, road crash fatalities that occurred at public transport facilities in the study area of Kingston and St. Andrew on 9 road sections.

The assessment process was carried out first using the iRAP methodology which focused on road attributes within the existing iRAP data base. Where road attributes were not identified, the needs-based assessment process was used. In this way, risk factors identified using the need-based approach were to expand the iRAP methodology, to develop a star rating equation for public transport pedestrian users. By extension, countermeasure interventions were introduced where these were not found to be included in the existing iRAP methodology. Furthermore, an economic analysis was done for two options using the FYRR method. The results demonstrated positive FYRRs', however the rate of return on investment depended on the cost to implement the countermeasure identified.

Dedication

This project is dedicated to Mrs. Vincella Salmon, Mrs. Zerish Minott, Wayne Minott, Mrs. Ruth Minott and my extended family whose love and support made this possible. I especially would like to make this dedication to the people of Jamaica and those who have lost loved ones in crashes that occurred at public transport facilities. I hope that with this study the importance of safety for those who use public transport facilities, such as bus shelters and transport centres will be given more priority in the traffic environment.

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Table of Contents

	Page
CHAPTER 1 Introduction	1
1.1 Background	1
1.2 Research problem definition	3
1.3 Purpose of research.....	4
1.4 Research questions.....	5
1.5 Aim.....	5
1.6 Objectives	5
1.7 Thesis structure	6
CHAPTER 2 Literature review.....	8
2.1 Introduction	8
2.2 Urban road safety	8
2.3 Safe systems approach	12
2.4 Sustainable safety.....	14
2.5 Vision zero.....	16
2.6 Decade of action for road safety 2011-2020.....	18
2.7 Road safety models.....	22
2.8 International road assessment programme.....	29
2.8.1 Use of iRAP.....	32
2.8.2 Risk maps.....	33
2.8.3 Road features.....	34
2.8.4 Data collection for iRAP	37

2.8.5 <i>Vida</i>	40
2.8.6 <i>Model equations in iRAP</i>	40
2.8.7 <i>Crash types and road user types in iRAP</i>	41
2.8.8 <i>Star rating</i>	43
2.8.9 <i>Star rating equations</i>	45
2.8.10 <i>Casualty estimation and calibration</i>	56
2.8.11 <i>Countermeasures in iRAP</i>	63
2.8.12 <i>Economic analysis</i>	63
2.9 Needs-based approach	68
2.10 Information quality level	72
2.11 Public transport facilities	73
2.11.1 <i>Intelligent transport systems</i>	75
2.11.2 <i>Bus rapid transit facilities</i>	76
2.11.3 <i>Bus Stops</i>	78
2.12 Summary	82
CHAPTER 3 Methodology and Transferability	83
3.1 Introduction	83
3.2 Study area	84
3.3 Data collection: primary source	87
3.4 Data collection: secondary source	97
3.5 Road safety integration and safety measures for public transport facilities such as bus shelters and transport centres	101
3.6 Public transport facility design practices and road safety interactions with	

Public transport pedestrian users	106
3.7 The assessment of the safety for public transport pedestrian users at public Transport facilities with the application of the iRAP methodology	123
3.8 Safety measures methodology for public transport pedestrian users star rating model equation at public transport facilities such bus shelter and transport centres.....	127
3.9 The integration of safety measures for public transport pedestrian users to expand the iRAP methodology to include public transport facilities such as bus shelter and transport centres.....	131
3.10 Summary.....	138
CHAPTER 4 Data	139
4.1 Introduction	139
4.2 Road crash data	139
4.3 Study area data assessment.....	143
4.4 Description of the institutional framework data collected and assessed using the needs analysis matrix as shown in Figure 3.13	156
4.4.1 <i>National transport policy</i>	156
4.4.2 <i>National road safety policy</i>	157
4.4.3 <i>Urban development plan</i>	157
4.4.4 <i>Management plan</i>	158
4.4.5 <i>Road traffic act</i>	158
4.4.6 <i>Road users</i>	159
4.4.7 <i>Road user behaviour</i>	159
4.4.8 <i>Road safety maturity</i>	160
4.4.9 <i>Funding</i>	160

4.4.10 Infrastructure maintenance	161
4.4.11 Traffic management.....	161
4.4.12 Road design	161
4.4.13 Transportation system	162
4.4.14 Transport authorities	162
4.4.15 Public transportation	162
4.4.16 Transport facilities / public	163
4.4.17 Urban road safety management.....	164
4.4.18 Land-use activities	164
4.4.19 Land-use control	165
4.4.20 Health authorities.....	165
4.4.21 Insurance association of Jamaica.....	165
4.4.22 Crash investigators / Assessors	166
4.5 Summary	166
CHAPTER 5 Model verification	167
5.1 Introduction	167
5.2 Verification process.....	167
5.3 Supporting data	168
5.4 Star rating equation worked example	169
5.5 Summary	170
CHAPTER 6 Discussion.....	171
6.1 Introduction	171
6.2 Road safety measures for public transport pedestrian users	171

6.3 The influence of public transport facility design on the interaction of road users	172
6.4 The use of iRAP to determine road attributes for public transport facility users	173
6.5 The methodology to improve safety for public transport facilities	175
6.6 The integration of public transport pedestrian users with the iRAP methodology	176
6.7 Economic analysis	177
6.8 Understanding outputs for public transport facilities	179
6.9 Limitations	180
6.10 Future research.....	181
6.11 Summary.....	181
CHAPTER 7 Conclusion.....	183
7.1 Introduction	183
7.2 Project overview	183
7.3 Improving road safety for public transport facilities o urban road networks	186
7.4 Summary	188
References	189
Appendix	205
Appendix A.....	206
Appendix B.....	208
Appendix C.....	211
Appendix D.....	216

Appendix E	218
Appendix F	222
Appendix G	229
Appendix H	238
Appendix I	245
Appendix J	253
Appendix K	255

List of figures

	Page
Figure 2.1 The iRAP star rating and safer road investment plan process	32
Figure 2.2 Standard procedure for producing RAP road risk mapping	34
Figure 2.3 iRAP star rating and investment plan coding manual	38
Figure 2.4 Example of data collection for iRAP star rating and investment plan coding manual.....	39
Figure 2.5 Example of data collection for iRAP star rating and investment plan coding manual.....	39
Figure 2.6 Star rating band ranges and related colour codes	45
Figure 2.7 Public transport pedestrian user moving along or across the road in a transport centre.....	51
Figure 2.8 Public transport pedestrian user standing or waiting at a bus shelter or transport centre.....	51
Figure 2.9 Economic cost and benefits for different BCR thresholds	66
Figure 2.10 Bus border stop and shelter facilities provided for public transport pedestrian users	79
Figure 3.1 Image of Kingston and St. Andrew road network: Study area	87
Figure 3.2 Coding options for recording.....	93
Figure 3.3 Categories for recording pedestrian peak hour flow across the road	94
Figure 3.4 Coding options for operating speed (85th percentile).....	94
Figure 3.5 Coding options for roads that cars can read	95
Figure 3.6 Coding options for star rating policy targets.....	95
Figure 3.7 Image of Constant Spring road, Kingston and St. Andrew road	

Network: Study area	102
Figure 3.8 Image of Molynes Road, Kingston and St. Andrew road	
Network: Study area	104
Figure 3.9 Image of Red Hills Road, Kingston and St. Andrew road	
Network: Study area	105
Figure 3.10 Image of Washington Boulevard, Kingston and St. Andrew road	
Network: Study area	106
Figure 3.11 Needs analysis specification	108
Figure 3.12 Needs analysis.....	110
Figure 3.13 Needs analysis matrix	115
Figure 3.14 Image of Constant Spring Road, Kingston and St. Andrew safety needs assessment for public transport pedestrian users.....	119
Figure 3.15 Image of Old Hope Road, Kingston and St. Andrew safety needs assessment for public transport pedestrian users.....	121
Figure 3.16 Image of Constant Spring Road, Kingston and St. Andrew safety needs assessment for public transport pedestrian users.....	121
Figure 3.17 Image of Molynes Road, Kingston and St. Andrew safety needs assessment for public transport pedestrian users.....	122
Figure 3.18 Image of Half-way Tree Road, Kingston and St. Andrew safety needs assessment for public transport pedestrian users.....	123
Figure 3.19 Image of Constant Spring Road, Kingston and St. Andrew safety needs assessment for public transport pedestrian users.....	124
Figure 3.20 Image of Darling St rural transport facility, Kingston and St. Andrew road attributes assessment: iRAP pedestrian model application ...	125
Figure 3.21 Image of Cross Roads, transport facility, Kingston and St. Andrew road attributes assessment: iRAP pedestrian model application ...	126

Figure 3.22 Image of Half-way Tree, transport facility, Kingston and St. Andrew road attributes assessment: iRAP pedestrian model application ...	126
Figure 3.23 Image of Half-way Tree taxi stand transport facility, Kingston and St. Andrew road attributes assessment: iRAP pedestrian model application ...	127
Figure 3.24 Methodology for the development of the crash allocation, star rating model for public transport pedestrian users at public transport facilities such as bus shelters and transport centres.....	129
Figure 3.25 New star rating model equation methodology for public transport pedestrian users at public transport facilities.....	135
Figure 4.1 Road crash fatalities per 100 000 inhabitants for International Transport Forum member countries.....	140
Figure 4.2 Road crash fatalities as a per cent change for International Transport Forum member countries.....	141
Figure 4.3 Road crash fatalities per 10 000 vehicles for International Transport Forum member countries	142
Figure 4.4 Road crash fatalities for all road users for the period 2001 to 2014	143
Figure 4.5 Crashes in the vicinity of bus stops by division: Highest priority in Kingston and St. Andrew represented in years from 1981 to 2018	144
Figure 4.6 Crashes in the vicinity of bus stops by division: Highest priority in Kingston and St. Andrew represented by division.....	145
Figure 4.7 Summary for Kingston and St. Andrew represented by number of Road sections and crashes	148
Figure 4.8 Summary for Kingston and St. Andrew represented by road sections and number of transport centres	149
Figure 4.9 Summary for Kingston and St. Andrew represented by road sections and number of bus stops.....	149
Figure 4.10 Crashes in the vicinity of bus stops by division: Highest priority in Kingston and St. Andrew represented by division and severity	152

Figure 7.1 Research project overview	185
Figure B.1 Map of Kingston and St. Andrew road network: Study area.	209
Figure B.2 Image of Kingston and St. Andrew road network: Study area.	210
Figure C.1 Image showing condition of median	212
Figure C.2 Image showing condition of median	213
Figure C.3 Image showing obstruction on sidewalk	214
Figure C.4 Image showing the intersection of Dunrobin Avenue and Constant Spring Road	215
Figure D.1 Image Eastwood Park Road, Kingston and St. Andrew study area	217
Figure E.1 Image Old Hope Road, Kingston and St. Andrew study area	219
Figure E.2 Image Eastwood Park Road, Kingston and St. Andrew study area	220
Figure E.3 Image Constant Spring Road, Kingston and St. Andrew study area	221
Figure J.1 Image #2790 Constant Spring Road, Kingston and St. Andrew study area	254

List of tables

	Page
Table 2.1 Global plan for the Decade of action for road safety 2011-2020	19
Table 2.2 Crash prediction models	24
Table 2.3 Road safety models	27
Table 2.4 Road user types and crash types included in iRAP star rating models	42
Table 2.5 Colour-coded risk bands and star rating of roads	44
Table 2.6 Crash initiation modes and crash type for new road user type	49
Table 2.7 Crash types included for the new road user type public transport pedestrian users	52
Table 2.8 Safety and operational features for on-site bus stop assessment	80
Table 3.1 Main roads representing the study area.....	85
Table 3.2 Data collection team and apparatus	89
Table 3.3 Colour coding and description of road attributes condition and provision.....	97
Table 3.4 Road crash data in the vicinity of public transport facilities collected from the study area in Kingston and St. Andrew by year and division	99
Table 3.5 Road accident data items 2001 to 2003 from the Jamaica Constabulary force	100
Table 3.6 Needs-based assessment of on-site bus stop safety and operational features	111
Table 3.7 Needs analysis matrix legend.....	117
Table 3.8 Risk factors and countermeasures	133
Table 4.1 Summary data: Kingston and St. Andrew study area	147

Table 4.2 Summary road crash data in the vicinity of public transport facilities collected from the study area in Kingston and St. Andrew by division	150
Table 4.3 Summary data collected from the study area in Kingston and St. Andrew using the iRAP methodology and needs analysis	154
Table F.1 Accident report form	223
Table G.1 Red Hill Road Kingston and St. Andrew study area crash data. Modified and obtained from: National Work Agency (2019)	230
Table G.2 Eastwood Road Kingston and St. Andrew study area crash data. Modified and obtained from: National Work Agency (2019)	231
Table G.3 Constant Spring Road Kingston and St. Andrew study area crash data. Modified and obtained from: National Work Agency (2019)	232
Table G.4 Hagley Park Road Kingston and St. Andrew study area crash data. Modified and obtained from: National Work Agency (2019)	233
Table G.5 Half way tree Road Kingston and St. Andrew study area crash data. Modified and obtained from: National Work Agency (2019)	234
Table G.6 Molynes Road Kingston and St. Andrew study area crash data. Modified and obtained from: National Work Agency (2019)	235
Table G.7 Old Hope Road Kingston and St. Andrew study area crash data. Modified and obtained from: National Work Agency (2019)	236
Table G.8 Washington Boulevard Kingston and St. Andrew study area crash data. Modified and obtained from: National Work Agency (2019).	237
Table H.1 Road crash data as at 2018 Modified and obtained from: Road safety unit (2019)	239
Table H.2 Road crash data as at 2017 Modified and obtained from: Road safety unit (2019)	240
Table H.3 Road crash data as at 2018 by division Modified and obtained from: Road safety Unit (2019).....	241

Table H.4 Road crash data as at 2018 by division Modified and obtained from: Road safety Unit (2019).....	242
Table H.5 Road crash data as at 2018 by division Modified and obtained from: Road safety Unit (2019).....	243
Table H.6 Road crash data as at 2018 by division Modified and obtained from: Road safety Unit (2019).....	244
Table I.1 Worked star rating example for public transport pedestrian commuters: Model validation: Reference image Appendix J, J.1	246
Table I.2 Worked star rating example for iRAP pedestrian model: Model validation: Reference image Appendix J, J.1.....	250
Table K.1 Authorities in Jamaica	256

Abbreviations

A	Analysis
AAS/DM	AASHTO/ DMRB
APM	Accident Prediction Models
ARM	Accident Risk Models
AusRAP	Australia Road Assessment Programme
BS/TC	Bus stop/ Transport centre
BCR	Benefit cost ratio
BRTS	Bus Rapid Transit Systems
C/F rate	Crash Fatality Rate
C10L	Certification: 10 lessons
CBD	Central business district
CP	Current population
CRUB	Control road user behaviour
CPM	Crash Prediction Models
CRM	Crash Risk Models
D	Design
D/L	Design life
D/M	Design/ Maintenance
DA	Data analysis
DLC	Diver's license certification
DO	Development order
Doc	Documents
E.R	Emergency response
EHC	Emergency health care
EU	European Union
EuRAP	European Road Assessment Programme
FIA	Federation International de l'automobile
FYRR	First year rate of return
G/P	Government/ Private
GPS	Global Positioning System
GO	Government organization
GOJ	Government of Jamaica

GRSF	Global Road Safety Facility
GTKP	Global Transport Knowledge Partnership
HWT	Half-way tree
HCFR	High crash fatality rate
IAJ	Insurance Agency of Jamaica
Imp/Inst	Implementing Institution
Infra	Infrastructure
Insur	Insurance
Insur. P	Insurance policy
IHT	Institute of Highways and Transport
ITDP	Institute for Transportation and Development Policy
	Information Quality Levels
IQL	International Road Assessment Programme
iRAP	International Traffic Safety Data and analysis Group
IRTAD	
ITA	Island Traffic Authority
ITS	Intelligent Transport Systems
JCF	Jamaica Constabulary Force
JMD	Jamaican Dollar
JUTC	Jamaica urban transit corporation
JO	Jamaica Observer
KiwiRAP	New Zealand Road Assessment Programme
KMR	Kingston Metropolitan Region
KMTR	Kingston Metropolitan Transport Region
KSAC	Kingston and St. Andrew Corporation
LAC	Latin American and Caribbean
LOE	Lack of enforcement
MA	Mixed activity
MAAP	Microcomputer Accident Analysis Package
MN	Manage Network
MOF	Ministry of Finance
MOLG	Ministry of Local Government
MOJ	Ministry of Justice

MPG	Movement of people goods and service
MTW	Ministry of Transport and Works
NASEM	National Academies of Science, Engineering and Medicine
NAS	Needs analysis specification
N/A	Not applicable
NCDI	No certified driving instructors
NI	Needs Improvement
NIP	National Industry Policy
NPA	National Planning Agency
NPIP	No policy in place
NPA	Needs to be Pro-active
NR	Needs Revision
NRA	National Road Administration
NRSCJ	National Road Safety Council of Jamaica
NRSP	National Road Safety Policy
NTP	National Transport Policy
NWA	National Works Agency
NZTA	New Zealand Transport Authority
OS	Office of Sustainability
P	Population
PAHO	Pan America Health Organisation
PIOJ	Planning Institute of Jamaica
PI	Policy Implementation
PN	Population needs
PRUB	Poor road user behaviour
PRACT	Predicting Road Accidents
PTF	Public Transport facility
PTS	Poor transport service
PTPU	Public transport pedestrian user
RAP	Road Assessment Programme
R/TF	Road/ Transport facilities
Rev.P	Revenue protection

RN	Road network
RNR	Role Needs Revision
RSUJ	Road Safety Unit of Jamaica
RT	Road transport
RUB	Road user behaviour
RUB/GI	Road user behaviour/ Government will
SCD	Signal control devices
SRIP	Safer Road Investment Programme
SRS	Star rating score
STATIN	Statistical Institute of Jamaica
SWP	Sidewalk provision
TAJ	Tax Administration Jamaica
TCP	Town and Country Planning
TMS	Traffic management system
TRL	Transport Research Laboratory
UA	University of Alberta
UN	United Nations
UNRSC	United Nations Road Safety Collaboration
USAID	United States Agency for International Development
VRU	Volume of road users
WEF	World Economic Forum
WHO	World Health Organisation

CHAPTER 1 Introduction

The rapid growth of populations in urban areas comes with increasing road safety problems and affects the use of the road infrastructure provided, (UNHSP, 2016). According to the World Bank (1984), safety concerns for road users in Jamaica had grown based on an increase in road crash fatalities and serious injuries. This was thought to coincide with increased car ownership as a result of an unreliable transportation system. The transportation system at that time was seen as overburdened, poorly organized and poorly managed, (World Bank, 1984).

Road crashes involving road users of different categories are defined by the Road safety unit of Jamaica (RSUJ). The RSUJ was established by Government of Jamaica (GOJ) in 1994. In particular the RSUJ records road crash data and presents statistical analysis of road fatality trends based on demographics and road user type, (RSUJ, 2016). Consequently, the road crashes of interest to this research project were those involving pedestrian road users using public transport facilities such as bus shelters and transport centres.

This research will take a qualitative approach to explore the safety of public transport facilities such as bus shelters and transport centres in Jamaica as a case study. By extension this case study on Jamaica is representative of a low and middle-income country. In this way the research methodology will seek to determine the road safety problems in a selected study area from the combined parishes of Kingston and St. Andrew. Most importantly the International Road Assessment Programme (iRAP) methodology will be used to determine road safety problems based on its successful application in other developing countries, (iRAP, 2013).

Thus, in the application of the iRAP methodology, it would be determined whether existing iRAP models, could be used to address road safety issues related to public transport facilities such as bus shelters and transport centres. Following this determination, a crash allocation star rating model for public transport pedestrian users would be developed to expand the iRAP methodology. As a result, the iRAP methodology would be expanded to include safety assessment and countermeasures for public transport facilities such as bus shelters and transport centres.

1.1 Background: Existing situation in Jamaica

In 1976, research carried out by G D Jacobs on the road network in Jamaica, with contrasts made to the Kenyan road network, revealed there were road safety design concerns for Jamaica.

CHAPTER 1 Introduction

These concerns were believed, could result in an increase of road crashes. During the early 1990's Jamaica experienced rapid motorization. As a result, the design concerns of the road network studied by G D Jacobs in 1976, were revealed in the form of increased road fatalities and traffic injuries, (Jacobs, 1976).

In 1991, Jamaica's road crash fatality rate reached an all-time high of 444 fatalities. And there after became a concern among road safety authorities in Jamaica. By 1996, Jamaica was ranked 14 out of 31 countries in the Latin American and Caribbean (LAC) region. This analysis compared LAC countries' road crash fatalities per 100 000 population, (GRSP, 2000). Since 1996, Jamaica has continued to experience challenges with high road crash fatalities and traffic injuries. The impact of which has been felt by all sections of society. At the start of this research project road crash fatalities at the end of December 2014 for Jamaica was 342 fatalities, (RSUJ, 2014).

Nonetheless, developed countries have made significant progress in addressing the problem of road safety, (WHO, 2004). According to WHO (2004), developed countries have taken a systematic approach to road safety that tries to balance road use, road user expectations and development. In the case of Jamaica, the design of the road network and road safety features suggests this balance has not been achieved. Hence the relationship with road user expectations, road use and development and correspondingly, their influence on road safety has not been established in Jamaica.

The approach taken by road safety authorities in Jamaica, has focused on education and enforcement of traffic safety laws, (NRSCJ, 2010). The enforcement of traffic safety laws, however, has been observed to be inconsistent. According to SWOV (2006), education is an important tool in the campaign for safe road use. But at the same time, it is not a substitute for other interventions, that share in the initiative of creating a safer and sustainable road user environment.

The safe systems approach was adopted by the United Nations for a decade of action for road safety. The safe systems approach focuses on crash injury prevention and suggests the approach to road safety should be evidence based. It encourages a softer approach to road design in favour of the road user and their vulnerability in the event of a crash, (WHO, 2004).

CHAPTER 1 Introduction

Conclusions can therefore be drawn about road crashes in Jamaica. And likewise, the approach to road design in contrast to the safe systems approach based on the number of road fatalities each year.

Traffic safety in Jamaica was further compounded by the lack of an organised and data-driven public bus transportation system with the supporting infrastructure. Road transport is the main means of movement within and across the island of Jamaica. Furthermore, driving was done on a poorly maintained and deteriorating road network. The increased dependency on road transportation has also contributed to an increase in car ownership. Correspondingly leading to an increase in vehicular traffic and road crashes. In particular, the increase in car ownership was also associated with the closure of the passenger rail transportation service in the late 1980's, (World Bank, 1984).

1.2 Research problem definition: Engineering problem

In defining the engineering problem for this research. Research about Jamaica in regard to road infrastructure development, performance and road safety were deficient. This represented a research knowledge gap in road safety for Jamaica and therefore determined the need for research in this area of study. Moreover, the research papers found were conducted in the mid 1970's and mid 1980's after which no comparable research of significance could be found.

The rapid growth in motorized traffic experienced by Jamaica occurred without the supporting policies to address issues related to road safety and the impact on road users. Consequently, the absence of these policies had a negative impact on road infrastructure development and land use planning. Thus, the result was inadequate road design features for pedestrians, parking, and public transportation and its facilities, (World Bank, 1984).

At present there are conflicts between road users at intersections and junctions on the road network. That is, especially where public transport facilities such as bus shelters and transport centres are located. These conflicts relate to road users sharing the same space with medium to heavy-duty vehicles at minimum speeds of 50 km/h. Though there are traffic control measures in place, they are overwhelmed, by the volume of road users competing for the same space to access land use activities, (World Bank, 1984).

CHAPTER 1 Introduction

The result was often road user behaviour that was not appropriate. If traffic control measures were not operational, road users also behaved outside the design envelope of the road. The placing of public transport facilities also affected the flow of traffic. Especially in cases where road markings and pedestrian crossings were faded, (World Bank, 1984).

Access also presented a challenge for pedestrians and pedestrians with mobility problems. This was related to access ramps to sidewalks, dimpled pavements, and the like. In locations where facilities were provided, road users were faced with additional challenges because of obstructions on sidewalks. These obstructions ranged from commercial activities such as vending, electric poles, guide wires, traffic lights, and junction boxes. As well as stubs from removed light poles, signs and bolts from previously installed traffic lights, and uneven or pothole riddled sidewalks, (PIOJ, 2009).

In Half-Way-Tree (HWT), a central business district (CBD) in St. Andrew, pedestrians are separated from vehicular traffic by guard rails. These rails only allow crossing at certain points on the road to control pedestrian traffic in HWT. This CBD has a high volume of pedestrian traffic generated from the transport centre. However, pedestrians, were observed outside the rails trying to cross the roadway at locations convenient to them, (NWA, 2018).

1.3 Purpose of research

Road crash fatalities and serious injuries had become a problem on the road networks of low to middle-income countries and in particular Jamaica. Within the data reported on road crash fatalities and serious injuries, vulnerable road users such as pedestrians are among those adversely affected. The crash data presented by the RSUJ focuses on road users involved in crashes that occur frequently, with high fatality rates. This was also the methodology adopted by iRAP to determine its road user types.

According to WHO (2004) any life lost was one life too many. This research project will focus on analysing data on road users that are involved in fatal and serious injury crashes that do not occur frequently and are not reported. In this way, a specific road user type within the traffic environment, can be identified based on their safety need. As a result, the road user type identified was public transport pedestrian users which use public transport facilities, such as bus shelters and transport centres. This road user type was not considered, used or referred to by the RSUJ nor in existing iRAP models.

CHAPTER 1 Introduction

The departure from the general approach used by the RSUJ and iRAP to present data, was to place emphasis on crashes involving road user types that do not occur frequently and are not reported. The data obtained will be used to develop a crash allocation star rating model for public transport facilities. That is, to improve safety for public transport pedestrian users at public transport facilities such as bus shelters and transport centres. At the end of this research, the findings will be presented.

1.4 Research questions

This research seeks to answer the following fundamental questions:

- What road safety measures exist for public transport pedestrian users at public transport facilities such as bus shelters and transport centres?
- How does the design of public transport facilities influence safety and the interactions between public transport pedestrian users and other road users?
- To what extent can the iRAP methodology be used to determine safety for public transport pedestrian users at public transport facilities such as bus shelters and transport centres?
- What methodology can be used to integrate safety measures for public transport pedestrian users and improve safety at public transport facilities?
- How can the methodology be integrated with the iRAP methodology?

1.5 Aim

The aim of this research is described as follows:

- To improve road safety for public transport pedestrian users at transport facilities such as bus shelters and transport centres on urban transport networks in low to middle income countries such as Jamaica

1.6 Objectives

The objectives of this research will seek to define the aim as follows:

- To investigate road safety and the integration of safety measures at public transport

CHAPTER 1 Introduction

facilities such as bus shelters and transport centres in Jamaica

- To investigate the influence of public transport infrastructure design practices on road safety interactions between public transport pedestrian users and other road users at public transport facilities in Jamaica using a needs-based approach
- To investigate the application of the iRAP methodology to assess the safety of public transport pedestrian users at public transport facilities such as bus shelters and transport centres
- To demonstrate a methodology for road safety that incorporates safety measures for public transport pedestrian users, to improve safety at public transport facilities such as bus shelters and transport centres in Jamaica
- To demonstrate the integration of the methodology in expanding the iRAP methodology to include road safety measures for public transport pedestrian users

1.7 Thesis Structure

To implement the above research the thesis structure demonstrates how the research will be carried out as follows:

- Chapter 1 introduces the research project and provides the background for its basis and the research aim and objectives
- Chapter 2 presents a review of related literature in areas of road safety and previous work of other researchers as well as discusses the concepts and principles related to the research
- Chapter 3 presents the methodology used to expand the iRAP model using a needs-based approach to include safety measures for public transport pedestrian users by focusing on the relationship of the objectives of the research project to the data collected and the star rating model being developed
- Chapter 4 presents the assessment of the data collected from primary and secondary sources in relation to road crashes and public transport facilities
- Chapter 5 discusses the model testing process used to introduce data collected from the

CHAPTER 1 Introduction

study area into the existing iRAP methodology

- Chapter 6 presents and discusses results obtained based on the data presented and the research questions in relation to the objectives of the research
- Chapter 7 presents the conclusions and recommendations of the findings of the research project

CHAPTER 2 Literature review

2.1 Introduction

The following literature review will discuss urban road safety and the improvements made by developed countries in reducing the number of road crash fatalities and serious injuries. The chapter will describe the safe systems approach in relation to the existing situation in low to middle income countries and the challenges that need to be overcome. The chapter will also discuss sustainable safety, to provide insight into its application and relevance to road safety in reducing road crash fatalities and serious injuries. This chapter also examines vision zero and the decade of action and their role towards achieving a safer road environment.

The application of accident prediction models was also discussed in relation to their role in road safety. With a detailed look at the iRAP methodology and its relevance to the approach taken in this research project. Following this the approach to the needs analysis was discussed in relation to the safety needs of road users, in addition to the role of Information Quality levels (IQL) in data assessment.

The chapter also addresses key issues related to public transport facilities and looks at the role of intelligent transport systems, as a modern approach to achieving efficiency in the use of these facilities. To further address the role of efficiency in the use of public transport facilities, bus stops was also discussed. The chapter also looked at bus rapid transit facilities and concludes with a summary of the chapter.

2.2 Urban road safety

The concept of urbanisation depends on the country that is defining the urban setting and its developing status. However, the general classification for most countries refers to population centres over 50 000, (Downing *et al.* 2000). Urbanisation is also generally referred to as the migration of people from rural to urban areas in search of better opportunities. (Spence, Annez and Buckley, 2009). It can be viewed as un-welcomed because there can be negative side effects. One such negative side effect is increased traffic, road crashes and budgetary concerns for road management and road improvement, (Milot, 2004).

However, urbanization is considered a necessary part of the evolution of a country from a lower income level to a higher income level. It brings with it, the possibilities of growth and prosperity and is a product of modernisation, which in-turn is a by-product of industrialization. It

CHAPTER 2 Literature review

therefore, has to be managed so that the real benefits can be realised, (Spence, Annez and Buckley, 2009). In countries such as the United Kingdom urbanised areas are classified according to the speed limit of the road. That is, it refers to an area where speeds are below 40 miles per hour and defines these roadways as urban, (Downing *et al.* 2000).

Since the decline of the sugar industry during the 1800's, Jamaica and other low to middle income countries have experienced the consequences of urbanization. The impact has been seen in the lack of infrastructure development needed to support migration into urban areas, (PIOJ, 2007). According to the UN (2015), 55 per cent of Jamaica's population lived in urban areas based on a mid-year assessment carried out in 2014. In comparison China, whose population is approximately 1.3 billion recorded 54 per cent of its population living in urban areas, (U N, 2015).

In the Latin American and Caribbean Region, Jamaica was ranked 10th, out of 26 countries with Guadeloupe being number 2 and Anguilla, Cayman Islands as well as Dutch Sint Maarten at number 1, (UN, 2015). Using Jamaica to represent low to middle income countries, the effects of urbanisation have affected economic growth, and the country's ability to provide adequate infrastructure, (PIOJ, 2007). By the same token in 2008, it was estimated that 20 per cent of Jamaica's population was living in slum like conditions, (Mullings *et. al.* 2018). This also extends to adequate provision of an efficient public transportation system and its supporting facilities, (World Bank, 1984).

The provision of transportation services in developed countries and developing countries are at different ends of the spectrum. Developed countries provide services that demonstrate a need to meet the expectations of customers, (NASEM, 2015). On the other hand, developing countries such as Jamaica, struggle to determine the expectation of their customers and the type services they desire. In the early years of Jamaica's independence in 1962, the transport network consisted of approximately 15 000km of roadway, a government owned railroad, 5 airports, 13 seaports and petroleum pipelines, (World Bank, 1974).

In comparison, in 2015 Jamaica's transportation system had 2 international airports, with a third in the parish of St. Mary in its early stages of development and 21 aerodromes serving privately owned aircrafts. This was in addition to approximately 21 000km of roadway and 2

CHAPTER 2 Literature review

major seaports. Only 6 out of the initial 13 seaports can be readily identified as operational. The railway system no longer offers services to passengers and is mainly used to transport bauxite (MTW, 2011). According to World Bank (1984), the Jamaican urban transport system relied on an extensive road transport network that was considered too dense for its land mass. Maintenance standards for the road network were considered poor, with design features that were also considered as modest by modern road design standards.

According to NASEM (2015), public transport should be seen as a viable alternative means of transportation. Public transport expectations should be met in relation to reliability, easy to access and its facilities provided in locations that are safe and convenient for use, (NASEM 2015). The urban transport system in Jamaica had significant deficiencies in meeting the expectations of its users and the condition of its facilities were considered as poor. (World Bank, 1984).

The urban areas of Kingston and St. Andrew account for 25 per cent or a quarter of Jamaica's population. Kingston has the smallest population of the two parishes with 89 057 inhabitants and St. Andrew accounting for 573 369 inhabitants. These population numbers increased when looking at the Kingston Metropolitan Region (KMR), which includes Kingston, St. Andrew and parts of St. Catherine. These areas that form the KMR represent a third, 933 333 inhabitants, out of a population of approximately 2 800 000 inhabitants, in Jamaica, (StatinJa, 2014).

The total active registered motor vehicles in Jamaica according to an Annual statistical report from the Ministry of Transport and Works (MTW), was estimated at 421 687 vehicles (MTW, 2011). Consequently, Kingston and St. Andrew accounted for approximately 121 000 registered vehicles. This represented under 30 per cent of the total active registered motor vehicles on the island, with a plus 15 per cent variance in any given year based on past data, (MTW, 2011).

On average, for the period 2000 to 2003 as shown in Table 3.1, road crashes in Jamaica were approximately 12 554 road collision each year. In addition, during the period 2002 to 2006 there was a total of 1 866 fatalities, from 1 641 fatal crashes (MTW, 2011). Based on the number of crashes per 100 000 population, this was recognized as a high road crash fatality rate for a country with a population of approximately 2 800 000 inhabitants, (WHO, 2004). A closer

CHAPTER 2 Literature review

look at the annually reported crashes for period 2002 to 2006, revealed 2002 had the highest number of road crashes.

Nevertheless, the number of road crashes were reported as 6 465 collisions occurring in Kingston and St. Andrew. The remaining 6 089 collisions were shared among the other 12 parishes. Of the 6 465 collisions from the combined parishes of Kingston and St. Andrew, 71 were fatal crashes, 306 serious injuries and 526 minor injuries. The remaining 5 562 collisions were reported as vehicle damage only. In 2002 Jamaica recorded 368 fatal crashes resulting in 408 fatalities, of which Kingston and St. Andrew had 86 fatalities reported from 71 fatal crashes, (Crawford and McGrowder, 2008).

Furthermore, the parish of St. Catherine had 75 fatal crashes, the highest recorded by any parish in 2002. However, this resulted in 82 fatalities, 4 fewer than Kingston and St. Andrew. The parish of Portland had 9 fatal crashes resulting in 9 fatalities the lowest of all 14 parishes. Other parishes such as St. Ann had 33 fatal crashes resulting in 35 fatalities. Westmoreland had 32 fatal crashes with 34 fatalities and Clarendon had 31 fatal crashes that resulted in 37 fatalities, (MTW, 2011).

In addition, the parish of St. James had 30 fatalities from 28 fatal crashes, followed by St. Mary and St. Elizabeth with 20 fatal crashes that resulted in 21 and 20 fatalities respectively. The parish of Manchester had 21 fatalities from 18 fatal crashes, along with St. Thomas that had 11 fatalities from 11 fatal crashes. While the parishes of Trelawny and Hanover both had 11 fatalities from 10 fatal crashes. During this period, the road crash fatality, mortality rate for Jamaica in 2002 was 15.56 per cent per 100 000 inhabitants. The scale for mortality rate risk assessment, ranges from 10 being low, 10 to 20 being medium and greater than 20 being observed as high, (MTW, 2011).

The mortality rate risk level assessment for Jamaica in 2002 was therefore observed as medium. For all the parishes previously mentioned, the highest number of fatalities occurred between the hours of 6 am to 8 am and 2 pm to 10 pm. These crashes were reported as occurring on Saturday and Sunday, during the month of August. The road user most affected with the highest number of fatalities were pedestrians, with 126 fatalities. The age group that had the most fatalities were individuals between 30 to 39 years of age, (Crawford and McGrowder, 2008).

CHAPTER 2 Literature review

Based on the number of fatalities, a proactive approach was needed to bridge the safety gaps in the traffic environment in Jamaica. In developed countries however, the approach to urban road safety reflects a coordinated and multi-sectorial approach, (WHO, 2004). Urban road safety in developed countries considered the role of urban and development strategies to manage the expansion of cities and its supporting infrastructure, (Downing *et al.* 2000). The role of community participation was also considered as a priority in the reduction of road traffic crashes in urban areas. From that angle, the approach to road safety in developing countries such as Jamaica appeared ad hoc in its implementation, with more reactive than proactive measures based on road crash fatality rates, (Downing *et al.* 2000).

The initiatives in developing countries such as Jamaica do not appear to consider the role of the different triggers that contribute to a road crash, (WHO, 2004). Thus, implies there was a lack of understanding of the real contributory factors to the crashes that were occurring on the island's road network. That is, since the recording of road crash data began in 1991, Jamaica has recorded approximately 20 to 30 road fatalities on average each month, every year as shown in Appendix H, Table H.4 for example.

This was despite the availability of interventions that could be implemented, at different stages of the pre-crash phase to positively impact one of the variables involved in causing a crash to prevent it, (Downing *et al.* 2000). The situation was further compounded by the top-down approach methodology that exists, when a bottom-up approach would be more suited to yield better results, (WHO, 2004).

2.3 Safe systems approach

In 2004 the WHO released the "World report on road traffic injury prevention". This report demonstrated the WHO's commitment to reducing the number of road crash fatalities and road traffic injuries, (WHO, 2004). The report presented the gains made by developed countries in their attempt to reduce the number of road crashes on their road networks. The report also provided recommendations, developing countries could adapt to their local conditions based on the successes of developed countries, (WHO, 2004).

The WHO report promotes the Safe Systems approach as a new model for road safety. Its emphasis was on an approach to road safety that takes into consideration the vulnerability of the human body. As well as placed human errors at its core in relation to vehicle design and

CHAPTER 2 Literature review

the design of the road environment, (WHO, 2004). This concept also seeks to look at road safety as a shared responsibility between the system designers and road users. In the Safe Systems approach, the system designers should take a humanistic approach to designing a system that results in a forgiving road environment in which road users can operate safely, (SWOV, 2006).

The accommodation of human errors within the road system design, was one aspect in the intervention process. And was among the series of events that lead to a crash and resulted in a fatality or serious injury. This approach was aimed at eliminating fatalities and serious injuries for road users, (Tingvall and Haworth, 1999). The experience and successes achieved by developed countries plays a key role in filling the gaps that exists between developed and developing countries. The aim is to change the approach of developing countries towards road safety, so that there is a transfer of knowledge and technology that can be adapted to suite the safety needs of low-income and middle-income countries, (WHO, 2004).

Correspondingly, Jamaica falls in the category of a developing country and more specifically is a middle-income country. Jamaica is a part of the Americas region that consists of countries from the Andean Sub-region, Latin Caribbean, Mesoamerica, Non-latin Caribbean, North America and the Southern Cone, (WHO, 2013). According to the Pan American Health Organisation (PAHO), (2013) road crash fatalities and serious injuries accounted for 142 000 fatalities during 2007 in the region of the Americas. In 2010 the number of road crash fatalities increased and was an estimated 149 992 fatalities with an average death rate of approximately 16.1 per cent per 100 000 inhabitants, (PAHO, 2013).

The Non-Latin Caribbean region accounted for 14.4 per cent of road crash fatalities and was ranked fifth out of the six regions in the Americas, (PAHO, 2013). According to PAHO (2013), Jamaica was ranked ninth behind St. Vincent and the Grenadines and in front of Guyana with respect to the number of road crash fatalities. This was based on the number of registered vehicles per 1 000 population count. Jamaica was noted as being one of the 10 countries of the Non-Latin Caribbean region to have implemented road safety programmes. This included laws to discourage drunk driving; enforcing the wearing of seat belts for vehicle occupants, helmets for motor cyclist and child restraints, (PAHO, 2013).

Most developed countries, including Australia, adopted the Safe Systems approach. Countries

CHAPTER 2 Literature review

such as Sweden and the Netherlands also developed other approaches with the principles of the Safe Systems approach at its core, (WHO, 2004). The adoption of the Safe Systems approach by Australia has resulted in the development of a National road safety strategy with targeted timelines for achieving its goals. This represented a holistic approach which saw the National Strategy being adapted to the unique situation that existed in each province in Australia. This was seen as integral to the success of the National Strategy, (DTMR, 2015).

The first target period for the National road safety strategy of Australia was 2001 to 2010, (DTMR, 2015). The implementation of this strategy presented learning opportunities and revealed that improvements were needed based on the evaluation process, (ATC, 2011). This learning experience was then rolled over into the National road safety strategy for the target period of 2011 to 2020, (DTMR, 2015). This target period was also under constant evaluation so that improvements could be made during the lifetime of the strategy to aid in its success, (ATC, 2011).

2.4 Sustainable road safety

The consideration for taking a sustainable approach to road safety emerged based on the predicted number road crash fatalities by the year 2020, (WHO, 2004). It was estimated that without the appropriate interventions the number of road crash fatalities was expected to exceed 1 900 000 fatalities (WHO, 2011). The sustainable safety approach taken by the Dutch authorities has the traits of the safety systems approach, (WHO, 2004). The sustainable safety approach was introduced in 1992 by the Dutch authorities in the Netherlands as the “Towards sustainably safe road traffic”. This initiative was later followed up with “Advancing Sustainable safety” in 2003, (SWOV, 2006).

The use of the word “Sustainable” by the Dutch authorities in conjunction with road safety may seem unusual to some. This could result in questions raised for example, “How does road safety relate to sustainability?” This was as a result of the term “Sustainable” being associated with long term development goals that are able to be maintain over time, (SWOV, 2010). According to the Oxford English Dictionary (2008), “Sustainable” is referred to as being related to continuity without harm to the environment.

An online search using Google and Dictionary.com, refers to several meaning all along the

CHAPTER 2 Literature review

lines of being able to be upheld or reused as well as systems that are able to maintain their viability. The University of Alberta (UA), Office of Sustainability (OS) refers to the meaning of sustainability as being able to meet a need without compromising the need of other generations to be able to meet their own needs. The UA, OS credits this definition to the Brundtland

Commission established in 1983 by the UN. The official name of the commission was the World Commission on Environment and development and was chaired by former Norwegian Prime Minister Gro Harlem Brundtland, hence the name Brundtland Commission, (UA, 2012).

Correspondingly, it was the Brundtland report that inspired the use of the word sustainable by the Dutch authorities for their road safety vision, (SWOV, 2012). According to SWOV (2005), the definition of sustainable from the Brundtland report was described as a development that answered the needs of the current generation. That is, while not harming the future generations opportunities to provide for their needs. The Dutch adapted this definition of sustainable development from the report and applied it to road safety. The definition for the Dutch now meant, no longer would the present generation hand over to the next generation a traffic system where road crash fatalities and serious injuries were tolerated as a consequence of road transport, (SWOV, 2005).

The Dutch road safety vision also gained traction from other industries such as aviation and the processing industries. These industries were designed with the knowledge that humans would be operating machinery and therefore accounted for the effects of human error, (SWOV, 2012a). According to SWOV (2012), the design outcome of a traffic system does not allow for it to effectively prevent road crash fatalities and serious injuries. The Sustainable safety approach considered man as the measure of all things. This meant, the traffic system should be adapted to the capacity of human beings and their limitations, (SWOV, 2006).

The high risk of a fatal error being made by a road user in the road environment, whether intentionally or otherwise, required provisions to be made within the road transport system, (SWOV, 2012). This was so that errors did not result in death or serious injury. It considered the vulnerability of road users within the traffic system, with vehicles of large masses and high speeds, (SWOV, 2007). The role therefore was structural adaptations in design, that achieved efficient and effective results in reducing the risk of road crashes in a short period of time.

Consequently, the Netherlands has one of the lowest road crash fatality rates in the world,

CHAPTER 2 Literature review

(SWOV, 2006). In 2016, the death rate for road crash fatalities was at 3.8 per cent for deaths per 100 000 population, (WHO, 2017). This, the Dutch authorities' credit to the performance of their Sustainable safety vision for road safety, (SWOV, 2006). In the concept of advancing sustainable safety, Dutch authorities have expressed a desire to maintain a continuous, proactive effort in reducing the number of road crash fatalities and serious injuries. It therefore can be determined that this desire demonstrates a will and what is understood and can be defined as sustainable road safety.

2.5 Vision zero

In 1997 Sweden adopted a vision zero approach to road safety to reduce road fatalities and road traffic injuries, (Johansson, 2009). This road safety policy presented a case where no fatality or serious injuries resulted from a road crash. The Swedish authorities recognised that there were deficiencies within their existing road design methodologies. These deficiencies did not take into consideration the inherent errors that would be made by road users, (Belin *et al.* 2012). The design of the road transport system relies on the human element to use the system in a safe manner. And at the same time can present a diverse environment with unpredictable behavioral patterns. The outcome of which was as diverse and unpredictable as its users, (EU, 2017).

It is suggested that the system did not recognize the needs of road users and ignored their ability to make mistakes, (WHO, 2004). It can be argued that the mind set of some road transport system designers saw the errors made by road users, as part of the need for mobility within the transport system. The growing desire for mobility parallels with expanding economies, as mobility has come to represent a symbol of prosperity. Therefore, increase mobility has the characteristics of different modes of transport and road users existing within the road traffic system simultaneously, (Johansson, 2009).

According to EU (2017), approximately 70 road users die on the road each day in the European Union. This translates to an estimated 500 road crash fatalities per week. In comparison 500 passengers on an airplane being killed in a week would attract significant attention with consequences to system designers and zero tolerance. If there is zero tolerance for deaths from air transport, Sweden Sverige argues, why should there not be a zero tolerance for deaths from road crashes. It was from this perspective that the vision zero approach made its case, (Sweden Sverige, 2016).

CHAPTER 2 Literature review

With road crash fatalities estimated to reach 1 900 000 fatalities by 2020, the approach taken by the designers of the road traffic system in comparison to air transport system were miles apart, (Sweden Sverige, 2016). Road crashes could therefore be labeled a silent killer because of the majority of crashes occurring within the road traffic system that went un-noticed.

Road crashes simply does not attract the attention as airplane crashes. The fact that road users make mistakes within the road transport system was a reflection of the road transport system designers, (Johansson, 2009). This was the same for system designers of air transport when pilots make mistakes, hence the approach of accounting for human errors within the system design, (Sweden Sverige, 2016).

The costs associated with road crashes has also silently and negatively affected growing economies. This was in addition to the cost of making corrections to unsafe design approaches within the road transport system, (WHO, 2004). In addition, most developing countries are not able to keep pace with the maintenance cost of road assets to provide safe road transport mobility, (Johansson, 2009). There were also costs for treating road trauma and the aftercare for severely injured road users, that impacted the healthcare system.

Rapid motorization was a phase never experienced by developed countries, (WHO, 2004). For developing countries however this was a harsh reality. Road transport mobility in developing countries outpaced the expansion of their road transportation system. This increase in traffic demand without the supporting policies and infrastructure resulted in the current situation of high road crash fatalities and serious injuries, (WHO, 2011). This unfortunately demonstrates road infrastructure design, lagging behind the science of the effects that sudden decelerating forces have on the human body, (Sweden Sverige, 2016).

Road safety management and road design for the traffic environment in low to middle-income countries requires significant change, (WHO, 2004). This change would begin with the adaptation of the principles as discussed in the (WHO 2004) report and Implementing the recommendations of the World report on road traffic injury prevention, published by the World Bank in 2009. According to OCED (2016), the political will is needed in low to middle-income countries. The will should take the same proactive effort as demonstrated by Swedish authorities for the Vision zero approach.

Through this single event a new approach can be taken towards safety in all sectors (Belin et

CHAPTER 2 Literature review

al. 2012). It has been demonstrated that road crash fatalities and road traffic injuries could be prevented, by breaking the chain of events that resulted in a road crash, (WHO 2007). However, presently in Jamaica and other developing countries, in the event there was a crash within the traffic system, the assessment was generally that it is the road user's fault. Vision zero however takes a shared relationship approach, (Tingvall and Haworth, 1999). Thus, the vision zero approach calls for system designers of the road transportation system to be obligated to assess each crash, (Tingvall and Haworth, 1999). In particular, to determine what could have been done to prevent it. The blame should not be on road users but to analyze the system as a whole, (Sweden Sverige, 2016).

The concept does not accept road crash fatalities and serious injuries as a consequence of road transport. The idea is to change the mind set about road crashes, so that the need for mobility can be fulfilled without loss of life, (WHO, 2004). The situation in Jamaica, however, is at the other end of the spectrum. Vision zero seeks to balance the need for mobility with road safety. Mobility however in Jamaica is primarily by road transport and road crash fatalities continue to exceed the Below 300 strategy each year since its inception in 2008 with the exception of 2012.

Below 300 was a road safety target and road safety programme implemented by the NRSCJ, that has the same objective of Vision zero but not as successful, (NRSCJ, 2017). According to the OCED (2016), Jamaica has adopted the Decade of action for road safety, which was also based on the Safe systems approach. However, based on previous research done in 2010, as discussed in Uter (2010), the NRSCJ has yet to fully embrace holistically the 6 recommendations of the (WHO, 2004) report. Therefore, a holistic approach to the Decade of action for road safety by Jamaican authorities similar to Vision zero in Sweden cannot be achieved by 2020.

2.6 Decade of action for road safety 2011-2020

Road crash fatalities and road traffic injuries have evolved as one of the top 10 leading causes of deaths, (WHO, 2004). It was ranked as high as malaria and tuberculosis in 2002, (WHO, 2011). It has been estimated that 1.3 million lives are lost every year on the world's roads, as a result of road crashes. It is also estimated that 20 to 50 million people are left injured or disabled, (OCED, 2016). Road crash is a preventable occurrence that has now become a public

CHAPTER 2 Literature review

health problem. Its effects on the world's economy and development are yet to be quantified, (WHO, 2011).

Developing countries such as Jamaica account for 48 per cent of registered motor vehicles worldwide, (WHO, 2004). However, they account for 90 per cent of road traffic fatalities and injuries occurring on the world's roads. This affects 46 per cent of vulnerable road users such as pedestrians, motor cyclists and bicyclists. The costs associated with road crashes was estimated at 1-3 per cent of GDP. The value was estimated at more than the combined social and economic costs for aid distribution worldwide, (WHO, 2011).

In an effort to reduce the number of road crash fatalities, the United Nations Road Safety Collaboration (UNRSC) and its global representation of stakeholders developed a global plan of action, (WHO, 2011). During the 64th session of the United Nations General Assembly in March 2010, the global plan of action, for the Decade of Action for road safety 2011-2020 resolution was adopted, (WHO, 2012). The Decade of Action for road safety 2011-2020 was officially launched in May 2011. The aim was to reduce the number of estimated road crash fatalities by half, by the year 2020, (WHO, 2011). This initiative was a follow-on to the (WHO, 2004), World report on injury prevention recommendations.

According to the WHO (2011), the main goal of the Decade of Action for Road Safety 2011-2020, was to guide global, national and local efforts to reducing road crash fatalities and road traffic injuries worldwide. The initiative aimed to achieve cost benefits corresponding to over 2.5 million lives saved and just over 37 million admissions to hospitals avoided. This was in addition to the savings from not treating the estimated 175 million road users for minor injuries, (GRSF, 2013). The cost saving to be derived from the Decade of Action 2011-2020 was estimated at 5 trillion US dollars by the end of the decade 2011 to 2020, (WHO, 2011).

Table 2.1 Global Plan for the Decade of Action for Road Safety 2011-2020

Pillars	Description	Performance indicators
Pillar 1 Road safety management	The focus of this pillar is to strengthen the institutional capacity of countries in their road safety initiative. This would include the	<ul style="list-style-type: none">▪ Number of countries participating▪ Number of road traffic deaths recorded

Table 2.1 (Continued)

Pillars	Description	Performance indicators
	establishment of a lead agency. Develop a national strategy with achievable targets and sufficient funding	<ul style="list-style-type: none"> • Amount of funding dedicated to road safety
<p>Pillar 2 Safer roads and mobility</p>	<p>This seeks to improve the safety of roads for all road users, without giving preference in design to one road user over the other. This should include improving road design approaches with safety-conscious planning, construction as well as operational. Improve road safety management and carry out frequent safety checks, to include developing a road infrastructure rating system. Improving mobility to meet mobility needs with safe infrastructure.</p>	<ul style="list-style-type: none"> ▪ Number of countries participating ▪ Number of road traffic deaths recorded ▪ Amount of funding dedicated to road safety
<p>Pillar 3 Safe vehicles</p>	<p>In this pillar the improvement of vehicle safety is emphasized and to encourage a coordination of vehicle safety standards globally. This would see the integration of technology in vehicle safety design. To improve safety performance in road crashes with increase occupant protection and technological features that compensate for human error</p>	<ul style="list-style-type: none"> ▪ Number of countries participating ▪ Number of road traffic deaths recorded ▪ Amount of funding dedicated to road safety

CHAPTER 2 Literature review

Table 2.1 (Continued)

Pillars	Description	Performance indicators
<p style="text-align: center;">Pillar 4 Road user behaviour</p>	<p>This will seek to implement programmes that are aim at improving road user behaviour. It would place emphasis on the need to implement legislation to improve compliance with road safety laws and to establish a graduate driver’s license programme for new drivers.</p>	<ul style="list-style-type: none"> ▪ Number of countries participating ▪ Number of road traffic deaths recorded ▪ Amount of funding dedicated to road safety
<p style="text-align: center;">Pillar 5 Post-crash care</p>	<p>This pillar will seek to improve healthcare for road crash victims. The implementation of pre-hospital care systems with efficient emergency response to crashes and post-hospital care systems for rehabilitation. It will emphasize the need to establish an adequately funded insurance scheme and increase investigative assessment of road crashes by authorizes with legal applicable support.</p>	<ul style="list-style-type: none"> ▪ Number of countries participating ▪ Number of road traffic deaths recorded ▪ Amount of funding dedicated to road safety

The Decade of action 2011-2020 seeks to implement an international coordination of activities. The global plan for a Decade of Action for Road Safety 2011-2020 is driven by five pillars as shown in Table 21. These pillars are further broken down into a series of activities aimed at their successful implementation. This global plan of action also uses performance indicators, along with established medium to long term milestones and evaluation techniques as a monitoring tool, (WHO, 2011).

CHAPTER 2 Literature review

The approach seeks to reaffirm that major changes were needed to transfer the main responsibility of road safety, from road users to the road transport system designers. Each pillar of the Decade of action for road safety 2011-2020 relates to a sector of the existing road safety management system in Jamaica. As illustrated in Figure 3.14 and further discussed in Section 4.4, Jamaica has a management system of road managers, traffic and transport engineers, traffic police, automotive companies, the Jamaican Parliament and political representatives. Whom were considered as the road transport system designers however, there were others that also played a key role. This includes health care services, nongovernment bodies, educational institutions; the judicial system and most importantly support from road users, (WHO, 2010).

Being built on the Safe systems approach, the Decade of Action for Road Safety takes a forgiving approach to human error and their limitations in the traffic environment, (WHO, 2011). Jamaica has indicated that despite institutional challenges, they have adopted the Decade of Action for Road Safety 2011-2020, (NRSCJ, 2012). This is despite not putting in place the recommendations of the World report on road traffic injury prevention, (NRSCJ, 2010). The adaptation of the Safe systems approach in Jamaica and the acknowledgment of its adoption by road management authorities, should have resulted in a greater impact on road crash fatalities, (NRSCJ, 2017).

The integration of which was thought to have replaced the traditional approaches to road safety as the country aimed to achieve Jamaica's version of Vision zero. It is yet to be seen however whether Jamaica's adaptation of the Decade of Action for Road Safety 2011-2020 within the context of existing conditions will produce the desired results. This was also with the observation that there has not been a revision of Jamaica's National Road Safety Policy (NRSP) since its publication in 2004, (NRSCJ, 2012).

2.7 Road safety models

The use of Accident prediction models for decision making, to implement treatments for road safety, was identified with countries that were at an advance stage of road safety maturity. It was also associated with guidelines such as road safety manuals by National Road Administrations (NRA), (La Torre, et al 2016). The use of the words "road accident" to describe crashes that occur on the World's road network has been rejected by the WHO. With this statement, the WHO since 2004, now uses the term road crashes instead of road accidents, (WHO, 2004).

CHAPTER 2 Literature review

This was based on proven best practices in developed countries which have achieved success in reducing road crash fatalities and serious injuries, (WHO, 2011). Through these successes, a road crash has been proven to be a preventable occurrence and not considered as a random event, (WHO, 2004). A road crash was described as a series of events that with appropriate interventions, the outcome can be changed to reduce the severity of the crash and avoid a fatality, (Geziary et al, 2004). Based on the announcement by the WHO in 2004, it is therefore reasonable that accident prediction models, should now be referred to as crash prediction models. The same extends to accident risk models, which should also now be referred to as crash risk models.

Crash prediction models (CPM) are used in assessing road safety countermeasures for reducing the number of road crashes on a road section in decision making, (La Torre, et al 2016). Assessing road crashes by CPM, predicts how frequent could severe road crashes occur on a section of road. This was based on its infrastructure, length, its traffic flow and speed limit over a period of five years., (Jurewicz and Excel, 2016). This differs from crash risk models (CRM) which analyses a road section, its road infrastructure features and road user type to determine the likelihood that a crash will occur and its severity, (iRAP, 2014).

The use of CPM considers road design methods rather than looking at specific road user types. The use of crash modification factors to compensate for contributory crash initiation factors are used with CPMs as well as CRMs. There are similarities in the approach taken by CPM and CRM. CPMs are best suited for crash data accumulated over many years. This data representation was more accurate than crash data related only to the road section being assessed (La Torre, et al 2016). Risk models such as iRAP however, can provide an assessment of the number of crashes related to road users with or without the availability of crash data, (iRAP, 2014). The risk assessment data however obtained using CRM can be used in CPM with the inclusion of CPM parameters to determine the prediction of road crashes, (Jurewicz and Excel, 2016).

Based on issues with unreliable road crash data or absence of road crash data in developing countries and rare instances of missing data in developed countries, (WHO, 2004). The use of the iRAP crash risk model would present an opportunity in the absence of data representation, (Lyam, 2012). The use of iRAP has also been proven to be successful in its adaptation and application in developing countries, (iRAP, 2013). For this reason, the iRAP crash risk model

CHAPTER 2 Literature review

was chosen to determine the risk to public transport pedestrian users at public transport facilities such as bus stop and transport centres in Jamaica.

Data presented on road crashes in Jamaica, has shown that there was no accurate representation for crashes that occurred at public transport facilities such as bus stop and transport centres, (RSUJ, 2016). The iRAP crash risk model has not been used to assess the safety at public transport facilities, based on published iRAP fact sheets, (iRAP, 2016). This highlights a gap in the iRAP crash risk model and its application. This also extends to published research on the safety of public transport facilities such as bus stop and transport centres and related crashes that occur at or into these facilities. Available research mainly addresses safety and crashes in relation to buses and transportation and is not profuse, (Brenac and Clabaux, 2005).

According to Mohammed *et al.* (2018), accident prediction models or as they are now called crash prediction models, are grouped based on those most often used. Table 2.2 presents the model type, its description and limitations.

Table 2.2 Crash prediction models

Model type	Description	Limitations
Multiple linear regression model	These predict crashes based the distribution of crash frequency within crash data as a function of risk factors, vector of regression coefficients linked to crash frequency and risk factors in relation to normally distributed errors	Regression outputs can lie outside the expect range and can be very sensitive to outliers.

Table 2.2 (Continued)

Model type	Description	Limitations
Poisson regression models	<p>These are similar to ordinary linear regression models with exceptions such as they assume errors follow a Poisson circulation and considers crash frequency as a linear function of vector coefficients. An assumption is that the mean and variance should be equal and when not conformed to this dispersion parameters can be applied for small differences and negative binomial regression model for large differences.</p>	<p>Can be negatively influenced by small sample size bias and is not able to process over and under-dispersion.</p>
Conway-Maxwell Poisson regression models	<p>These models are speculative models of Poisson circulation that are capable of handling under-dispersed and over-dispersed crash data. This model is preferred for handling under-dispersion of crash data that are not able to be modeled by Poisson and Negative Binomial models.</p>	<p>Does not consider multivariate extensions and can be negatively impacted by small sample size bias.</p>

Table 2.2 (Continued)

Model type	Description	Limitations
Artificial neural networks	These are classified as computational intelligence tools that can predict and categorize problems. They can model complex non-linear function using learning procedures that are similar to the cognitive system of the human brain. These models do not depend on predefined relationships between variables.	Cannot be used to extrapolate results as needed.
Fuzzy logic models	These models have demonstrated the capability of predicting crashes using logic applications. They are considered as logic system models that are able to map non-linear data to scalar output data.	Cannot be used to extrapolate results as needed.

According to Yannis et al (2016), the Predicting Road Accidents (PRACT) project was launched to develop an accident prediction model (APM) that could be applied across Europe. This methodology would be structured and calibrated so that it could be transferred across different European road networks. The PRACT project was based on core principles that questioned the application of a single APM across Europe and its practicality. The implications for National road administration would be demanding and whether they had the resources, capacity and time to adapt to the project objectives (La Torre, et al 2016).

CHAPTER 2 Literature review

The assumptions underlying the PRACT project was that in order to address these issues, guidelines were needed. These guidelines would be required to be transferable to the unique local conditions of the diverse road network within countries across Europe, (La Torre, et al 2016). The fundamental belief of the PRACT project was that APMs and CMFs developed in a European country should be capable of being adapted to the conditions of other countries with an evidence based scientific application, (Yannis et al 2016), Notwithstanding APMs were not widely used by many countries across Europe in decision making to treat road crashes, (La Torre, et al 2016).

In an assessment of available road safety models, the Transport research laboratory (TRL) considered 21 road safety models as shown in Table 2.3. These models were reviewed to determine the application in the United Kingdom (UK). According to TRL (2015), the models were placed through an assessment process that provided a summary of the model, its technical comprehensive abilities and its relevance to the local authorities in the UK. These models are a representation of models used in 10 countries and by 2 international road safety organizations. The models considered are presented in Table 2.3 below with the country of application and model type.

Table 2.3 Road safety models

Models	Country of Application	Model type
High-risk rural roads guide (HRRG)	New Zealand	Risk based and crash history
Manual for selective safety improvements on high risk rural roads (HRRR)	United States of America	High risk roadway features and severe crash history
Systemic safety project selection tool (SSPST)	United States of America	High risk roadway features and severe crash history
iRAP risk mapping	International	Crash history based
User' safety on existing roads (SURE)	France & Germany	Reactive with some inspection

CHAPTER 2 Literature review

Table 2.3 (Continued)

Models	Country of Application	Model type
Regional road safety explorer (RRSE)	Netherlands	Crash data
Route analysis tool	United Kingdom	Reactive- Crash analysis based
PVT Visum safety	International	Mix of risk based and crash history
Safety analyst	United States of America	Proactive, Network screening and project prioritisation
17-38 Spreadsheets for Applying the highway safety manual predictive methodology for rural two-lane, two-way roads (17-38 spreadsheets)	United States of America	Reactive, Accident predictive models
HiSafe: Companion software to the highway safety manual (HiSafe)	United States of America	Reactive, Accident predictive models
Interactive highway safety design model (IHSDM)	United States of America	Proactive, Crash prediction models for identifying site specific improvement potential
International road assessment programme (iRAP) star rating	International	Risk based

CHAPTER 2 Literature review

Table 2.3 (Continued)

Models	Country of Application	Model type
NetRisk rating tool (NetRisk)	Australia	Risk based
Ranking for European road safety (Rankers)	Europe	Risk based with an applied factor for crash history
Identification of hazard location and ranking of measures to improve safety on local rural roads (IASP)	Italy	Proactive, Inspection based
Road infrastructure safety assessment (RISA)	New Zealand	Risk based model
Road safety inspection and assessment (RSI / RSA)	International	This comprises a set of procedures and is not considered as a model in the true sense
Australian national risk assessment model (ANRAM)	Australia	Risk based and crash history
Safety network evaluation tool (SafetyNet)	New Zealand	Mix of risk based and crash history
Road safety risk manager (RSRM)	Australia	Risk based

2.8 International Road Assessment Programme (iRAP)

The International Road Assessment Programme (iRAP), was developed as a coordinated effort that began with EuroRAP in 1999, (iRAP, 2013). This coordinated effort was as a result of a

CHAPTER 2 Literature review

working group of several road safety organisations from across the globe, (Lynam, 2012). It also included contributions from (Elvik and Vaa, 2004) and (Elvik *et al.* 2009). Since the initial development of the iRAP model there have been several versions, (TRL, 2015). In the early development of EuroRAP, the model was rated based on its ability to assess road attributes for road crashes involving safety barriers. The assessment considered the level of protection, safety barriers gave car occupants during a road crash, (iRAP 2013). The development of the EuroRAP model was followed by AusRAP but with the view of considering the likelihood of a road crash occurring, (Lynam, 2012).

The inclusion of the likelihood of road attributes impacting the safety of road users in AusRAP, was an expansion of the EuroRAP model. Similarly, AusRAP also included considerations for the level of safety road attributes provided to car occupants. Following the completion of the AusRAP model it was used to assess highways in Australia from 2006 to 2008. The development of KiwiRAP was born out of the AusRAP model by adaptation to the conditions in New Zealand. The KiwiRAP model was then later used in 2010 to assess the safety of 10 000km of highway, (iRAP 2013). With the expansion of each version of the iRAP model, considerations for other road users were added, (Lynam, 2012). The model expanded from its earlier version of assessing car occupants to the assessment of crashes involving pedestrians, motor cyclist and bicyclists, with the introduction of version 3.0 in 2012, (iRAP, 2013).

The iRAP model is constantly under review for expansion and improvement. This is in an effort to assess road attributes based on crash data for instances where the impact on particular road users is underestimated, (iRAP, 2013). As a result, preventing or reducing the number of road crashes, road crash fatalities and serious injuries. On the other hand, iRAP has sort to limit frequent changes as this was assumed could affect programs and performance tracking, (iRAP, 2014). The introduction of iRAP protocols also saw improvements in the model. Following this, the model expanded to include new road attributes and equations. In particular this, resulted in the development of Risk maps, Star ratings, Safe road investment plans and performance tracking. That is, these protocols were introduced to evaluate and advance the need for safer roads within the World's road network, (iRAP, 2014).

Following the release of the WHO's, World report on road traffic injury prevention in 2004, the road safety issues being faced by low and mid-income countries were highlighted. On that account, in 2006, the Federation international de l'automobile (FIA) engaged iRAP, to adapt

CHAPTER 2 Literature review

the iRAP model to meet the needs of low and mid-income countries, (iRAP, 2013). In particular, the iRAP model was considered suitable for low and mid-income countries with a history of unreliable data collection and reporting. This was as a result of the iRAP model's ability to be used with or without road crash data to address such problems. The iRAP methodology achieves this by conducting road surveys. These surveys are based on assigning risk values associated with road attributes and a star rating system for each road section. In this way, the iRAP model estimates the number of fatalities and serious injuries. In addition, the model predicts the reduction of crashes and cost benefit ratios according to assigned countermeasures, (Lynam, 2012).

Accordingly, it was also established that low and mid-income countries had road design features similar to the countries where iRAP was developed. This addressed the issue of adaptation based on road design features requirements for road attributes data in iRAP, (Lynam, 2012).

The iRAP model was developed to be consistent with global protocols for road safety as follows:

iRAP road safety protocols

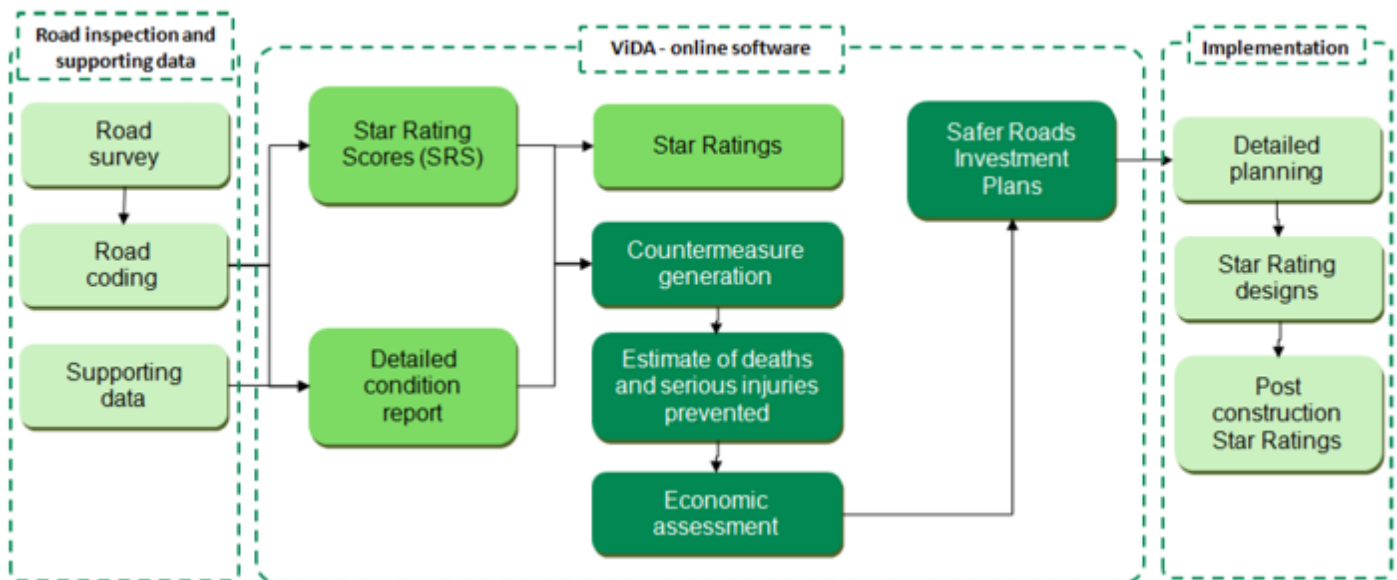
- Risk maps
 - Visual representation of crash data based on number road crashes that occur on the roadway
- Star ratings
 - Assignment of a rating to the road that indicates the level safety built into the roadway
- Safer roads investment plans
 - Provides economically viable options for road infrastructure improvement for the development of safer roads
- Performance tracking
 - Provides a means of tracking the progress of road infrastructure improvements with the use of star ratings and risk mapping

Source iRAP (2014)

CHAPTER 2 Literature review

The iRAP model is presently in operation in over 70 countries. Its implementation and improvement are administered by iRAP staff and the Global technical committee (GTC), (iRAP, 2013). The iRAP model is considered as a crash allocation model and uses a methodology to collect data, assess crashes and recommends countermeasure interventions that are proactive, (TRL, 2015). By extension, the Safe Roads Investment Plans (SRIP) within the iRAP model also looks at the design of the road infrastructure, to determine the type of countermeasures that could be economically implemented, (iRAP, 2009).

Figure 2.1 The iRAP Star rating and safer roads investment plan process. Modified by Uter (2018) and obtained from iRAP (2018)



2.8.1 Use of iRAP

The use of the iRAP model and its methodology to determine the design safety features of a roadway in the likelihood of a crash, was dependent on how road users use the roadway, (iRAP, 2014). Similarly, the level of safety experienced by road users was determined by their behavior and whether it coincided with the design considerations of the road. Even more the safe use of the roadway by road users also depended on the type of facilities provided. Thus, the ability of the iRAP model to determine the safety of the type of facilities provided, creates an opportunity for its data collection methodology to be adopted for the study area in Jamaica. Therefore, data on the type of facilities provided would determine how road users were allowed to operate within the design envelope of the roadway.

CHAPTER 2 Literature review

The iRAP methodology was used to collect and code road attributes data on the roads selected of the study area. The road attributes data collected was in relation to public transport pedestrian users at public transport facilities such as bus shelters and transport centres. The data collected on the type of road attributes present was assessed to determine their influence on the likelihood and severity of a crash involving public transport pedestrian users. In particular to achieve objective one, objective two and objective three.

To achieve objective four the iRAP methodology for star rating model equations was used to develop a star rating model equation for public transport pedestrian users. This was in addition to developing causality estimation equations and an economic analysis of the countermeasures to be recommended. That is, to reduce the likelihood and severity of a crash for public transport pedestrian users. This further supports the use of iRAP for the assessment of road design safety features within the study area for this research project., (iRAP, 2013). The use of iRAP as a decision support tool was a major step towards closing the gap and changing the perception of road crashes, (iRAP, 2014).

2.8.2 Risk maps

The International road assessment programme also includes risk mapping as part of its methodology as shown in Figure 2.2. The use of risk maps though not included as part of the methodology for this research project, forms part of the overall iRAP application process.

The iRAP methodology uses 3 main documents to assist with risk mapping as follows:

Documents used in iRAP for risk mapping

- Rap risk mapping design specification
- Rap road risk mapping manual: Technical specifications
- Risk mapping template

Source iRAP (2013)

CHAPTER 2 Literature review

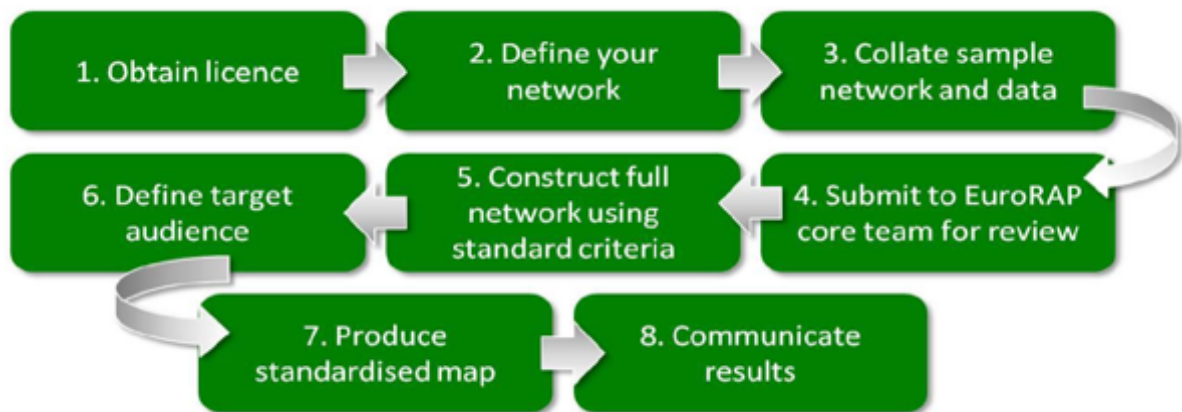


Figure 2.2 Standard procedure for producing RAP road risk mapping. Modified by Uter (2018) and obtained from iRAP (2018)

The focus of Rap risk mapping is to develop safer routes rather than looking at improving the safety of individual crash sites at low costs. Risk mapping entails colour coding the road network into sections that represents the level of safety designed into a roadway for road users. In this way the roadway was colour coded and assigned a level of safety for each road user type separately. It follows then that each road user was able of determined the level of safety afforded to them before travelling on the roadway, (iRAP, 2013).

As a result, mapping was considered a decision support tool that was used to guide road safety policies and initiatives. Moreover, it facilitated the identification of high risk and low risk roads for road users and presented a concentrated look at the number of road crashes, road crash fatalities and serious injuries that could occurred on roadway. By extension the use of this methodology also allowed for comparisons in tracking the improvement of road safety countermeasures, before and after their implementation, (iRAP, 2014).

2.8.3 Road features

The choice of road attributes also called road features was based on road safety inspections that determines whether, these features had a significant impact on road crash fatalities and serious injuries. In order to determine the impact road attributes, have on road users in the likelihood of a crash, the iRAP methodology coded road attributes according to the iRAP star rating and investment coding manual shown in Figure 2.3. There are two versions of the manual in use, driving on the left and driving on the right. The driving on the left version for example is shown in Figure 2.3, with Figure 2.4 and Figure 2.5 showing examples of road attributes data and how risks were identified and coded for different road user groups. This was also further discussed

CHAPTER 2 Literature review

in *Section 2.8.4*, (iRAP, 2014).

The coding manual was used along with iRAP road attribute risk factor factsheets. These factsheets presented recommendations for risk factors or crash modification factors assigned to each road attribute in the iRAP database, (iRAP, 2013). Thus, the iRAP methodology surveyed and coded the road infrastructure, to represent road features in relation to the safety afforded to road users on the roadway, (Lynam, 2012).

The online iRAP road safety toolkit and iRAP methodology factsheet 4, provided a list of road attributes and the expected outcome based on road user type and crash type, (iRAP, 2015). The deficiencies identified during road surveys represented the gap between the existing road safety situation, and the desired. Consequently, this also presented an opportunity to provide sustainable options to maintain and bridge gaps with the use of available resources for road safety, (Kaufman and Valentine, 2007).

The International Road Assessment Programme (iRAP) plays a significant role in assessing the existing situation on the urban road network in Kingston and St. Andrew. According to the World Bank (1984), the road network in Jamaica and by extension Kingston and St. Andrew was considered dense. As a result, only roads from the A-road network were considered for assessment. On that account the roads selected from the A-road network were representative of the type of roads within the road network of Kingston and St. Andrew.

It follows then that, the road attributes collected and assessed from the A-road network were a representation of the data for this research project. The data was also assessed to determine the level of safety designed into roadway and by comparison the safety needs of public transport pedestrian users. This was according to the type of road features present for the safety of public transport pedestrian users and to determine whether iRAP could be used to define those features. Following this the needs-based approach would be used to determine the safety needs for public transport pedestrian users on the roads selected for assessment.

The road sections for assessment were chosen not only because they were a part of the main road network but where most of the road crashes occurred, (RSUJ, 2015). These roads were also considered the main arteries of the road network in Kingston and St. Andrew, (NWA, 2015).

CHAPTER 2 Literature review

Moreover, they were also the location of a combined total of 162 public transport facilities in the corporate area and transportation network used by the Jamaica Urban Transit Corporation (JUTC), (JUTC, 2015). The corporate area is considered the main business hub in Jamaica and most important of all, includes Kingston, the countries capital. Together with St. Andrew and by extension parts of the neighboring parish of St. Catherine forms the corporate area also known as the KMTR, (MLG, 2015)

The selected roads, moreover were also considered because of their importance to providing accessibility and in particular acting as collector and through roads for road users. The nine road sections are considered are follows.

The 9 road sections chosen from the A-road network of Jamaica

- Constant Spring Road
- Half-Way Tree Road
- Old Hope Road
- Hope Road
- Washington Boulevard
- Red Hills Road
- Eastwood Park Road
- Monlynes Road
- Hagley Park Road

These road sections form junctions and intersects with each other at various points along the road network as shown in Appendix B, Figure B.1 and Figure B.2. In addition, they also act as distributor and in some instances access roads. By assessing these road sections using the iRAP methodology, by extension they were being assessed against best practices for road safety in developed countries. And by the same token the overall process was done in accordance with the objectives of this research project.

CHAPTER 2 Literature review

2.8.4 Data collection for iRAP

The collection of road attribute data for the iRAP model was done by road inspections as discussed in section 2.8.3. Road surveying and road coding were carried out by photographing or taking video footage of the roadway at pre-determined distances. The coding manual provided guidelines for recording road attributes captured in photographs and videos taken as shown in Figure 2.4 and Figure 2.5. In addition, road attributes data were recorded in a Microsoft excel spread sheet template in the order they were captured in the photographs and videos, (iRAP, 2014).

The road segment was first coded according to its name, section and location. And at the same time photographs and videos are geo-referenced to provide a Global positioning system (GPS) location, (iRAP, 2014). As a result, photographing of the roadway was done for each 100m segment of the roadway to capture the type of road attributes present and the road condition, (iRAP, 2014f).

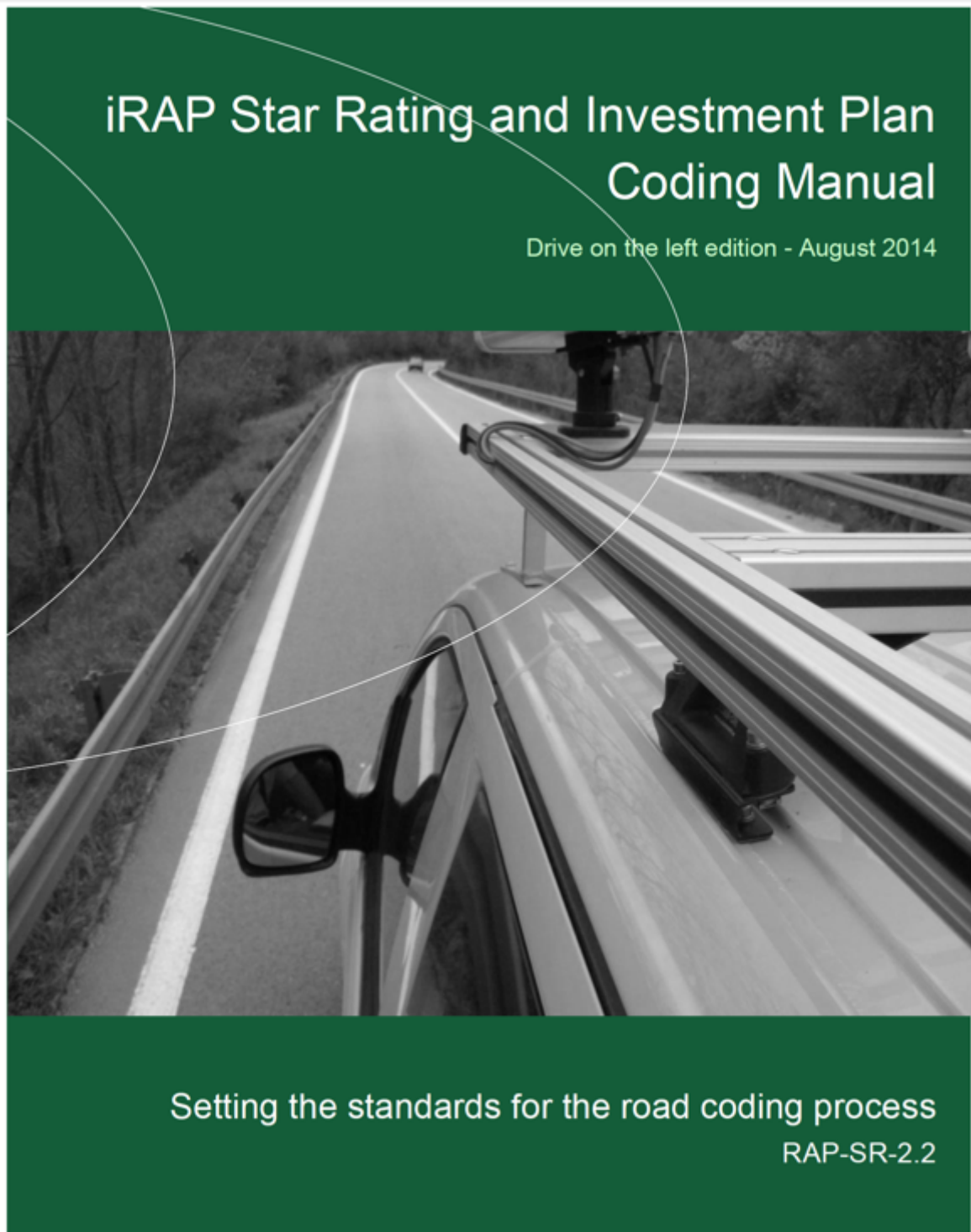


Figure 2.3 iRAP Star rating and investment plan coding manual. Modified by Uter 2018, and obtained from iRAP (2018)

CHAPTER 2 Literature review

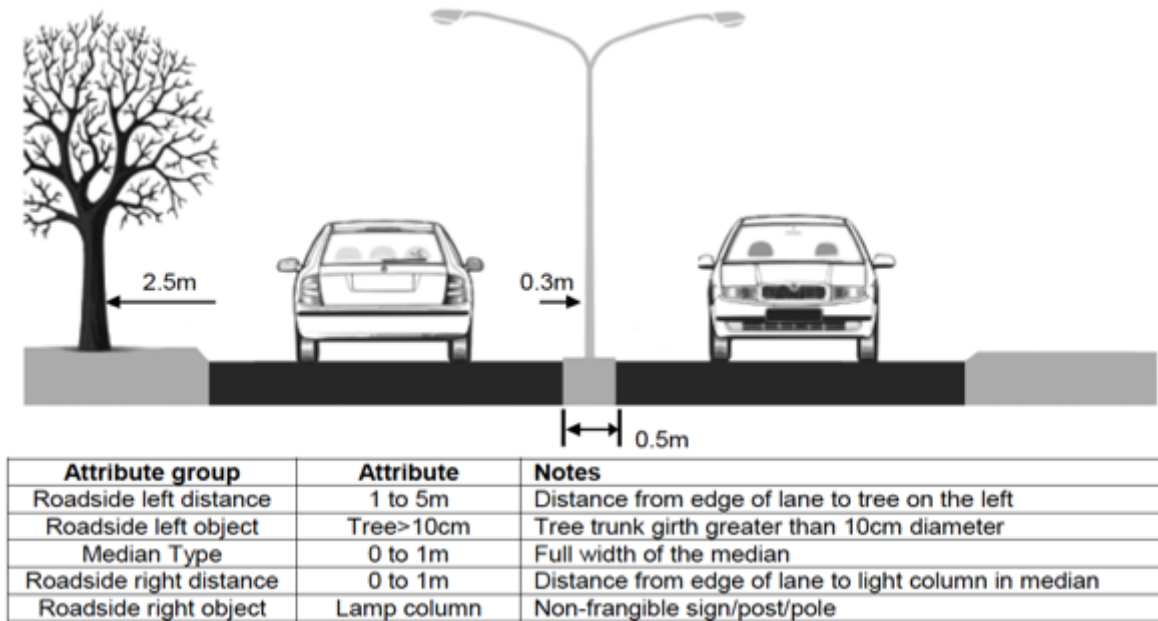


Figure 2.4 Example of data collection for iRAP Star rating and investment plan coding manual. Modified and obtained from iRAP (2018)

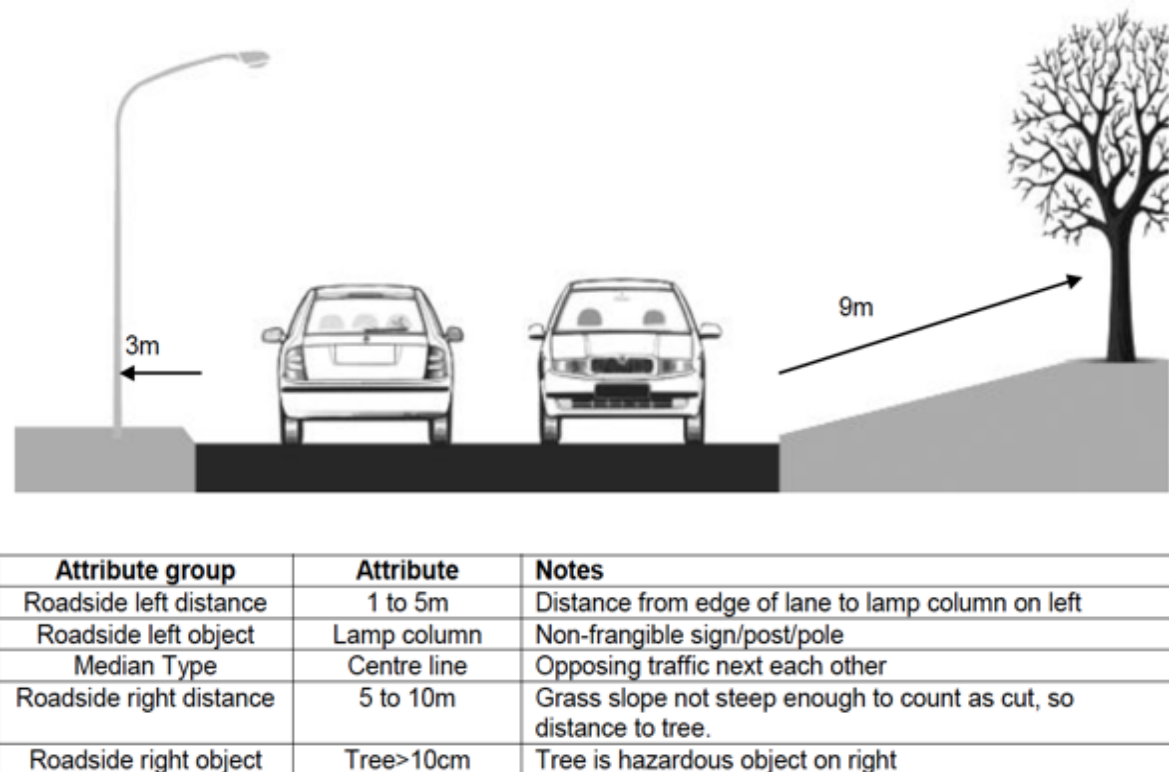


Figure 2.5 Example of data collection for iRAP Star rating and investment plan coding manual. Modified by Uter (2018) and obtained from iRAP (2018)

CHAPTER 2 Literature review

The road attributes data collected in the traffic environment will as a result, determine the gaps in the infrastructure for the provision of the safety needs for public transport pedestrian users. The needs analysis is used to identify road infrastructure that are overlooked and not included in the iRAP road attributes database. It then follows that the coding of road features and road user in the images with an assigned crash modification factor, presents a descriptive representation of safety risks faced by a public transport pedestrian user, (iRAP, 2014).

In this way road users are able to relate road attributes to existing or future crashes. According to Crash Modification Factor Clearing House (2017), CMF is a multiplying factor used to determine the anticipated number of road crashes. This is after the implementation of a countermeasure for a site being assessed. It follows then that the risk factor assigned is by extension used as a tool to support safety initiatives for development projects for the implementation of countermeasures based on the data collected.

2.8.5 ViDA

ViDA is iRAP's online software application used to determine the star rating of a roadway and to develop appropriate Safer road investment plans, (iRAP, 2014). ViDA software is available free online through a registration process. The software has online tutorials that enable the user to use ViDA appropriately and extract the information needed. It allows for the user to upload existing data from their road network with the use of templates from iRAP methodology.

There are also online specifications available for additional guidance along with manuals on the iRAP resource website. The user can also do preliminary testing of the data collected from their road network using ViDA demonstrator, (iRAP, 2018). The ViDA demonstrator was used to test the software for data compatibility with the data collected from a road within the study area. This was done to determine a star rating for the selected road and to check for similarities with the iRAP methodology and Jamaican road design practices.

2.8.6 Models equations in iRAP

Star rating model equations included in the iRAP methodology are based on casualty estimation, calibration and economic analysis. This includes equations for estimating serious injuries and as further discussed in *Section 2.8.9*. As previously discussed, these equations were used to develop similar equations for public transport pedestrian users not previously considered by iRAP. The iRAP methodology, uses a star rating score to provide a 5-star rating system for

CHAPTER 2 Literature review

roads according to design features, road user type and crash type. The assigned star rating was also based on risk mapping and road safety data, according to safety features provided as a reflection of the road users impacted. The iRAP model uses this approach to determine and highlight the level of safety designed into a roadway.

2.8.7 Crash types and road user types in iRAP

The crash types included in the iRAP methodology were representative of the type of crashes that occurred most frequently on the road network, (Lynam, 2012). The road users included as crash types in the iRAP methodology, were road users involved in those crashes. As a result, equations used by iRAP for model development were also based on those crashes that accounted for the majority of road crash fatalities and serious injuries, (iRAP, 2013). According to iRAP (2013), crashes that were infrequent, were not considered nor were the road users involved represented. This was based on the perceived difficulty in modeling such crashes.

However, as mentioned in iRAP (2013), crashes that occurred with less frequency, could be covered in future models as the relevant data became available. This represented a gap in the iRAP methodology for crash assessment. As well as road user type crash representation and countermeasures necessary, to reduce the outcome of a crash for those crashes and road users not represented. In the meantime, iRAP considered these crashes to be covered by including external flow factors in their fatality estimation equations, (iRAP, 2014).

The assessment of road crash data was also used to determine road users to be considered for crash type model equations in the iRAP methodology. This was also based on the various type of crash scenarios, the degree of severity and contributing factors. The type crashes involving road users were referred to as crash types in iRAP. Correspondingly, this was based on the crash scenario at the time the crash occurred and is further explained in Table 2.4.

The road users considered by the existing iRAP model are as follows:

Road users

- Vehicle occupants
- Motorcyclists
- Bicyclists
- Pedestrian

CHAPTER 2 Literature review

Source: iRAP (2013)

Table 2.4 Road user types and crash types included in iRAP Star rating models

Road user types	Crash types					
Vehicle occupants	Run-off	Head-on (loss of control)	Head-on (overtaking)	Intersection	Property access	
Motorcyclists	Run-off	Head-on (loss of control)	Head-on (overtaking)	Intersection	Property access	Along
Bicyclists	Run-off	Along	Intersection			
Pedestrians	Along	Crossing (inspected road)	Crossing (side road)			

Source: IRAP (2014)

Although the assessment of road safety data carried out by iRAP represented crashes that occurred frequently. By extension another assessment was needed for crashes that did not occur frequently. It follows then, that this was necessary to determine the road user types and crashes not represented in existing crash type model equations. The data required to support this, was within the road attributes data collected using the iRAP methodology, (iRAP, 2013). As well as the road crash data for each roadway within the study area.

On that account, this was considered consistent with addressing the issue of non-represented road users and crashes not identified. And as a result, addressing the gap in the iRAP model and its methodology. It also highlights a need for facilities other than traditional road features provided by present road infrastructure design practices. To analyse this need, a needs-based approach was needed to determine which road user infrastructure safety needs were not being met, (Watkins *et al.* 2012). This analysis was based on comparing road crash data from the road section and road attributes data collected using the iRAP methodology.

CHAPTER 2 Literature review

Consequently, a needs-based approach is not specific to road safety, (Watkins *et al.* 2012). The defining of a needs analysis specification was needed to determine the focus of the needs-based approach and moreover the criteria's for the needs analysis. And by extension linking road crash fatalities or serious injuries affecting road users to road infrastructure present or absent. In this way the findings from the assessment using the needs analysis determined the safety needs of road users.

Therefore, in determining the gaps in the iRAP model for road user types and moreover, for crashes involving other categories of road users not included in existing iRAP model equations. But at the same time were relevant to crash data because the crash and fatality or serious injury did occur. It follows then that the focus was on analyzing crash data for excluded categories of road users. In analyzing the road crash data, a road user type not included in existing iRAP models, related to crashes that occurred at public transport facilities such as bus shelters and transport centres. On that account, this introduced a new road user type and crash types that was related to public transport facilities. This new road user type for public transport facilities was described as follows:

New road user type

- Public transport pedestrian users

2.8.8 Star rating

The iRAP methodology uses a Star rating system ranging from 1 to 5 associated with the assessment of road attributes and their influence on the likelihood and severity of a crash. The star rating system is defined as using actual stars and a number rating system, with the number of stars corresponding to the assigned number rating. It follows then that a Star rating represents a safety rating for the roadway, and moreover represents the level of safety designed into the road for a road user, (Lynam, 2012).






For example, a Star rating of 1 was the lowest and most unfavorable safety rating that a road could be assigned. But at the same time a Star rating of 5 represents the highest and most favorable safety rating for a road, (iRAP, 2011). As a result, a 5-star rating road was therefore assumed to have the lowest crash rates and the highest safety design features built into the roadway, (iRAP, 2011). The iRAP star ratings methodology determines the gaps within the

CHAPTER 2 Literature review

safety design features of the roadway for road users. Thus, will be applied to public transport facilities in an attempt to determine the safety design gaps in the infrastructure for public transport pedestrian users within the study area.

In addition, the iRAP methodology also uses colour-coded risk bands to further define the severity of risk on a road for road users as shown in Table 2.5. This was based on the type of road attributes present or absent from the road infrastructure, (iRAP, 2013). Colour coding was also used for star rating with the assign colour being a reflection of the star rating given to the road for the road user type. Using colour coded risk bands as shown in Table 2.5, a high-risk road was given a star rating of one and assigned a black colour code. Road users can then use the colour code and star rating to determine the level of risk they will face while traveling on a particular road.

Table 2.5 Colour-coded risk bands and star rating of roads used by iRAP. Modified by Uter (2018) and obtained from RAP road risk mapping manual: Technical specification (2013)

Colour	Description	Star	Rating
Low	Low risk road		5
Low - medium	Low - medium risk road		4
Medium	Medium risk road		3
Medium-high	Medium – high risk road		2
High	High risk road		1

According to iRAP (2013), star ratings are based on the star rating score obtain from the product of the likelihood, severity and external flows and summation of each crash type score. The star rating band scale provided a rage that rated the roadway being assessed on a scale of 1 to 5 as shown in Figure 2.6. A star rating score 22.5 and above for vehicle occupants and motorcyclists meant the roadway was assigned a star rating of 1. Depending on the road user type being assessed for the section of roadway, a star rating of 1 was an indication that a road user had a high risk of being involved in a fatal crash or being severely injured. The range of the scale for the star rating and star rating score for each road user type is shown in Figure 2.6. The

CHAPTER 2 Literature review

range increases based on the vulnerability of the road user ,as the star rating moves closer to 1 and decrease as star rating moves closer to 5, (iRAP, 2013).

Star Rating bands and colours

Star Rating	Star Rating Score		
	Vehicle occupants and motorcyclists	Pedestrians	Bicyclists
5	0 to < 2.5	0 to < 5	0 to < 5
4	2.5 to < 5	5 to < 15	5 to < 10
3	5 to < 12.5	15 to < 40	10 to < 30
2	12.5 to < 22.5	40 to < 100	30 to < 60
1	22.5 +	100 +	60+

Figure 2.6 Star rating band ranges and related colour codes
 Modified by Uter (2018) and obtained from the iRAP (2013)

2.8.9 Star rating model equations

According to iRAP (2014), Star rating scores (SRS) were determined for each road user type based on the road attributes recorded on the roadway. It follows then that Star rating equations are calculated for each road user type, for each 100m segment of roadway. But at the same time SRS were also based on crash types representing the type of crashes that occur on the roadway, (iRAP, 2013). As a result, Star rating scores were derived from Star rating equations determined from the sum of crash type scores for each type of crash that occurred along the roadway as shown in equation 2.1, (iRAP, 2014).

Thus, equation 2.1 for example represents SRS determined from the sum of the crash type scores. It follows then that equation 2.1 when expanded to equation 2.2, represents the total crash type score to be calculated for each type of crash affecting a road user type, (iRAP, 2011). In addition, each score obtained for a crash type follows a summation of all crash type scores for the road user type to determine the SRS for the roadway. Therefore, by extension in equation 2.2 the likelihood (L), severity (S), operating speed (OS), external flow influence (EFI) or median traversability (MT) represents a crash type score for one type of crash affecting a road user, (iRAP, 2014).

CHAPTER 2 Literature review

It follows that the SRS each road user type is determined using the equations below as follows:

$$SRS = \Sigma \text{ Crash type scores} \quad (2.1)$$

Where *SRS* = representative scores for the relative risk of death and serious injury for each road user type.

And

Therefore, Crash type scores to be determined for each crash type affecting a road user type

$$\text{Crash type scores} = L \times S \times (OS) \times (EFI) \times (MT) \quad (2.2)$$

Where *L = Likelihood* = road attribute risk factors that could result in the initiation of a crash

S = Severity = road attributes risk factors that determine the severity of a crash

(OS) = Operating speed = factors related to the level of risk associated with changes in speed

(EFI) = External flow influence = factors relate to the level of risk associated with a person being involved in a crash as a result of another person's use of the road

(MT) = Median traversability = factors relate to the probability of an errant vehicle crossing a median (this considers vehicle occupants, motor cyclists run-off and head-on crashes)

Source iRAP (2014)

The iRAP methodology star rating equations considers 4 road user types in the present model, (iRAP, 2013). As a result, the crash type for each road user differs depending on the mode of

CHAPTER 2 Literature review

transport used, (iRAP, 2014). It follows then, that for each road user type, the iRAP model considers 5 crash types for vehicle occupants, 6 crash types for motorcyclists; 3 crash types for bicyclists and 3 crash types for pedestrians as previously shown in Table 2.4, (iRAP, 2013). This was in relation to the likelihood or severity of a crash based on the impact the type of road attributes present or absent, from the road infrastructure affected the road user, (Lynam, 2012).

As an example of star rating score equations for road user types, the equation for pedestrians is presented. This is to demonstrate and explain the equations used in calculating the star rating scores all road user types in the iRAP model.

The equation for pedestrian road user type according to iRAP (2014) is as follows:

$$Pedestrian\ SRS = \Sigma\ Crash\ type\ scores \tag{2.3}$$

Where *Pedestrian SRS* = the score for the relative risk of death and serious injury for pedestrians.

And it follows then that from equation 2.2 and expanding equation 2.3

$$Crash\ type\ scores = A + (CIR) + (CSR) \tag{2.4}$$

Where *A = Along score* = the score for the relative risk of death and serious injury to a pedestrian walking along the roadway

(CIR) = Crossing score for inspected road = the score for the relative risk of death and serious injury to a pedestrian while crossing the inspected road

(CSR) = Crossing score for side road = the score for the relative risk of death and serious injury to a pedestrian while crossing from a side road

Also presented as an example is the along crash type score equation representing the calculation

CHAPTER 2 Literature review

of one crash type for pedestrians. This is as demonstrated in equation 2.2 and further in equation 2.4. This is representative of the equations used for all crash type scores within the iRAP model as described according to iRAP (2014).

The equation for the along crash type score is as follows:

$$\text{Along score} = L \times S \times (OS) \times (EFI) \quad (2.5)$$

$$\begin{aligned} \text{Also } L = \text{Likelihood} &= (Sw) \times C \times (QC) \times (SD) \times (LW) \times D \times G \times (RC) \times (SM) \text{ or } (TC) \\ &\quad \times (VP) \times (SRss) \times (SL) \times (SZwg) \quad (2.6) \end{aligned}$$

Where <i>(Sw)</i>	= Sidewalk
<i>C</i>	= Curvature
<i>(QC)</i>	= Quality of curve
<i>(SD)</i>	= Sight distance
<i>(LW)</i>	= Lane width
<i>D</i>	= Delineation
<i>G</i>	= Grade
<i>(RC)</i>	= Road condition
<i>(SM) or (TC)</i>	= Traffic calming
<i>(VP)</i>	= Vehicle parking
<i>(SRss)</i>	= Shoulder rumble strips
<i>(SL)</i>	= Street Lighting
<i>(SZwg)</i>	= School zone warning
And <i>S= Severity</i>	= Sidewalk present or absent

CHAPTER 2 Literature review

(OS) = Operating speed = factors related to the level of risk associated with changes in speed

(EFI) = External flow influence= factors related to the level of risk associated with a person being involved in a crash as a result of another person's use of the road

As discussed in section 2.8.7, the introduction of a new road user type was needed for crashes that occur at public transport facilities such as bus shelters and transport centres. This is based on the iRAP methodology and its model application processes as shown in Table 2.4, (iRAP, 2013). Similarly, in considering the new road user type, the development of a new star rating equation was also needed, (iRAP, 2014).

In this way the iRAP model was being expanded to include a new road user type, a new star rating equation and new crash type equations as shown in Table 2.6. And moreover, a new method of assessment for public transport facilities such as bus shelters and transport centres, not previously carried out by existing iRAP models, (iRAP, 2013).

Table 2.6 Crash initiation modes and crash type for new road user type modified by Uter (2018) and obtain from iRAP (2013)

Initiation mode	Contributing factor	Crash type	Example
A public transport pedestrian user is walking along the road in a transport centre (on pavement)	A vehicle is present	Public transport pedestrian user along (on pavement in a transport centre)	See Figure 2.7
A public transport pedestrian user is crossing the road in a transport centre	A vehicle is present	Public transport pedestrian user crossing (road in a transport centre)	See Figure 2.7

CHAPTER 2 Literature review

Table 2.6 (Continued)

Initiation mode	Contributing factor	Crash type	Example
A public transport pedestrian user is standing or waiting at a bus shelter or in a transport centre and a vehicle departs from the lane (loss of control) and mounts the platform or sidewalk	There is no oncoming vehicle present and a public transport pedestrian user is on the platform or sidewalk at a transport centre or bus shelter	Public transport pedestrian user along (standing or waiting at a bus shelter or transport centre)	See Figure 2.8

The crash types discussed in Table 2.6 are illustrated in Figure 2.7 and Figure 2.8. This illustration represents the crash types as they occur in the traffic environment. And moreover, is a representation of the crash types in accordance with iRAP’s risk assessment models for existing crash types. The following illustrations demonstrates the risk assessment for public transport pedestrian users at public transport facilities as follows:

CHAPTER 2 Literature review

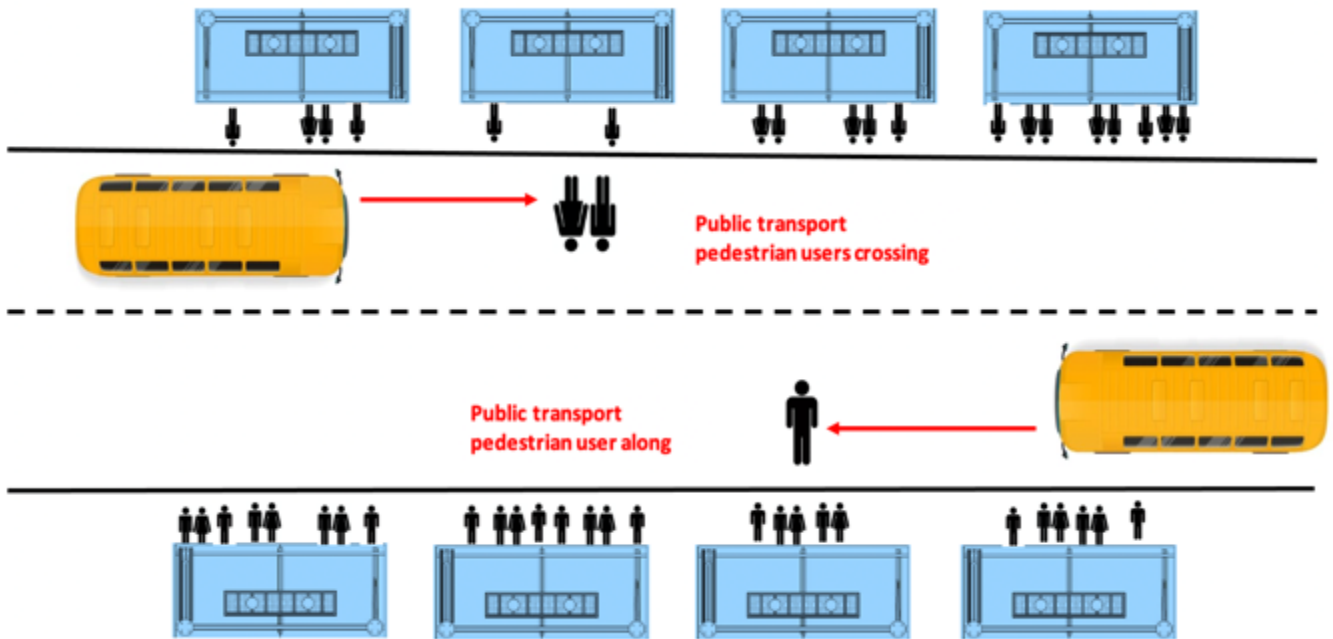


Figure 2.7 Public transport pedestrian user moving along or across the road in a transport centre. Modified by Uter (2018) and obtained from iRAP (2013)

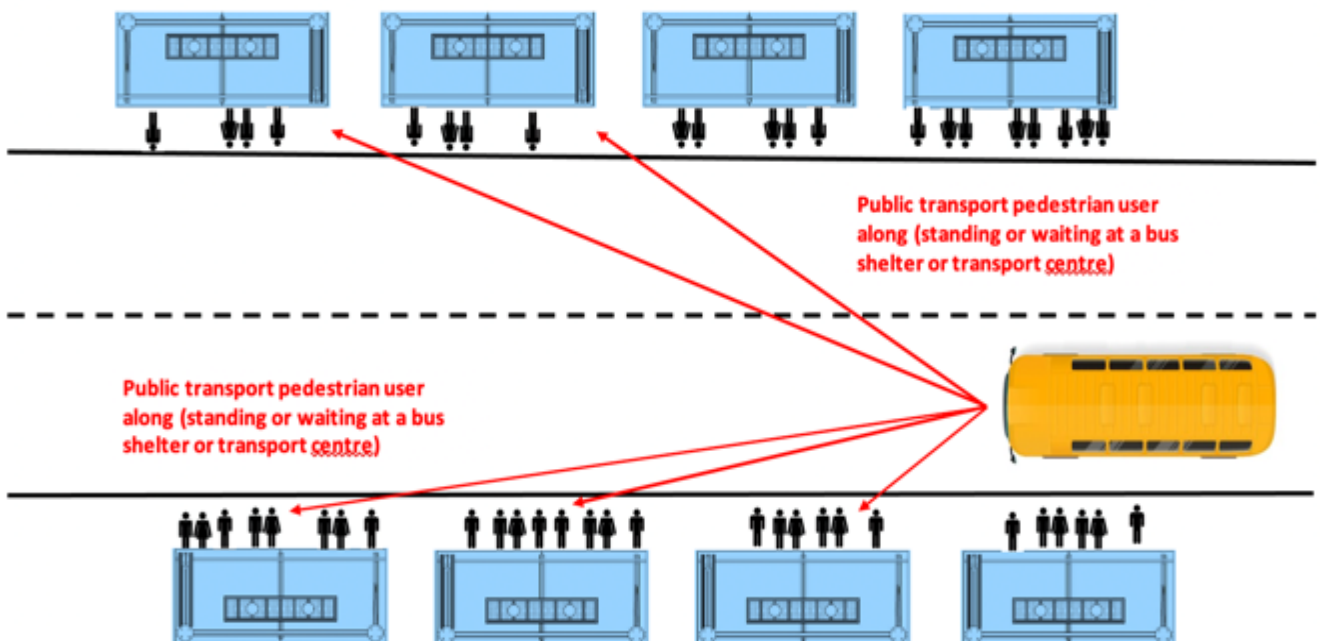


Figure 2.8 Public transport pedestrian user standing or waiting at a bus shelter or transport centre. Modified by Uter (2018) and obtained from iRAP (2013)

CHAPTER 2 Literature review

The new road user type and crash types were determined as discussed in *Section 2.8.3*, *Section 2.8.4*, and with further discussions in Chapter 3. Therefore, the road user type identified from the analysis of crash data was included in fatality estimation and casualty equation as discussed in *Section 2.8.10*. And in particular, in the assessment of data as shown in Table 3.5 and star ratings model equations as represented by Equation 2.7 to Equation 2.11. This was to be consistency with existing iRAP models, in development, application, adaptation and implementation in low to middle-income countries, (iRAP, 2014).

Table 2.7 Crash types included for the new road user type public transport pedestrian users

New road user type	Crash types		
Public transport pedestrian users	Along (on pavement in a transport centre)	Crossing (road in a transport centre)	Along (standing or waiting at a bus shelter or transport centre)

Three crash types were determined for the new road user type for public transport facilities as shown in Table 2.7. This was according to similar crash initiation modes used for existing iRAP star rating models. The crash initiation modes for public transport pedestrian users were shown in Table 2.6, Figure 2.7 and Figure 2.8, (iRAP, 2013).

The new star ratings equations for public transport pedestrian users are as follows:

$$Public\ transport\ Pedestrian\ users\ SRS = \sum\ Crash\ type\ scores \quad (2.7)$$

Where *Public transport Pedestrian users SRS*=the score for the relative risk of death and serious injury for public transport pedestrian users.

$$And\ Crash\ type\ scores = A + C + (AS)\ or\ (AW) \quad (2.8)$$

CHAPTER 2 Literature review

Where $A = \textit{Along score}$ = the score for the relative risk of death and serious injury to a public transport pedestrian user walking along the pavement in a public transport facility such as a transport centre

$C = \textit{Crossing score}$ = the score for the relative risk of death and serious injury to a public transport pedestrian user while crossing in a public transport facility such as a transport centre

$(AS) = \textit{Along score (Standing)}$ = the score for the relative risk of death and serious injury to a public transport pedestrian user while standing at a public transport facility such a bus shelter or transport centre

$(AW) = \textit{Along score (Waiting)}$ = the score for the relative risk of death and serious injury to a public transport pedestrian user while waiting at a public transport facility such a bus shelter or transport centre

Also presented as an example is the along score equation used for calculating one crash type score for public transport pedestrian users. It is to be noted that for the along crash type score, the driver and passenger sides are to be calculated separately, (iRAP, 2014).

The representative equations for the along crash types score for public transport pedestrian users is as follows:

CHAPTER 2 Literature review

$$\text{Along score} = L \times S \times (OS) \times (EFI) \times (PT) \text{ or } (ST) \quad (2.9)$$

$$\begin{aligned} \text{Also } L = \text{Likelihood} &= (Sw) \times (QC) \times (SD) \times (LW) \times D \times G \times (RC) \times (SM) \text{ or } (TC) \\ &\times (VP) \times (SRss) \times (SL) \times (RF) \times (RD) \times (RO) \times (TFL) \times (KH) \\ &\times PF \times (PT) \text{ or } (PQ) \quad (2.10) \end{aligned}$$

Where (Sw)	= Sidewalk
(QC)	= Quality of curve
(SD)	= Sight distance
(LW)	= Lane width
D	= Delineation
G	= Grade
(RC)	= Road condition
(SM)	= Speed management
(TC)	= Traffic calming
(VP)	= Vehicle parking
(SRss)	= Shoulder rumble strips
(SL)	= Street Lighting
(RSF)	= Roadside fiction
(RD)	= Road drainage
(RSO)	= Roadside object
(TFL)	= Transport facility lighting
(KH)	= Kerb height
(PF)	= Pedestrian fencing

CHAPTER 2 Literature review

(KH) = Kerb height

(PT) = Platform type

(PQ) = Platform quality

And $S = \text{Severity} = (PFQ) \times (PT) \text{ or } (PQ) \times (SM) \text{ or } (TC) \times (Sw)$ (2.11)

Where *(PFQ)* = Pedestrian fencing quality

(PT) = Platform type

(PQ) = Platform quality

(SM) = Speed management

(TC) = Traffic calming

(Sw) = Sidewalk

And *(OS) = Operating speed* = factors related to the level of risk associated with changes
in speed

(EFI) = External flow influence = factors related to the level of risk associated with a
person being involved in a crash as a result of another person's
use of the road

(PT) = Platform traversability = factors related to the probability of a
public transport pedestrian user being hit by an
errant vehicle mounting the transport facility
platform

CHAPTER 2 Literature review

$(PS) = \text{Sidewalk traversability} = \text{factors related to the probability of a}$

public transport pedestrian user being hit by an

errant vehicle mounting the transport facility

sidewalk

2.8.10 Casualty estimation and calibration

Casualty estimation and calibration equations are used to determine the total number of fatalities based on the number road crashes on the road network based on its condition, (Lynam, 2012). The equations are used as part of the safer road investment plans (SRIP) to assess the best economic benefit to be gained from the implementation of countermeasures aimed at crash reductions. Furthermore, casualty estimation and calibration equations are based on fatality estimation equations that determine the number of fatalities for all road user group, (iRAP, 2014).

The equations of each crash type, for each road user group were calculated separately to determine the number of fatalities that occur within each situation. Moreover, the equations also considered crash types based on the impact on each road user type, (iRAP, 2014). It follows then that calibration is achieved by comparison between road sections of similar design and similar star ratings. Yet, calibration factors are introduced to collaborate the total number of road crashes. In this way, the actual number of road crash fatalities and serious injuries that occurred in relation to the number of crashes that occurred on the road network is determined, (Lynam, 2012).

Mean speed calculations are also accounted for based on location and its influence on road crashes. Therefore, when applied across the road network, the total number of serious injuries was also determined. Following this, the appropriate countermeasures were implemented to reduce road crash fatalities and serious injuries, (Lynam, 2012). On that account, the outcome of the countermeasure was dependent on the crash reporting and data collection methods in the country where the road network was being assessed. It follows then, that the total number of road crash fatalities and serious injuries were determined based on the implementation of the iRAP methodology within its parameters, (iRAP, 2014).

CHAPTER 2 Literature review

Fatality estimations equations for public transport pedestrian users were developed based on existing iRAP model fatality estimation formulae for consistency. The road user types used by existing iRAP models in existing fatality estimation formulae focused on vehicle occupants, motorcyclist, pedestrians and bicyclist. The following formula demonstrates the inclusion of public transport pedestrian users in existing iRAP crash allocation model equations as follows:

The total number of fatalities F_{Total} on a road in a year is as follows:

$$F = \sum_{n=1}^n (VO_F + MC_F + P_F + B_F + PTPU_F) \quad (2.12)$$

where:

F = fatalities

n = the number of 100 metre segments of road

VO_f = vehicle occupants fatalities

MC_f = motorcyclists fatalities

P_f = pedestrians fatalities

B_f = bicyclists fatalities

$PTPU_f$ = public transport pedestrian users fatalities

The number of public transport pedestrian commuter fatalities ($PTPU_{Fatalities}$) on a 100 metre segment of road in a year was as follows:

$$PTPU_F = PTPU_{A-D} + PTPU_{A-P} + PTPU_C + PTPU_{A(S/W)} \quad (2.13)$$

where:

$PTPU_{A-D}$ = public transport pedestrian user along (driver side) fatalities

$PTPU_{A-P}$ = public transport pedestrian user along (passenger side) fatalities

$PTPU_C$ = public transport pedestrian user crossing fatalities

$PTPU_{A(S/W)}$ = public transport pedestrian user along (standing/waiting at fatalities)

CHAPTER 2 Literature review

The number of public transport pedestrian user along fatalities ($PTPU_A$) on a 100 metre segment of road in a year was as follows:

$$PTPU_{A-D} = SRS_{A-D} \times a (AADT_{PTPU})^b \times CF_{PTPU\ A-D} \times 365 / 10^9 \quad (2.14)$$

where:

SRS_{PTPU} = Star rating score for public transport pedestrian users

a = $AADT_{PTPU}$ multiplier

$AADT_{PTPU}$ = annual average daily traffic (or public transport pedestrian users flow) for public transport pedestrian users on the carriageway

b = $AADT_{PTPU}$ power

$CF_{PTPU\ A-D}$ = Calibration factor for public transport pedestrian users along (driver side) crash fatalities

$$PTPU_{A-P} = SRS_{A-P} \times a (AADT_{PTPU})^b \times CF_{PTPU\ A-P} \times 365 / 10^9 \quad (2.15)$$

where:

SRS_{PTPU} = Star rating score for public transport pedestrian users

a = $AADT_{PTPU}$ multiplier

$AADT_{PTPU}$ = annual average daily traffic (or public transport pedestrian users flow) for public transport pedestrian users on the carriageway

b = $AADT_{PTPU}$ power

$CF_{PTPU\ A-P}$ = Calibration factor for public transport pedestrian user along (passenger side) crash fatalities

The number of public transport pedestrian user crossing fatalities ($PTPU_C$) on a 100 metre segment of road is a year is as follows:

$$PTPU_C = SRS_C \times a (AADT_C)^b \times CF_{PTPU\ C} \times 365 / 10^9 \quad (2.16)$$

CHAPTER 2 Literature review

where:

SRS_{PTPU} = Star rating score for public transport pedestrian users

a = $AADT_{PTPU}$ multiplier

$AADT_{PTPU}$ = annual average daily traffic (or public transport pedestrian user flow) for public transport pedestrian users on the carriageway

b = $AADT_{PTPU}$ power

CF_{PTPUC} = Calibration factor for public transport pedestrian user crossing crash fatalities

The number of public transport pedestrian user along (standing/ waiting at fatalities) ($PTPU_{A(S/W)}$) on a 100 metre segment of road is a year is as follows:

$$PTPU_{A(S/W)} = SRS_{A(S/W)} \times a (AADT_{A(S/W)})^b \times CF_{PTPUC} \times 365 / 10^9 \quad (2.17)$$

where:

SRS_{PTPU} = Star rating score for public transport pedestrian users

a = $AADT_{PTPU}$ multiplier

$AADT_{PTPU}$ = annual average daily traffic (or public transport pedestrian user flow) for public transport pedestrian users on the carriageway

b = $AADT_{PTPU}$ power

$CF_{PTPU A(S/W)}$ = Calibration factor for public transport pedestrian user standing/ waiting crash fatalities.

The calibration of the equations for, public transport pedestrian users at public transport facilities was done for consistency with existing iRAP model equations. The calibration methodology was based on determining that number of crashes on the road network that reflected the actual number of fatalities in the crash database. The methodology focused on the risks factors that influenced the fatality or serious injury of public transport pedestrian users at public transport facilities, (iRAP, 2014).

CHAPTER 2 Literature review

The calibration factor formula to include the new road user type, public transport pedestrian users along (PTPU_A) crash fatalities was defined as follows:

$$CF_{PTPU\ A-D} = \frac{\text{Actual number of public transport pedestrian users along (driver side) crash fatalities on the road network}}{\sum^n_{i=1}} = (SRS_{A-D} \times a \times (AADT)^b \times PT_{PTPU} \times FG) \quad (2.18)$$

where:

$CF_{PTPU\ A-D}$ = Calibration factor for public transport pedestrian user along (driver side) crash fatalities

n = the number of 100 metre segments of road

SRS_{PTPU} = Star rating score for public transport pedestrian users

a = AADT multiplier

$AADT$ = annual average daily traffic

b = AADT power

PT_{PTPU} = public transport pedestrian users AADT

FG = fatality growth exponent

And

$$CF_{PTPU\ A-P} = \frac{\text{Actual number of public transport pedestrian users along (passenger side) crash fatalities on the road network}}{\sum^n_{i=1}} = (SRS_{A-P} \times a \times (AADT)^b \times PT_{PTPU} \times FG) \quad (2.19)$$

where:

$CF_{PTPU\ A-P}$ = Calibration factor for public transport pedestrian user along (passenger side) crash fatalities

n = the number of 100 metre segments of road

SRS_{PTPU} = Star rating score for public transport pedestrian users

CHAPTER 2 Literature review

a = AADT multiplier

$AADT$ = annual average daily traffic

b = AADT power

PT_{PTPU} = public transport pedestrian users AADT

FG = fatality growth exponent

The calibration factor formula to include public transport pedestrian users crossing (PTPUC) crash fatalities was defined as follows:

$$CF_{PTPUC} = \text{Actual number of public transport pedestrian user crossing crash fatalities on the road network} / \sum_{i=1}^n (SRS_C \times a (AADT)^b \times PT_{PTPU} \times FG) \quad (2.20)$$

where:

CF_{PTPUC} = Calibration factor for public transport pedestrian user crossing crash fatalities

n = the number of 100 metre segments of road

SRS_{PTPU} = Star rating score for public transport pedestrian users

a = AADT multiplier

$AADT$ = annual average daily traffic

b = AADT power

PT_{PTPU} = public transport pedestrian users AADT

FG = fatality growth exponent

CHAPTER 2 Literature review

The calibration factor formula to include public transport pedestrian users along (standing/ waiting) ($PTPU_{A(S/W)}$) crash fatalities was defined as follows:

$$CF_{PTPU_{A(S/W)}} = \frac{\text{Actual number of public transport pedestrian users along (standing/ waiting) crash fatalities on the road network}}{\sum_{i=1}^n (SRS_{A(S/W)} \times a (AADT)^b \times PT_{PTPU} \times FG)} \quad (2.21)$$

where:

$CF_{PTPU_{A(S/W)}}$ = Calibration factor for public transport pedestrian user along (standing/ waiting) crash fatalities

n = the number of 100 metre segments of road

SRS_{PTPU} = Star rating score for public transport pedestrian user

a = AADT multiplier

$AADT$ = annual average daily traffic

b = AADT power

PT_{PTPU} = public transport pedestrian users AADT

FG = fatality growth exponent

The existing iRAP serious injuries model equation uses fatality numbers that includes the new road user type, based on Equation 2.12 for public transport pedestrian users at public transport facilities. The total number of serious injuries was therefore based on the total number of fatalities per 100m of roadway being assessed.

The existing serious injuries equations that now includes public transport pedestrian users was defined as follows:

$$SI = \frac{\text{number of fatalities calculated in equation (2.12)} \times \text{actual number of serious injuries in the jurisdiction}}{\text{actual number of fatalities in the jurisdiction}} \quad (2.22)$$

CHAPTER 2 Literature review

and

$$SI_{TOTAL} = \sum_{i=1}^n (SI) \quad (2.23)$$

where:

n= number of 100 metre segments

and

The total number of fatalities and serious injuries (FSI_{TOTAL}) is:

$$FSI_{TOTAL} = F_{TOTAL} + SI_{TOTAL} \quad (2.24)$$

2.8.11 Countermeasures in iRAP

The application of countermeasures in iRAP is based on the assessment of the road network and the data collected using iRAP methodology. Therefore, road attributes data was representative of the level of risk faced by road users and the appropriate countermeasures were selected based on the one that would bring the most economic benefit, (Lynam, 2012). The iRAP methodology uses iRAP's approach to road surveying to increase the accuracy of data collection, and moreover to determine the influence a road attribute has on the safety of road users, (Lynam, 2012).

Data obtained using risk maps guides the process of choosing appropriate countermeasures that are aimed at yielding crash reductions. Within iRAP there are 94 countermeasures aimed at achieving crash reductions to various crash sites. Based on the type of crashes that affect public transport pedestrian users, the 94 countermeasures in iRAP were analyzed to determine their appropriateness. The outcome of the application of countermeasures however was dependent on the circumstances that led to the crash, (iRAP, 2013f).

2.8.12 Economic analysis

Economic analysis equations are used in iRAP to optimize appropriate countermeasures based on constrained budgets. These were adopted from (McHahon and Dahdah, 2008) and the outcome was expected to yield the best benefit cost ratio results. This adaptation was based on the lack of evidence to support the value of human life. The rule of thumb referred to in (McHahon and

CHAPTER 2 Literature review

Dahdah, 2008) places the statistical value of a human life at 60 to 80 times gross domestic product (GDP) per capita, (iRAP, 2013).

This was equivalent to the current price for the country where the analysis was being conducted. It assumes that 10 serious injuries will occur for each crash fatality and the value of a serious injury was equivalent to 25% of the statistical value of a human life. That is, this considered the present value of economic benefit for each 100m road section in a budget year and over the analysis period. It takes into account the economic benefit of preventing road crash fatalities and serious injuries. And as a result, the relationship to the number of lives saved and serious injuries prevented, (iRAP, 2013).

The economic benefit equations are as follows:

$$\begin{aligned} \text{Economic benefit} &= [\textit{number of fatalities prevented} \times 70 \times \textit{GDP per capita (current price)}] + [\textit{number of serious injuries prevented} \times 0.25 \times 70 \\ &\qquad \qquad \qquad \textit{GDP per capita (current price)}] \end{aligned} \tag{2.25}$$

$$\begin{aligned} \text{Present value economic benefit per 100m road section (given year)} &= \textit{economic benefit for 100m road section} / (1+r)^{\textit{year}} \end{aligned} \tag{2.26}$$

where r = discount variable rate

$$\begin{aligned} \text{Present value economic benefit per 100m road section (analysis period)} &= \sum_i^n \textit{present value economic benefit per 100m road section (given year)} \end{aligned} \tag{2.27}$$

where n = number of years in analysis period (usually 20 years)

$$\begin{aligned} \text{Present value economic benefit all 100m road section (analysis period)} &= \sum_i^n \textit{present value economic benefit per 100m road section (analysis period)} \end{aligned} \tag{2.28}$$

CHAPTER 2 Literature review

where n = number of 100m sections

The economic cost is also determined based on the cost of construction and expected functional performance data of the countermeasure in a budget year with present value analysis (iRAP, 2013). The equation is as follows:

$$\text{Present value economic cost per 100m road section (given year)} = \frac{\text{total countermeasure cost per 100m road section}}{(1+r)^{\text{year}}} \quad (2.29)$$

also $\text{total countermeasure cost} = \frac{\text{the sum of construction/reconstruction costs for countermeasure selected}}{\text{measure selected}} \quad (2.30)$

where r = discount variable rate

$$\text{Present value economic cost per 100m road section (analysis period)} = \sum_i^n \text{present value economic cost per 100m road section (given year)} \quad (2.31)$$

where n = number of years in analysis period (usually 20 years)

$$\text{Present value economic cost all 100m road section (analysis period)} = \sum_i^n \text{present value economic cost per 100m road section (analysis period)} \quad (2.32)$$

where n = number of 100m sections

The benefit cost ratio is determined based on the present value economic benefit and present value economic costs. This can be calculated for single or multiple countermeasures for each 100m road section in a given year or analysis period (iRAP, 2013).

CHAPTER 2 Literature review

The equation for benefit cost ratio is as follows:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{present value economic benefit}}{\text{present value economic cost}} \quad (2.33)$$

The benefit cost ratios obtained, were then compare to the benefit cost ratio threshold to determine optimal investment opportunities. The BCR threshold was be predetermined based on the available budget to prioritize countermeasures. Countermeasures with BCR that do not surpass the BCR threshold were not considered for SRIP. In Figure 2.9 an example of the economic cost and economic benefit for different thresholds are shown. This demonstrates that affordable investment plans can be produced from countermeasures with high BCR thresholds, (iRAP, 2013).

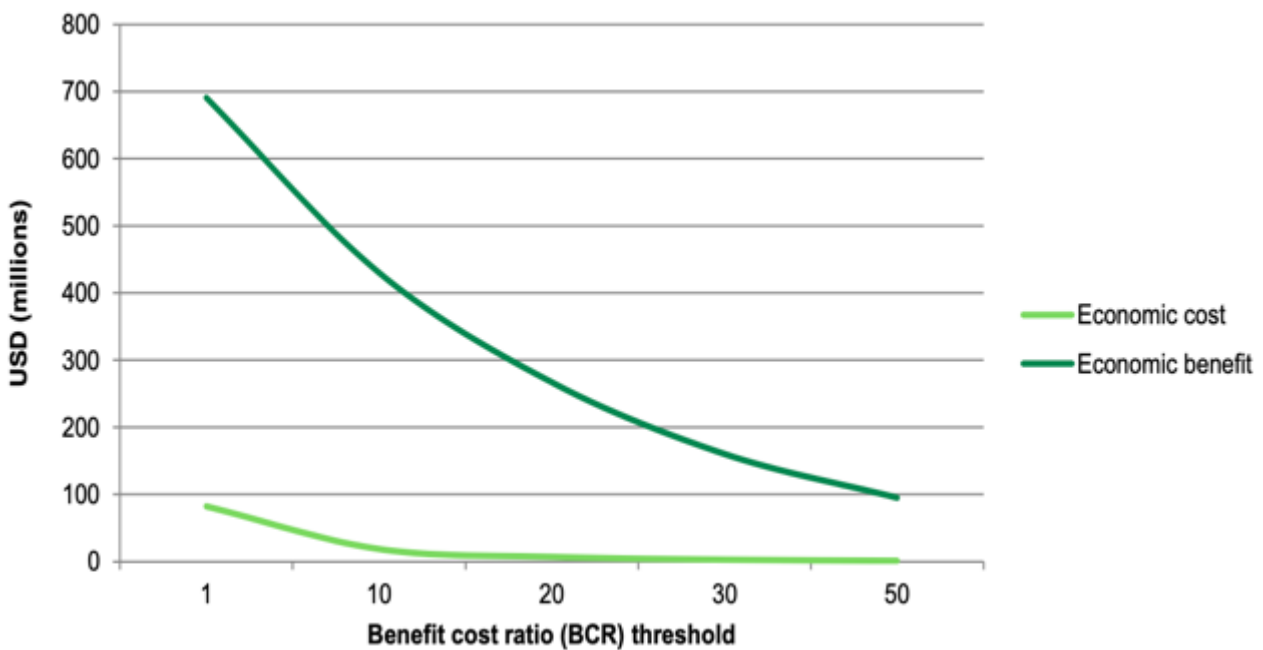


Figure 2.9 Economic costs and benefits for different BCR thresholds. Modified by Uter (2018) and obtained from iRAP (2014)

Based on the economic assessment used for iRAP's model development process for existing countermeasures, the countermeasures for public transport facilities would be assessed in the same way. However, it is to be noted that the economic assessment within iRAP was carried out for the actual implementation of the SRIP over a period of time based on the past performance and research carried out on existing countermeasures.

CHAPTER 2 Literature review

Therefore, for the purpose this research project, the proposed economic benefit would not be reasonably determined until the actual implementation of the proposed countermeasures for public transport pedestrian users.

Hence the theoretical application of the economic benefit cost equation as shown in Equation 2.25 to Equation 2.33 would apply. At the same time this would only take into consideration countermeasures where research was available and already proven to yield predetermined crash reduction based on performance over time. As a result, countermeasures recommend would also need to be tested over time to determine their performance in reducing the number of road crashes.

Therefore, an economic assessment of the countermeasures would not be practical at this time based on the scope and limitations of this research project. Notwithstanding, based on the performance of other countermeasures in iRAP it is assumed that there would be a reduction in road crash fatalities. This was also based on which countermeasure was the most economical and effective at improving the safety of public transport pedestrian users. The economic assessment process for public transport pedestrian users would also consider the benefit cost ratio's for comparisons with the benefit cost ratio threshold according to the iRAP methodology for implementation, (iRAP, 2013).

But at the same time an alternative economic assessment process could be applied for the purpose of this research project as a reasonable option to the iRAP economic assessment process. This alternative recommendation would be the economic assessment for the First-year rate of return (FYRR) used for schemes in road safety engineering. The economic assessment for FYRR is recommended based on its application that allows for an estimated per cent reduction in road crashes for the countermeasure to be implemented. The FYRR economic assessment process is as follows:

$$\text{FYRR (\%)} = \text{annual accident saving} \times 100 / \text{Scheme cost (countermeasure cost)} \quad (2.34)$$

CHAPTER 2 Literature review

where

Annual accident savings =

[((#of accidents x estimated % reduction based on scheme) / target period) x average cost of an injury: including allowance for damage only]

and

Scheme cost = Cost of constructing and implementing the scheme or countermeasure

2.9 Needs-based approach

Needs in regard to road safety has been discussed in research to varying degrees. In Papadimitriou and Yannis (2014), the analysis of needs was discussed with specific reference to the priorities of stakeholders in road safety for making evidence-based decisions. Needs in regard to road safety was also discussed in (Dupont *et al.* 2012). According to Dupont *et al.* (2012), experts agree that a concerted effort was needed to make scientific evidence-based decisions a requirement for road safety. Also discussed in SWOV (2010), needs were considered linked to achieving sustainable road safety. This was achieved by providing for the needs of the current generation without harming their ability to provide solutions to their own needs in the future, (UA, 2012).

Needs as stated in WHO (2013) and Wittink (2001), refers to road safety mobility and pedestrians from the perspective of engaging in a safety analysis for specific road users. According to Watkins *et al.* (2012), assessing needs is an essential tool in data collection and decision making. As part of the assessment process, a needs-based approach with the use of data from the study area was used to determine the safety needs of public transport pedestrian users in the traffic environment. This approach was aimed at developing a system that provides logical steps for assessing the data collected using the iRAP methodology for a specific road user. The information was assessed to determine the level safety built into the road infrastructure for public transport pedestrian users.

A needs assessment is carried out before implementing an action as a decision support tool. It is also done to develop a strategic approach for activities already implemented to achieve specific outcomes, (Watkins *et al.* 2012). Whether the assessment is used as a decision support tool or to gain a strategic advantage. The aim is to determine the need, the triggers associated

CHAPTER 2 Literature review

with need and the options available to address the need. The assessment is done in relation to those affected and the appropriate decisions made based on an established set of criteria's, to achieve the desired outcome, (Watkins *et al.* 2012). The process is considered as a careful assessment of the gaps between the existing situation and the desired situation that represents the need.

This careful assessment results in identifying actions that provide options to bridge the gap in the data presented. The available options provide a decision support tool to fill the need, (Watkins *et al.* 2012). The development of a needs analysis that focuses on road safety was seen as introducing a systematic investigative approach, to determine the needs of road users within the traffic environment, (Watkins *et al.* 2012). This is based on the determination that the assessment of the need, was established on targeting problems and solving them, (McKillip, 1987).

Each road user has a different need within the traffic environment. This need affords each road user the ability to use the road safely and to be safe on the road. The needs analysis will assess the road infrastructure to determine its impact on road use. This is to identify the problems at the interface of the road infrastructure and public transport facilities as well as the interactions between road users. With the use of data collected using the iRAP methodology, informed decisions can be made to fill the gaps in relation to the current use of the network, (Watkins *et al.* 2012).

The aim of the principles of the needs analysis process was to identify the mobility problems that existed within the study area. According to Wittink (2001) problems associated with mobility were related to the level on integration of the different modes associated with movement of road users in the design envelope of the road infrastructure. The present design practices in Jamaica, other low to middle-income countries and in some developed countries, primarily allows for road design features that give preference to vehicular transport. This in most cases excluded two-wheel modes of transport and vulnerable road users such as pedestrians, (iRAP, 2013).

According to Cadar *et al.*, (2016), travel behavior of road users was generally influenced by the level of mobility and determined the modal choice based on economic conditions and the design of the traffic system. In determining the mobility problems that exist for road users,

CHAPTER 2 Literature review

each 100m segment of roadway was assessed according the design standards and the iRAP road safety toolkit. The comparison of the data collected and the design standards in iRAP road safety tool kit was aim at revealing the type of mobility problems that exists.

The mix of road users and land use activities within the design envelope of the road environment also determined the type of road crashes and its current use. Therefore, the mix of road users should guide the approach to infrastructure design, (iRAP, 2013). The design of the road infrastructure and its ability to meet road user expectations, also depended on the level of road safety maturity. This was in addition to the proactive nature of the management system implemented by road safety authorities, (WHO, 2004). The road safety situation that existed in most low to middle-income countries showed similarities however differed in comparison to high - income countries based on the level of road safety maturity, (iRAP, 2013).

In addition, the principles of the needs analysis also determined the suitability of the road network within the study area for public transport pedestrian users by assessing safety needs. In particular, the Decade of action for road safety implemented a global plan addressed key issues for suitability of use. That is, the design and implementation of suitability for use were based on the role of authorities with oversight for road safety. And therefore, the level of service provided to road users was a measure the road network's performance. To the extent where road user expectations, road user satisfaction and road crash statistics were seen as a by-product of the suitability for use, (iRAP, 2013).

However, it was the expectation that road users would use the road in a safe manner and that operators of the road network would incorporate a safe system design approach that protects road users. The provision of adequate road infrastructure also depended on road safety maturity of the organization with oversight for road safety and road design and its available budget, (WRA, 2018). According to the World Road Association (2018), the need of road users can be summarized as follows:

CHAPTER 2 Literature review

Summary of the needs of road users

- Efficient traffic flow
- Efficient transportation network
- Reduced road traffic crashes
- Efficient traffic flow through road improvement sites
- Intelligent transport systems that allow for good travel decisions
- Level of driving comfort

Road user interactions within the traffic environment can be very complex. The various interactions that occurred were dynamic and unpredictable, based on the mix of road users, their demographic nature and road user types. The combination of the interactions between road users are also limitless and are influenced by personality types, modes of travel and the design of the road infrastructure, (Charlton and Bass, 2002).

Moreover, road users of different characteristics all use the roadway at the same time and have different road use patterns, travel by different modes; have different perceptions of risk and interpret the road environment differently, (Charlton and Bass 2002). The demographic makeup of road users can be classified for example as follows:

Road user demographics

- Age
- Gender
- Social background
- Race
- Level of experience

The demographic of road users can also be spread across different road user types as follows:

Road users

- Vehicle occupants
- Motorcyclists
- Bicyclists
- Pedestrians

CHAPTER 2 Literature review

Even more the situation was further complicated by the different modes of transport based on size, speed of travel and the vulnerability of some road users when compared to others. The ethical nature of road users and their interpretation of the road environment also made road use even more complex by the availability of appropriate facilities. The time spent in the traffic system and distance travelled were also other factors that contributed to the unpredictable nature of what occurred on the road network, (Charlton and Bass, 2002).

According to WHO (2004), road designers should take a more humanistic approach to designing forgiving road infrastructure to save lives. A softer approach to the design of road infrastructure, would mean safer roads all road users. The safe design approach is aimed at taking into account the errors that could be made by road users, based on the dynamic mix and unpredictable nature of the traffic environment, and minimizing them, (Sweden Sverige, 2018).

2.10 Information quality level (IQL)

Information quality levels (IQL) is a process of collecting and using data. IQL was introduced by the World Bank and was utilized for road management programmes. This was to ensure that the right amount of data was collected in relation to those who intend to use it. The IQL concept was also aimed at reducing the costs associated with the collection of data and to increase the efficiency of data collection and management. The data collected within IQL considered 4 levels of information, that is IQL-I, IQL-II, IQL-III and IQL-IV. Each level of information was based on its application to road management programmes, and to appeal to different levels of management. The different management levels in turn used the data to plan the various programmes in relation to their role in the management cycle, (Robinson et al., 1998).

The application of the IQL concept to road management programmes and the process involved in its application, was considered as a method of data collection and processing that could be adopted and applied to this research project. The use of the IQL concept for this research project looked at the type of data that coincided with this research. The data collected at IQL-I consists of the highest level of detail for data collection. It represents a detailed data collection process that is used by implementers of policies on the ground. The use of this level of detailed data requires trained staff and sometimes specialized equipment that would be used to plan and implement programmes on the ground, (Robinson, R. et al., 1998). The level of detailed data collection and processing required at IQL-I was suited for collecting road attributes data using

CHAPTER 2 Literature review

the iRAP methodology from primary sources as discussed in Chapter 3. The data obtained from IQL-I can be used to extract data for IQL-II, IQL-III and IQL-IV as needed to meet data requirements.

2.11 Public transportation facilities

Transportation may be considered as one of the sectors that can impact economic growth, poverty reduction and the environment, (CSIR, 2005). The development of transport systems such as land, air, sea, inland waterways and pipelines, to deliver goods and services, may depend on the country and its social and political background. The method of delivery for these transport systems, in particular public transportation, may largely depend on the public or private sectors. These systems may be formal or informal as well as incorporate established public private partnerships (PPP), (World bank, 2010).

Public transportation may also be considered as a means of reduce the costs associated with private motor vehicle ownership. However, this may only be seen as a reasonable means of alternative transportation, if the transport system can meet the needs and expectations of its customers, (Cheng, 2015). At the interface of the transit system is its infrastructure and facilities. This determines the level of safety afforded to public transport pedestrian users while using these facilities. The location, reliability, safety, accessibility and condition of these facilities has an impact on commuters. They determine whether commuters see the transit system as a viable means of alternative transport. An efficient, safe and comfortable transit system thus seeks to break the vicious cycle that exists between the need for private car ownership versus the negative perception of bus transit, (TRB, 2015).

The urban transport system in Jamaica mainly focuses on the Kingston Metropolitan Transport Region (KMTR). This comprises of Kingston, St. Catherine, St. Andrew, (MLG, 2015). These three parishes account for approximately 1/3 of Jamaica's population and approximately 60 per cent of all road crashes, (World Bank, 1984). Over the last three decades however, this has changed. The parishes of Kingston, St. Andrew and St. Catherine now account for 45 per cent of the country's population and a higher percentage road crashes and fatalities, (StatinJ, 2014). Research carried out by the World Bank in 1984 revealed that the KMTR formerly identified by the World Bank as the Kingston Metropolitan Region (KMR), had approximately 1440km

CHAPTER 2 Literature review

of roads. Of the total, 169 km are main roads and an estimated 909km are designated as bus routes, (World Bank, 1984).

According to the World Bank (1984), the public transport system in Jamaica had 4000 registered vehicles. This included both bus and taxi operators. It was estimated at the time, that the transport system handled approximately 1.6 million commuter trips on a daily basis. The urban transport system however had shown significant deficiencies in meeting the needs and expectations of its customers. In addition, the locations of most bus shelters were estimated to be 274m from most homes and the condition of these facilities was considered to be poor. These facilities were serviced by an unreliable bus transportation service where commuters had to wait at least a half hour for already over loaded buses, (World Bank, 1984).

The situation was made even more undesirable by poor road surface conditions, a poorly managed traffic management system and a high number of road traffic crashes. These crashes resulted in multiple fatalities when they occurred. These inefficiencies also resulted in high operating costs. According to the World Bank (1984), designated bus transit routes were not properly planned and resulted in duplication of services. The travel demand throughout the KMTR was and still is to date designated, as very high with approximately 70 000 commuters using the transport system on a daily basis at an estimated 780 000 passenger trips daily. The system was also plagued by illegal public transport operators, which took advantage the high demand and inefficiencies within the bus transit system, (World Bank, 1984).

The urban transport system is still today plagued by the same problems but are more compounded. There have been attempts to improve the urban transport system by introducing transport centres, franchised routes and a re-invented government owned bus company, the Jamaica Urban Transit Corporation (JUTC), (JUTC, 2016). The provision of public transportation in developed countries has a different concept than in Jamaica. The adaptation of technological transfer and the application of policies from developed countries to the circumstances that exists in Jamaica, could result in an improved transportation system, (USAID, 2018).

According to NZTA (2014), a one size fits all approach to public transport infrastructure will not yield the best results and therefore solutions for local conditions should be determined on a case-by-case basis. But at the same time NZTA (2014), have recommended 9 basic

CHAPTER 2 Literature review

considerations that are important to providing and delivering high quality public transport infrastructure with supporting facilities. These 9 basic considerations are as follows:

Basic considerations public transport infrastructure

- Applicable bus stop design
- Appropriate bus stop shelters
- Personal safety and security
- Information provision
- Bus stop access hierarchy
- Environmental impact
- Commercial opportunities
- Location of stops
- Public transport operational requirements

2.11.1 Intelligent transport systems

The consideration for a sustainable urban transport system is based on an evaluation of previous policy initiatives that are geared towards sustainability. This demonstrates an attempt to move towards an efficient, safe and sustainable urban transport system that is beneficial to all its users, (USAID, 2018). According to Debnath *et al.* (2012), the evaluation is done by looking at the mistakes and achievements made in the past. This is determined by which approach is in line with sustainable outcomes. The introduction of Intelligent Transport Systems (ITS) is seen as a method that could aid in the modernisation of Jamaica's transport system. This would result in significant benefits to the public transport bus transit system.

The development of a sustainable transport system in Jamaica that integrates ITS can result in improved public transport facilities and safety for public transport pedestrian users. To facilitate this, the implementation of strategies with measurable outcomes, and performance indicators can have a major influence. This should include the integration of transportation and land-

CHAPTER 2 Literature review

use activities in favor of sustainability outcomes, (Debnath *et al.* 2012). According to Debnath *et al.* (2012), the development of the bus transit system as a viable option to private motorcar ownership, is based on supply measures, demand management, and environmentally friendly technologies. This represents a logical approach to improving transportation and forms the basis for the implementation of ITS.

The adaptation of smart technologies can impact the traditional approaches to road use by road users, (Zimmerman *et al.* 2012). This would influence the socio-economic, political and locations for the consideration of public transport facilities. The implementation of these policies is aimed at achieving sustainable transport. Moreover, it considers the existing transportation and mobility needs of the users that use the system. The assessment of public transport facilities using the needs-based approach considers this as an important step in determining the safety needs of public transport pedestrian users. This also considers sustainability in relation to the impact on the needs and expectations of future generations. The use of ITS, results in a corrective system that is capable of operating with minimum human intervention and improved safety, (Debnath *et al.* 2012).

2.11.2 Bus rapid transit facilities

According to Poku-Boansi and Marsden (2018), Bus rapid transit systems (BRTS) has been implemented in an estimated 206 cities in 45 countries worldwide. BRTS is an innovative approach to low-cost mobility. It delivers fast and comfortable mass transportation service, for public transport commuters when compared to other forms of transportation, (ITDP, 2018). The BRTS has evolved as a solution to poorly regulated and informal road transport systems that are usually considered as unsafe. It is also a response to situations where cities are experiencing rapid urbanization, (Poku-Boansi and Marsden, 2018).

As stated in Poku-Boansi and Marsden (2018) and as discussed in *Section 2.11.1*, with supporting research from (World Bank 1984) report, the Jamaican transportation system has all the characteristics that requires the implementation of a BRTS. The implementation a BRTS with ITS in Jamaica can improve the efficiency of the transportation system as well as the safety of road users in the traffic system, (Poku-Boansi and Marsden, 2018). The implementation and success of BRTS depends on the willingness to reform the existing transport system

CHAPTER 2 Literature review

by system designers and transport planners. It also relies on the overall maturity of governance in regard to the nature and importance of road transport systems, (USAID, 2018).

In the expansion of urban areas as a result of migration, cities search for opportunities for sustainable growth and development. In this rapidly growing urban environment BTRS is seen a transportation solution that can be quickly implemented to normalize the transport system, (Poku-Boansi and Marsden, 2018). The use of BTRS in cities such as New York with reference to Webster Avenue bus route, serves an estimated 71 per cent of 200 000 persons. These are commuters reside within 10 mins of a designated transport facility, (Beaton et al. 2013). In the case of Singapore that has a land mass of 710.2 square kilometres consisting of an estimated 4.8 million people. The integration of technology in areas that are considered integral to the transport system, has resulted in efficient and controlled motorization, (Debnath et al. 2011).

According to Debnath et al. (2011), Singapore implemented a people-oriented BRTS public transportation system that serves both mass and light rapid transportation on 344 transit routes. The fleet consisted of over 3 268 buses covering an approximately 148 kilometres of rapid transport routes and is considered one of the worlds most efficient and reliable BRTS. The technological integration with the transport system demonstrates the sustainable goals sort by Singapore in establishing BTRS that centres around its users, means of transport and the environment. This is in contrast to Jamaica that is said to have an unusually complicated bus transit system, that does not cater effectively to the needs of its users, (USAID, 2018).

As discussed in Kumar et al. (2011) and cited in (Poku-Boansi and Marsden 2018, p.1), the approach to the successful implementation of a BRTS will depend on addressing the existing inadequacies within the present transport system. The implementation of a successful BRTS results in a shift to a regulated and controlled transportation system. This involves the efforts of multi-government agencies and ministries in coordinated planning, financing and operating a newly established transport system. The supporting infrastructure such as transport facilities is also needed to support BRTS. These facilities depend on the number of public transport pedestrian users that depend the on service being provided. As well as the routes being served by the BRTS, (Poku-Boansi and Marsden, 2018).

According to the World Bank (1984), the public transportation system in Jamaica was not a reflection of the ideal public transportation system. The introduction of BRTS and ITS in

CHAPTER 2 Literature review

Jamaica by adopting best practice approaches for example from Singapore can result in an efficient and safe public transportation system. The steps to be taken however require a change in policy and investments strategies to achieve the desired results for the transportation system to be seen as a viable alternative.

2.11.3 Bus Stops

Within the transit system bus stops are considered to play an important role in providing comfort and safety to customers that use the service, (TRB, 1996). Bus shelters and transport centres are commonly referred to as bus stops and provide access to bus transit services. A bus stop refers to a space along the roadway or sidewalk that represents a point of interchange from pedestrian to bus modes of travel, (NZTA, 2014). It is at this transition point that a pedestrian which walks along a sidewalk and stops to wait for a bus mode of transport becomes public transport pedestrian user as discussed in Section 2.8.10.

The quality and design of bus stop facilities increases its safety performance function and reduces its design life cycle costs. Attempts should be made to standardize the design of public transport facilities. This is important in reducing the cost of installation by using a modular approach and should be a reflection of the location and level of service, (NZTA, 2014). These facilities should provide safe access to the bus transit network while waiting and using the bus service, (Schoon, 2019). Safety also extends to the broader infrastructure and facilities supporting the bus transit network, (Schoon, 2019). Safety for public transport pedestrian users is dependent on their interaction with buses and the overall traffic. This also extends to buses and their interaction with other vehicles, (TRB, 1996).

The public transport facility design should have key considerations built in, to enable buses to stop close and align to the kerb, (TRB, 1996). According to Chetty and Phayane (2012), indented bus stops are not ideal because they present safety challenges for buses in parallel docking and for access to public transport pedestrian users. This is especially in situations where the stops are shared with buses from multiple routes. There are however locations where travel speeds and other road safety issues may require indented stops, (IHT, 1999). However, this should be justified and designed to accommodate full bus lengths. Bus border stops that are considered ideal, are as shown in Figure 2.10. This design facilitates parallel docking of buses

CHAPTER 2 Literature review

and reduces the risk of parking conflicts, but it also has its draw backs. That is, is becomes a hazard to bicyclist and pass traffic, (NZTA, 2014),



Figure 2.10 Bus border stop and bus shelter facilities provided for public transport pedestrian users. Modified by Uter (2018) and obtained from NZTA (2014)

Pedestrian safety is also of concern and is considered separate from public transport pedestrian users. This relates to spacing and the influence public transport facilities have on pedestrian flow and vehicular traffic at or near bus stops, (Schoon, 2019). The impact on safety at bus transit facilities also considers buses stopping at bus stops, buses re-entering traffic and the overall interaction with private vehicles, (TRB, 1996). Safety and comfort for public transport pedestrian users is therefore reliant on the coordination between the different agency with oversight of the traffic environment and transportation services. According to TRB (1996) safety and operational features are based on, on-site assessments as shown in Table 2.8 as follows:

CHAPTER 2 Literature review

Table 2.8 Safety and operation features for on-site bus stop assessment

Safety features	Operation features
Passenger protection from passing traffic	Adequate kerb space for the number of buses expected at the stop at one time
Access for people with disabilities	Impact of the bus stop on adjacent properties
All-weather surface to step from or to the bus	On-street automobile parking and truck delivery zones
Proximity to passenger crosswalks and curb ramps	Bus route patterns which include individual movement at intersections
Proximity to major trip generators	Direction and width of intersections
Convenient passenger transfers to routes with nearby stops	Type of traffic signal controls
Proximity of stop for the same route in the opposite direction	Volume and turning movements of other traffic
Proper pedestrian circulation	Width of sidewalks
Direct access to bus stop	Pedestrian activity through intersections
Presence of street lighting	Proximity and traffic volumes of nearby driveways

The accommodation of these features shown in Table 2.8 is aimed at improving the safety and the operation of these facilities and should be considered in the initial design of the roadway, (Transfort, 2015). This influences the use of the roadway by road users and determines their exposure in the traffic environment to crashes. The greater the distance between public transport and the traffic lane, increases the safety for these road users, (Chetty and Phayane 2012). The functional design of the bus stop should not compromise the safety of public transport pedestrian users for the sake of art or advertising, (TRB, 1996). Panels should not limit the view of the bus driver from observing inside the bus shelter. Similarly, public transport pedestrian users should be able to see passing traffic and approaching buses. For this reason, where advertising panels are placed on bus shelters, they should be placed downstream to the flow of traffic, (Transfort, 2015).

CHAPTER 2 Literature review

The type of bus stops placed on the side of the roadway is also influenced by advertising opportunities, (NZTA, 2014). This seems to take priority over the needs of public transport pedestrian users in Jamaica based on the design of these facilities, (NWA, 2016). Advertising however is not permitted at all stops in developed countries and is limited by the area. The permit for the advert depends on its appropriateness and compatibility to the characteristics of the area, (Transfort, 2015). The inclusion of commercial advertising at public transport facilities can, however, enhance its appeal and level of safety. This is in relation to illumination, travel information and passive surveillance which improves service performance, (NZTA, 2014).

The placement of bus stops is a representation of the intended interaction between those who use the service and the infrastructure provided. The efficiency of the service provided helps to encourage bus transit as an alternative mode of transportation, (Transfort, 2015). In developed countries, the consideration for placement of these facilities is guided by the safety, comfort and the needs, of public transport pedestrian users. This is also based on their place of origin and final destination. However, there are common challenges faced by developed and developing countries such as the availability of space, (NZTA, 2014).

The availability of space impacts the design of bus shelters and transport centres. In Jamaica transport operators spill over into the roadway of surrounding streets contributing to congestion and public transport pedestrian users over crown sidewalks, (World Bank, 1984). The issue of space also relates to protection from weather occurrences, adequate sidewalk used by pedestrians and sidewalks that connect between stops. In the case of Jamaica, the design of bus shelters and transport centres does not appear to be a priority based on facilities provided, (Transfort, 2015).

According to Transfort (2015), the placing of bus shelters and transport centre is influenced by road design features. The practice in developed countries is to design these facilities based on standard road design practices. In Jamaica, the main factor that influences placement however is sight distance and is aimed at limiting the conflicts between bus and other vehicular traffic. The final decision for placement rests with the road authorities, (NWA, 2016).

CHAPTER 2 Literature review

2.12 Summary

Globally road safety has become a major concern especially in the case of developing countries. Jamaica being one such country continues to struggle with high road crash fatality rates as a result of the deficiencies in its road transport infrastructure. In the review of literature the issues of urbanization and its compounding effects on urban road safety if not managed appropriately were discussed. The WHO in its efforts to reduce the number of road crash fatalities had taken several initiatives. One such initiative was the WHO 2004 recommendations that encourages the adaptation of the safe systems approach now being implemented in several developed countries in various forms with much success.

The use of road safety models and in particular the iRAP methodology was reviewed and its role in improving road safety in developing countries. The method of collecting data at different IQL levels was determined based on the iRAP methodology and its role for providing data to assess the safety needs in the application of needs-based approach. The iRAP methodology and its approach to developing equations for public transport facilities was also reviewed. In developed countries motor vehicle ownership was more prevalent than in developing countries. The role of an efficient, safe public transport system in improving road safety and the economic benefits were discussed as well as the effects of increasing accessibility while reducing vehicle ownership.

CHAPTER 3 Methodology and Transferability

3.1 Introduction

The approach taken for this research project as mentioned in Chapter 1, was a qualitative approach. This research design method is known for exploring and understanding social and human problems based on inquiry. This allows for in-depth analysis of events over a period of time, (Creswell, 2014). It was therefore preferred because of this association and for achieving research objectives by using case studies. It follows then, its appropriateness on the basis that, this research project is a case study on road safety in Jamaica, for the safety of public transport facilities.

In addition, road safety is recognized as a public health problem experienced by humans and has social relations, (WHO, 2004). At the same time, this project analyses an event, in this case road crashes, based on primary and secondary data collected over a period of time. Furthermore, road safety is still considered as an emerging methodology based on its continued active and passive implementation of solutions. And by extension, qualitative research is also used in studying emerging situations, with observation data, document data and image analysis all of which are used in this research, (Creswell, 2014).

The iRAP methodology was used to collect the primary source of data for road safety analysis as discussed in *Section 2.8.3* and *Section 2.8.4*. The primary source of data collected by iRAP was in the form of images. The images were taken and coded according to the iRAP methodology for road safety feature analysis and the safety needs assessed using a needs-based approach. Primary source of data was also collected using road surveys. Following this the primary data was merged with the secondary data for road crashes and traffic flows from the RSUJ and NWA respectively to determine the existing situation. As a result, the gaps between the existing situation and the desired in meeting the safety needs was identified and safety measures introduced.

The crash database used in Jamaica is management by the Road Safety Unit of Jamaica (RSUJ) in the Ministry of Transport and Mining. The software application used to process crash data by the RSUJ is the Microcomputer Accident Analysis Package (MAAP) developed by the Transport Research Laboratory (TRL), (RSUJ, 2017). The RSUJ road crash data uses secondary data obtained from organisations as follows:

CHAPTER 3 Methodology and Transferability

Secondary data sources of road crash data in Jamaica

- Jamaica Constabulary Force (JCF)
- Island traffic Authority (ITA)
- National Works Agency (NWA)
- Tax Administration Jamaica (TAJ)
- Statistical Institute of Jamaica (STATIN)
- Jamaica Gleaner

Source: RSUJ (2017)

The crash data collected by the JCF was recorded according to a set criterion required for MAAP crash database set up as shown in Appendix F, Table F.1. The information within the crash data based is used to present various statistical analysis of crashes. This was based on road user type and various demographics used for analyzing road crash patterns, (RSUJ, 2017). It follows then that the road crash data used for analysis in this research project was also obtained from secondary sources.

3.2 Study area

Data collected from the road network in the study area was obtained from primary and secondary sources ad discussed in Section 3.1. As also discussed in *Section 2.8.3* the study area consisted of 9 main roads out of 359 main roads that make up the main road network in Kingston and St. Andrew that span across the city. The 9 main roads selected from the study area, are considered as the main arteries that carry large volumes of vehicular and pedestrian traffic. The roads being analyzed with in the study area, facilitates movement between shopping, recreational attractions and school districts, (NWA, 2017).

The 9 main roads that make up the study area as shown in Table 3.1 and Figure 3.1 are as follows:

CHAPTER 3 Methodology and Transferability

Table 3.1 Main roads representing the study area

Road name	Direction	Start	End	Length	Speed Limit
Constant Spring Road	North to South	Begins in Manor park	At the intersection of Hope road/Hagley Park Road/ Half-way tree road	5 km	50 km
Old Hope Road	Northwest then curves West to East	Cross Roads at the intersection with Half way tree road	Papine Square	6.9 km	50 km
Hope Road	West to East	At the intersection with Half-way tree road	At the intersection with Old Hope Road	3.4 km	50 km
Half-Way Tree Road	North to South	At the intersection with Hagley Park Road/Hope Road/ Constant Spring Road	At the intersection with Old Hope Road	3.6 km	50 km

CHAPTER 3 Methodology and Transferability

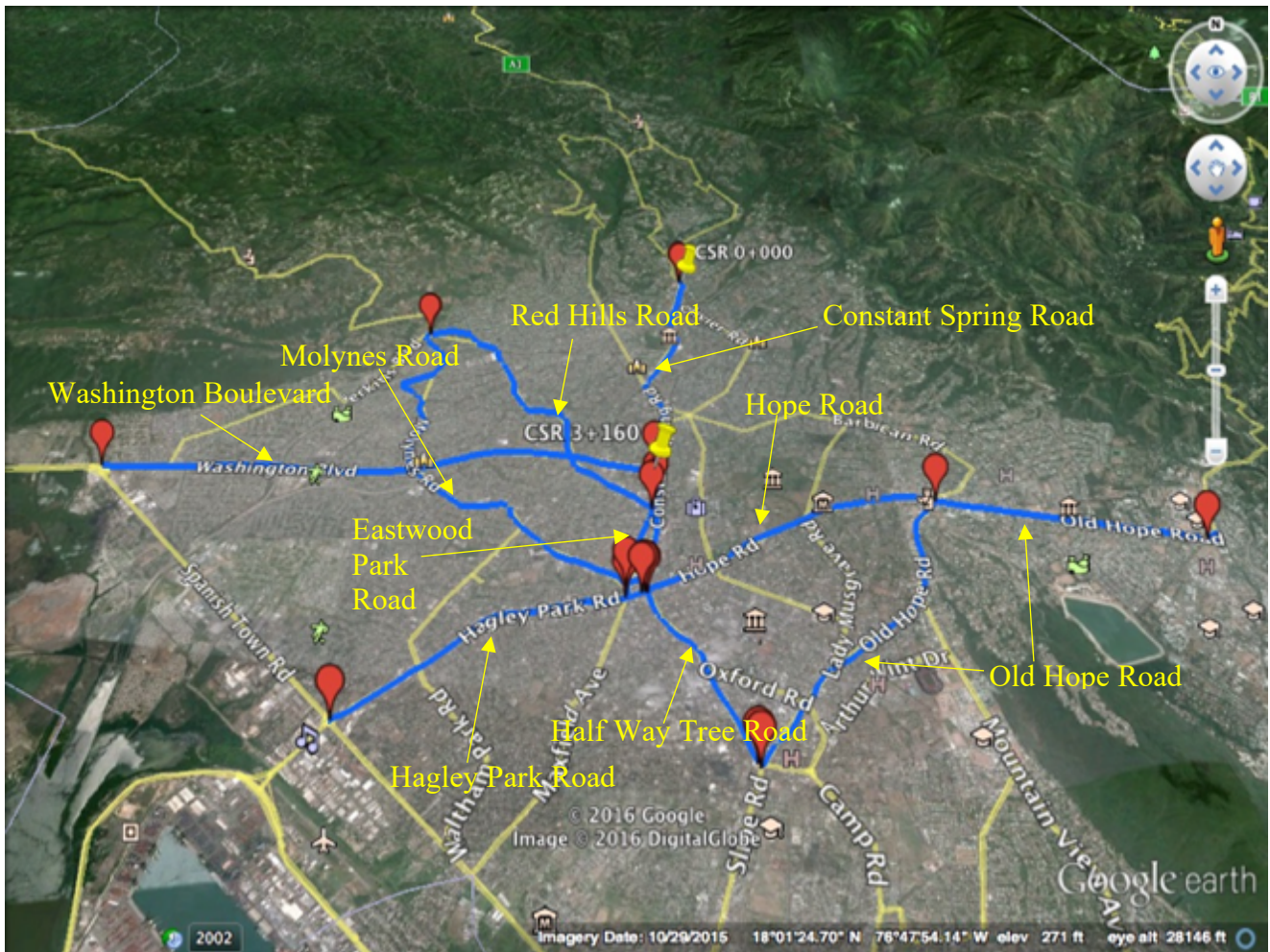
Table 3.1 (Continued)

Road name	Direction	Start	End	Length	Speed Limit
Hagley Park Road	West to East	At 3-miles	At the intersection with Hope Road/ Half-way Tree Road/ Constant Spring Road	3.7 km	50 km
Washington Boulevard	West to East	At 6-miles	At the intersection with Constant Spring Road	6.3 km	50 km
Red Hill Road	North to South	At with Constant Spring Road	At the intersection with Perkins Boulevard	4.4 km	50 km
Molynes Road	North to South	At intersection with Eastwood Park Road	At the intersection with Perkins Boulevard/ Red Hills Road	5.9 km	50 km
Eastwood Park Road	North to South	At with Hagley Park Road/ Maxfield Avenue	At the intersection with Constant Spring Road	1.3 km	50 km

Source: NWA (2017)

CHAPTER 3 Methodology and Transferability

The 9 main roads that make up the study area as discussed in Table 3.1 are as follows:



**Figure 3.1 Image of Kingston and St. Andrew road network: Study area
Modified by Uter (2016) and obtained from: Google imagery (2016)**

3.3 Data collection: primary source

The data collection from primary source was done according to the iRAP methodology along each roadway in the study area using IQL-I data collection application as discussed in Section 2.10. The Star rating and investment plan: Road survey and coding specification, provided a detailed description of the data collection process and protocols that were observed to ensure accuracy of the data collected, (iRAP, 2014). This was used to provide guidance to ensure the iRAP methodology was followed as closely as possible to aid in the data collection process.

CHAPTER 3 Methodology and Transferability

The data collection began by assembling a team consisting of 6 persons, acquiring a reliable motor vehicle, writing pads and a camera. The team was made up of a driver, photographer, two measuring tape runners and two observers. The role of each participant was defined before the start of the data collection process as discussed in Table 3.2. Route planning was observed as an important aspect of the data collection process because this determine the amount of time spent in the field and the amount of petrol used. Therefore, the route to be traveled by the team was decided before the start of data collection. A risk assessment was also done for the overall data collection process, each individual team member and the route to be travelled. This was to ensure the health and safety of the team during the data collection process.

The traffic pattern for each route was also taken into consideration to avoid peak hour periods where congestion for both vehicular and pedestrian traffic would impact the collection of data. This was also done in relation to reducing the impact of the team's operation as a contributing factor to traffic congestion, and the safety of road users. The focus of the data collection exercise was to collect primary data. According to iRAP (2014), road attributes data was best collected in free-flowing traffic and not when the roadway were congested.

Consideration was also given to peak hour period of public transport operation. It was decided however, that in order to capture a true representation of the use of transport facilities such as bus shelters and transport centre, a separate day to collect this data should be set aside. This would enable photographs to be taken of the transport facility in use by public transport pedestrian users. It was also decided that a separate day should set aside for the video recording of each route within the study area.

The preferred motor vehicle to be used during the data collection process was a pick-up truck as discussed in Table 3.2. This was chosen in the event a situation arose where it would prove difficult for the photographer to take photographs outside the vehicle. In such cases the photographer would take photographs from inside the back of the pick-up. It also made it less challenging for the measuring tape runners to exist and entre the vehicle to measure 20m internals not available on the vehicle's speedometer. This was also done to reduce the duration of stops that would have impacted the flow of traffic.

The choice of the camera to be used for taking photographs was a smart cell phone that had a good camera as mentioned in Table 3.2. Most modern smart cell phones from various

CHAPTER 3 Methodology and Transferability

manufacturers are equipped with cameras that take excellent photographs as professional cameras. They are also equipped with geo-referencing software. This improved the accuracy of image recording and the identification of road features based on their location on the road section as discussed in *Section 2.8.4*. In Table 3.2 the list of team members is presented, along with the equipment used and their assigned tasks.

The roles and area of responsibility for each team member was as shown in Table 3.2 is as follows:

Table 3.2 Data collection team and apparatus

Team members	Equipment		Assigned tasks
	Type	Description	
Driver	Motor vehicle	Pick-up truck	<ul style="list-style-type: none"> • Observe traffic safety • Stop vehicle at 20m intervals • Stop vehicle at 100m intervals • Observe overall distance travelled from start to the end of the control section • Travelling at the speed limit
Photographer	Camera	Cell phone	<ul style="list-style-type: none"> • Taking photographs 500m beyond the start of the control section • Taking photographs at 20m interval • Taking photographs to reflect 160-to-180-degree field of view • Taking clear images • Taking photographs 500m beyond the end of the control section

CHAPTER 3 Methodology and Transferability

Table 3.2 (Continued)

Team members	Equipment		Assigned tasks
	Type	Description	
Measuring tape runners	Wheel tape/ 30m hand tape	metric	<ul style="list-style-type: none"> • Measuring 20m intervals • Measuring distances between the road edge and roadside objects • Verifying road design features • Verifying public transport infrastructure design features
Observer 1	Note pad	Ruled	<ul style="list-style-type: none"> • Quality control • Ensuring speed limit is not exceeded • Ensuring driver observes traffic safety • Ensuring vehicle stops at 20m intervals • Ensuring vehicle stops at 100m intervals • Recording vehicle milage at each stop • Recording overall length of control section • Tracking control sections • Record number of bus stops/transport centres

CHAPTER 3 Methodology and Transferability

Table 3.2 (Continued)

Team members	Equipment		Assigned tasks
	Type	Description	
Observer 2	Note pad	Ruled	<ul style="list-style-type: none"> • Quality control • Ensuring photographs are taken at 20m intervals • Ensuring photographs are taken 500m beyond start of control section • Ensuring photographs are taken 500m beyond end of control section • Recording distance each photograph is taken • Verifying quality of photographs taking

As discussed in Table 3.2, the driver’s responsibility was to ensure traffic safety was observed, that the vehicle was stopped at every 20m and at 100m as shown on the speedometer. As well as to observe the total metres or kilometers travelled from the start to the end of the road control section while traveling at the designated speed limit. This was monitored by observer one that remained inside the vehicle with the driver at all times. The assigned tasks for observer one overlapped with the driver to maintain quality control of this aspect of the data collection process, to keep within range of the iRAP data collection guidelines. Observer one also had the additional task of recording the number of bus stops on each route.

As mentioned in Table 3.2, the photographer had the responsibility for taking photographs of good quality 500m before the designated start and at the end of the control section. The photographer also took photographs every 20m internal as indicated by the measuring tape runners. The photographs taken by the photographer were forward facing from the front of the vehicle and facing the opposite directing from the rear of the vehicle with a 180-degree field of view.

CHAPTER 3 Methodology and Transferability

Observer two had the responsibility of verifying the quality of the photographs taken and also had overlapping responsibilities with the photographer. This was done to ensure quality control of the image recording aspect of the data collection process, also in line with iRAP data collection guidelines.

The measuring tape runners used metric wheel tapes to ensure the vehicle was stopped at 20m intervals between photographs. They were also responsible for checking the distances between the road edge and roadside features as requested, as well as verifying road design and public transport facility features. The measuring tape runners were also used to ensure quality control. In the event the wheel tape malfunctioned the 30m hand tape would be used. This would require both measuring tape runners using the hand tape to measure the 20m intervals. However, the wheel tape did not malfunction, so the measuring tape runners took turns in using the wheel tape to avoid over exertion from walking alongside the motor vehicle. The data collected from each route was then stored according to their control sections in folders on a computer for further analysis.

As discussed in *Section 2.8.4* coding of road attributes began with recording the road segments name, section and location. The Microsoft excel spread sheet provided by iRAP presented 62 coding attributes and 10 post-coding attributes to be recorded. The coding attributes represented was a series of 62 road features including road users to be recorded from the images taken for each 100m road segment, (iRAP, 2014). Once present in the image the road attribute or road user were coded according to coding options provided by iRAP in the iRAP Star Rating and Investment Plan Coding Manual as shown in Figure 3.2.

CHAPTER 3 Methodology and Transferability

Coding options







 8+	8+ pedestrians along right side	8 + pedestrians observed walking along the right side of the road per 100m	
 6-7	6 to 7 pedestrians along right side	6 to 7 pedestrians observed walking along the right side of the road per 100m	
 4-5	4 to 5 pedestrians along right side	4 to 5 pedestrians observed walking along the right side of the road per 100m	
 2-3	2 to 3 pedestrians along right side	2 to 3 pedestrians observed walking along the right side of the road per 100m	
 1	1 pedestrian along right side	1 pedestrian observed walking along the right side of the road per 100m	
 NONE	None	No pedestrians observed walking along the right side of the road	

Figure 3.2 Coding options for recording. Modified by Uter (2018) and obtained from iRAP Star Rating and Investment Plan Coding Manual (2014)

The 10 post-coding attributes represented in the iRAP Star rating and investment plan coding manual was in relation to road user flow rates, operating speeds, roads that could be read by cars and star rating policy targets. These post-coding attributes were coded and recorded if present along the 100m road segment in the images taken, as well as if they were a part of the road safety management system. For road user flow rates these were assigned categories as shown in Figure 3.3. However, for operating speeds, road that cars can read and star rating policies, these were assigned coding options as shown in Figures 3.4, Figure 3.5 and Figure 3.6 respectively.

CHAPTER 3 Methodology and Transferability

Categories

1	0	No pedestrians crossing the road within a peak hour
2	1 to 5	1 to 5 pedestrians cross the road on average within a peak hour
3	6 to 25	6 to 25 pedestrians cross the road on average within a peak hour
4	26 to 50	26 to 50 pedestrians cross the road on average within a peak hour
5	51 to 100	51 to 100 pedestrians cross the road on average within a peak hour
6	101 to 200	101 to 200 pedestrians cross the road on average within a peak hour
7	201 to 300	201 to 300 pedestrians cross the road on average within a peak hour
8	301 to 400	301 to 400 pedestrians cross the road on average within a peak hour
9	401 to 500	401 to 500 pedestrians cross the road on average within a peak hour
10	501 to 900	501 to 900 pedestrians cross the road on average within a peak hour
11	900+	900+ pedestrians cross the road on average within a peak hour

Figure 3.3 Categories for recording pedestrians peak hour flow across the road. Modified by Uter (2018) and obtained from iRAP Star Rating and Investment Plan Coding Manual (2014)

Coding options – km/h

≥150km/h	85th percentile speed is 150km/h or greater
145 to 149 km/h	85th percentile speed is 145 to 149 km/h
140 to 144 km/h	85th percentile speed is 140 to 144 km/h
135 to 139 km/h	85th percentile speed is 135 to 139 km/h
130 to 134 km/h	85th percentile speed is 130 to 134 km/h
125 to 129 km/h	85th percentile speed is 125 to 129 km/h
120 to 124 km/h	85th percentile speed is 120 to 124 km/h
115 to 119 km/h	85th percentile speed is 115 to 119 km/h
110 to 114 km/h	85th percentile speed is 110 to 114 km/h
105 to 109 km/h	85th percentile speed is 105 to 109 km/h
100 to 104 km/h	85th percentile speed is 100 to 104 km/h
95 to 99 km/h	85th percentile speed is 95 to 99 km/h
90 to 94 km/h	85th percentile speed is 90 to 94 km/h
85 to 89 km/h	85th percentile speed is 85 to 89 km/h
80 to 84 km/h	85th percentile speed is 80 to 84 km/h
75 to 79 km/h	85th percentile speed is 75 to 79 km/h

Figure 3.4 Coding options for operating speed (85th percentile). Modified by Uter (2018) and obtained from iRAP Star Rating and Investment Plan Coding Manual (2014)

CHAPTER 3 Methodology and Transferability

Coding options

	Does not meet specification	
	The road does not meet the "roads that cars can read" specification.	
	Meets specification	
	The road meets the "roads that cars can read" specification.	

Figure 3.5 Coding options for roads that cars can read. Modified by Uter (2018) and obtained from iRAP Star Rating and Investment Plan Coding Manual (2014)

Coding options – for each user group

Not applicable	No Star Rating policy has been set for specific user group
1 Star	Minimum 1 Star policy set for specific user group
2 Star	Minimum 2 Star policy set for specific user group
3 Star	Minimum 3 Star policy set for specific user group
4 Star	Minimum 4 Star policy set for specific user group
5 Star	Minimum 5 Star policy set for specific user group

Figure 3.6 Coding options star rating policy targets. Modified by Uter (2018) and obtained from iRAP Star Rating and Investment Plan Coding Manual (2014)

According to the iRAP (2014), the approach to data collection is done in 2 phases. The first phase consisted of road surveys where the images were taken. In the second phase road attributes were coded every 100m from images taken on the road segment. The first phase of data collection in iRAP was previously discussed. During the second phase of the data collection process, road attributes were coded off site after all the roads within the study area were surveyed. However, the focus of this research project was not to determine star ratings for existing road users. Nor to code road attributes according to the specifications of existing iRAP models for existing road users.

CHAPTER 3 Methodology and Transferability

But instead, to use the iRAP methodology to collect data on road attributes that influenced the likelihood and severity of a crash for public transport pedestrian users. However, since the iRAP methodology was not used before to collect road attributes data for public transport pedestrian users at public transport facilities such as bus shelters and transport centres. It follows then that an assessment of the safety needs for public transport pedestrian users at public transport facilities was carried out. As a result, the influence of the design practices of public transport facilities was assessed using the needs-based approach to achieve the second objective of this research project.

But at the same time, as part of the first objective for this research project, the data collection methodology in iRAP was first used at IQL-I, to collect road attributes data. This was to determine the integration of safety measures for public transport facilities. In addition to using road attribute fact sheets as well as star rating worked examples provided by iRAP. That is, to guide the process of determining star ratings and colour coding for public transport pedestrian users. This simplified the coding application process and was also used to determine star rating for pedestrians as a comparison with the star rating produced for public transport pedestrian users as discussed in Chapter 5 and Appendix I, Table I.1 and Table I.2.

Therefore, it is to be noted that for the first objective, road attributes that affected the likelihood or severity of crashes for public transport pedestrian users, were identified from the images taken. This was done by using colour coding to describe the condition, level of provision or severity of the road feature present or absent in the photographs taken. The colour coding application was adopted from the iRAP methodology which also used colour coding descriptions for road attributes and star rating as discussed in *Section 2.8.8*, (iRAP. 2013).

In addition, the colour code was also used for the second objective of this research project. This was to determine the influence the design of public transport facilities had on road safety interactions between public transport pedestrian users and other road users. By extension to achieve this objective the colour coding of road attributes was done in relation to the safety needs determined from the application of the needs-based approach as further discussed in *Section 3.4*.

CHAPTER 3 Methodology and Transferability

Table 3.3 Colour coding and description of road attribute condition and provision. Modified by Uter (2018) and obtained from RAP road risk mapping manual: Technical specification (2013)

Colour	Description
Green	Good condition/ adequate provision
Yellow	Fair condition/ moderate provision
Red	Poor condition/ inadequate provision / hazardous
Black	Sever/ absent / not visible

Furthermore, in using the iRAP methodology to assess the safety of public transport pedestrian users, the third objective was also achieved. This was achieved by identifying risk factors for public transport pedestrian users, using the iRAP methodology. This was done by applying risk factors to public transport facilities based on road attributes included in the iRAP star rating and investment plan manual as well as road attribute fact sheets. The road features that posed a risk to public transport pedestrian users were identified and then compared to the risk factors identified during the safety needs analysis for road attributes from objective two.

In addition, there were no star rating model equations in the existing iRAP methodology to determine star ratings for public transport pedestrian users. Therefore, new star rating model equations were developed along with casualty estimation equations and countermeasures for public transport pedestrian users. In developing these equations, the fourth objective for this research project was achieved. This is further discussed in Section 3.6.

3.4 Data collection: secondary source

As discussed in Section 3.1, road crash data was obtained from secondary sources at IQL-IV data collection application. Road crash data was obtained mainly from the RSUJ and NWA on the road network in Jamaica. The data was representative of crashes that occurred on the A-road network. This included road crash data for all road user types. As discussed in *Section 2.8.7* road crashes involving public transport pedestrian users are among the road crash

CHAPTER 3 Methodology and Transferability

data collected by the RUSJ. As also discussed in Section 2.7 these crashes do not occur frequently. They were grouped with other crash types based on the road user categories defined by existing road crash assessment models.

According to a search of the Jamaica Gleaner archives, there were records of crashes that had occurred directly into bus stops. The Jamaica Gleaner article reported one such crash having occurred in January 2011 where a car lost control and ran into a bus stop along Old Hope Road, in the Liganuea area as shown in Figure 3.1. There were 2 fatalities and 3 seriously injured, one of the fatalities of this crash involved a visually impaired person and the three persons that were serious injured were also visually impaired. There were also so other reports of crashes that occurred in Kingston and St. Andrew however sources could not be verified.

On that account it is also worth mentioning, that in August of 2013 there was a crash that occurred at a bus stop but at a location outside of the study area. This was on the north coast of the island in the second city, Montego Bay. In this crash there were no fatalities however 4 persons were seriously injured. It was reported that a car lost control along the Montpelillier main road and crashed into a bus stop. Even though road crash data for crashes into bus stops were reported to the RSUJ, the data presented does not identify these crashes as occurring at bus stops but as occurring in the vicinity of bus stops, and were listed as highest severity crashes (RSUJ, 2016).

As shown in Table 3.4, road crashes involving public transport facilities such as bus stops and transport centres were recorded as crashes occurring in the vicinity of bus stops, (RSUJ, 2016). The data was presented for Kingston and St. Andrew and parts of St. Catherine that make up the Kingston Metropolitan Region (KMR). As stated in Table 3.4, these crashes occurred from 1981 to 2018 with 541 crashes recorded as highest severity crashes.

CHAPTER 3 Methodology and Transferability

Table 3.4 Road crash data in the vicinity of public transport facilities collected from the study area in Kingston and St. Andrew by year and division. Modified by Uter (2018) and obtained from the Road safety unit (2018)

Crashes in the vicinity of bus stops by divisions : Highest Severity									
Date	St. Andrew South	St. Andrew Central	Kingston Eastern	St. Catherine South	St. Catherine North	St. Andrew North	Kingston Western	Kingston Central	Total
1981	0	1	0	0	0	0	0	0	1
1995	0	1	2	1	0	0	0	0	4
1996	0	1	1	0	1	0	0	0	3
1997	0	2	0	1	1	1	0	0	5
1998	1	5	1	3	2	7	0	0	19
1999	1	6	4	5	1	10	0	0	27
2000	1	11	4	5	0	5	0	0	26
2001	3	39	2	14	0	10	0	2	70
2002	8	24	2	9	2	4	1	0	50
2003	0	1	0	1	0	0	0	0	2
2004	14	3	1	3	0	4	0	1	26
2005	7	7	3	6	2	7	1	0	33
2006	3	1	3	8	1	1	0	2	19
2007	16	2	2	4	1	10	2	0	37
2008	6	2	3	4	1	3	1	0	20
2009	11	1	5	9	2	16	0	0	44
2010	1	1	2	2	0	3	0	0	9
2011	1	3	5	7	1	2	0	2	21
2012	0	6	5	9	3	6	0	2	31
2013	9	3	7	2	2	8	1	0	32
2014	0	5	8	3	6	7	0	2	31
2015	0	2	1	5	2	1	2	0	13
2016	0	2	4	0	1	0	0	0	7
2017	1	0	5	1	0	1	1	0	9
2018	1	0	0	0	0	0	0	1	2
Total	84	129	70	102	29	106	9	12	541

In Table 3.5 the data is representative of the JCF’s summary of crashes and causes based on investigation. Attempts to obtain more recent data has been made however the information was not forthcoming. According to the RSUJ (2015), the JCF presents separate information based on their internal reporting methods. The information presented in Table 3.5 was included as part of the summary statistical data presented by the RSUJ, which reports crashes in relation to demographics and crash types.

Data from other secondary sources such as the NWA are shown in Appendix G. The data obtained from the NWA does not contain details such as the location where the crash occurred on the roadway which was relevant to public transport pedestrian users. The data however from the NWA as shown in Appendix G does provide the total number of crashes that occurred on these control sections and whether these crashes were fatal or serious injury crashes. Yet still this does not provide details on the road users involved nor the location on the roadway.

CHAPTER 3 Methodology and Transferability

It follows then that to assess this data the IQL methodology as discussed in *Section 2.10.4* was used because of the type of data that was available from these sources. The data collected from secondary sources was used to determine the functional performance of the roads in the study area for road safety. The assessment of this road crash data was consistent with the most frequent crashes that caused fatalities and serious injuries for road users involved, (Lynam, (2012).

Table 3.5 Road accident data items 2001 to 2003 from the Jamaica Constabulary Force. Modified by Uter (2018) and obtained from the National Road Safety Policy of Jamaica (2004)

CAUSES OF ACCIDENTS	2000		2001		2002		2003	
	ACCIDENTS	%	ACCIDENTS	%	ACCIDENTS	%	ACCIDENTS	%
Apparent error of judgment/negligence	2,030	18%	2,800	20%	330	3%	276	2%
Following too closely	1,079	10%	1339	9%	2021	17%	2,180	17%
Turning without due care	713	6%	817	6%	583	5%	501	4%
Misjudging clearance/distance	869	8%	1009	7%	395	3%	321	3%
Crossing heedlessly	384	3%	571	4%	615	5%	729	6%
Losing control	920	8%	1250	9%	456	4%	363	3%
Failing to keep to near side	481	4%	731	5%	1036	8%	1011	8%
Excessive speed	597	5%	689	5%	477	4%	530	4%
Improper overtaking	491	4%	601	4%	730	6%	744	6%
Improper change of lane	677	6%	873	6%	385	3%	296	2%
Disobeying stop signs	698	6%	0	0%	0	0%	0	0%
Skidding	200	2%	290	2%	187	2%	224	2%
Disobeying traffic light	740	7%	1560	11%	420	3%	473	4%
Defective vehicle	238	2%	433	3%	131	1%	75	1%
Under influence of alcohol	66	1%	85	1%	10	0%	5	0%
Road bad/not maintained	280	3%	390	3%	29	0%	28	0%
Unknown	0	0%	0	0%	35	0%	1809	14%
Other factors	109	1%	189	1%	4318	35%	2776	22%
Pedestrian walk/run road off footpath	0	0%	0	0%	0	0%	218	2%
Disobeying pedestrian crossing	573	5%	630	4%	72	1%	26	0%
TOTAL	11,145	100	14,257	100	12,230	100	12,585	100

CHAPTER 3 Methodology and Transferability

3.5 Road safety integration and safety measures for public transport facilities such as bus shelters and transport centres

The photographs taken during the data collection process from the study area represents how the road was used by road users. It follows then that how the roadway was used by road users was based on their interpretation according to the design of the road transport system, public transport facilities and existing road safety management system. As a result, images shown in Figure 3.7 to 3.10 is a representation of the data collected and thus shows how the road was used by road users based on their interaction with the infrastructure provided.

Furthermore, as discussed in Chapter 2, road safety looked at some of the issues and pro-active responses of road safety strategies used in different countries. This, in an effort to reduce the number of crashes and related fatalities and serious injuries based contributing factors that influence road crashes. The approach to the first objective was to determine these contributing factors based on road surveys and inspection of the roads within the study area as discussed in Section 3.2. Thus, highlighting road safety risk hazards to road users was done by colour coding as shown in Table 3.3.

Therefore, the type colour coding used for the images as shown in Figure 3.7 to 3.10 represented the risk level of road safety risk hazards identified and the impact on road users. Road safety risk hazards that also impacted safety at public transport facilities were also colour coded. The colour coding of the images was determined using the iRAP methodology, in particular sample risk factor highlights from previously assessed roads by iRAP. In addition to road attribute risk factor sheets and the iRAP star rating and investment plan coding manual. The identification of road features as discussed in Section 2.8 was also based on previous research that determined the road features presences or absence influenced road crashes as discussed in Lynam (2012), Schoon (2019) and Elvik et al. (2009).

Each image shown in Figure 3.7 to 3.10 was also representative of the functional performance of roads within the study area in regard to road safety and according the infrastructure provided for road users. Figure 3.7 was taken during the peak hour period 330m from the start of the Constant Spring Road control section to show public transport facilities in use. Most important of all on that day it rained. Consequently, the image shown in Figure 3.7 highlights the situation faced by road users in the traffic environment and was colour coded accordingly.

CHAPTER 3 Methodology and Transferability

In Figure 3.7 pedestrians and in this case, school children can be seen trying to cross a flooded roadway, as a result this was colour coded red. After crossing the flooded road, pedestrians were yet again faced with a flooded sidewalk thus this was also colour coded red. Once arriving at the transport facility which in this case was a bus stop, public transport pedestrian users had to wait on a flooded platform until public transportation arrived. This along with the absence of bus boarder markings and a low kerb was also colour coded red indicating the impact on the safety of public transport pedestrian users using the facility.

The flooded roadway not only affected pedestrians and public transport pedestrian users but also motor vehicles using the roadway resulting in slow moving traffic. Thus, the flooded roadway affecting vehicular traffic was also colour coded red which was an indication of inadequate road drainage. This no doubt extended the time spent in the traffic environment by public transport pedestrian users. This mix of pedestrians and vehicular traffic and more importantly school children highlight the risk faced by these road users and in particular public transport pedestrian users.



**Figure 3.7 Image of Constant Spring Road, Kingston and St. Andrew road network:
Study area**

CHAPTER 3 Methodology and Transferability

Figure 3.8 presents a different road user experience from Figure 3.7. This image was taken on the Molynes Road control section. In Figure 3.8 the presents of road safety risk hazards and in particular an electric pole in the middle of the sidewalk was a roadside risk hazard. This not only displaces pedestrians but was measured to be within 1m from the road edge and was colour coded black. According to iRAP (2014) this roadside object can result in a fatality or serious injury for vehicular occupants, motor cyclists and bicycles during a run-off crash. The situation in Figure 3.8 is further compounded by the presence of a vending stall on the sidewalk.

This also further reduces the sidewalk capacity for pedestrian and displaced them to share the roadway with vehicular traffic. Moreover, for a different category of pedestrian such as a disabled person, either visually impaired or using a wheelchair, the risks of a crash resulting from a shared space with a motor vehicle increases. These road user types mentioned were also not defined by existing iRAP methodology and are classified as those with special needs. This can also be extended to pedestrians with other mobility issues, as a result, this was colour coded black.

In addition, the sidewalk was in a poor condition, with a low kerb, and therefore was colour coded red. Similarly, the placing of planter boxes also displaced pedestrians and reduced the capacity of the sidewalk for pedestrian flow. According to Schoon (2019), the required spacing was suggested to be a minimum of 1.5m or greater depending on the pedestrian flow. Roadside friction was also increase by the presence of the vendor which affected the flow of traffic and the risks of a head-on crash were increase by the park vehicle facing oncoming traffic.

CHAPTER 3 Methodology and Transferability

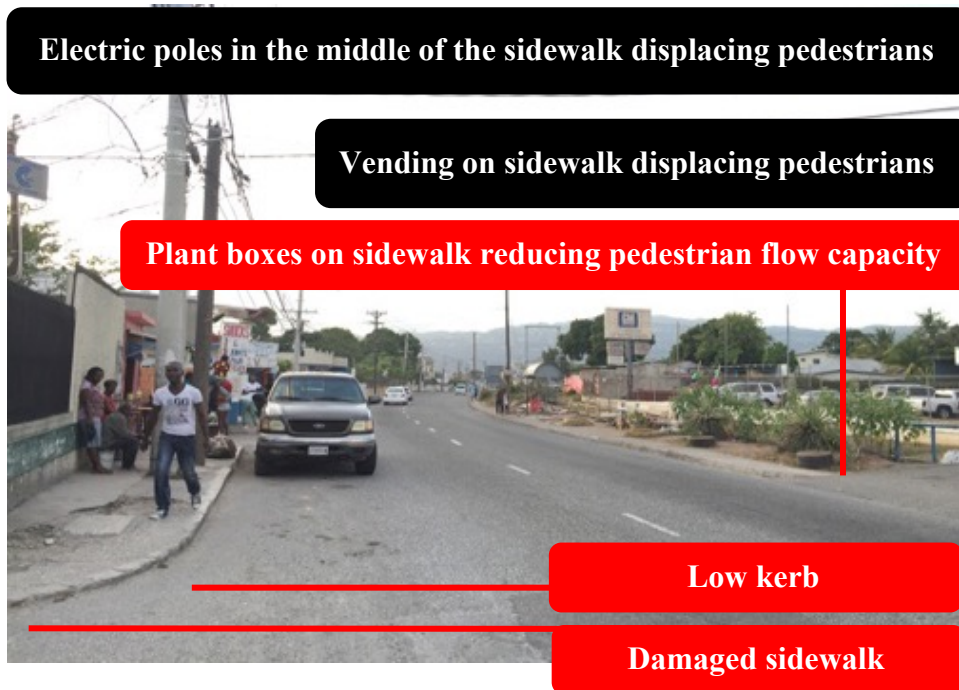


Figure 3.8 Image of Molynes Road, Kingston and St. Andrew road network: Study area

Similarly, in Figure 3.9, road users were faced with comparable road safety risk hazards as shown in Figure 3.8. Figure 3.9. Figure 3.9 was taken along the Red Hills Road control section and shows the displacement of pedestrians. In this assessment road safety risk hazards were colour coded black based on the impact of roadside objects and the absence of road features. The average road width was measured to be 7.2m. The absence of road markings to guide road users to judge their position on the road based on this road width was an indication of poor delineation (iRAP, 2010). Given that this was an undivided roadway that accommodates 2-way traffic at a speed limit of 50 (km/h), a colour code of black was assigned.

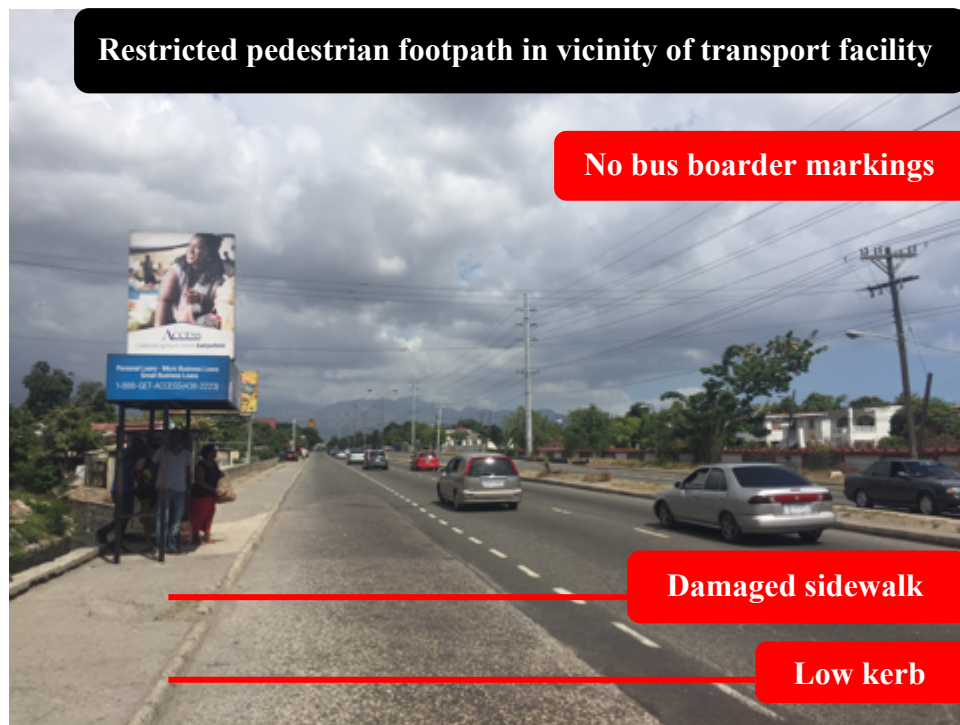
CHAPTER 3 Methodology and Transferability



Figure 3.9 Image of Red Hills Road Kingston and St. Andrew road network: Study area

The image shown in Figure 3.10 shows a segment of the Washington Boulevard control section and the provision of a transport facility. As shown, the type of bus shelter design restricts the footpath for pedestrians and was assigned a colour code of black. This presented challenges for pedestrians using this shared space which created conflicts with public transport pedestrian users at the transport facility. The absence of bus boarder markings at the transport facility was colour code of red, along with a poorly maintained sidewalk and low kerb placement.

CHAPTER 3 Methodology and Transferability



**Figure 3.10 Image of Washington Boulevard, Kingston and St. Andrew road network:
Study area**

In Figure 3.11 the image shown was taken in the Darling St transport centre in Downtown Kingston. In this image public transport pedestrian users are displaced by vending on the transport platform. This along with the mixing of public transport pedestrian users was colour coded black. The mixing vulnerable road users and vehicular traffic increases the likelihood of fatal crash or serious injury. The absence of bay markings and road markings to guide vehicular traffic in and out and within the transport facility increased the likelihood of a crash and was colour coded red.

3.6 Public transport facility design practices and road safety interactions with public transport pedestrian users

As discussed in Section 2.11 the Government of the Jamaica (GOJ), re-establish a public transportation bus service in 1998 for the Kingston Metropolitan Region (KMR). The number of passenger trips had declined since 1998 such that in 2006 to 2007 passenger trips were approximately 273 639 passenger trips daily, (MTW, 2011).

CHAPTER 3 Methodology and Transferability

In addition, the length of time spent in traffic system was compounded by congested roadways and overcrowded intersections. This contributed to longer waiting times at public transport facilities, (World Bank, 1984). By comparison there is little difference presently in relation to the location of public transport facilities, overcrowded public transport facilities due to long waiting times, congested streets and intersections, (MTW, 2011). According to the World Bank, (1984) the policies for road infrastructure and public transport facilities, were out paced by rapid motorization.

As discussed in Section 2.9, a needs-based approach was adopted to assess the safety needs of public transport pedestrian users. As a result, a needs analysis process was developed for public transport pedestrian users to determine the gaps that existed within the existing road safety management system for this road user group. In this way, the actions that were required to bridge the gaps in the road safety management system for this road user group were used as a decision support tool to determine the appropriate countermeasures. The countermeasures presented options to fulfil the safety needs and were aimed at preventing a fatality or serious injury for public transport pedestrian users.

In Section 3.2 it was explained that the needs analysis process was used to assess data collected using the iRAP methodology. It follows then, that as described in Section 2.9, the goal of the assessment was to determine the need and, in this case, the safety needs and its triggers based on established criteria for public transport facilities. That is, the established criteria were based on safety and operational features for on-site bus stops as discussed in Table 2.8, (TRB, 1996). To determine the safety needs, the triggers of the safety needs were first identified. This was done with the introduction of a needs analysis specification to establish conditions to guide the assessment process for identifying the triggers of the safety need from the data collected.

As a result, the needs analysis specification as shown in Figure 3.11, was defined based on the criteria from Table 2.8, to assess the existing road safety management system for public transport facilities. To fulfil the requirements of the need analysis specification, the assessment process was done in the form of a need analysis as shown in Figure 3.12. Thus, the needs analysis specification determined the principles of the needs analysis used to assess the established criteria from Table 2.8. That is, to identify the triggers of the safety need for public transport pedestrian users at public transport facilities such as bus shelters and transport centres. The conditions for the needs analysis specification are as follows:

CHAPTER 3 Methodology and Transferability

Needs Analysis Specification conditions

- Identify key issues and causes
- Identify impact on road users
- Identify problems at the interface of infrastructure and road users/ public transport
- Identify impact on public transport and interactions

The diagram in Figure 3.11 also demonstrates the application of the conditions of the needs analysis specification as follows:

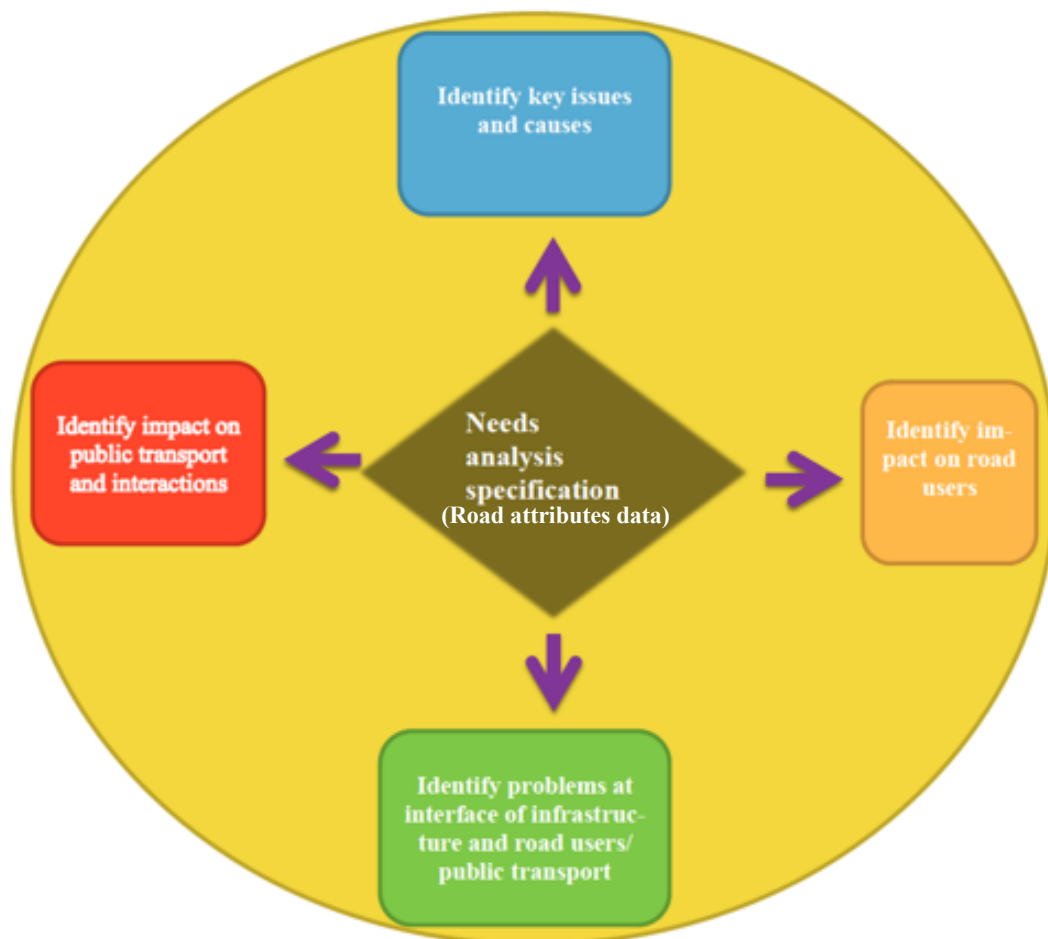


Figure 3.11 Needs analysis specification

CHAPTER 3 Methodology and Transferability

In the diagram shown in Figure 3.11 the needs analysis specifications sort to establish conditions for the implementation of the needs analysis. This was done by identifying key issues and causes in relation to road safety. Following this, the identification of the safety impact on road users in regard these key issues and causes was then determined. Thus, as a result the problems at the interface of the public transport infrastructure and road users were identified. In this way, the impact on public transport based on the interactions with road users was determined according to the established criteria for public transport facilities

The conditions for the needs analysis established by the needs analysis specification determined 8 principles to identify the triggers for the safety needs of public transport pedestrian users. The 8 principles of the needs analysis were applied in 2 phases with each phase consisting of 4 principles as shown in Figure 3.12. In the first phase, the 4 principles coloured green were defined from the 4 conditions of the needs analysis specification.

Following this the second phase of the 4 principles coloured purple were defined from the principles of the first phase of the needs analysis as shown in Figure 3.12. In this way, the assessment focused on safety and operational features for on-site bus stops in regard to the existing road safety and public transport management system coloured blue, as shown in Figure 3.12.

The principles in phase one of the needs analysis process were as follows:

Needs Analysis principles phase 1

- Determine mobility problems
- Determine safety issues
- Determine current use of network
- Determine suitability for functions

The principles in phase two of the needs analysis process were as follows:

Needs Analysis principles phase 2

- Needs of road users
- Road safety inspection
- Identify road users/interactions
- Assess infrastructure design/transport

CHAPTER 3 Methodology and Transferability

The needs analysis assessment process was done as shown in Figure 3.12 as follows:

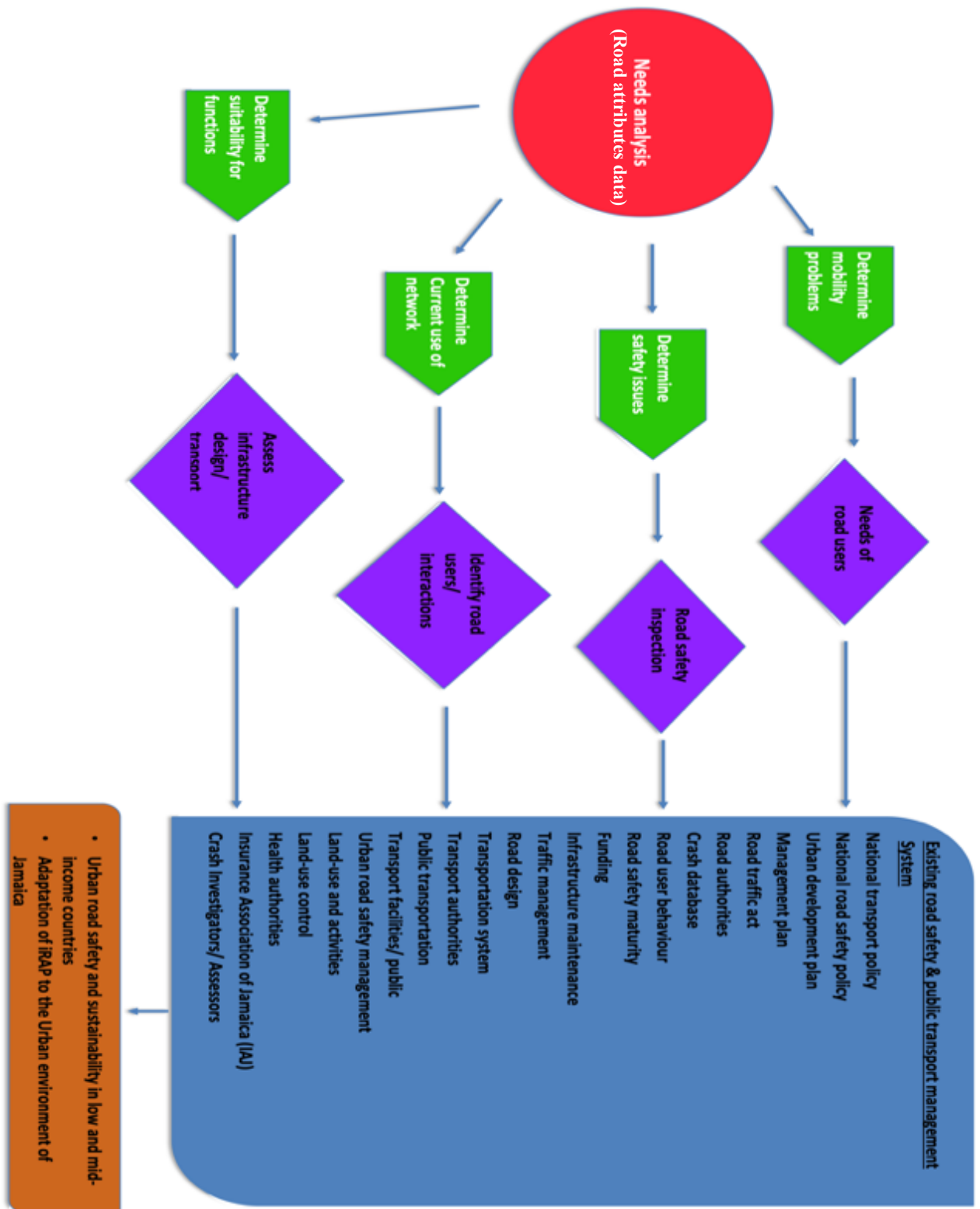


Figure 3.12 Needs analysis

CHAPTER 3 Methodology and Transferability

The application of the needs-based approach to assess safety and operational features for on-site bus stops, from the data collected using the iRAP methodology is further illustrated in Table 3.6. In Table 3.6 the safety and operational features shown in Table 2.8 were grouped according to the specific conditions of the needs analysis specification and the principles of the needs analysis. Moreover, Table 3.6 demonstrates the relationship of the needs analysis to the conditions of the needs analysis specification to determine the influence of design practices for public transport facilities, on the safety needs of public transport pedestrian users.

Table 3.6 Needs-based assessment of on-site bus stop safety and operational features

Needs analysis specification	Need analysis		Safety and operational features	
			Safety features	Operational features
Identify key issues and causes	Determine mobility problems	Needs of road users	Passenger protection from passing traffic; Access for people with disabilities; Direct access to bus stop	Proximity and traffic volumes of nearby driveways
Identify impact on road users	Determine safety issues	Road safety inspection	Width of sidewalks; Proper pedestrian circulation	Impact of the bus stop on adjacent properties;

CHAPTER 3 Methodology and Transferability

Table 3.6 (Continued)

Needs analysis specification	Need analysis		Safety and operational features	
			Safety features	Operational features
Identify problems at interface of infrastructure and road users/ public transport	Determine current use of network	Identify road users/ interactions	<p>Proximity to passenger cross-walks and curb ramps;</p> <p>Proximity of stop for the same route in the opposite direction</p> <p>Proximity to major trip generators;</p> <p>Type of traffic signal controls;</p> <p>Pedestrian activity through intersections;</p>	<p>Bus route patterns which includes individual movement at intersections;</p> <p>Direction and width of intersections;</p> <p>Volume and turning movements of other traffic</p>

CHAPTER 3 Methodology and Transferability

Table 3.6 (Continued)

Needs analysis specification	Need analysis		Safety and operational features	
			Safety features	Operational features
Identify impact on public transport and interactions	Determine suitability for functions	Assess infrastructure design/ transport	All-weather surface to step from or to the bus; Presence of street lighting; Convenient passenger transfers to routes with nearby stops	Adequate kerb space for the number of buses expected at the stop at one time; On-street automobile parking and truck delivery zones

In Figure 3.13 the needs analysis was further expanded into a matrix to demonstrate the assessment of the existing road safety and public transport management system. The data was collected using IQL-III data collection application by identifying the institutional framework in place to manage road use and road users. Based on the assessment carried out, a data list was compiled representing the institutional framework. The data list was then assessed by the conditions of the matrix which determined the role, capability and capacity of the institutional framework in its oversight for road safety and public transport facilities.

In this way the deficiencies in the implementation of the existing road safety and public transport management system were determined. Thus, as shown in Figure 3.13 the analysis process determined whether the management system or programmes were present and in what form were they present. After that the assessment looked at why they were required and how they were implemented. Following this it was then determined who was responsible for

CHAPTER 3 Methodology and Transferability

implementing them and when were they required to be implemented. After that it was determined where they were implemented and whether performance indicators were in place as a measure of the performance of the management system.

CHAPTER 3 Methodology and Transferability

The needs analysis matrix was done as shown in Figure 3.13 as follows:

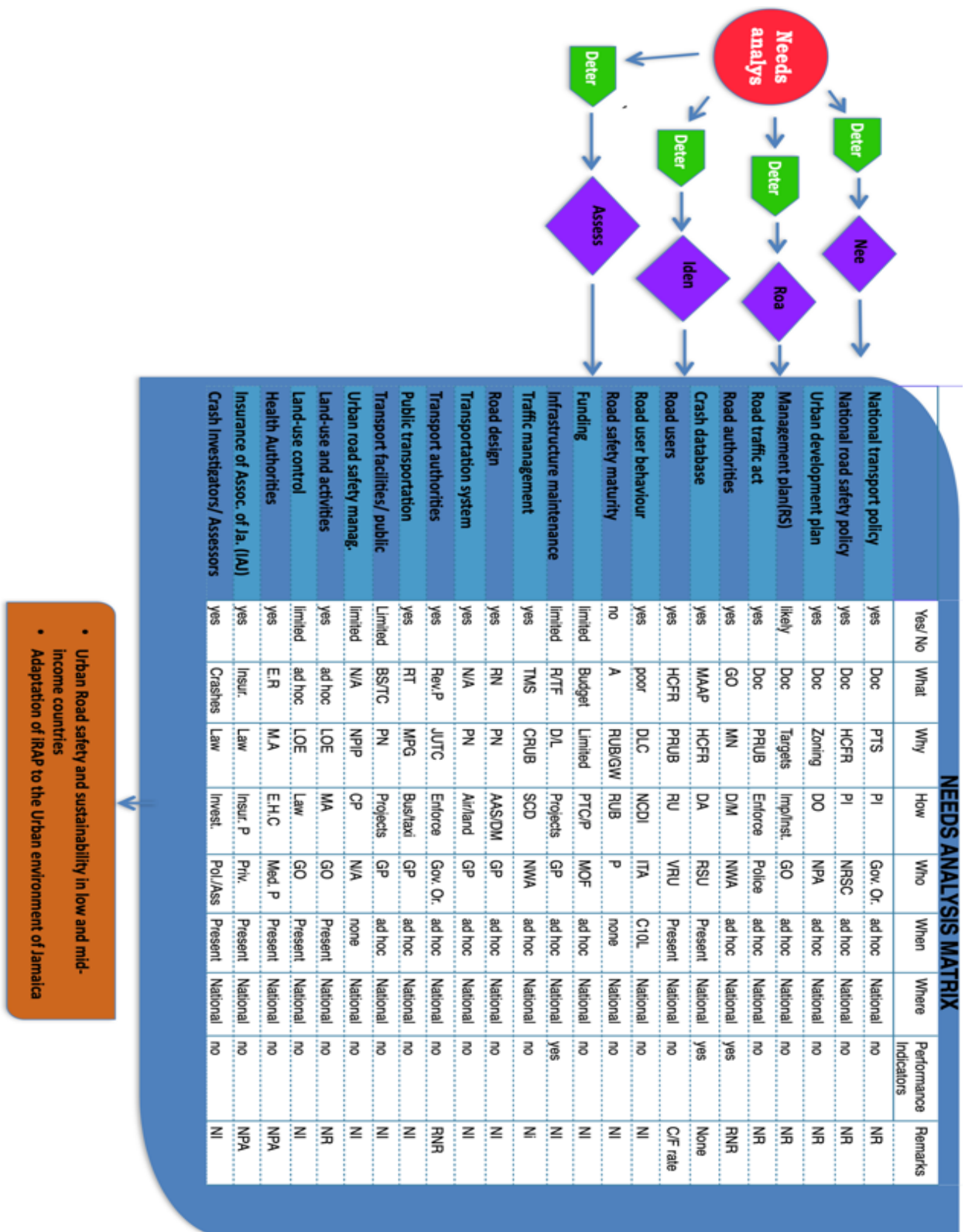


Figure 3.13 Needs analysis matrix

CHAPTER 3 Methodology and Transferability

The needs analysis matrix shown in Figure 3.13 represented the analysis of the institutional framework. The deficiencies identified were reflected in the remarks column based on the findings from the analysis. Thus, represented the triggers of the safety need and the gaps within the system. Therefore needs-based approach determined the triggers of the safety need within the existing road safety and public transport management system. Thus, presenting options for a decision support tool to improve safety and operational features for public transport facilities. And at the same time bridging the gap within the existing road safety and public transport management system. In Table 3.7 below the abbreviations used in the needs analysis matrix are presented.

CHAPTER 3 Methodology and Transferability

Table 3.7 Needs analysis matrix legend

Abbreviations	Meanings
A	Analysis
Doc	Documents
PTS	Poor transport service
HCFR	High crash fatality rate
PRUB	Poor road user behaviour
AAS/DM	AASHTO/ DMRB
NPIP	No policy in place
PN	Population needs
GO	Government organisation
CRUB	Control road user behaviour
RT	Road transport
BS/TC	Bus stop/ Transport centre
RN	Road network
MA	Mixed activity
LOE	Lack of enforcement
DLC	Diver's license certification
NCDI	No certified driving instructors
N/A	Not applicable
RUB/GI	Road user behaviour/ Government will
P	Population
E.R	Emergency response
Infra	Infrastructure
R/TF	Road/ Transport facilities
Rev.P	Revenue protection
Insur	Insurance
Insur. P	Insurance policy
EHC	Emergency health care
D/L	Design life
JUTC	Jamaica urban transit corporation
RUB	Road user behaviour
MPG	Movement of people goods and service
D	Design
NWA	National Works Agency

CHAPTER 3 Methodology and Transferability

Table 3.7 (Continued)

Abbreviations	Meanings
NPA	National Planning Agency
G/P	Government/ Private
PI	Policy Implementation
D/M	Design/ Maintenance
ITA	Island Traffic Authority
CP	Current population
NRSC	National Road Safety Council
RSU	Road Safety Unit
DA	Data analysis
MOF	Ministry of Finance
VRU	Volume of road users
DO	Development order
C10L	Certification: 10 lessons
MN	Manage Network
SCD	Signal control devices
TMS	Traffic management system
Imp/Inst	Implementing Institution
NI	Needs Improvement
NR	Needs Revision
NPA	Need to be Pro-active
RNR	Role Needs to be Revision
C/F rate	Crash Fatality Rate

The needs analysis process used primary data collected using the iRAP methodology to assess the safety of road users as they interacted with the road infrastructure in the traffic environment. In Figures 3.14 to 3.18 an assessment of the safety needs of public transport pedestrian users was done using the needs analysis process. In these images' road features were colour coded according to Table 3.3 with an emphasis on public transport facilities.

This was done to determine the gaps that existed in road safety and the desired situation for public transport pedestrian users. Each image that was assessed had similar safety needs based on the approach taken to the design of public transport facilities in Jamaica.



Figure 3.14 Image of Constant Spring Road, Kingston and St. Andrew safety needs assessment for public transport pedestrian users

In Figure 3.7 road safety and design concerns were colour coded red. It follows then that for the same image now Figure 3.14, with the application of the needs analysis to determine safety needs for public transport pedestrian users there were other concerns. These concerns in particular were in line with Table 3.3 and were colour coded accordingly to reflect the level of risk posed to public transport pedestrian users. Therefore, in Figure 3.14 the safety needs colour coded red were given to reflect poor weather protection, no street lighting and no pedestrian crossing facilities. This was according to TRB (1996) and as further stated in TRB (2015) and ATC (2013).

Weather protection, street lighting and pedestrian crossing facilities were considered important to the design of bus shelters and affected how public transport pedestrian users use these facilities, (TRB, 1996). The colour coding of red was also given to the speed limit of 50km/hr according to (iRAP, 2015), as this was shown to increase the risk of a fatal or serious injury crash. The lack of pedestrian crossing facilities was also supported by (iRAP, 2015) and was seen as playing an import role in road safety between bus shelters as well as transitioning from

CHAPTER 3 Methodology and Transferability

a public transport pedestrian user to a pedestrian, (Schoon, 2019). Its absence was also known to increase the risk of a crash for pedestrians, (iRAP, 2015). The colour code of yellow was given for the transport facility, sidewalk provision, all-weather surface and the absence of a defined bus boarder.

This was done as a result of these features being important to the safety needs of public transport pedestrian users. The provision of which were not adequate to meet the safety needs based on design standards as discussed in Schoon (2019) and TRB (1996). Also discussed in Schoon (2019) and TRB (1996), drainage at transport facilities was considered important to prevent flooding and the displacement of users. In this case shown in Figure 3.14 the flooding of this transport facility was colour coded black reflecting poor drainage.

Similarly, in Figure 3.15 the features colour coded in red, yellow and black are comparable to those colour coded in Figure 3.14 however with one addition. The presence of a light pole in the middle of the sidewalk was considered a hazardous obstruction. In addition, it was placed in front of the bus shelter blocking access for public transport pedestrian users and a clear pathway for pedestrians. According to TRB (1996), PTAWA (2010) and Schoon (2019), access to public transport facilities such as bus shelters and transport centres, improves safety for those who use such facilities such as public transport pedestrian users and for free flow passage of pedestrians.

CHAPTER 3 Methodology and Transferability

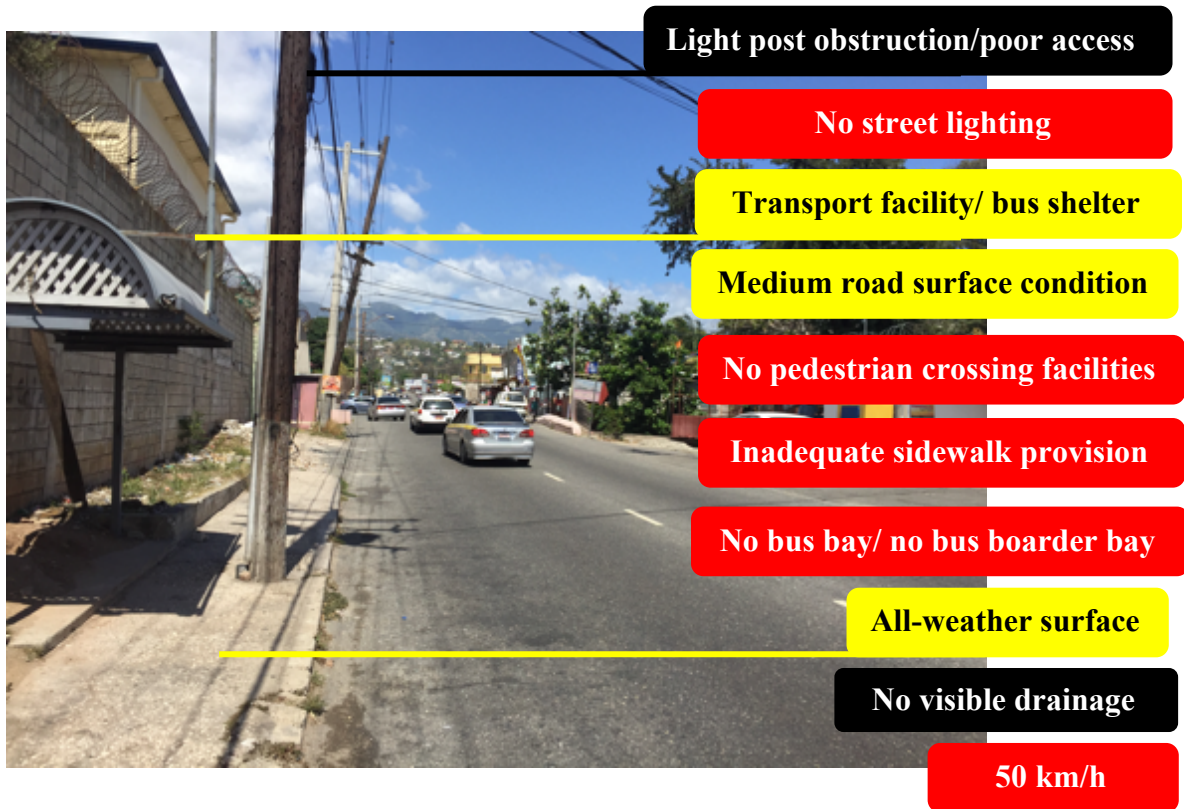


Figure 3.15 Image of Old Hope Road, Kingston and St. Andrew safety needs assessment for public transport pedestrian users

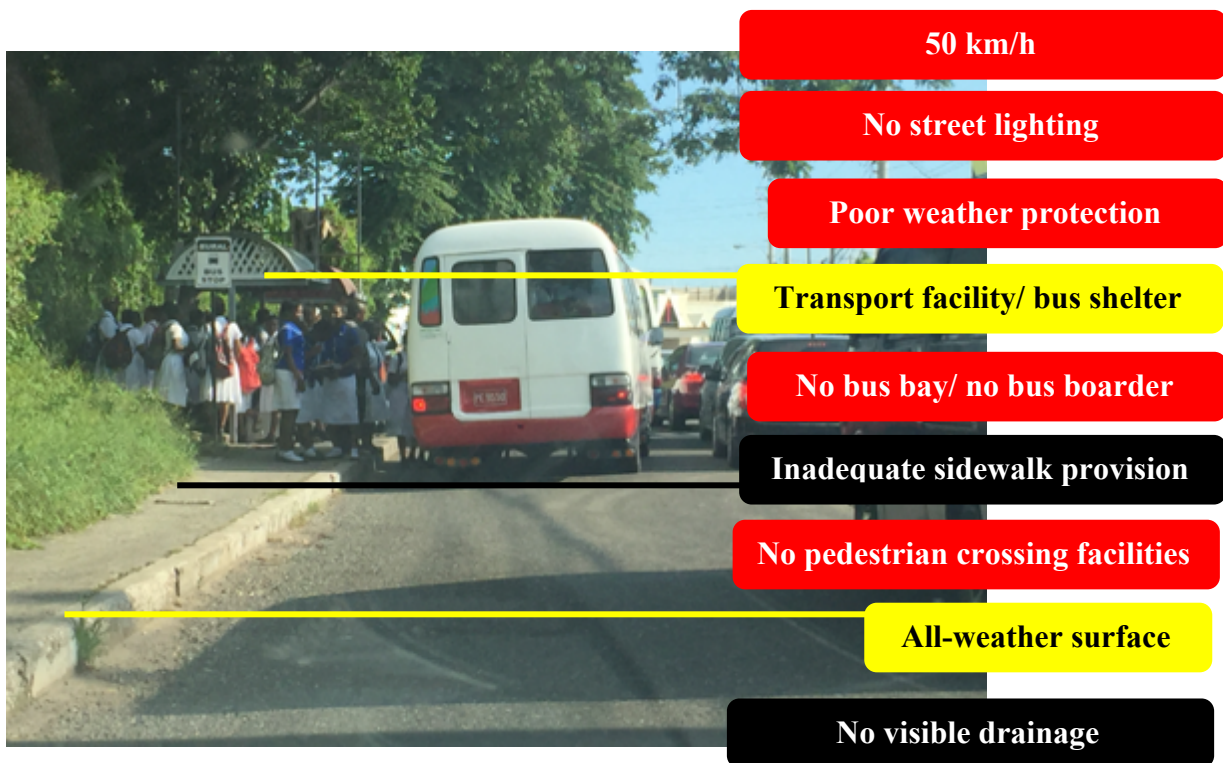


Figure 3.16 Image of Constant Spring Road, Kingston and St. Andrew safety needs assessment for public transport pedestrian users

CHAPTER 3 Methodology and Transferability

In the assessment of Figure 3.16 the safety needs of public transport pedestrian users are colour coded similarly as shown in Figure 3.14 and Figure 3.15. However as shown in Figure 3.16 the transport facility was overcrowded and indicated that the design for this bus stop did not coincide with the demand usage of public transport pedestrian users. This also affected the use of the sidewalk in the vicinity of the transport facility by pedestrians. As discussed in NTA (2014) safety is impacted by the design of the transport facility. Therefore, the appropriate infrastructure should be provided for safe use and to accommodate the expected demand on the facility based on its location.

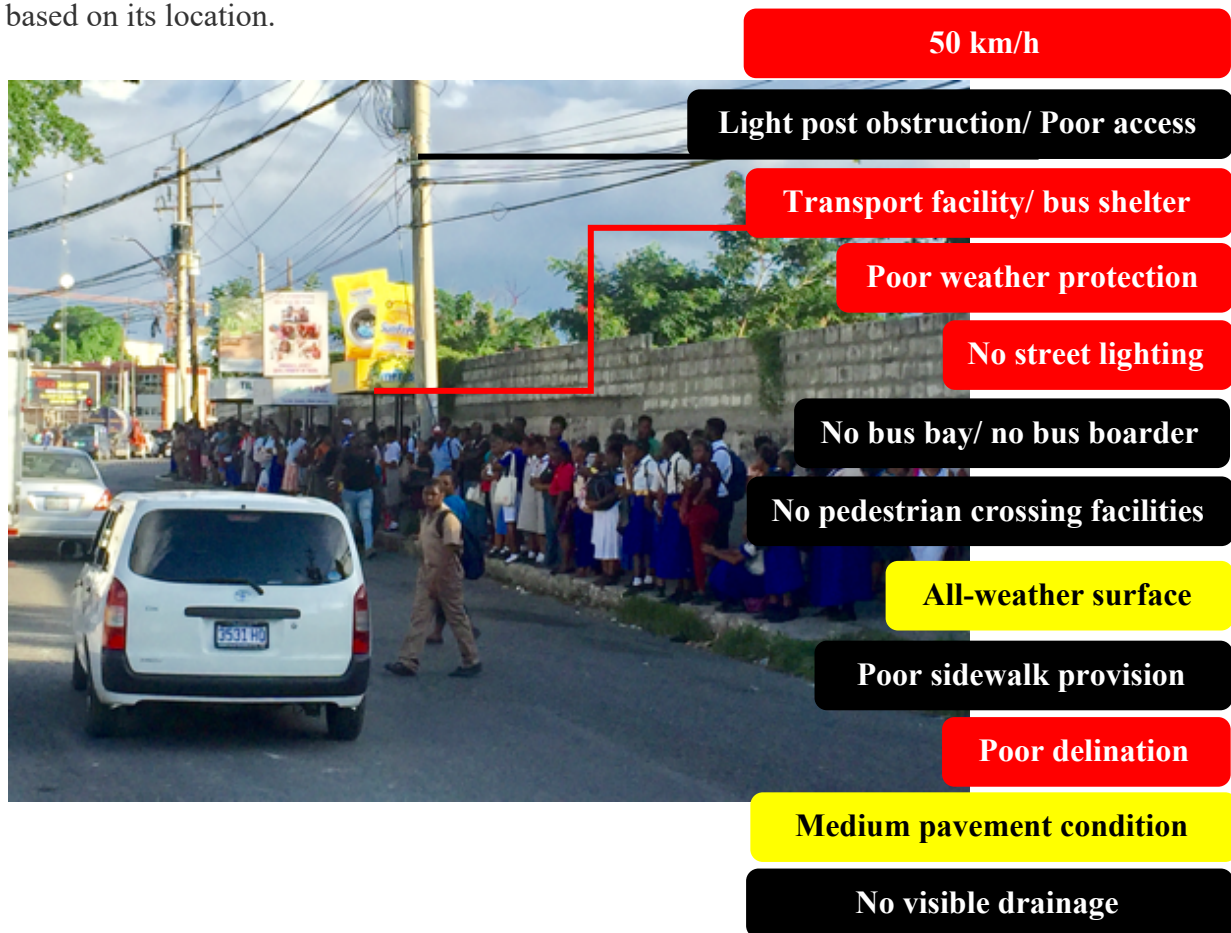


Figure 3.17 Image of Molynes Road, Kingston and St. Andrew safety needs assessment for public transport pedestrian users

As shown in Figure 3.17 an even more overcrowded transport facility was seen than in Figure 3.16 where the demand far exceeds the design capacity. Based on the safety needs and demand on this facility by public transport pedestrian users, colour coding was elevated to black for most of the similar features assessed in Figure 3.16. In Figure 3.18 the colour coding given are also similar to that of Figures 3.14 to Figure 3.17, however with noticeable improvements in

CHAPTER 3 Methodology and Transferability

the design of the transport facility and in this case a transport centre. In this assessment colour coding of green was given for these improvements in design that increase the safety for public transport pedestrian users. It is to be noted however that there were still other features that received colour coding of red and black as with previously assess transport facilities.



Figure 3.18 Image of Half Way Tree Road Transport Centre, Kingston and St. Andrew safety needs assessment for public transport pedestrian users

3.7 The assessment of the safety for public transport pedestrian users at public transport facilities with the application of the iRAP Methodology

As discussed in *Section 2.8.8* and *Section 3.2* the iRAP methodology uses colour coding to highlight the risk of a fatality or serious injury to a road user based on the presences or absence of road features. This application was used to determine whether the risk to public transport pedestrian users could be identified according to the existing road attribute databased used in the iRAP tool kit, and the iRAP Star rating and investment plan: Road survey and coding specification. To determine the third objective the iRAP methodology was used to assess Figure 3.19 to Figure 3.23.

CHAPTER 3 Methodology and Transferability

Therefore, to assess the images in Figure 19 to Figure 23 which represent transport facilities from the study area, the road user type closest to public transport pedestrian users was used. This road user type was pedestrians, hence the road features present or absent that could influence a fatal or the severity of a crash was used according to (iRAP, 2015). The colour coding according to Table 2.5 was used to identify road features at public transport facilities and the risk level for pedestrians. In Figure 3.19 a colour coding of red was given to the absence of pedestrian facilities, a speed limit of 50km/hr, no street lighting and poor delineation. The colour code of green was then given to the provision of sidewalk.



Figure 3.19 Image of Constant Spring Road, Kingston and St. Andrew road attributes assessment: iRAP pedestrian model application

Similarly, in Figure 3.20 the road features present or absent were comparable to Figure 3.19. This was also discussed in Section 3.5 for the assessment of safety needs for public transport pedestrian users based on design practices. However, within this transport centre there was provision of lighting and this was given a colour code of yellow. In Figure 3.21, the use of the iRAP pedestrian model application only resulted in 3 public transport features colour coded red based on the design approach. These road features were also similar to Figure 3.19

CHAPTER 3 Methodology and Transferability

and Figure 3.20, however in the design of the transport centre in Figure 3.22 additional public transport features were present and colour coded.

The colour code of red was given for poor delineation, no pedestrian crossing facilities and the poor condition of a broke out pedestrian fencing. Though there was provision made for sidewalk, this was colour coded yellow because of the presence of the bus shelter and vending. According to Schoon (2019), pedestrian access to pedestrian facilities determines the level of safety and should allow free flow access based on the volume of pedestrian. The presence of street lighting also was given a colour code of yellow. This was also according to Schoon (2019) and IRAP (2015), based lighting being highlighted as important to increase visibility for pedestrians and the safety use of pedestrian facilities at night.



Figure 3.20 Image of Darling St rural transport facility, Kingston and St. Andrew road attributes assessment: iRAP pedestrian model application

CHAPTER 3 Methodology and Transferability



Figure 3.21 Image of Cross Roads transport facility, Kingston and St. Andrew road network: road attributes assessment: iRAP pedestrian model application



Figure 3.22 Image of Half-way-tree bus terminus, Kingston and St. Andrew road network: road attributes assessment: iRAP pedestrian model application



Figure 3.23 Image of Half-way-tree taxi stand, Kingston and St. Andrew road network: road attributes assessment: iRAP pedestrian model application

By extension the image shown in Figure 3.23 displays the existing safety measures integrated into the design of public transport facilities. Similarly, the image also shows the influence of infrastructure design practices of public transport facilities and on road safety interactions. In particular the interactions show a mixing of public transport pedestrian users and vehicular traffic. Consequently, the colour coding of yellow and red were given to similar road attributes as previously discussed based on the level of safety afforded to pedestrians.

3.8 Safety measures methodology for public transport pedestrian users star rating model equation at public transport facilities such as bus shelter and transport centres

The crash database was assessed as discussed in Section 3.3 to examine whether there were crashes involving public transport users and if these crashes occurred at public transport facilities. According to data from RSU (2016), there were crashes recorded in MAAP, however there were no reference to public transport facilities.

The analysis of crash data, in Table 3.4, identified specific road user groups at IQL-I level data application and formed the basis that defined road users that were not represented in

CHAPTER 3 Methodology and Transferability

frequent crashes. The identification of road users according to the level of exposure in the traffic environment and availability or provision of facilities, further defined road users according to road use and crash types. Crash data related to public transport facilities, were therefore defined as crashes involving public transport pedestrian users as discussed in *Section 2.8.7*.

The methodology for the development of a crash allocation star rating model for public transport pedestrian users is shown in Figure 3.24. In Figure 3.24 the steps shown are representative of the preceding sections. The methodology flow chart thus far shows steps to determining the needs analysis and the risk factors associated with the safety needs of public transport pedestrian users. In this section the formulation of the methodology flow chart shown in Figure 3.24 determined the fourth objective. In determining the fifth objective in Section 3.8 the other steps in the methodology continuing with countermeasures was demonstrated.

CHAPTER 3 Methodology and Transferability

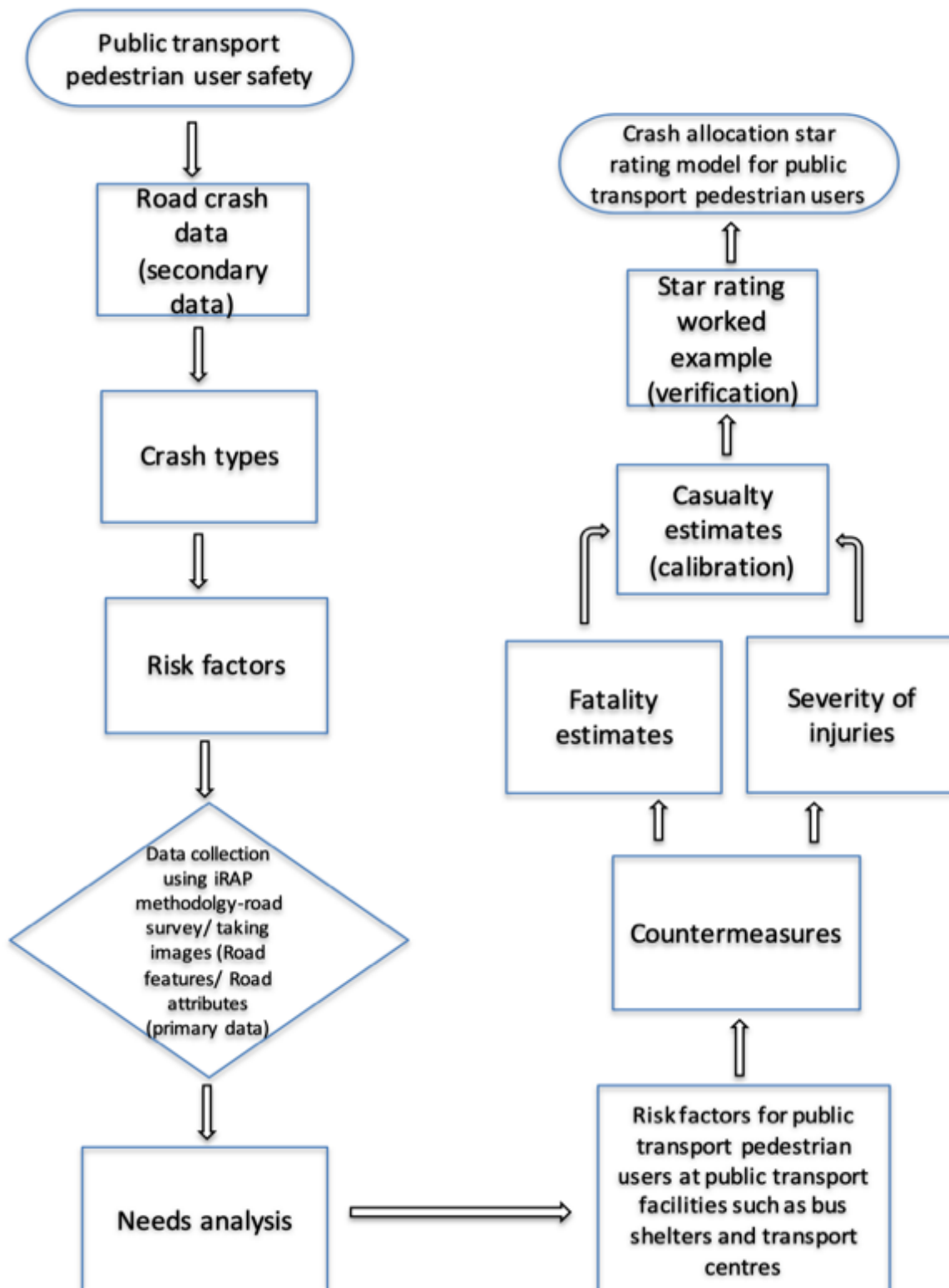


Figure 3.24 Methodology for the development of the crash allocation star rating model for public transport pedestrian users at public transport facilities such as bus shelters and transport centres

CHAPTER 3 Methodology and Transferability

The risk factor and countermeasures shown in Figure 3.24 were developed in accordance with existing iRAP models. This was to determine the minimum number of risk factors to be included to determine appropriate countermeasures to improve safety at public transport facilities. The risk factors included for public transport facilities were those that were thought to significantly influence a fatality or severe injury to public transport pedestrian users.

The methodology flow chart shown in Figure 3.24 also demonstrates the calibration and verification of the crash allocation star rating model for public transport pedestrian users. The SRS equation for public transport pedestrian users discussed in *Section 2.8.9* was developed based on risk factors with crash types at public transport facilities. The data collected from the study area was used to verify the star rating score for public transport pedestrian users. It follows then that the data collected as discussed in *Section 3.2* was entered according to the iRAP methodology worked example for star ratings in Fact sheet 6, (iRAP, 2013). This was done against the star rating score for the existing pedestrian iRAP model.

The introduction of the new road user type, PTPU in the existing fatality estimation equation, in the iRAP model, represented a model equation for fatality estimation. The model equation was then calibrated according to iRAP methodology fact sheet 10, as discussed in *Section 2.8.10* (iRAP, 2014). The calibration process used existing road user types in the iRAP model, with the introduction of the new road user type for PTPU. The introduction of the new road user type, PTPU in the existing iRAP model calibration factor formula, resulted in the calibration factor formula for fatality estimation, (iRAP, 2014).

In developing the fatality estimation equation and calibration formula the number of road users seriously injured in relation to PTPU was also determined. The inclusion of the new road user type presented a new outcome for the total number of fatalities and serious injuries. The new total for fatalities and serious injuries represented the impact of the new road user type on the existing iRAP models and total number of fatalities and serious injuries on a road section.

The verification of the star rating model for PTPU as discussed in Chapter 5 was done to establish consistency with current iRAP models. As a result, verification was done by inputting data collected on a 100m segment of a road within the study area. Therefore, following the format for data entry according to the iRAP methodology for worked examples in Fact sheet 9. In Fact sheet 9, the iRAP methodology demonstrated how the star ratings were calculated,

CHAPTER 3 Methodology and Transferability

(iRAP, 2013). The verification of the star rating model presented a crash allocation star rating model for public transport pedestrian users at public transport facilities for low to middle-income countries, with applications for high-income countries.

3.9 The integration of the safety measures for public transport pedestrian users to expand the iRAP methodology to include public transport facilities such as bus shelter and transport centres

The integration of public transport pedestrian users focused on the conditions that led to the development of the iRAP model and its application to developing countries. Moreover, the key issues and causes of road safety relate to the human, vehicular and road environment which are widely considered as the main components contributing to crashes, (WHO, 2004). According to Kaufman and Valentine (2007), the gaps that existed within the management system represented the need to be filled. The reduction of the gap represented the desired result needed to be attained, to bridge the gap between what exists and is to be maintained, once the closing of the gap was achieved, (Kaufman and Valentine, 2007).

In this way, a relationship between the new road user type public transport pedestrian users and existing iRAP models was established to show consistency with the iRAP methodology. Moreover Table 3.8 and Figure 3.25 also shows the integration of safety measures for public transport pedestrian users at public transport facilities. As a result, this demonstrated the expansion of the iRAP methodology to include public transport pedestrian users as a new road user type that achieved the third objective.

The iRAP standard countermeasures shown in Table 3.8 were based on the crash types as discussed in *Section 2.8.9* and as shown in Table 2.6. By the same token, Figure 2.7 and Figure 2.8 further illustrated the type of crashes public transport pedestrian users were exposed to at public transport facilities such as bus shelters and transport centres. The number of fatalities that occurred on the roadway as discussed in Section 3.3 and as shown in Table 3.4 was approximately 541 fatalities associated with public transport facilities such as bus shelters and transport centres.

The risk faced by public transport pedestrian users was related to the length of time in the traffic system, (SWOV, 2002). Therefore, the length of time in the traffic system represented the time spent waiting on public transportation or the time it took to walk in a transport facility to the

CHAPTER 3 Methodology and Transferability

point of departure or exit from the transport facility. As a result, risk factors related to public transport pedestrian users were also based on the number of meters travelled, (SWOV, 2002). The type of risks identified were determined as shown in Figure 2.7 and Figure 2.8. Thus, the countermeasures were determined based on the type of exposure to the risks identify from the crash types shown in Figure 2.7 and Figure 2.8. By extension the time spent in the traffic system also influenced a fatal or severe crash based on the transport facility provided.

In addition, in determining the impact of the traffic environment on road users. The needs analysis specification (NAS) as shown in Table 3.5 was used to assess the problems that existed at the interface of the road infrastructure and road users. In looking at these problems that existed at the interface of the road infrastructure, the NAS was used to further determine the impact on public transportation and the type of interaction that existed. In this way the considerations for public transport facilities and the recommended countermeasures as shown in Table 3.8 were based on the current use of the road network.

As a result, this established suitability of function of public transport facilities such as bus shelters and transport centres based on the infrastructure design of public transport facilities. The use of iRAP as a crash allocation model and a decision support tool, to assess the road safety was aimed at identifying the risks associated with the factors that influence road crashes. So even though risk factors and countermeasures for the iRAP model as shown in Table 3.8 were used to determine the risks in the traffic system for public transport pedestrian users. Where risks and countermeasures for the iRAP models did not apply to public transport pedestrian users, new countermeasures were introduced under enhanced countermeasures also as shown in Table 3.8.

Moreover, the integration of the countermeasures done in Table 3.8 for public transport pedestrian users was based the ideal situation needed to enhance safety at public transport facilities. However preferred countermeasures were also recommended so that interventions were determined based on available budgets. In this way a minimum threshold for safety needs at public transport facilities was determined based on risk indicator as shown in Table 3.8. Therefore, risk factors included for public transport facilities, were those that pose the greatest risk to public transport pedestrian users as shown in Figure 2.7 and Figure 2.8. It follows then that the countermeasures shown in Table 3.8 were those that reduced the impact of road crashes

CHAPTER 3 Methodology and Transferability

involving public transport pedestrian users in the traffic system according to crash types, (Lynam, 2012).

Table 3.8 Risk factors and countermeasures

Risk Factor Countermeasure Matrix							
Mode	Crash type	Likelihood risk factors	Severity risk factors	IRAP Standard Countermeasures	Enhanced Countermeasures / Intervention protection factors for public transport pedestrian users	Preferred Countermeasures/ Intervention protection factors for public transport pedestrian users	Risk indicators
Public transport pedestrian users	Along score (on pavement in a transport centre driver and passenger sides calculated separately)	Sidewalk provision Quality of curve Road side friction Road drainage Road side object Delineation Sight Distance Lane width Road condition Speed management/ traffic calming Vehicle parking Street lighting Transport facility lighting Kerb height Pedestrian fencing Platform type/quality (Public transport facility) Grade	Pedestrian fencing quality Platform type/quality (Public transport facility) Speed management/ traffic calming Sidewalk provision	Sidewalk Delineation Pedestrian fencing Pedestrian refuge island Regulate roadside commercial activity Parking improvements Shoulder sealing Speed management Traffic calming Sight distance- (obstruction removal) Road surface rehabilitation School zones Street lighting	Hazard removal Regulate roadside commercial activity Sidewalk Pedestrian fencing Regulate roadside commercial activity Parking improvements Shoulder sealing Speed management School zones Street lighting Standard safe design for public transport facilities	Sidewalk provision Pedestrian fencing Regulate roadside commercial activity Shoulder sealing School zones	Provision of adequate infrastructure Road side activity
	Crossing (road in a transport centre)	Number of lanes Road side friction Pedestrian crossing facility (Transport facility) Skid resistance/ grip Transport facility lighting Sight Distance Vehicle parking Speed management/ traffic calming Street lighting Sidewalk provision Tactile pavement Ramp quality Median type Delineation Intersection type School zone warning Facilities for public transport Road drainage Facilities for public transport	Speed management/ traffic calming Pedestrian crossing quality (Transport facility)	Pedestrian refuge island Pedestrian crossing- unsignalised Sidewalk Delineation Pedestrian fencing Regulate roadside commercial activity Parking improvements Shoulder sealing Speed management Traffic calming Sight distance- (obstruction removal) Road surface rehabilitation Street lighting	Sidewalk Delineation Regulate roadside commercial activity Parking improvements Traffic calming Sight distance- (obstruction removal) Road rehabilitation Lighting Standard safe design for public transport facilities Pedestrian crossing facility	Sidewalk provision Regulation of roadside commercial activity Speed management Traffic calming Pedestrian crossing facility Delineation	Provision of adequate infrastructure Road side activity
	Along (Standing/waiting at a bus shelter or transport centre)	Road drainage Sidewalk provision Kerb height Quality of curve Pedestrian fencing Speed management/ traffic calming Road condition Grade Sight distance Lane width Facilities for public transport Platform type/quality (Public transport facility) Road side friction	Pedestrian fencing quality Platform type (Public transport facility) Sidewalk provision	Pedestrian fencing Parking improvements Shoulder sealing Speed management Traffic calming Sight distance- (obstruction removal) Road surface rehabilitation Skid resistance Regulate roadside commercial activity	Pedestrian fencing improvements Traffic calming Sight distance- (obstruction removal) Lighting Regulate roadside commercial activity Standard safe design for public transport facilities	Sidewalk provision Pedestrian fencing Traffic calming Regulate roadside commercial activity	Provision of adequate infrastructure Road side activity

CHAPTER 3 Methodology and Transferability

The existing iRAP SRS equations for vehicle occupants, motorcyclist, bicyclist and pedestrians were analyzed to determine the risk factors included for the SRS equation. The risk factors of existing SRS equation were then assessed to determine, similarities in the crash types identified for public transport pedestrian users. The crash types for public transport pedestrian users was then determined as shown in Figure 3.25 based on risk factors and the facilities provided. The risk factors were determined from the data collected from the study area by using the iRAP methodology as shown in Table 4.3.

In Figure 3.25 the diagram shown further demonstrates the integration of safety measures for public transport pedestrian users to expand the iRAP methodology. The methodology in Figure 3.25 shows the application of the star rating model equation for public transport pedestrian users as discussed in *Section 2.8.9*. That is, it showed the relationship between public transport pedestrian users, the crash types involved as well as likelihood and severity risk factors and countermeasures for road crashes at public transport facilities. This was also done in relation to the crash types shown Figure 2.7 and Figure 2.8.

The star rating score for public transport pedestrian users in Figure 3.25 was a summation of the crash types involved in crashes at public transport facilities as discussed in *Section 2.8.9*. Moreover, the crash types were a product of the likelihood and severity risk factors and at the same time included external flow factors as external contributory factors, as well as operation speed factors as internal contributory factors. As a result, the countermeasures in Table 3.8 were determined based on the road features present or absent as a product of the likelihood initiating risk factors as shown in Figure 3.25.

The crash types for pedestrians in the iRAP model considered crashes involving pedestrians walking along the roadway and crossing the roadway. Public transport pedestrian users face increased exposure in the traffic environment, thus, being stationary at a public transport facility such as a bus shelter or transport centre determined the type of crash that occurred. Therefore, in Figure 3.25 the boxes coloured yellow highlights the new aspects of the star rating equation and the new risk factors included were also worded in yellow. By expanding the existing iRAP model to include public transport pedestrian users as discussed in section 2.8.7 the result was the star rating model for public transport facilities.

CHAPTER 3 Methodology and Transferability

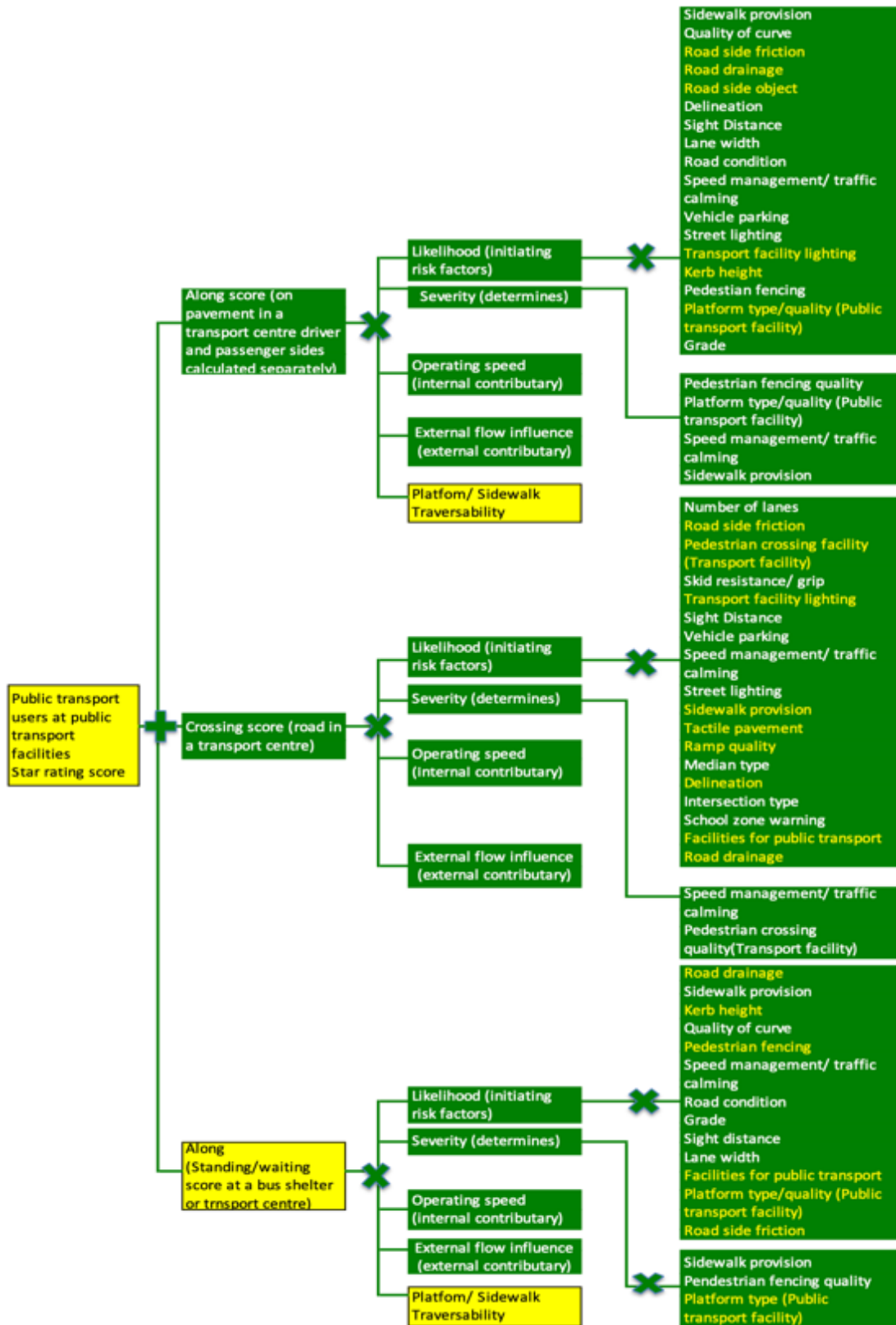


Figure 3.25 New star rating model equation methodology for public transport pedestrian users at public transport facilities

CHAPTER 3 Methodology and Transferability

Based on the road user types presently included in the existing iRAP model, the application of the needs-based approach focused on road user types not included in iRAP such as public transport pedestrian users (PTPU). There was limited research available on the influence iRAP risk factors and road attributes had on PTPU, as reference was only made to public transport vehicles when discussed by iRAP, (iRAP, 2010).

Therefore, the methodology development process determined the risk factors and road attributes associated with the likelihood and severity of a crash, for PTPU at public transport facilities (PTF). The star rating model equations for PTPU was based on the three crash types as discussed in *Section 2.8.9* and as shown in *Figure 2.7* and *Figure 2.8*.

Crash type for public transport pedestrian users

- Along (on pavement in a transport centre)
 - A collision with public transport pedestrian users occurs while they were walking on the pavement of a transport facility and hit by an errant vehicle
 - The along crash type for public transport pedestrian user was considered with in the same context as the along crash type for motorcyclist, bicyclist and pedestrians
 - In addition to the likelihood, severity, operating speed and external flow factors that were included for motorcyclist, bicyclist and pedestrians, when calculating their along scores. The inclusion of a platform/ sidewalk traversability was added that was specific to public transport pedestrian users and how they used the roadway
 - Based on the road attributes included for motorcyclist, bicyclist and pedestrian in existing star rating equations, road attributes were omitted and added in relation to the likelihood score such as roadside friction, transport facility lighting; kerb height, pedestrian fencing, and platform type/ quality as shown in *Figure 3.25*.
 - In relation to severity score pedestrian fencing quality, platform type/ quality; speed management/ traffic calming and sidewalk were seen as some of the factors that could impact the severity of a crash as shown in *Figure 3.25*.
- Crossing (road in a transport centre)
 - A collision occurs with a public transport pedestrian users while they were crossing the road in a transport facility/ transport centre

CHAPTER 3 Methodology and Transferability

- The crossing crash type was considered within the context of the crossing score for pedestrians in the existing iRAP star rating equation however was applied to reflect the crossing of a roadway in a transport facility.
- The factors considered were the same as those used in determining the cross score for pedestrians in the existing iRAP star rating score equation for pedestrians in relation to likelihood, severity factors, operating speed and external flow influence.
- The road attributes considered in relation to the crossing score for public transport pedestrian users in a transport facility, in regard to the likelihood of a crash were roadside friction, pedestrian crossing facility, transport facility lighting; sidewalk provision, tactile pavement, ramp quality and delineation as shown in Figure 3.25.
- The factors that were considered in regard to severity were speed management/ traffic calming and pedestrian crossing quality as shown in Figure 3.25.
- Along (standing or waiting at a bus shelter or transport centre)
 - A collision with public transport pedestrian users while they are waiting at public transportation facility.
 - In assessing the crash types for public transport facilities the likelihood, severity, operating speed, external flow factors and platform/ sidewalk traversability were considered, as in the along crash type for pedestrians in the iRAP model. The application of these factors was therefore consistent with the iRAP star rating methodology, in relation to the type of crashes involving public transport pedestrian users.
 - The road attributes considered for the along crash type (standing/ waiting at a bus shelter or transport centre) score were determine in relation to similar crash types and road attributes used in existing iRAP star rating equations. Road attributes were also introduced in relation to the likelihood and severity factors of a crash. The likelihood factors considered were kerb height, roadside object, quality of curve, pedestrian fencing, speed management and traffic calming; road condition, grade, sight distance, lane width; facilities for public transport, platform type/ quality and roadside friction.
 - The road attributes considered in relation to the severity factor were sidewalk provision, pedestrian fencing quality, and platform quality.

CHAPTER 3 Methodology and Transferability

In the development of the star rating model for public transport pedestrian users the sequence of development followed existing iRAP models. This took a systematic approach to providing countermeasures to reducing road crash fatalities and serious injuries. This approach also allowed for appropriate countermeasures to be determined in an effort to reduce the number of road crash fatalities and serious injuries related to public transport pedestrian users.

3.10 Summary

The use of iRAP was to establish a methodology for determining the types of crashes and the provision against crashes and injuries within the design of road infrastructure for public transport pedestrian users. The collection of data at different IQL levels from primary and secondary sources on road crashes and road attributes was also a part of the process. As discussed, the process was aimed at determining whether iRAP could be used to assess road sections to improve the existing situation at public transport facilities in the urban road environment. Similarly, the data was assessed using the needs-based approach to determine the safety needs of road users against best practice design principles for public transport facilities in develop countries.

The assessment and collection of data also formed the basis to determine and demonstrate the approach to achieving the objectives of the research project. And in particular the integration of public transport pedestrian users according to the iRAP star rating model development process, to expand the iRAP methodology. That is, by including the assessment processes, road attributes and countermeasures for public transport facilities. The crash types identified to influence the countermeasures considered, determined the need for improving the safety of public transport facilities such as bus shelters and transport facilities for public transport pedestrian users

CHAPTER 4 Data

4.1 Introduction

Data used for analysis was based on primary and secondary sources as discussed in Section 3.2. In particular, the approach taken was to assess the existing situation in Jamaica in relation to road safety as discussed in Section 1.1. Thus, data was broken down into primary and secondary data sources according to Section 2.10 to reflect the various areas that impacted road safety and road users in Jamaica. As a result, a needs-based approach was adopted, and a needs analysis process developed to determine safety needs at public transport facilities. The identification of the gaps that existed in the existing road safety management system and the countermeasures needed to bridge and maintain the gap, were in respect to the data collected for public transport facilities on urban roads in Jamaica.

4.2 Road crash data

As discussed in Section 3.3, road crash data for crashes that occurred on the Jamaican road network was obtained from secondary data sources. This data was then reported to at the national and international level to determine the performance of road safety strategies being used by road safety authorities in Jamaica. The data was reported using the format of IQL IV which was the data format used at the policy level. This presented the most generalized summary of road crash data according to international standards.

According to OECD (2018), Jamaica was ranked fourth out of 41 countries for road fatalities with 13.9 fatalities per 100 000 inhabitants as shown in Figure 4.1. This ranking was based on 2016 road crash data and was also recorded as not verified by the International Traffic Safety Data and Analysis Group (IRTAD). Nonetheless road crashes were also assessed based the per cent change in road crash fatalities as shown in Figure 4.2. In this comparison Jamaica was ranked second with a positive per cent increase in road crash fatalities of 18.8 per cent for the period 2010 to 2016. In Figure 4.3 Jamaica was also ranked second for road crash fatalities per 10 000 vehicles in 2016, where there were 9.6 fatalities per 10 000 vehicles (OECD, 2018).

CHAPTER 4 Data

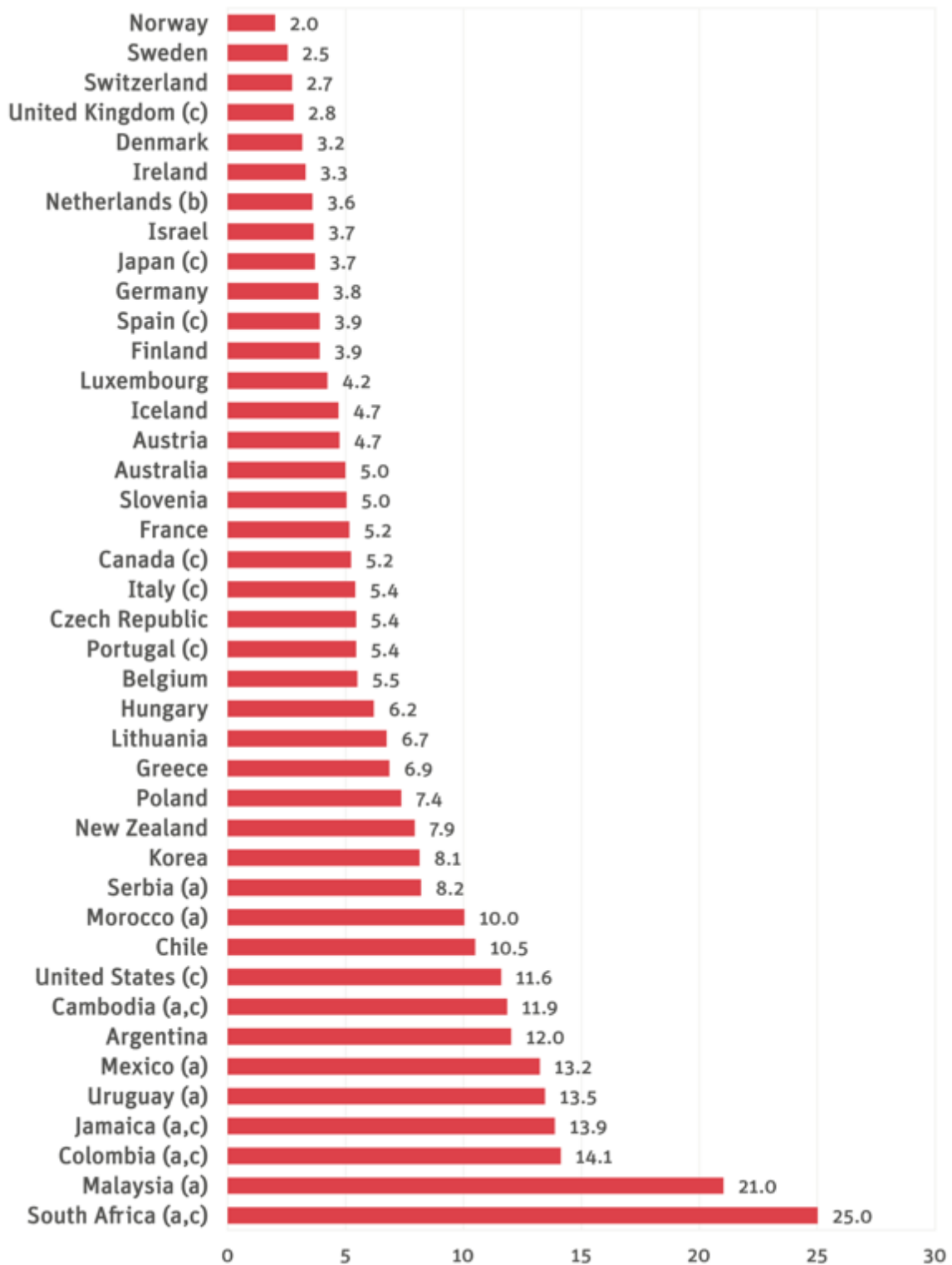


Figure 4.1 Road crash fatalities per 100 000 inhabitants for International Transport Forum member countries. Modified by Uter (2018) and obtained from OECD (2018)

CHAPTER 4 Data

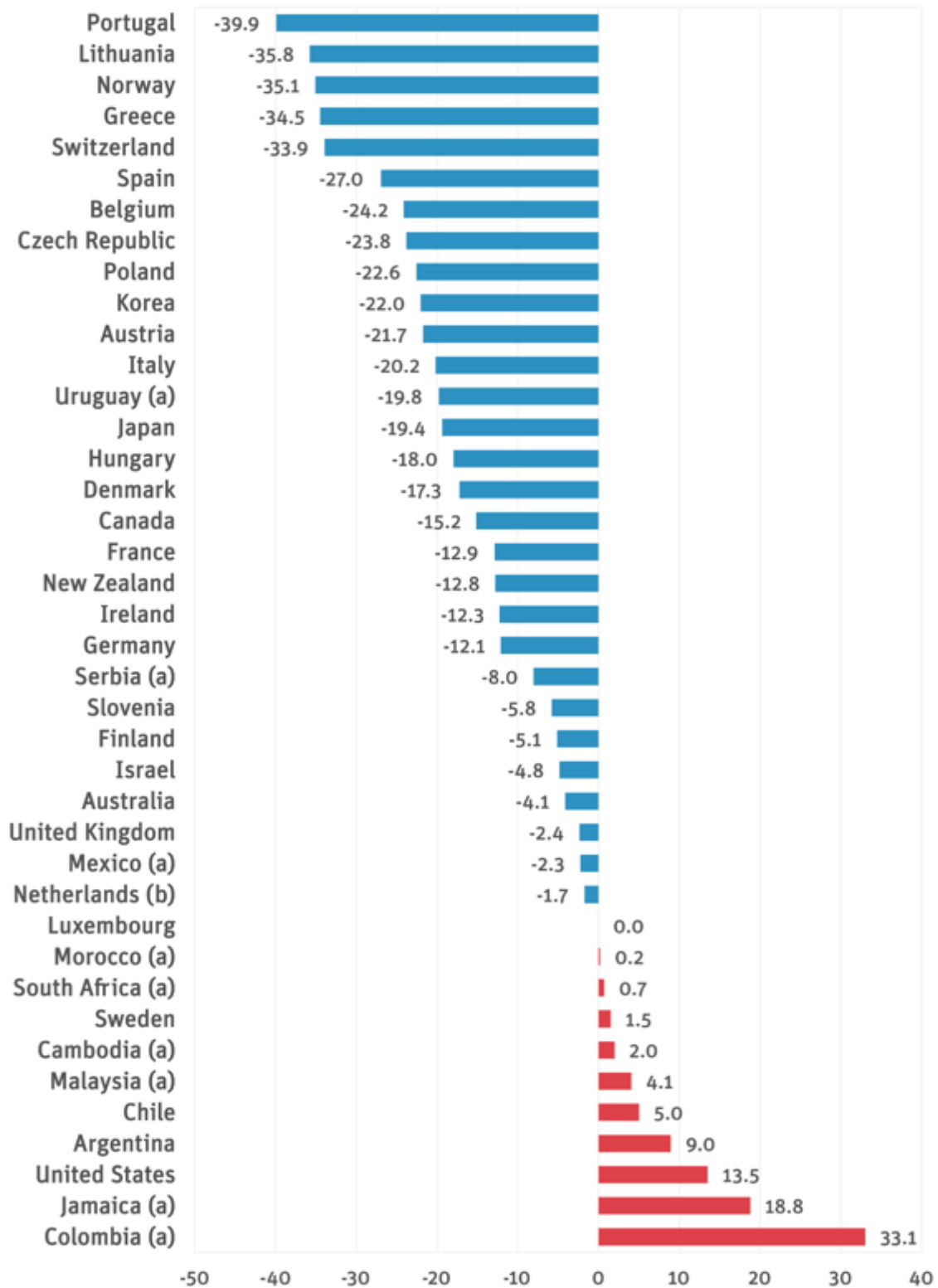


Figure 4.2 Road crash fatalities as a per cent change for International Transport Forum member countries 2010 to 2016. Modified by Uter (2018) and obtained from OECD (2018)

CHAPTER 4 Data

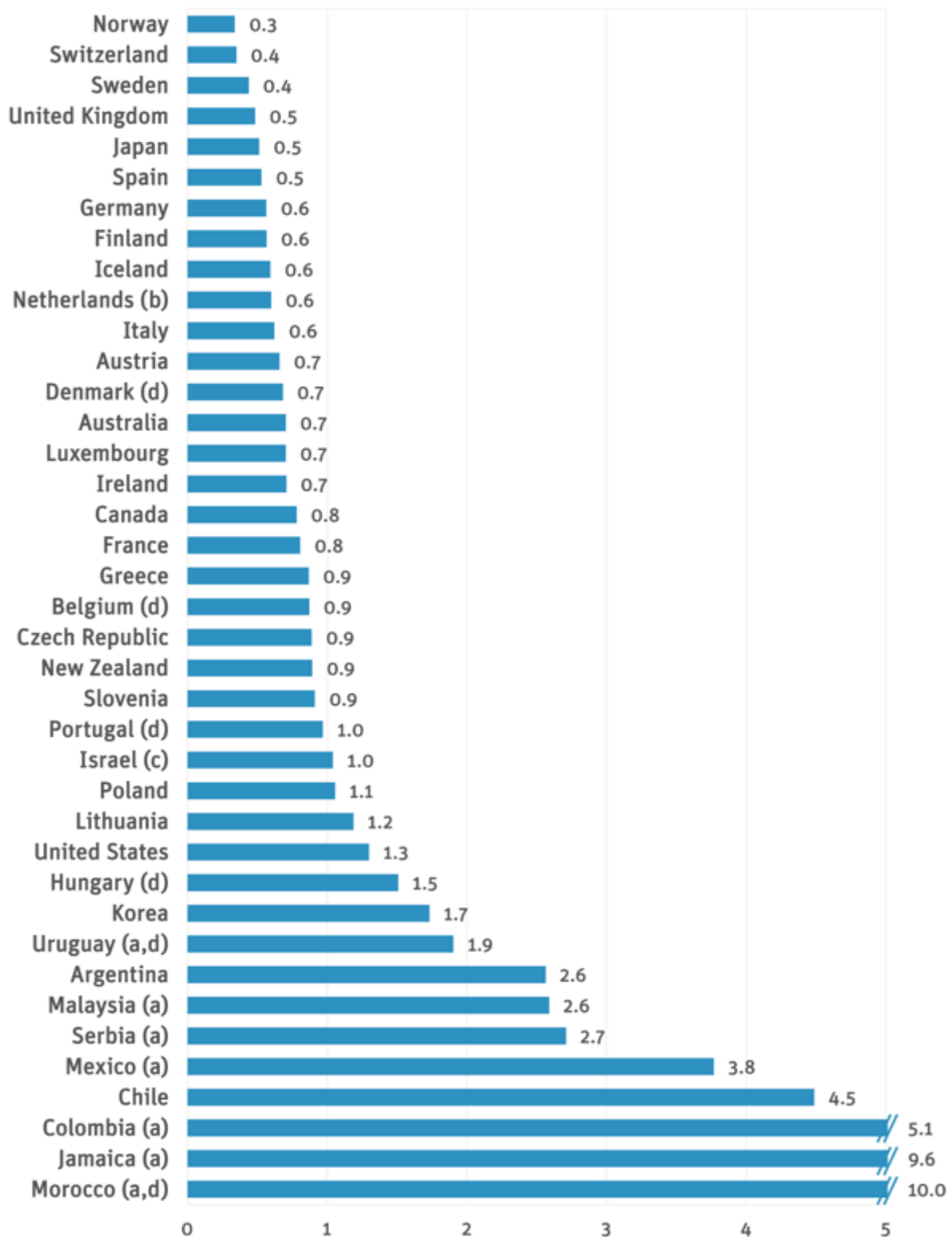


Figure 4.3 Road crash fatalities per 10 000 vehicles for International Transport Forum member countries 2016. Modified by Uter (2018) and obtained from OECD (2018)

CHAPTER 4 Data

4.3 Study area data assessment

Correspondingly road safety was recognized as a safety problem in Jamaica since the early 1990's with the earliest data on road safety being reported in 1991, (NRSCJ, 2017). Road crash data obtained from the RSUJ as discussed in Section 1.1, was above 300 fatalities in 2014. However, in 2012 Jamaica recorded approximately 260 road crash fatalities, as shown in Figure 4.4, (RSUJ, 2015). Consequently, this was the first since 1999 Jamaica achieved below 300 road crash fatalities since the launch of the Below 300 programme in 2008, (NRSCJ, 2017).

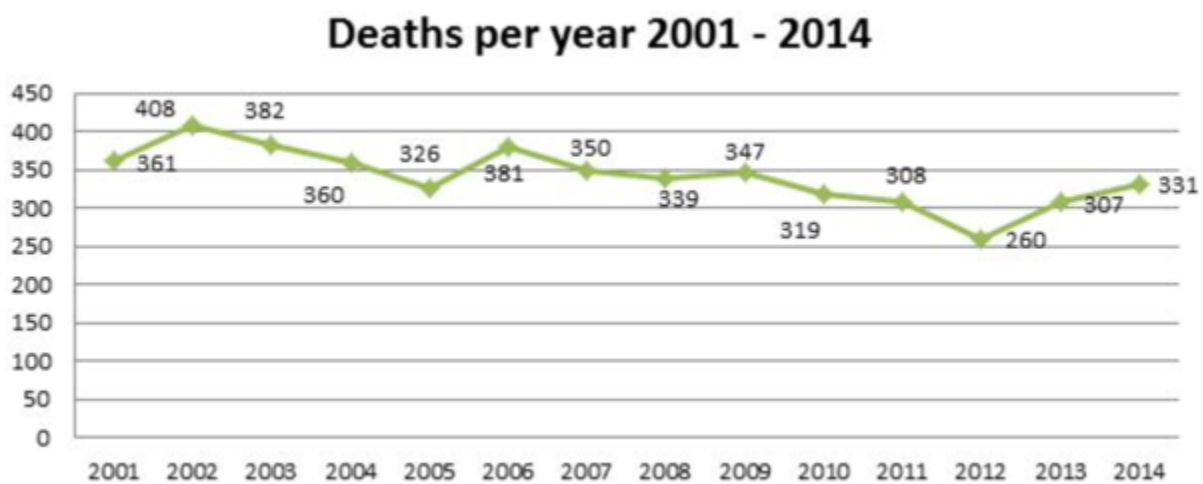


Figure 4.4 Road crash fatalities for all road users for the period 2001 to 2014. Modified by Uter (2018) and obtained from RSJU (2015)

By the same token, Jamaica and the world at large experienced a recession in 2009, (WEF, 2017). The NRSCJ accredits the approximately 260 road crash fatalities achieved in 2012 to the initiatives under the Below 300 programme, (NRCJ, 2013). However, the effects of the 2009 recession, which had its onset from the financial crisis of 2008, were felt in Jamaica for the period 2009 to 2012, due to slow economic recovery, (Johnston and Montecino, 2012).

Moreover, for the period 2010 to 2012 as shown in Figure 4.4 road crash fatalities were trending downwards. Not surprisingly, this coincided with Jamaica's slow economic recovery period of 2010 to 2012 from the onset of the recession in 2009. The road crash data represented in Figure 4.4, also showed road crash fatalities increased above 300 the following year in 2013. This also coincided with an increase in road crash fatalities at public transport facilities as shown in Figure 4.5, (RSUJ, 2015).

CHAPTER 4 Data

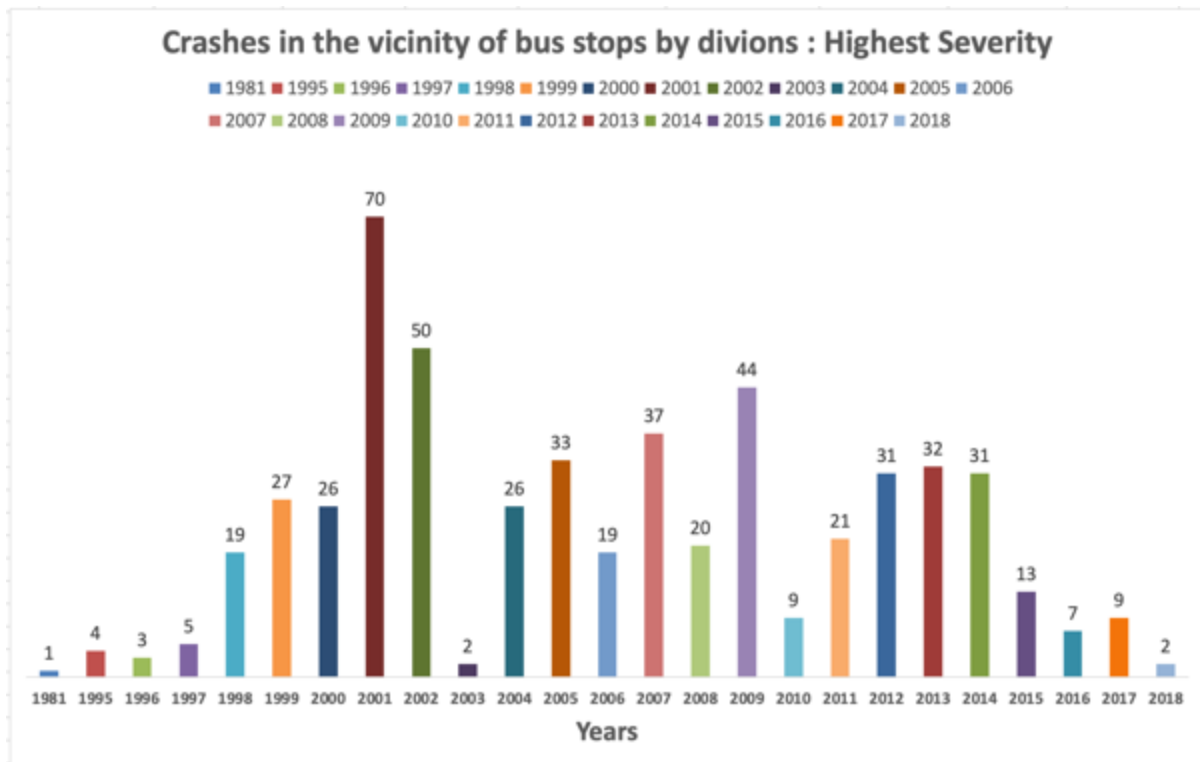


Figure 4.5 Crashes in the vicinity of bus stops by division: Highest priority in Kingston and St. Andrew represented in years from 1981 to 2018

In 2013 Jamaica’s economy began to show tangible signs of recovery but was not expected to re-claim pre-recession outputs until 2015 from the 2009 recession, (Johnston and Montecino, 2012). According to the WHO (2004), road crash fatalities decline during periods of economic recessions, as a result of road users having less disposable income and traveling less. During corresponding period of the slow economic recovery from 2010 to 2012, St. Andrew and St. Kingston recorded 60 road crashes occurring in the vicinity of bus stops as shown in Table 3.4 by the summation of the 3 respective years.

In Figure 4.5 this was also shown and resulted 8 fatalities in 2010, 21 fatalities in 2011 and 31 fatalities in 2012, reflecting an upward trend. Moreover, this was not a reflection of the reduction in the national trend for road crash fatalities for the corresponding period as shown in Figure 4.4. However, the number of fatalities recorded in 2010 was a significant reduction from the previous year 2009, which had 44 fatalities occurring in the vicinity of bust stops. In particular 2009 had the third highest number of road crash fatalities occurring in the vicinity of bus stops from 1981 to 2018.

CHAPTER 4 Data

From the data shown in Figure 4.5 during the previous 3 years of 2006 to 2008 prior to the onset of the 2009 recession, a total of 101 fatalities were recorded in Kingston and St. Andrew occurring in the vicinity of a bus stop. This was from 19 fatalities in 2006, 37 fatalities in 2007 and 20 fatalities in 2008. Correspondingly the number of road crash fatalities in 2006 in Figure 4.5, was also not a reflection of the national trend from the previous year for the total number of fatalities as shown in Figure 4.4. For the period 2006 to 2008, 2006 had the lowest road crash fatalities occurring in the vicinity of bus stops but the highest number of road crash fatalities nationally.

Notwithstanding 2007 had the highest number of road crash fatalities in the vicinity of bus stops for the period 2006 to 2008 and the second highest national total for road crash fatalities as shown in Figure 4.4. Moreover, the number of road crash fatalities in 2007 was the fourth highest number of fatalities occurring in the vicinity of bus stops as shown in Figure 4.5. Similarly, in Table 3.4 and as shown in Figure 4.5 road crashes fatalities in the vicinity of bus stops for the period 2013 to 2015 in Kingston and St. Andrew had a total of 76 fatalities. In particular this increased from total of the previous three years and corresponded with the period of economic recovery after the 2009 recession. Moreover, this also corresponded with the upward trend in road crash fatalities nationally.

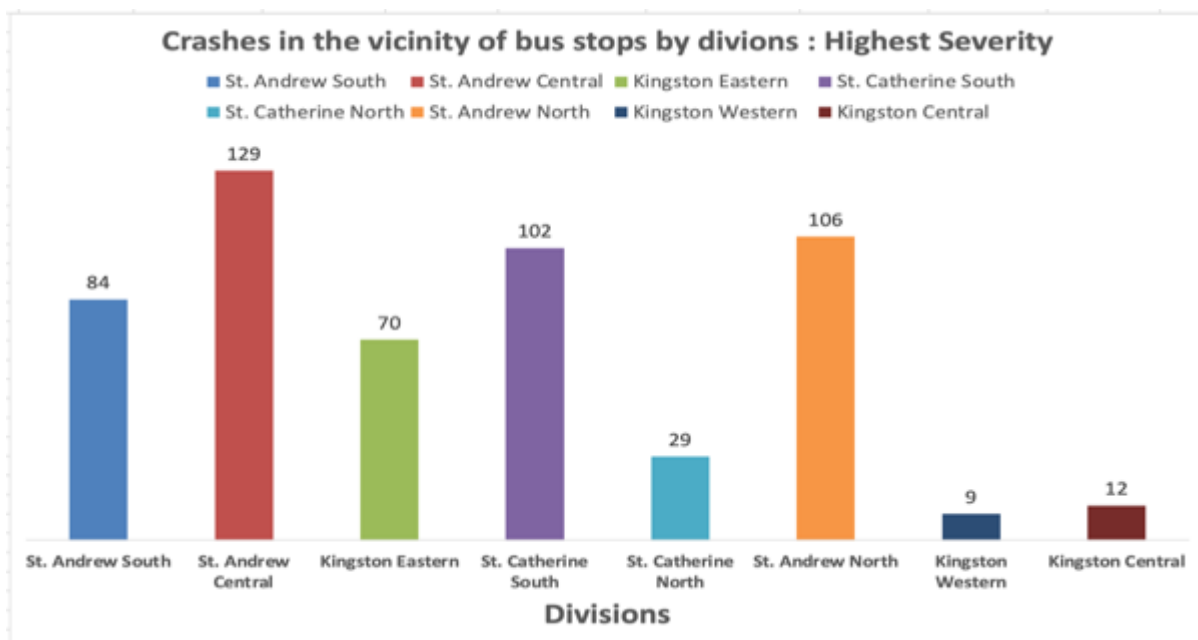


Figure 4.6 Crashes in the vicinity of bus stops by division: Highest priority in Kingston and St. Andrew represented by division

CHAPTER 4 Data

The study area of Kingston and St. Andrew was broken down into 6 divisions, however as discussed in Section 3.3, the KMR was made up of Kingston and St. Andrew and parts of St. Catherine. The parts of St. Catherine include were northern and southern regions closest to Kingston and St. Andrew. Therefore, the data presented in Table 3.4 was representative of the data collected and presented to include St. Catherine North and St. Catherine South by the RSUJ as shown in Figure 4.6. In Figure 4.6 the division that recorded the highest number of road crash fatalities occurring in the vicinity of bus stops from 1981 to 2018 was St. Andrew Central.

Correspondingly, St. Andrew Central division coincides with the location of the Constant Spring Road road section as shown in Figure 3.1. In Table 4.1 and as shown in Figure 4.7, Constant Spring Road had 1066 road crashes occurring on the road section. This was the highest number of reported road crashes for any road section within the study area. The data for Table 4.1 was obtained as discussed in Section 3.2 and represented a primary source of data collected from the study area at IQL-I. Moreover, Constant Spring Road had the highest number of transport centres and the second highest number of bus stops recorded within the study area as shown in Figure 4.8 and Figure 4.9 respectively, when compared to Old Hope road.

Following this the division with the second highest road crash fatalities that occurred in the vicinity of bus stops was St. Andrew North which had 106 fatalities as shown in Figure 4.6. Similarly, Constant Spring Road was also located in the St. Andrew North division and as such accounted for some of the road crash fatalities as previous discussed. The total number of road crash fatalities however also included Red Hills Road which was likewise located in the St. Andrew North division as shown in Figure 3.1. This road section recorded 513 road crashes, the third highest in the study area as shown in Table 4.1 and Figure 4.7 and also had 18 bus stops as shown in Figure 4.9.

The division with the third highest road crash fatalities that occurred in the vicinity of bus stops was St. Andrew South. As shown in Figure 3.1, St. Andrew South included sections of Half-way Tree Road, Old Hope Road and Hagley Park Road and had 81 fatalities. In Figure 4.7 the number of road crashes that occurred were 449 on Hagley Park Road, 306 on Half-way Tree Road and 293 on Old Hope Road. Nonetheless as shown in Figure 4.8 only Old Hope Road had a transport centre and at the same time had 31 bus stops, the highest number within the

CHAPTER 4 Data

study area as shown in Figure 4.9. The number of bus stops recorded on Half-way tree Road and Hagley Park Road were 12 and 15 respectively.

The data shown in Table 4.1 presents a summary of the data collected from primary and secondary sources as follows:

Table 4.1 Summary data: Kingston and St. Andrew Study area

Kingston and St. Andrew - Study area					
Summary data					
Road name	Road length in (km)	Number of bus stops	Number of transport centres	Speed limit	Number of crashes on road section
Constant Spring Road	5	22	3	50 km/ hr	1066
Old Hope Road	6.9	31	1	50 km/ hr	293
Hope Road	3.4	18	1	50 km/ hr	data not available
Half Way Tree Road	3.6	12	0	50 km/ hr	306
Hagley Park Road	3.7	15	0	50 km/ hr	449
Washington Boulevard	6.3	24	0	50 km/ hr	583
Red Hills Road	4.4	18	0	50 km/ hr	513
Moylnes Road	5.9	20	1	50 km/ hr	329
Eastwood Park Road	1.3	2	1	50 km/ hr	190
Total	40.5	162	7		3729

The road section with the lowest road crashes was Eastwood Park Road with 190 crashes as shown in Figure 4.7. In addition, Eastwood Park Road as shown in Figure 3.1 was located in St. Andrew Central division which had the highest number of crashes in the vicinity of bus stops. The Eastwood Park Road control section as shown in Figure 4.8 and Figure 4.9 had one transport centre and 2 bus stops respectively. At the same time Washington Boulevard and Molyne's Road as shown in Figure 3.1 were also a part of the St. Andrew Central division.

Washington Boulevard had the second highest road crash total as shown in Figure 4.7 and 24 bus stops as shown in Figure 4.9 but no transport centre. By the same token Molyne's Road had 329 road crashes with one transport centre and 20 bus stops. It is to be noted that road crash data for Hope Road was not available as shown in Table 4.1 and Figure 4.7, however had one

CHAPTER 4 Data

transport centre and 18 bus stops. Hope Road was also located in the St. Andrew Central division as shown in Figure 3.1.

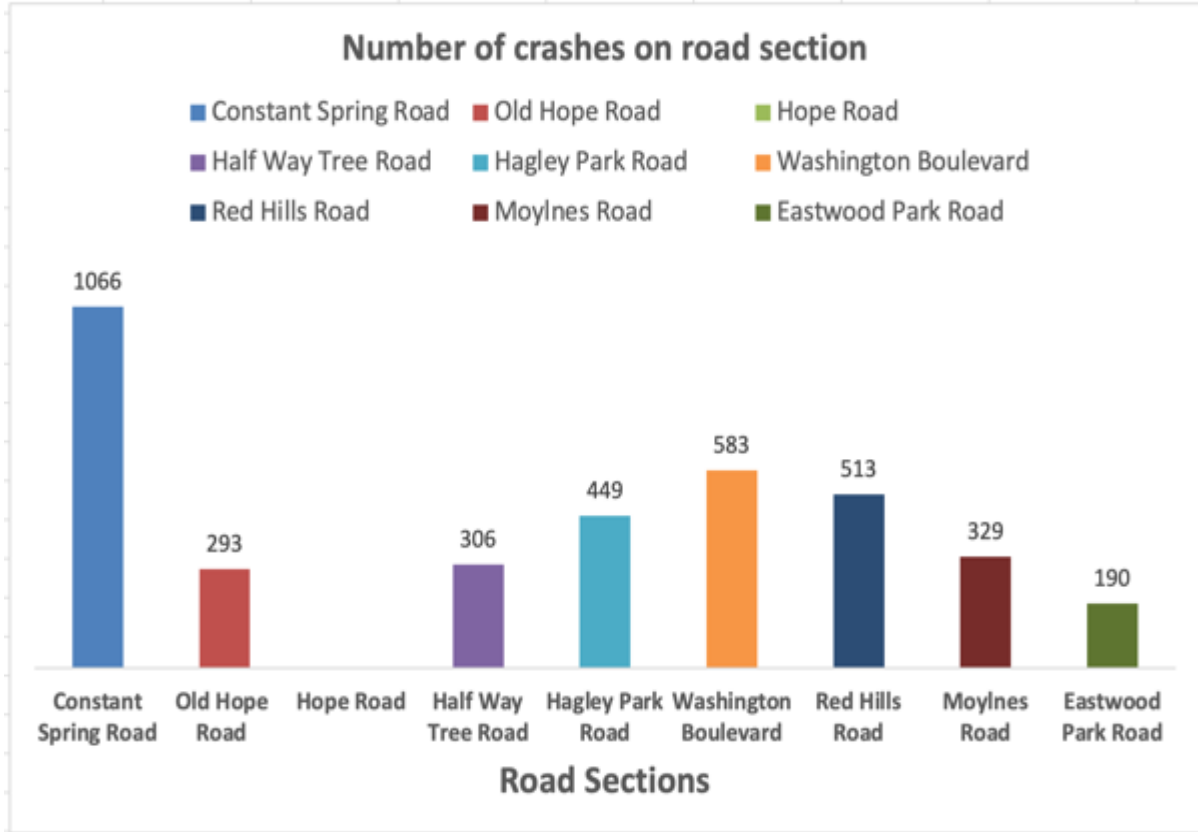


Figure 4.7 Summary for Kingston and St. Andrew represented by number of road sections and crashes

CHAPTER 4 Data

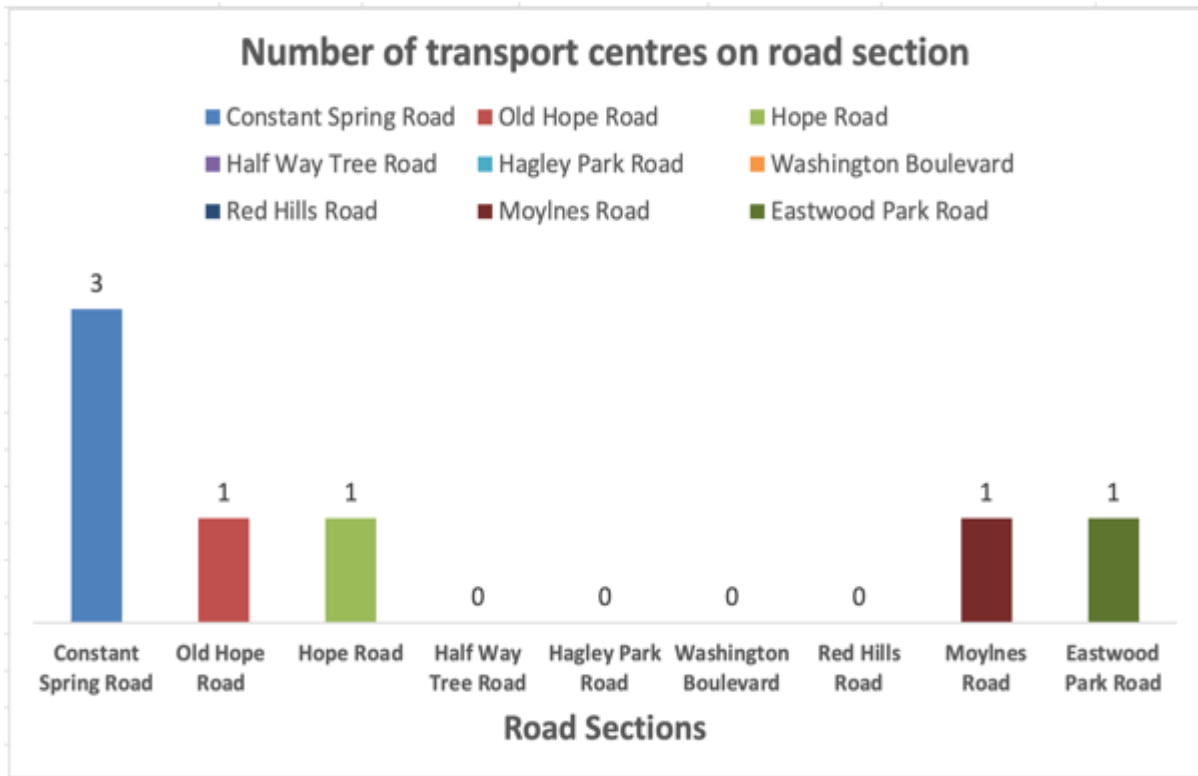


Figure 4.8 Summary for Kingston and St. Andrew represented by road sections and number of transport centres

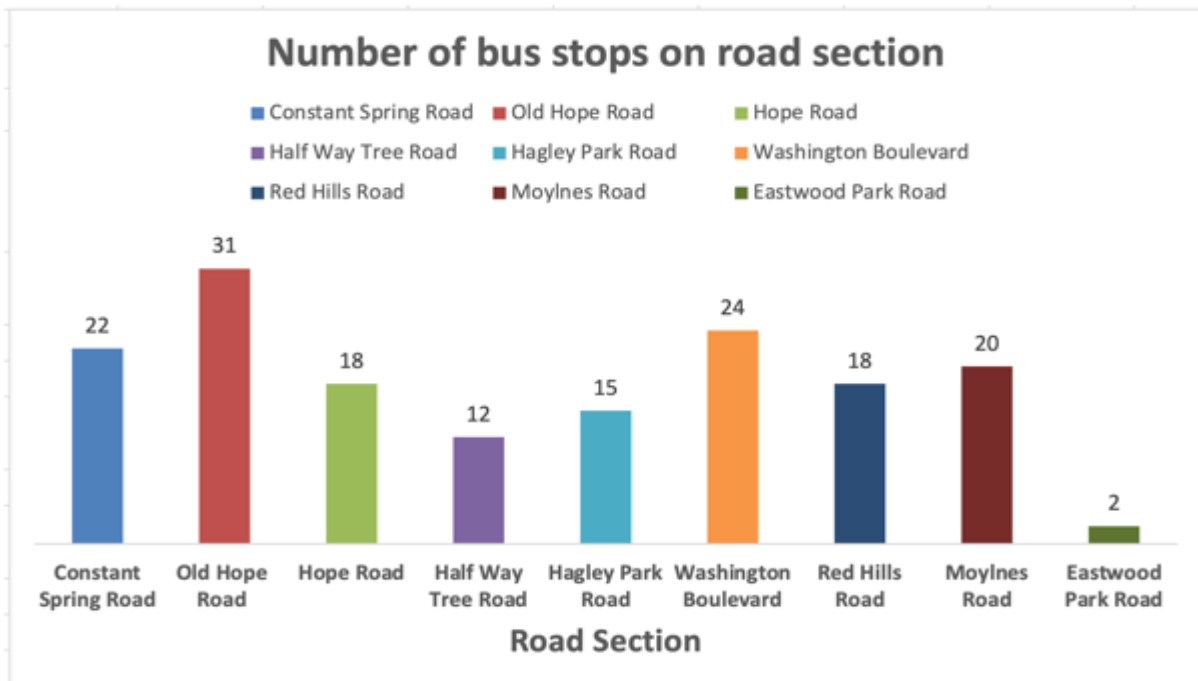


Figure 4.9 Summary for Kingston and St. Andrew represented by road sections and number of bus stops

CHAPTER 4 Data

In addition, Table 4.2 showed that the highest number of crashes were property damage only, with St. Andrew Central having the highest property damage total. Not surprisingly this coincided with the number of crashes that occurred on each road section in the study area as shown in Table 4.1. The corresponding data for Table 4.1 was shown in Figure 4.7 and the corresponding data for Table 4.2 was also represented in Figure 4.10. Based on the design of the road network as shown in Figure 3.1, most of the road sections within the study area were located in the St. Andrew Central division. As a result, the trend indicated in Figure 4.10 showed St. Andrew Central among the highest for all categories of crashes for Kingston and St. Andrew.

Table 4.2 Summary road crash data in the vicinity of public transport facilities collected from the study area in Kingston and St. Andrew by division, Modified and obtained from the Road safety unit (2018)

Crashes in the vicinity of bus stops : Highest Severity					
Division Number	Fatal accident	Serious accident	Minor accident	Property damage only	Total
Kingston Eastern	2	9	9	50	70
Kingston Western	0	0	1	8	9
Kingston Central	0	0	0	12	12
St. Catherine South	3	11	16	72	102
St. Andrew Central	2	9	17	101	129
St. Andrew South	1	1	7	75	84
St. Catherine North	2	2	11	14	29
St. Andrew North	0	4	14	88	106
Total	10	36	75	420	541

CHAPTER 4 Data

The representative summary data shown in Table 4.2 was obtained from the Road Safety Unit of Jamaica as discussed in Section 3.3. Nonetheless the data presented in Table 4.1 in comparison to Table 4.2 showed that 3 729 crashes occurred on the road sections in the study area. This was 14.5 per cent higher than the combined total for crashes that occurred in the vicinity of bus stops for the KMR as shown in Table 4.2. As discussed in Section 3.3 the JCF reported the locations where crashes occurred. However, based on the data correlation method used by the RSUJ, such crashes were presented as occurring in close proximity to public transport facilities. And as a result, was combined with other road user groups and crash types

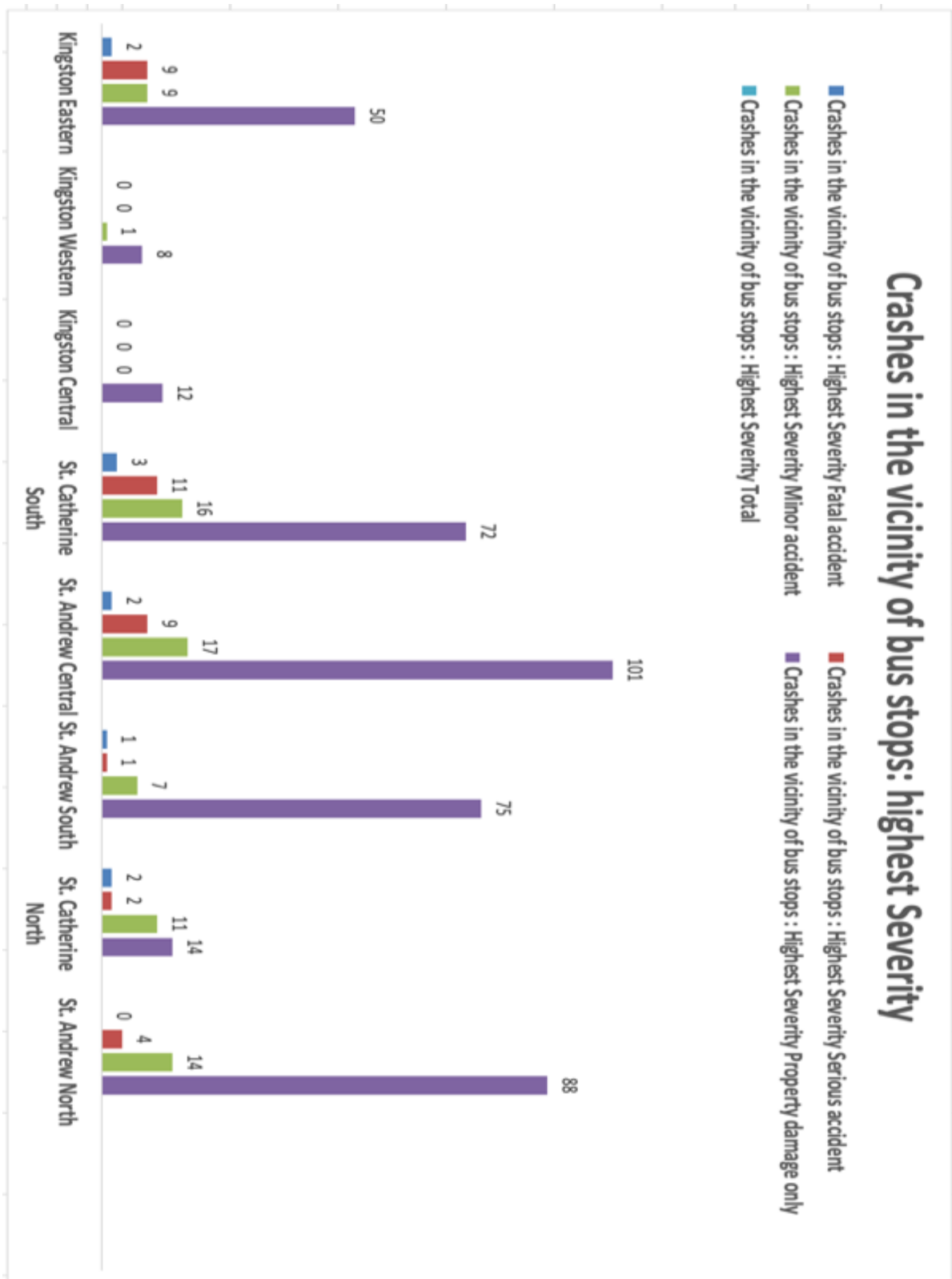


Figure 4.10 Crashes in the vicinity of bus stops by division: Highest priority in Kingston and St. Andrew represented by divisions and severity

CHAPTER 4 Data

The data collected from the study area as discussed in Section 3.2, was further defined into specific areas related to the iRAP methodology and the needs analysis process as shown in Table 4.3. The data was assessed as discussed in Table 3.6 and further represented in Table 4.3 as follows:

CHAPTER 4 Data

Table 4.3 Summary data collected from the study area in Kingston and St. Andrew, using the iRAP methodology and needs analysis

Kingston and St. Andrew - Study area			
Summary data for road attributes present in study area			
Data on road features collected	Description of data collected	Condition of data collected	Observed interactions of road users with road features
Speed limit	50 km/h	N/A	Not safe
Transport facility	Present	Moderate	No clear separation
Bus shelter	Present	Moderate	Over crowded
Bus bays	Inadequate	Poor	Inadequate
Transport facility drainage	Not present	N/A	Flooding
Transport facility platform	Present	Not adequate	Inadequate/overcrowding
Protection from passing traffic	Not present	N/A	Not protected
Bus boarders	Not present	N/A	Not protected
All-weather surface	Present	Not adequate	Inadequate/overcrowding/flooding
Sidewalk	Present	Not adequate	Inadequate/overcrowding
Pedestrian facilities	Inadequate	Poor	Inadequate
Pedestrian crossing	Inadequate	Poor	Unsafe crossing practices
Pedestrian fencing	Inadequate	Moderate	Not always obeyed
Road markings	Present	Poor	Improper lane use
Kerb access	Not present	N/A	No access
Kerb height	Present	Moderate	No access
Street lighting	Inadequate	Poor	Poor visibility
Hazardous objects	Present	Less than 1m to road way	Unsafe/ blocks pedestrian path
Road drainage	Inadequate	poor	Flooding
Weather protection	Inadequate	Moderate	Inadequate/overcrowding
Road condition	Asphalt concrete	Moderate	Moderate
Median	Kerb type	Moderate	Not always obeyed
Signalized roadway	Present	Moderate	Not always obeyed
Tactile pavements	Not present	N/A	Unsafe/ not present
Lane width	2.7 to 3m	Moderate	Improper lane use
Sight distance	Moderate	Moderate	Poor
Vehicle parking	Not present	N/A	Unsafe practices
Road side friction	Present	Poor	Unsafe/ blocks pedestrian path
Number of lanes	Two	Moderate	Not always defined
Quality of curve	Present	Moderate	Moderate

CHAPTER 4 Data

The data in Table 4.3 was used to present the interactions of road users with the road infrastructure identified on road sections in the study area as shown in Table 3.1 In addition the effectiveness and efficiency of the management system was determined by the observed interactions of road users in the study area. Moreover, the number of road crash fatalities in the vicinity of bus stop also determined the performance of the management system. In particular, Table 4.2 and Figure 4.10 showed the severity of the crashes that occurred in the KMR by divisions.

The data on road attributes collected from the study area was compared to the pre-existing data in the iRAP star rating plan coding manual. Based the data required to meet the objectives of this research project as discussed in Section 3.2, the comparison with data collected showed road attributes related to public transport facilities were not included as part of the pre-existing data in the iRAP methodology. Therefore road attributes on the Jamaica road network related to public transport facilities not included as pre-existing data in the iRAP methodology were highlighted in yellow as shown in Table 4.3 and are as follows:

Road Attributes related to public transport facilities

- Transport facility
- Bus shelter
- Bus bays
- Transport facility drainage
- Transport facility platform
- Protection from passing traffic
- Bus Boarders
- All-weather surface
- Kerb access
- Kerb height
- Road drainage
- Weather protection
- Tactile pavements
- Roadside friction

CHAPTER 4 Data

The data collected on public transport facilities were along the main bus routes and was representative of the most travelled by public transport commuters, (JUTC, 2017). The data collected was compared to road attributes within the iRAP methodology and the characteristics of the roadway according to the existing road design determined. This was according to the type of road attributes present in the road environment related to the public transport pedestrian users in the images provided from the study area.

4.4 Description of the institutional framework data collected and assessed using the needs analysis matrix as shown in Figure 3.13

The needs analysis matrix assessed the institutional framework and management system established to manage road safety as shown in Figure 3.14. As discussed in Section 3.5 the need analysis matrix assessed the institutional framework based on what was present, why it was established; how it was being done, who was responsible; when it was implemented and where it was being implemented. The process also determined whether performance indicators were established to determine the effectiveness of the existing management system. The following sub-sections presents an analysis of the role and intention of each area identified in the institutional framework according to the principles of the needs analysis.

4.4.1 National transport policy

The National transport policy of Jamaica is a policy document developed by the Government of Jamaica in the Ministry of Transport and Mining. The document was originally drafted in 1993, however was never completed. In 1998 the document was recommissioned with the help of Transport Canada. The National Transport Policy (NTP) was drafted in an effort to create a systematic approach towards implementing an efficient transportation system. The policy document focused on improving the movement of people goods and services by air, water, road and rail, (MTW, 2007).

The implementation of the NTP takes an inter-agency approach. This was in an effort to build awareness and to encourage inter-agency co-ordination and participation, to achieve the national transport goal and to improve the transport industry. Through this initiative the NTP was aimed at supporting the National Industrial Policy (NIP) goals for a sustainable approach towards economic growth and development. The NTP was also aimed at increasing the

CHAPTER 4 Data

efficiency of all modes of transport in Jamaica. As well as appeal to the private sector, to encourage public private partnerships, to develop and improve all modes of transport used in Jamaica, (MTW, 2007). The present state of its implementation is not known because there have been reports made available to the public since 2007.

4.4.2 National road safety policy

The drafting of the National road safety policy of Jamaica (NRSPJ) was initiated at a two-day conference organized by the National road safety council and the Pan- American Health Organization in 1997. The NRSPJ was launched in June 2004 to coincide with road safety month in an effort to guide road safety strategies that were aimed at reducing the number of road crash fatalities and serious injuries on Jamaica's road network. The policy was said to undergo a review process every four years to remain current and coincide with the international effort to reduce road crashes fatalities. However there have been no updated versions of the policy since it was first published in 2004, (NRSCJ, 2016).

The NRSPJ takes a 5E's approach to road safety. The 5E's strategy was aimed at taking a multi-government agency approach with support from the private sector. The 5E's strategy spans across difference areas of responsibility. The strategies for the NRSPJ are as follows:

National road safety policy of Jamaica road safety strategies

- Engineering and enforcement
- Education and information
- Enforcement and legislation
- Emergency and response
- Evaluation and other comprehensive actions

Source: NRSCJ (2016)

4.4.3 Urban development plan

According to McHardy (2002), cited in the (Vision 2030 Jamaica-National development plan: Urban planning and regional development sector plan, 2009), planning had its origins with the local authority since the 1664 when Jamaica was under British rule. In 1957 the Town planning department was established under the Town and planning act of 1957. The act was

CHAPTER 4 Data

implemented, to address social and economic concerns that had emerged since the 1950's. The Town planning department undertakes planning in certain areas with consultation from local authorities that have oversight for local planning within parish boundaries, (PIOJ, 2009).

Present day urban planning is done according to development orders from the Town and Planning act of 1957 and is implemented by central and local government authorities. There have been several acts past since 1957 giving powers to central and local bodies that overlap or contradict the development order of the 1957 act, (PIOJ, 2009). The Government of Jamaica in spite of the challenges, has announced its Vision2030 initiative by publishing a series of section plans aimed at achieving developed status by 2030.

4.4.4 Management plan

An examination of the management system in place for the Jamaican road network reveals that, there was no single document that could be considered as representing a management plan. However, there are central and local authorities that have oversight for the road network depending on the classification of the road. Each central and local authority is guided according to their role by the different acts of the Parliament of Jamaica, (PIOJ, 2009). There are several documents and acts of the Parliament of Jamaica that guides the overall approach to manage the road network.

4.4.5 Road traffic act

Since 1938 Jamaica's road network has been governed by the Road traffic act of 1938. There have been efforts since the 1990's to have the Road traffic act of 1938 repealed. Thus, replacing the Act with a version that is equipped to address the high incidents of inappropriate road users behavior, and high road crash fatalities and serious injuries. On February 6, 2018, the Jamaican House of Representatives voted to have the Road Traffic Act of 1938 repealed and replace with a new Road Traffic Act, (MOJ, 2018).

The new Road Traffic Act, tentatively called the Road Traffic Act of 2018, is aimed at solving Jamaica's problem of inappropriate road user behavior and high rate of road crash fatalities and serious injuries. The new Act redefines road usage and its expectations of all road users and includes increased traffic fines for breaches. The fines included within the new act have been increased in some instances by over 300%. The aim of which is to act as a deterrent to

CHAPTER 4 Data

road users who attempt to break the laws that govern road use as well as give more empowerment to the traffic police in enforcing the law, (MOJ, 2018).

4.4.6 Road users

According to data provided by the Road safety unit of Jamaica, road user types recorded in the crash database, as reported by the various secondary sources are classified as follows:

Road user types according to the RSUJ

- Pedestrians
- Pedal cyclists
- Motor cyclists
- Pillion passengers
- Public passenger vehicle (PPV) passengers
- Private motor car (PMC) passengers
- Commercial motor car (CMC) passengers
- Public passenger vehicle (PPV) Drivers
- Private motor car (PMC) Drivers
- Commercial motor car (CMC) Drivers
- Other

Source: RSUJ (2010)

4.4.7 Road user behaviour

The number of road crashes on the road network in Jamaica puts emphasis on road user behavior. The data collect by the Road safety unit of Jamaica could be used to gauge road user behavior based on the number of road crash fatalities. According to the data provided by the Road safety unit of Jamaica (RSUJ) pedestrians were the most killed and seriously injured on the Jamaican road network each year. This would suggest poor road user practices by pedestrians as indicated by the National road safety council of Jamaica (NRSCJ), (NRSCJ, 2018). However, this example of high crash rates for pedestrians also suggests that there is a lack of proper facilities to facilitate good road user behavioral practices and decision making from pedestrians, (Nelson, 2014).

CHAPTER 4 Data

In other road user categories used by the RSUJ that show high crash rates in the analysis of the road crash data. The designation by the NRSCJ was also of poor road user behaviour. According to Lynam (2012) poor road user choices by one road user type could result in the fatality or serious injury of another. The conclusions drawn by the RSUJ and the NRSCJ are based on the high crash rates among road users groups such as PMC driver, PMC passengers and motor cyclists. This suggests that, the high crashes rates are driven by speeding, non-wearing of helmets and non-wearing of seat belts, (NRSCJ, 2018). There are however other factors that could result in other conclusions being draw in relation to the high crash rates according to modern road safety practices in developed countries, (Sweden Sverige, 2016).

4.4.8 Road safety maturity

According to the WHO (2004), road safety maturity was a reflection of the level of safety built into a road by the road system designers, the level of commitment of government officials and the appropriateness of road user behavior on the road network. In a case study based on the Asian community carried out after the 2015 Australaesan road safety conference, a road safety maturity index was developed. The road safety maturity index used weighted, measurable factors as a guide for road safety strategies based on the Global road safety report published in 2013, (Oviedo-Trespalcios and Haworth, 2015).

The road safety maturity index used a percentage scale ranging from 0 per cent for low road safety maturity to 100 per cent for high road safety maturity. The index focused on 10 Asian countries using the context analysis approach and the binary methodology to rate the level of road safety maturity. The road safety maturity rating was then compared with countries that were listed in the Global status report on road safety 2013, (Oviedo-Trespalcios and Haworth, 2015).

4.4.9 Funding

Funding for road safety is solely provided by Government of Jamaica. The present model of the Government of Jamaica sees funding being allocated to all the critical agencies that manage road infrastructure. The National Road Safety Council is one such entity and based on the issues that presently exist with road safety in Jamaica, more funding is needed, (NRSCJ, 2017). The sustainability of road safety programmes need the support of government and should be

CHAPTER 4 Data

adequately funded however in low to mid-income countries there are still challenges, (WHO, 2004).

4.4.10 Infrastructure maintenance

The maintenance of the road infrastructure is carried out in Jamaica according to the various entities based on their area of responsibility and oversight. The National Works Agency has the responsibility for maintaining the main road network, sidewalks, bridges, traffic signals; flood control systems, road signage and the like. The local Municipal Corporations and the Ministry of Industry, Commerce, Agriculture and Fisheries have the responsibility for farm roads, community roads and some township roads. Along with there related infrastructure such as bridges, sidewalks, streetlighting, road signs; vehicular and foot bridges and the like, (NWA, 2007).

The National Road Operating Construction Company manages toll roads and its related infrastructures such as road network, drainage, bridges, fencing and the like. Funding for the maintenance of the infrastructures related to the National Works Agency and the National Road Operating and Constructing Company are provided by the Government of Jamaica, (MTW, 2007). While the local Municipal Corporation receives the majority of its funding from property taxes, fees from advertisement signs, market fees and local professionals such as barbering and the like, (MLG, 2015). There is no mention in any detail of developing or maintenance of public transport facilities. Nor is there an indication of a designated entity which has the assigned responsibility, (MTW, 2007).

4.4.11 Traffic management

The National Works Agency has oversight for traffic management and the installation, erection and maintenance of its infrastructure. The Jamaica Constabulary Force, traffic division enforces the road traffic act under the law and assists the NWA and the Ministry of Transport and Mining with its traffic management initiatives, (NWA, 2007).

4.4.12 Road design

The National Works Agency has oversight for the design and implementation of designs for the main road network. The National Road Operating and Constructing Company has oversight for the design of the toll roads and also implements its designs with consultation with the

CHAPTER 4 Data

National Works Agency. The design and layout of farm and community roads are done by the local Municipal Corporations and the Ministry of Industry, Commerce, Agriculture and Fisheries. The design and layout of community and farm road also require the approval of the National Works Agency, (NWA, 2007).

4.4.13 Transportation system

The transportation system in Jamaica is described as a multi-modal system and is considered to consist of road transport, air transport and sea transport, (MTW, 2007). The inter-island transport system in Jamaica is one of the densest road networks in the world that is not properly maintained, (World Bank, 1984). The island also has international airports, local aerodromes and seaports around the island. There are inland waterway facilities but accessible only to tourist or local vacationers. This mode of transport was not developed as a part of the national transport industry. However, it is utilized by local communities where there is access. There are also rail tracks present but no passenger trains. The passenger railway system was discontinued in the early 1990's giving way to rapid motorisation, (MTW, 2007).

4.4.14 Transport authority

Transportation in Jamaica is the responsibility of the Transport Authority or that was the thought based on the name designation of this entity. The Transport Authority has the role of monitoring and regulating the public transportation system. The entity is empowered by Acts of Parliament and assumes the role of revenue protection for the state-owned Jamaica Urban Transit Corporation (JUTC). The determination of routes and the licensing of all public transport vehicle outside of the JUTC public transport bus system are managed by the Transport Authority. Other areas of transportation such as air and sea are regulated by the Civil Aviation Authority and Port Authority respectively, (MTW, 2007).

4.4.15 Public transportation

According to the World Bank (1984), the Jamaican public transportation system was at the time estimated to carry 1.6 million passenger trips per day. The system was considered inefficient not being able to meet its demand as commuters wait an average of 20 minutes before getting transportation. The wait was considered long, even though most of the communities in Kingston had a bus stop with in approximately 274 metres from their homes. After waiting 20

CHAPTER 4 Data

minutes on transportation, passengers were not able to board the buses as they were already overcrowded. The journey time was also extended by very poor road surfaces.

The main trip generators for the transport system were primarily work, school and commercial activities. The bus routes designated to public passenger vehicles were not known to use routing plans for optimum bus routing efficiency. The result was overlapping bus routes and over-extension of services to sub-urban areas. During peak hours traffic congestion at intersections were a source of discontent with insufficient capacities, which resulted in increased journey times. Peak hours in the morning range from 7am to 9:30am and 3pm to 6pm in the evenings with the commuting public travelling from 6am to mid-night. The result is an estimated 70 000 passenger volumes per hour on 77 routes, (World Bank, 1984). Observations of the present-day public transportation system sees no significant improvement.

4.4.16 Transport facilities/ public

A search to determine the number of transport facilities and the responsible entity with oversight for transport facilities in Jamaica, did not yield favorable results. Though there was mentioned of a report done by the Transport Authority in 2012 that was said to contain information regarding the number of passenger terminal facilities. According to Jamaica Observer (2014), the report mentions that there are over 228 passenger terminal facilities in Jamaica of which 51 are formal and 177 informal. There was no mention by the Jamaica Observer as to what facilities fit the criteria to be considered as passenger terminals facilities.

Though it is not clear as to who had direct oversight, there was information available on the website of the Kingston and St. Andrew Corporation (KSAC), that indicated the entity had some level of responsibility, (MLG, 2015). The responsibility appears to be shared with the Transport Authority as indicated on the Jamaica Information Services, (JO, 2014). Discussions with a member of the Jamaica Urban Transit Corporation, who wanted to remain anonymous, revealed, that though the JUTC was responsible for transporting public transport passengers, it was not responsible for the erection of bus stops or transport facilities nor their designated locations.

Transport facilities are used as locations that attract prime time advertising opportunities for businesses. Discussions with one such entity that erects bus shelters, reveals that, the advertising companies erect aluminum steel framed bus shelters free of cost to the state, for providing

CHAPTER 4 Data

advertising opportunities to businesses. The locations were chosen based on convenience to commuters where most waited on public transportation. The locations were agreed by the Parish Council and the National Works Agency, with attention only being paid to sight distance related to drivers of motor vehicles.

The advertising companies then paid an annual fee to the Parish Council for the space to erect the bus shelter. While they collected payments from their customers for advertising at the bus shelters. A drawing was required from the Parish Council but this was provided by the advertising company. This indicated there was no standard design for bus shelters in place. Bus shelters were also erected by churches, community associations and charitable organizations. These entities seek permission for erecting bus stops and bus shelters also at locations of convenience. The basis for the most convenient location, was also a reflection of where most community members waited for public transportation.

4.4.17 Urban road safety management

Urban road safety management is the responsibility of the National Works Agency (NWA). Though the NWA's primary function is to manage and improve the main road network and flood control systems, the entity oversees the implementation of all traffic management and road design related activities. This includes but is not limited to road markings, pedestrian facilities, road signs and other road safety features. The NWA also has the responsibility for approving all development plans and to ensure they conform to acceptable design standards, (NWA, 2007).

4.4.18 Land-use and activities

Land use activities are determined by the central and local government authorities. Landowners are required to make applications and submission for proposed land use activities that should relate to development orders for the desired location. The approval process includes submissions to the Municipal Corporations, National Works Agency, National Environmental and Planning Agency and the Fire Department. The submissions are made through the Municipal Corporations and disseminated to the other entities in the form of plans. The approval process also extends to land-use involving entertainment activities, (MLG, 2015).

CHAPTER 4 Data

The prevailing situation of land-use activities within the study area of the main roads assessed showed mixed developments. Areas which were once primarily residential areas, have given way commercial activities, from local corporate businesses to schools and entertainment. The mixing of land-use activities without proper planning has affected infrastructure development. This has resulted in attraction destinations and the mixing of road users in situations that sometimes are overwhelming beyond their capacity. The effects are road crashes, as a result of the lack of properly designed facilities as well as infrastructure that gives priority to one road user over another, (World Bank, 1984).

4.4.19 Land-use control

The Town and Country Planning (TCP) Act of 1957 was used to re-define land use control based on the social and economic problems of the 1950's. The re-defining of land-use was considered as an important step in determining Jamaica's economic future. Presently land-use is determined by central and local authorizes, however they are still bounded by TCP Act of 1957. There is evidence to suggest that though the act is in place, central and local authorities are empowered by Acts of Parliament of their own that sometimes conflict and may override the TCP Act of 1957, (PIOJ, 2009).

4.4.20 Health authorities

The health care system in Jamaica is managed by the Ministry of Health, it's agencies, Health Centre's, public and private practices and public and private hospitals. The Ministry of Health is the oversight body and provides policy guidance as disseminated by the House of Representatives and the elected Government. The implementation of health care policies is done by the 4 Regional Health Authorities, which are the Agencies of the Ministry of Health. The goal of the health care system is to provide good health service in a healthy environment and to promote healthy lifestyle and environmental practices, (MOHW, 2018).

4.4.21 Insurance association of Jamaica

The Insurance association of Jamaica is considered to be the voice of the insurance industry. The association mandate is to assist the insurance industry by effectively lobbying and making representation on key issues affecting the insurance industry. The association also has the mandate of fostering sound ethical behavior and practices from its members in the best interest of

CHAPTER 4 Data

the public. The association also maintains a database that pools statistics from its industry members. The database held by the association can be used as a reference for road crashes, based on the total number of reported crashes made to member insurance companies, (IAJ, 2018).

4.4.22 Crash investigators/ Assessors

The investigation of road crashes is carried out by the Jamaica Constabulary Force (JCF) and loss adjusters. The JCF carries out on the seen crash investigation, log crashes and provides a police report with their conclusions. The JCF may also charge road users for offences committed under the law, in relation to a crash and recommend criminal prosecution. Loss adjusters are responsible for carrying out crash investigations in relation to insurance claims. Loss adjusters provide a report at the end of their investigations and may assign blame to one road user or another based on the evidence of the crash investigation, (RSUJ, 2018).

4.5 Summary

The data assessed was collected from primary and secondary sources. In the assessment Jamaica's ranking for the number of road crash fatalities and serious injuries was a cause of concern. Based on the trend of road crashes there have been instances where Jamaica was able to achieve the targets set out in its road safety strategy. However, there does not appear to be a sustained approach based missed road strategy targets which results in road crashes being above 300. At the same time the method of reporting data distorts the representation of crashes in the locations where they occurred, for example referring the crashes as in the vicinity of bus stops. The roads within the study area were representative of the A-road network and were assessed within their designated divisions. Of all the divisions assessed within the study area St. Andrew Central was the division that had the most road crashes and therefore suggests there was must work to be done to reduce the number of road crash fatalities and serious injuries.

CHAPTER 5 Model verification

5.1 Introduction

In the development of the new star rating model for public transport pedestrian users at public transport facilities, data collected from the study area was used to determine the star rating according to the iRAP star rating worked examples fact sheet 9. The input of values obtained from the study area in worked examples in the iRAP methodology, was to verify the output of the new starting model for public transport pedestrian users. In representing the values within existing star rating worked examples in the iRAP methodology, an attempt was not only being made to verify the star rating equation for public transport pedestrian users. As well as to determine also whether the goal of the model had been achieved.

5.2 Verification process

In the verification of the new model for public transport pedestrian users the use of actual data demonstrated the application of the model in the existing road safety management system. The data used in the verification process was not only from primary sources as discussed in Section 3.2 but also from secondary sources as discussed in Section 3.3. The data presented by the NWA and RSUJ are also shown in Appendix G and Appendix J respectively. The data from the study area was also used in worked star rating examples for pedestrian as shown in Appendix I.

This was done so that the results from the star rating model equation for public transport pedestrian users had a basis of comparison. Thus, the results of the star rating equation for pedestrians and public transport pedestrian users were compared using the same data. This determined the risk factors associated with road attributes present. And at the same time, demonstrated whether there were strengths and weaknesses in the application of the star rating equation model to the existing road safety management system.

Therefore, the verification process consisted of testing the model to determine the areas of adaption and adjustment. This was so the star rating was reflective of the risks faced by public transport pedestrian users at public transport facilities. The adaption and adjustment process were not only to be done for the existing situation in Jamaica but also in other low to middle-income countries and by extension also for developing countries. The risk values used for the verification of the star rating model for public transport pedestrian users was done according

CHAPTER 5 Model verification

to the risk factors identified in Table 3.8 and further illustrated in Table 4.3. The risk factors were applied according to the worked star rating example in iRAP methodology fact sheet 9, (iRAP, 2013). The risk factors for the likelihood and severity were applied in the same context as in existing iRAP models. This was according to the worked star rating example as shown in the iRAP methodology fact sheet 9 to demonstrate consistency. During testing it was also observed as discussed in Section 4.3 that not all road attributes related to public transport pedestrian users were included in the iRAP star rating and investment plan-coding manual.

Therefore, assumptions for risk factors were made for road attributes not included. When assigning risk factors to road attributes not included in the iRAP star rating and investment plan-coding manual, a value of 1 was assigned based on recommendations according to (Lynam, 2012). Where road attributes for public transport pedestrian users were similar to existing iRAP models, comparable values were assigned as risk factors.

5.3 Supporting data

The supporting data used for verification were based on road attributes data collected from the study area as well as data provided by the NWA and RSUJ. Post road attributes data were checked if applicable from the images of the road sections but was obtained from the NWA's traffic data as discussed in Section 3.2. The post attributes considered were as follows:

Post road attribute factors for star rating equation worked example

- Vehicle flow (AADT)
- Motorcycle %
- Pedestrian peak hour flow across the road
- Pedestrian peak hour flow along the road driver-side
- Pedestrian peak hour flow along the road passenger-side
- Bicycle peak hour flow
- Speed- 85th percentile

The resulting star rating score was an indication of the level of safety built into the road design for public transport pedestrian users at public transport facilities such as bus shelters and transport centres.

CHAPTER 5 Model verification

5.4 Star rating equation worked example

The road attributes identified for public transport pedestrian users were each categorized according to whether they were present, absence, quality or size as indicated in the iRAP road attribute risk factors series. The iRAP risk factor series were specific to each road attribute in the iRAP pre-existing database according to research that demonstrated their performance in the traffic environment. Where research and data were not available for a specific road attributes a minimum standard was adopted by iRAP, (Lynam, 2012).

The risk factor assigned to each road attribute was an indication of the impact that each would have on the likelihood and severity of a crash and the implication for the road user group. The risk factor scores for the likelihood and severity in regard each road attribute was determined from the product of the risk factors associated with each road attribute as shown in Figure 3.25, (Lynam, 2012). The risk factor scores obtained were then used to determine the star rating score for each crash type by the inclusion of post road attribute data.

Other factors that also impacted the outcome of a crash, were external influences, operating speeds, and median traversability as shown in Figure 3.25. In the case of public transport pedestrian users, platform/ sidewalk traversability was introduced. This was instead of median traversability which was used in reference to vehicle occupants and motorcyclists in existing iRAP models. The data description for road attributes collected was also represented in the star rating worked example in Appendix I, Table I.1.

For each road attribute the description of the road attribute was included beside the risk factor type listed as category. The star rating score for each crash type was determined from the product of the risk factor scores for likelihood and severity, along with external flow influence and operating speed scores as shown in Appendix I. The star rating score was obtained by adding the score for each crash type previously calculated. The star rating work example as shown in Appendix I was representative of Equation 2.7 to 2.11 for public transport pedestrian users as discussed in *Section 2.8.9*.

As shown in Appendix I, Table I.1, and according to Equation 2.7 to 2.11, the along crash type score for public transport pedestrian users had separate values determined for the drive side and passenger side. That is, for the drive side score and passenger side score were calculated separately. This was as a result of the road attributes on the drive side may differ than

CHAPTER 5 Model verification

the road attributes on the passenger side and determined the impact of the crash for the road user affected. The external influences differed according the crash types considered for public transport pedestrian users and the impact on a crash. The star rating score obtained was compared to the star rating band scale as shown in Figure 2.7 to determine the final star rating score, (iRAP, 2013). The along score for pedestrians drive and passenger sides were also calculated separately based on the similar crash type represented as shown in Appendix I, Table I.2.

The star rating score determined in Appendix I was for the 100m segment of roadway on Constant Spring Road, as shown in Appendix J, Figure J.1 image reference number 2 790. The verification process was consistent with the procedure demonstrated in the iRAP star rating worked example fact sheet 9. The star rating score obtained for the existing iRAP pedestrian road user type was also compared to the iRAP methodology fact sheet 7, (iRAP, 2013). The use of iRAP fact sheet 7 was to determine where on the star rating band scale was the score of the existing iRAP model. The scale of the star rating band had a range of 1 to 5 as shown in Figure 2.7. The results obtained was an indication of the level of safety built into the roadway for the existing pedestrian iRAP model, (iRAP, 2013).

5.5 Summary

The verification process for the star rating equation for public transport facilities used data from the study area in worked star rating examples. In so doing the star rating for public transport pedestrian users was determined. The data collected was also used to determine the star rating for pedestrians according to the existing iRAP model. The star rating was done for both road users on the same 100m of road segment based on the supporting data. The results obtained were then compared to the star rating band to determine the scale value.

CHAPTER 6 Discussion

6.1 Introduction

The purpose of this research project was to investigate the existing road safety situation in Jamaica as discussed in Section 1.3. In this way road crash data was assessed to determine the road users that were represented when crashes were reported. This in relation to the type of crashes that occurred on the road network. Furthermore, the assessment of road crashes was done in relation to number of fatalities and sever injuries that occurred, as well as the road users affected. Therefore, the emphasis was not on the frequency of the road crashes that affected those road users but the on occurrence of the crash. Research questions were developed on this basis to establish the framework for the research project.

According to WHO (2004), several principles and concepts such as the Haddon matrix helped to shape the approach now being taken to road safety. This was aimed at reducing the number of road crash fatalities and serious injuries. The World report on road traffic injury prevention supported the Haddon matrix implementation of the safe systems approach to road safety. The data collected from the study area of Kingston and St. Andrew in Jamaica as a representative low to middle-income country demonstrated the need for this implementation.

During the World Bank's assessment of the transportation system in Jamaica in 1984. It was revealed that the transportation system did not provide an efficient service to meet the needs of commuters as a safe and reliable means of transportation. In the assessment carried out for this research project, the findings of the 1984 report can be used as a reference for the existing situation. In particular, the data collected from the study area is a reminder of the findings of the 1984 report by the World bank because of its relevance 34 years after publication.

6.2 Road safety measures for public transport pedestrian users

The approach taken to this research project sought to determine a conceptual framework that demonstrated a systematic approach to investigating the safety needs for public transport pedestrian users. As discussed in Chapter 3, the iRAP methodology was adopted to collect data on road features present within the traffic environment related to public transport facilities. In using the iRAP methodology the road features highlighted in yellow as shown in Table 4.3 were not included in the pre-existed iRAP road attributes database. The coding of those road

CHAPTER 6 Discussion

attributes identified were therefore not recorded according the iRAP star rating and investment coding manual.

Though the iRAP methodology was not used to code those road attributes, the recording of other road attributes was done as shown in Table 4.3 that were not highlighted yellow. The number of road crashes occurring in the vicinity of bust stops as discussed in Section 4.2 was an indication of the road safety measures present for public transport facilities. As shown in Table 3.5 the safety needs of public transport pedestrian users had different expectations from existing road users in the iRAP methodology. It follows then that the likelihood and severity factors that influenced a crash for public transport pedestrian users was based on the crash types involved as shown in Figure 2.7 and Figure 2.8. And moreover, determined the countermeasure as an intervention to prevent the occurrence of those crash types or reduce the severity of such crashes as shown in Table 3.8.

The images taken of the road sections in the study area as discussed in Section 3.4 showed the road features present within the traffic environment. The road feature present or absent was a clear indication of road user priority within the design of the road infrastructure and road safety management system. In the images discussed in Section 3.4 the challenges faced by public transport pedestrian users and pedestrians were the same on all road sections within the study area. Therefore, as discussed in Section 3.5 a needs-based approach was taken to assess the safety needs of public transport pedestrian users to bridge the gap for this road user within the existing traffic system.

6.3 The influence of public transport facility design on the interaction of road users

The development of the needs analysis process was done to determine the safety needs of public transport pedestrian users. In so doing, the interaction of public transport pedestrian users with other road users and the infrastructure provided was determined. And at the same time was colour coded according to their impact on safety. The image shown in Figure 3.14 was colour coded red, yellow and black. According to Table 3.3 the general provision of the infrastructure provided, and safety concerns were fair to moderate, poor or inadequate and severe in all cases of the road sections within the study area as discussed in Section 3.6. The colour coding of the features present at bus shelters and transport centres was an indication of the

CHAPTER 6 Discussion

design approach used for public transport facilities and the priorities of the road transport management system.

As a result, this is further reflected in Table 4.2, which as discussed in Section 4.3, road crashes in the vicinity of bus stops were 14.5 per cent of the total crashes that occurred on the road sections within the study area. The number of fatalities and sever injury crashes was also a cause for concerns. Though the data represented in Table 4.2 was collected over a 34-year period as shown in Table 3.4, there were multiple crashes recorded for each year reported with the exception of 1981 when there was one crash reported. And according to Table 3.4 this crash occurred in the St. Andrew Central division. As discussed in Section 4.3, the St. Andrew Central division reported the highest number of crashes and was the location of most of the road sections within the study area.

It is to be noted that, there was no data presented by the RSUJ for the years 1982 to 1994 as shown in Table 3.4. The 12-year gap in the data presented was an indication of the deficiencies in reporting that existed in low to middle-income countries, (WHO, 2004). The missing data over the 12 years impacts the data presented and therefore was not a true representation of the crashes that occurred. Based on the trend as shown in Figure 4.6 for the crashes that occurred in the vicinity of bus stops, it can be assumed that for the 12 years of missing data, at least one crash did occur. As a result, if those crashes were taken into account the result would be an increase from 541 to 553.

A hypothesis would also be that those crashes would have occurred in the St. Andrew Central division. This would be based on the trend of data presented as shown in Table 3.4, where the division recorded at least 1 crash each year since 1981 with the exception of 2017 and 2018 where no crashes were reported. The absence of data nevertheless was not a clear indication that a crash did not occur. This was the assumption for all cases where there were no crashes reported. This was based on the known deficiencies that exists in reporting road crashes in low to middle income countries. Nonetheless the data was accepted as it was presented and assessed based on the crashes reported on.

6.4 The use of iRAP to determine road attributes for public transport facility users

As discussed in Section 3.6 the iRAP methodology also used colour coding to highlight the risks faced by road users on a road section. This was done according to the road risk factors in

CHAPTER 6 Discussion

the presence or absence of road features on the road section being assessed as well as the road users involved. The safety needs of the road user being assessed was the new road user type public transport pedestrian users as discussed in Section 3.6. As discussed in *Section 2.8.7*, public transport pedestrian users were not previously considered in the iRAP methodology. As shown in Table 3.6 public transport pedestrian users have specific safety needs when compared to other road user groups.

The safety features of public transport facilities such as bus shelters and transport centres as shown in Table 3.6 indicates the safety needs. Some of which were not included in the pre-existing road attributes database in the existing iRAP methodology. As discussed in *Section 2.11.3*, the design and safety of public transport facilities such as bus shelters and transport centres impacted the operation performance. And moreover, determined ridership within the transport system, (TRB, 1996). In Section 3.6 the road features were colour coded in Figure 3.19 using the iRAP methodology for pedestrians. When compared to the road features colour coded in Section 3.5, for example in Figure 3.14 using the safety needs assessment for the needs analysis. The road features identified by the needs analysis were more detailed than in Figure 3.19.

As a result, the application of the needs-based approach as shown in Table 3.6 in relation to Figure 3.14 determined road features specific to public transport pedestrian users. Similarly, the road features present or absent related to public transport pedestrian users as shown in Table 3.6 resulted in a star rating of 3. This was as discussed in Section 5.4 for the 100m of road section on Constant Spring Road as shown in Appendix I. This was in contrast to the star rating score of one for pedestrians along the same 100m segment of roadway. It is to be noted that the star rating determined for public transport pedestrian users, was in relation to road features related to public transport facilities, likelihood and severity factors.

At the same time the star rating for pedestrian was based on road attributes within iRAP's pre-existing database and corresponded to pre-existing risk factors. The star rating score produced was an indication of the difference in road features assessed for both road users. There were many instances where a risk factor of one was applied in the star rating for public transport pedestrian users based on no pre-existing risk factors being available for reference. As discussed in Section 5.4 where research was not available for the influence of the road attribute on the likelihood and severity of a crash, a factor of one was applied, (Lynam, 2012). This

CHAPTER 6 Discussion

contributed to the star rating of 3 for public transport pedestrian users along the 100m segment of roadway on Constant Spring Road. When compared, the risk factors for pedestrians, as shown in Appendix I, Table I.2, most of the risk factors were recommended by iRAP based on research and their influence on the likelihood and severity of a crash.

6.5 The methodology to improve safety for public transport facilities

The number of crashes as shown in Table 3.4 highlights the need to improve safety at public transport facilities such as bus shelters and transport centres for public transport pedestrian users in Jamaica. In Figure 3.24 the methodology for the development of a crash allocation star rating model for public transport pedestrian users was shown. As discussed in Section 3.7 the data obtained from secondary sources was assessed and the crash types determined. As discussed in Section 6.4 the data obtained was not conclusive and therefore the number of crashes could be more than what was presented. The crash types determined were based on the risk factors that influenced that likelihood and severity of a crash for public transport pedestrian users.

As shown in Table 3.8 the risk factors that influence a crash were determined based on the presence or absence of road features. The risk factors were determined based on the collection of data using the iRAP methodology. Following this the data collected on the road sections in the study area were then assessed according to the principles of the needs analysis to determine the safety needs of public transport pedestrian users at public transport facilities. As shown in Table 3.6 the assessment process of the needs-based approach looked at the specific needs of public transport pedestrian users at public transport facilities. This determined the risk factors to be included in the expansion of the iRAP methodology to include public transport pedestrian users.

In Figure 3.24 the identification of risk factors determined the countermeasures that were needed for appropriate interventions to improve safety at public transport facilities as shown in Table 3.8. However not all countermeasures were included in the existing iRAP methodology. Therefore, design recommendations for public transport facilities as discussed by Schoon (2019) and TRB (1996) that were known to improve safety and functionality were used as countermeasures. Based on the road user types included in the existing iRAP methodology, the star rating and casualty estimates of each road user type were included in fatality estimates and

CHAPTER 6 Discussion

serious of injury calculations. As a result, the new road user type public transport pedestrian user was also included as discussed in *Section 2.8.9* and *Section 2.8.10*.

6.6 The integration of public transport pedestrian users with the iRAP methodology

The improvement of safety at public transport facilities looked at the conditions of existing iRAP models and the development process as discussed in (Lynam, (2012). As shown in Figure 3.24, the integration of public transport pedestrian users to expand the iRAP model was initiated with the assignment of risk factors to the associated crash types. According to Equation 2.7, the sum of the crash scores determined the star rating for public transport pedestrian users. It follows then, that in order to obtain the star rating score, the crash type scores would be based on crash initiation risk factors, (Lynam, 2012).

The crash types determined as shown in Figure 2.7 and Figure 2.8 and further supported in Figure 3.25 resulted in the star rating model equation methodology to arrive the required score. The road sections of the study area were assessed and, in the assessment, carried out standard countermeasures as shown in Table 3.8 were determined based on the road attributes present. Similarly, as shown in Table 3.8 enhanced countermeasures were also presented. The enhance countermeasures for the safety needs of public transport pedestrian users were determined according to Table 3.6. As discussed in *Section 2.8.9* and *Section 2.8.10*, public transport pedestrian users were integrated in the star rating model equation and casualty estimation calculations.

This was based on the methodology shown in Figure 3.24, where the countermeasures applied would determine fatality and severity estimates as a result of their influence in reducing road crash fatalities. As discussed in Section 2.8.10, for Equation 2.12 to arrive at the estimated fatalities, the fatalities for PTPU was added to the fatalities of the existing road users types in iRAP. However, to determine the fatalities for PTPU as show in Equation 2.13 and as demonstrated in Figure 3.25, with further support from the star rating worked example in Appendix I, Table I.1, the crash type scores were dependent on the likelihood and severity risk factors. Thus, was as a result demonstrated the integration of the public transport pedestrian road user type into the iRAP methodology. Consequently, the use of iRAP star rating worked examples in Appendix I, provided a star rating score based on the road attributes associated risk factors in the traffic environment.

CHAPTER 6 Discussion

6.7 Economic analysis

As discussed in *Section 2.8.12*, using the iRAP methodology to carry out the economic assessment presented challenges in representing the data required. The data required was related to the number of fatalities prevented, and serious injuries prevented to determine the economic benefit. The economic benefit was needed to determine the present economic value. This would then be used to determine the benefit cost ratio. Whereas the economic cost could be determined because this was related to the cost of constructing the countermeasure and then would be used to determine the present value economic cost.

Based on this, the FYRR was used to determine the economic benefit of the recommended countermeasure. The use of this method however would require the economic benefit of each scheme to be determined individually. As an example, reference is made to Table 3.8 which considers enhanced countermeasures and preferred countermeasures. Enhanced countermeasures are countermeasures that would be recommended under the ideal budget situation where adequate funding was available. However, as in that case of road safety that is not always the case, especially in low to middle-income countries such as Jamaica, (WHO, 2004). There were preferred countermeasures also recommended to address the issue of budgetary constraints. Preferred countermeasures would therefore include retrofitting or making adjustments to existing public transport facilities.

To determine the economic benefit of implementing an intervention, one countermeasure each was selected from the enhance and preferred recommended countermeasures. From Table 3.8 the enhance countermeasure selected was, design of public transport facilities and from the preferred countermeasures, sidewalk provision. To determine the economic benefit of the design of public transport facilities, this would include the construction of a new facility. Similarly, and to determine the economic benefit of sidewalk provision, this would result in improving accessibility to the sidewalk. As an example of design of public transport facilities, Figure 3.16 from Constant Spring Road was used, also as an example of sidewalk provision, Figure 3.10 Washington Boulevard was used. Therefore, from Equation 2.34 the economic benefit for design of public transport facilities and sidewalk provision was as follows:

- As shown in Table 3.4, the year 2009 was selected which had an annual total of 44 crashes in the vicinity of bus stops. The assumption was to reduce the number of crashes by 50 per

using the design of public transport facilities and 10 per cent also using sidewalk provision over a 2-year period. The cost of constructing a new transport facility replacing what was shown in Figure 3.16 to include all best practice safety design considerations was estimated at (JMD) \$950 000 dollars. Similarly, the cost for sidewalk improvement as well as improving the transport facility by including a bus boarder was estimated at (JMD) \$380 000 dollars. The cost of an injury was based on treating an injury at the accident and emergency in the hospital. Though there were other factors that determined the type injury to be treated, the assumption was based on an average health care cost of (JMD) \$100 000 dollars.

Hence,

$$\begin{aligned}
 \text{FYRR (\%)} \text{ for PTF} &= [(((44 \times 0.5) / 2) \times 100\,000) / 950\,000] \\
 &= [((22 / 2) \times 100\,000) / 950\,000] \\
 &= [(11 \times 100\,000) / 950\,000] \\
 &= [1\,100\,000 / 950\,000]
 \end{aligned}$$

$$\text{FYRR (\%)} \text{ for PTF} = 1.16$$

And

$$\begin{aligned}
 \text{FYRR (\%)} \text{ for SWP} &= [(((44 \times 0.5) / 2) \times 100\,000) / 380\,000] \\
 &= [((22 / 2) \times 100\,000) / 380\,000] \\
 &= [(11 \times 100\,000) / 380\,000] \\
 &= [1\,100\,000 / 380\,000]
 \end{aligned}$$

$$\text{FYRR (\%)} \text{ for SWP} = 2.89$$

The FYRR determined for both schemes was positive. The FYRR for PTF was positive at 1.16 per cent which indicates a positive return within the first year and though it was lower than the FYRR for sidewalk and bus boarder provision at 2.89 per cent, the difference was based on the cost of each scheme.

CHAPTER 6 Discussion

6.8 Understanding outputs for public transport facilities

In the development and integration of the star rating model equations for public transport pedestrian users, the methodology resulted in outputs related to the objectives in answering the research questions. The outputs of the model were determined based on the methodology used to assess the data collected from the study area to produce the star ratings and countermeasures for public transport facilities. By establishing the overall approach to assessing the existing road safety management system, the outputs achieved were aimed at reducing the number of road crash fatalities and serious injuries at public transport facilities. The outputs from the research project according to the objectives are as follows:

Outputs from research project

- Needs analysis specification
- Needs analysis
- Needs analysis matrix
- SRS equation PTPU
- Countermeasures

The introduction of public transport pedestrian users was to distinguish those who use public transport facilities from existing road user groups. In addition, the Jamaican crash database also includes categories of road users not included in the iRAP methodology. In the Jamaica crash data-based reference was made to a road user group known as public passenger vehicle passengers and public passenger vehicle drivers, (RSU, 2017).

Based on the use of the public passenger vehicle passengers and public passenger vehicle driver road user categories in the Jamaican crash database, it follows then that a road user group could be defined as public transport pedestrian users. This was considered necessary based on the time spent in the traffic environment by this road user group in a stationary position and their exposure to mass casualties according to the crash types in Figure 2.7 and Figure 2.8.

There are however design concerns related to public transport facilities within the study area based on the data collected. These concerns relate to the likelihood and severity of road crash fatalities specific to public transport pedestrian users from the data obtained and discussed in Chapter 4. In the assessment of the institutional framework done in the needs analysis matrix,

CHAPTER 6 Discussion

there was no evidence to suggest that the designs used conform to best practices. There was one example of a best practice approach from a developed country, this was public transport facility provided by the United States Embassy.

6. 9 Limitations

In the application of the methodology to determine the outputs for public transport facilities, there were noticeable challenges. One such challenge related to the access to data from reporting Government institutions. There was reluctance on their part in every way, in the form of scepticism. Of primary concern to the authorities approached was, what was the data going to be used for. In instances where the entity was not performing according to their mandate, discussions were not entertained. However, the data that was obtained was enough to reveal the existing situation based on the institutional framework and management system practices.

Limitations within the research also existed in available literature in relation to road crash fatalities and serious injuries that affected public transport pedestrian users. This was primarily because of the general classification of road users and the emphasis on crashes that occurred more frequently. In addition, research literature on the safety of public transport facilities in relation to the type of crashes that occurred while waiting at these facilities, was also a challenge. The primary concern within most literature for safety was in regard to the prevention of robberies.

The application of the iRAP methodology also had its challenges based on the number of components within iRAP and what was needed from the output of this research project. The data entry and collection procedures were primarily geared towards the SRIP. Hence based on the required output of the objectives care had to be taken to know how much data entry and assessment was required to achieve the desired output. The desired output in this case was to determine the star rating score for public transport pedestrian users.

Following this road crash data and road attributes data also had its challenges. As discussed in Chapter 4, there were uncertainties in the data presented for crashes that occurred at public transport facilities. There were also instances of missing as well as the data not being available in its original form. This being said, the data needed could not be extracted or presented in a format as needed. In relation to road attributes data, there was no specific guidance from iRAP in relation to public transport facilities. This could be attributed to public transport pedestrian

CHAPTER 6 Discussion

users not considered as a crash type. Therefore, no consideration was given for road attributes that impacted the likelihood and severity of a crash in those instances.

Other limitations existed in the economic analysis using the iRAP methodology based on the data required. This required assumptions to be made and therefore highlighted a weakness within the approach to determine the countermeasure that was most economically appropriate. Other weaknesses were also previously mentioned in the form of available data that could compromise the output of the research based on its objectives. As well as determining the appropriate risk factors related to public transport facilities.

6.10 Future research

Based on the aim and objectives of this research project, it was determined that crashes involving public transport facilities was an area that could be assessed in relation to the type of crashes that occurred. Even though the data collected from the Jamaican authorities were not able to provide the exact location with reference to public transport facilities. The available data required more accurate representation. That being said existing road user types being used, included other types of road users within the transportation system that could be represented separately. Future research therefore was needed to determine the extent of the road users impacted by crashes not included in existing iRAP models.

The implementation of the outputs of this research relies on available budgets and resources, for a sustained effort to reduce the likelihood of a fatality or severe injury at public transport facilities. Further research was therefore needed to determine the extent of existing public transport facility design on the safety of public transport pedestrian users. This is to explore the development of best practice design standards based on the expectations of public transport pedestrian users, in addition to other road users.

6.11 Summary

The determination of the safety measures that exist for public transport facilities was discussed and the interventions that could be implemented. In addition, the influence of the design for public transport facilities determined the level of safety offered to public transport pedestrian users. Even more the extent of assessment determined a methodology that resulted in

CHAPTER 6 Discussion

integration of public transport pedestrian users in the iRAP methodology with recommended countermeasures.

CHAPTER 7 Conclusion

7.1 Introduction

Road crashes have significantly impacted the most vulnerable road users in low and middle-income countries. And in particular those who use public transport facilities. The aim of this research project was to improve road safety for public transport pedestrian users at public transport facilities such as bus shelters and transport facilities. It follows then that the objectives to achieve this aim focused on determining the existing situation in regard to road safety and its impact on Jamaica. And at the same time provided insight into the priorities of road safety authorities based on the facilities provided and safety measures in place to reduce the impact on road users.

7.2 Project overview

Road crash fatalities in low to middle-income countries accounted for 85 per cent of deaths on the world's roads, (WHO, 2004). It was estimated that low to middle-income countries would experience an increase in road crash fatalities and serious injuries, while high-income were expected to experience a 30 per cent decrease, (WHO, 2004). The road design practices of low to middle income countries gives preference to one road user over another. To reduce the number of road crash fatalities and serious injuries these design practices should be tailored to include all road users, (WHO, 2004).

The WHO (2004) document on World report on road traffic injury prevention and supported by (Bliss and Breen, 2009), outlines a framework for developing countries to develop a sustainable programme for road safety. This related not only to the ability of developing countries to provide the appropriate policy framework but also the infrastructure and emergency care services to reduce road crash fatalities and post-crash care for serious injuries. Their ability to administer post-crash care and the economic implications to families due to a loss of life of family members, are yet to determined, (WHO, 2004).

One pathway for low and middle-income countries was to begin adopting proven best practices in road design and road safety from high-income countries. The suitability of the design differs for road users in regard to the type of facilities included in the design and determines the level of safety, based on the mix of road users in the traffic environment, (iRAP, 2013). As discussed in Lynam (2012), the iRAP model development procedures provided an understanding of the

CHAPTER 7 Conclusion

iRAP model. The assessment of road safety in the study area, using the needs-based approach to identify gaps aided in determining safety needs of public transport pedestrian users at public transport facilities.

The type of data required for the assessment, prioritization, implementation, monitoring and evaluation was done at different IQL levels that determined the existing situation as stated in (Robinson *et al.*, 1998). The worked star rating example demonstrated the application of the star rating model equation for public transport pedestrian users for the existing road safety management system. And at the same time road attributes risk factors were based on the different crash types associated with each road user type.

The comparison between the star ratings for both road user types demonstrated that the 100m segment of road presented different safety levels for each road user type, (iRAP, 2014). It was concluded that the difference in star rating scores for public transport pedestrian users and pedestrians for the same 100 m segment of road was based on the difference in road attribute risk factors used. Therefore, the scores obtained when compared to the star rating band scale and was an indication of the level of safety built into the roadway. This level of safety was for the existing pedestrian included in the iRAP model, and public transport pedestrian users not included in the existing iRAP model (iRAP, 2013). As shown in Figure 7.1 the research project focused on achieving this aim in relation to objectives that determining the risk factors and road safety measures.

The aim of the research project and its objectives were realised using the methodology in shown in Figure 7.1 as follows:

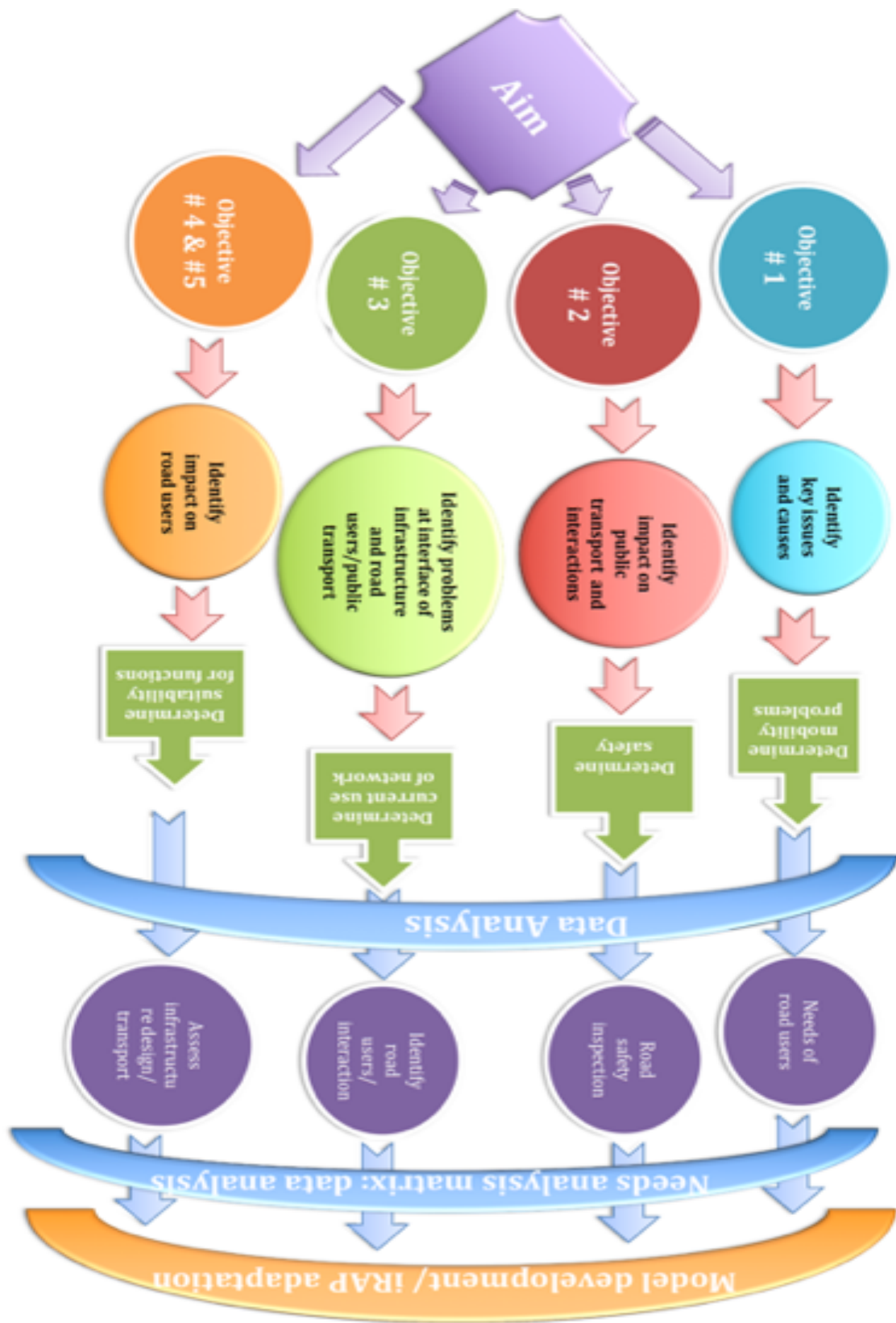


Figure 7.1 Research project overview

CHAPTER 7 Conclusion

7.3 Improving road safety for public transport facilities on urban road networks

The data obtained from the study area determined the existing situation and the safety measure afforded to road users. In addition, the data also provided insight into the type of road users affected. The examination of the type of road users within the traffic environment and the type of crashes reported on, was an indication on the integration of type of road safety measures provided. By adopting an existing methodology to assess the existing infrastructure provided for road safety also revealed the road users that were a priority but also those who not. As a result, it was shown that the emphasis was only on crashes that occurred most frequently. And therefore, was not in relation to the loss of life of the road users based on their classification regardless of how often the crash they were involved in occurred.

The development of a star rating model equation for public transport pedestrian users addresses one such problem and was done by adopting the iRAP methodology. In so doing this placed emphasis on the need for more research in other areas of road safety and not only in those areas where crashes occur most frequently. In this way the reason for the inclusion of facilities for all road users in the design of road infrastructure would not be seen as optional resulting in one road user being given priority over the other. This has a direct relationship to the safe systems approach of the WHO. In fact, it emphasises the need for a more humanistic approach to road safety at the lowest level of the implementation of road safety strategies. In this way placing emphasis on the dynamic nature of the mix of road users within the traffic environment and the need to be as dynamic in road safety design methodologies.

The use of the needs analysis to determine the gaps that existed between the existing situation and the desired, formed the basis to determine the safety at public transport facilities. The needs analysis process being supported by the iRAP methodology that further strengthened the assessment process. This by focusing on road attributes and risk factors to determine the level of safety built into the roadway for each road user present in the traffic environment. This was one of the weaknesses of the assessment process associated with the availability of data and affected the accuracy of the output of the research project. This however emphasized the importance of research in road safety and highlights that it is still an emerging science. Hence the reasons for existing versions of the iRAP and other road safety models being developed to address road safety concerns in developing and developed countries, (iRAP, 2012).

CHAPTER 7 Conclusion

Based on the application and testing of the existing road safety models the accuracy of crash data reporting has been a long-standing issue in low to middle-income countries. Not surprisingly the system of recording in Jamaica, and the data collected was a representation of data management methods. The resources needed to implement countermeasures depends the availability of data and the capacity of the local authorities that have oversight for public transport facilities. Moreover, support for the initiatives are also based on the will and financial resources available from policy makers. The use of road crash data that is all inclusive and represented from a bottom-up approach that focuses on all crashes where they occur. As well as the capacity of road use when the crash occurred would allow for informed and evidence-based decisions to guild road safety initiatives.

The importance of understanding the influence of road design on road users, as well as the influence of facilities provided on how road users use the road forms the basis to address the existing road safety situation. This is further supported by the (WHO, 2004) policy of one life lost was one too many. In particular, situation reflects on the considerations of the safe systems approach, where all road user needs should be catered. Hence, as shown if not addressed the relationship between the gaps in the existing road safety management system in relation to the interactions between road users and the road infrastructure will continue to widen. The identifying these various issues in developing counties and the methodologies needed for implementation would reduce the number of serious road traffic injuries and road crash fatalities.

However, based on the existing road safety management system, there is a need to develop a management system in Jamaica, that coordinates the transportation system with the expectations road users. This should include countermeasures aimed at reducing the likelihood and severity of a crash involving public transport pedestrian users. The re-classification of road users and type road crashes to include all crashes puts into focus the unique situation of each crash to be assessed as a preventable event. In the way, the cause of a crash that relates to three main factors of the human, vehicular and the road environment can be addressed on its own merit. Making this change to the role of any of the three main factors can result in crash avoidance.

The implementation of road user friendly road design practices and improved vehicle design that takes into consideration the vulnerability of the human body. As well as road user behavior that fits with in the design envelop of the road infrastructure, are seen as ways to reduce road

CHAPTER 7 Conclusion

crashes. This approach puts focus on the system designers to implement road design practices taking into account human error. The result is that a human error should not result in a road fatality or serious injury, (WHO, 2004).

7.4 Summary

The proposed methodology for this research project was aimed at improving road safety for PTF on urban transport networks in low to middle income countries. The methodology was to achieve the aim and objectives as follows:

- The development of a star rating model equation for public transport pedestrian users at public transport facilities for integration into the iRAP methodology to improve road safety for public transport facilities such as bus shelters and transport centres
- Use of the needs-based approach to assess the existing road within the urban environment
- The use of the needs-based approach and iRAP to determine safe design practice for public transport facilities on urban road networks

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APPENDIX

APPENDIX A

Appendix A



UNIVERSITY OF BIRMINGHAM

College of Engineering and Physical Sciences

School of Engineering

Department of Civil Engineering

PhD in Civil Engineering

A needs-based investigation to manage the safety of public transport infrastructure using Jamaica as a case study

by

Leighton H. Uter

The University of Birmingham
School of Civil Engineering
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January 31, 2019

APPENDIX B

Appendix B

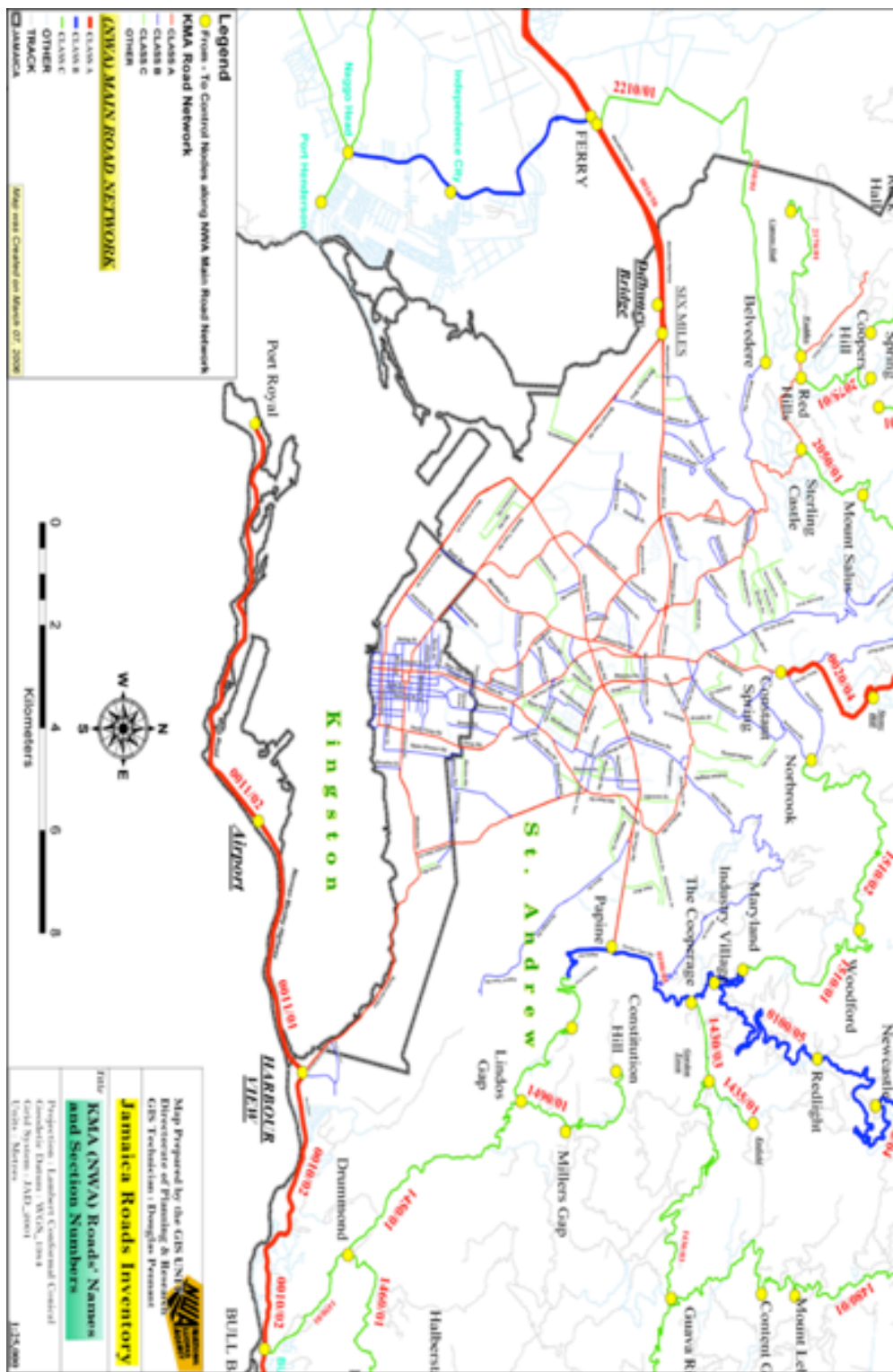


Figure B.1 Map of Kingston and St. Andrew road network: Study area Modified by Uter (2018) and obtained from: National Works Agency-GIS Unit (2010)

Appendix B

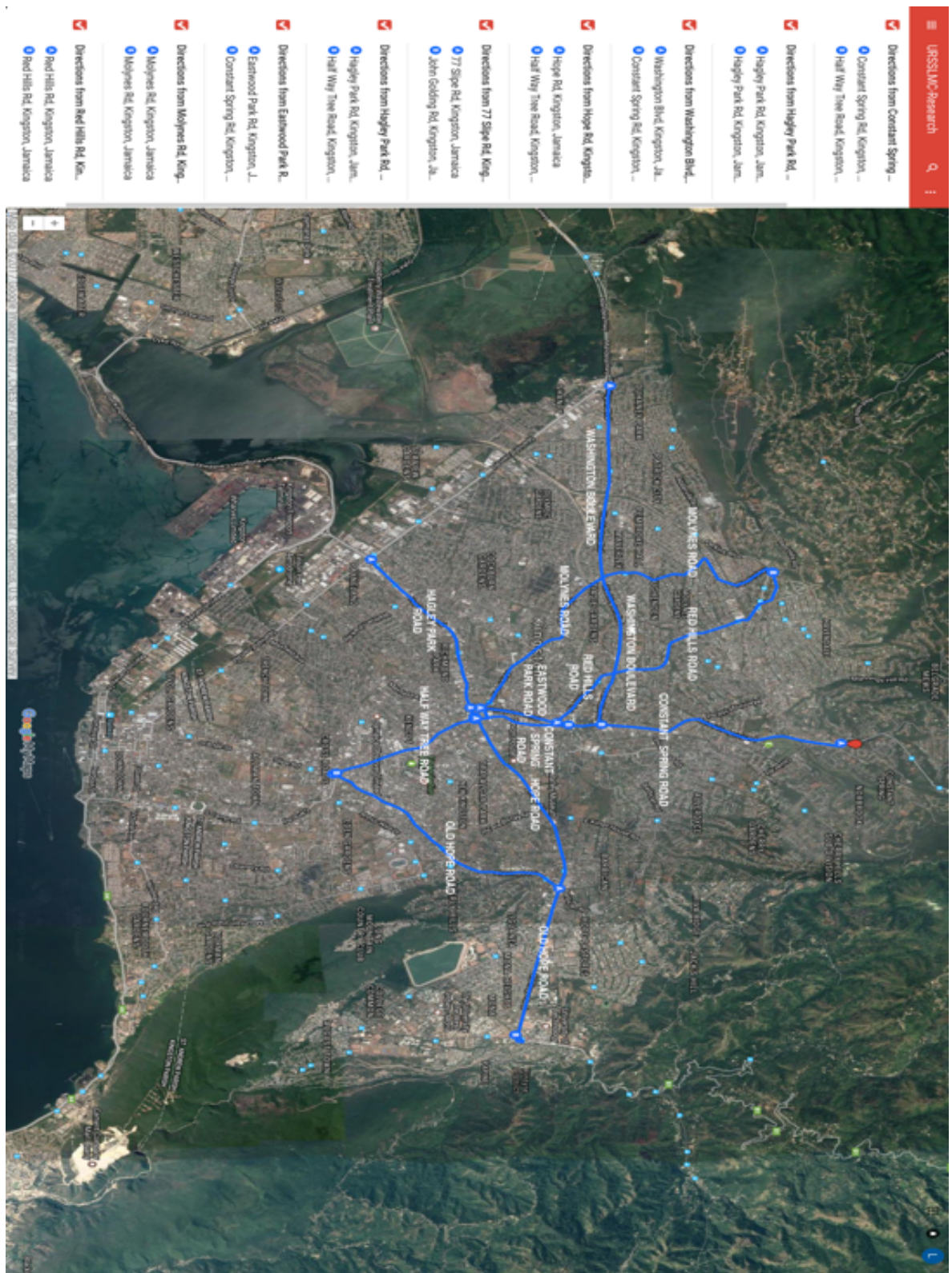


Figure B.2 Image of Kingston and St. Andrew road network: Study area Modified by Uter (2018) and obtained from: Google imagery (2016)

APPENDIX C

Preliminary research assessment data



Figure C.1 Image showing condition of median

Appendix C



Figure C.2 Image showing condition of bus stop and sidewalk obstructions

Appendix C



Figure C.3 Image showing obstruction on sidewalk

Appendix C



Figure C.4 Image showing the intersection of Dunrobin Avenue and Constant Spring Road

APPENDIX D

Appendix D

iRAP assessment data

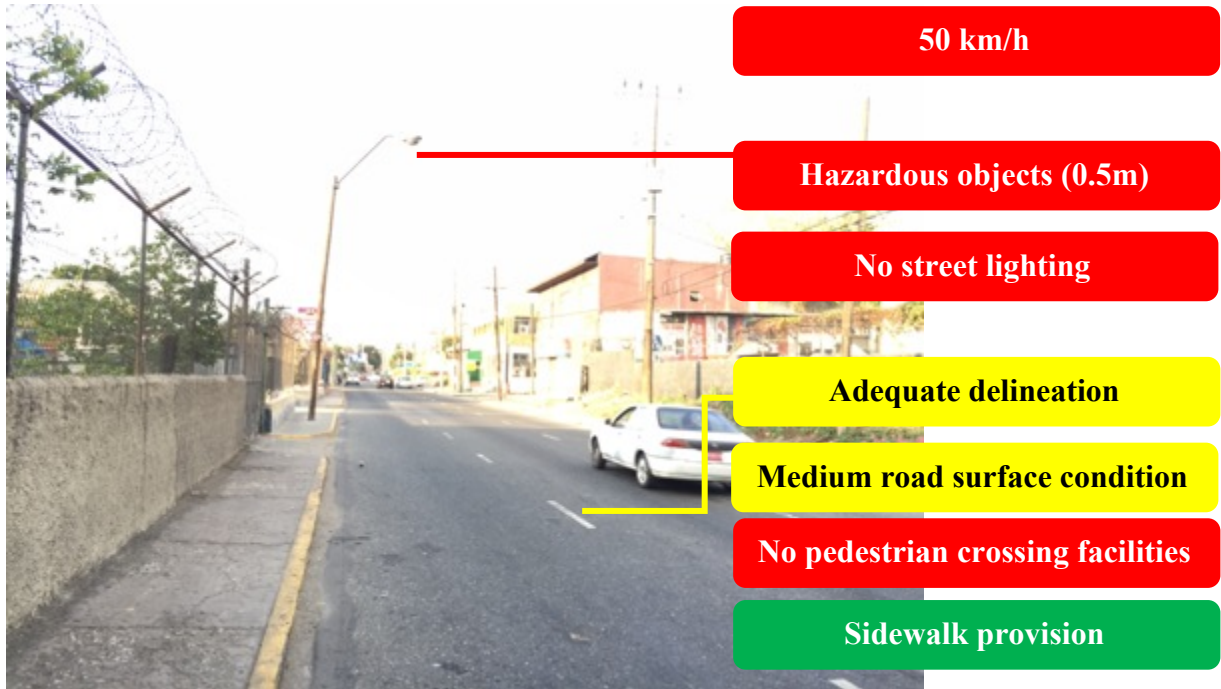


Figure D.1 Image of Eastwood Park Road, Kingston and St. Andrew: Study area

APPENDIX E

Appendix E

Needs analysis assessment data

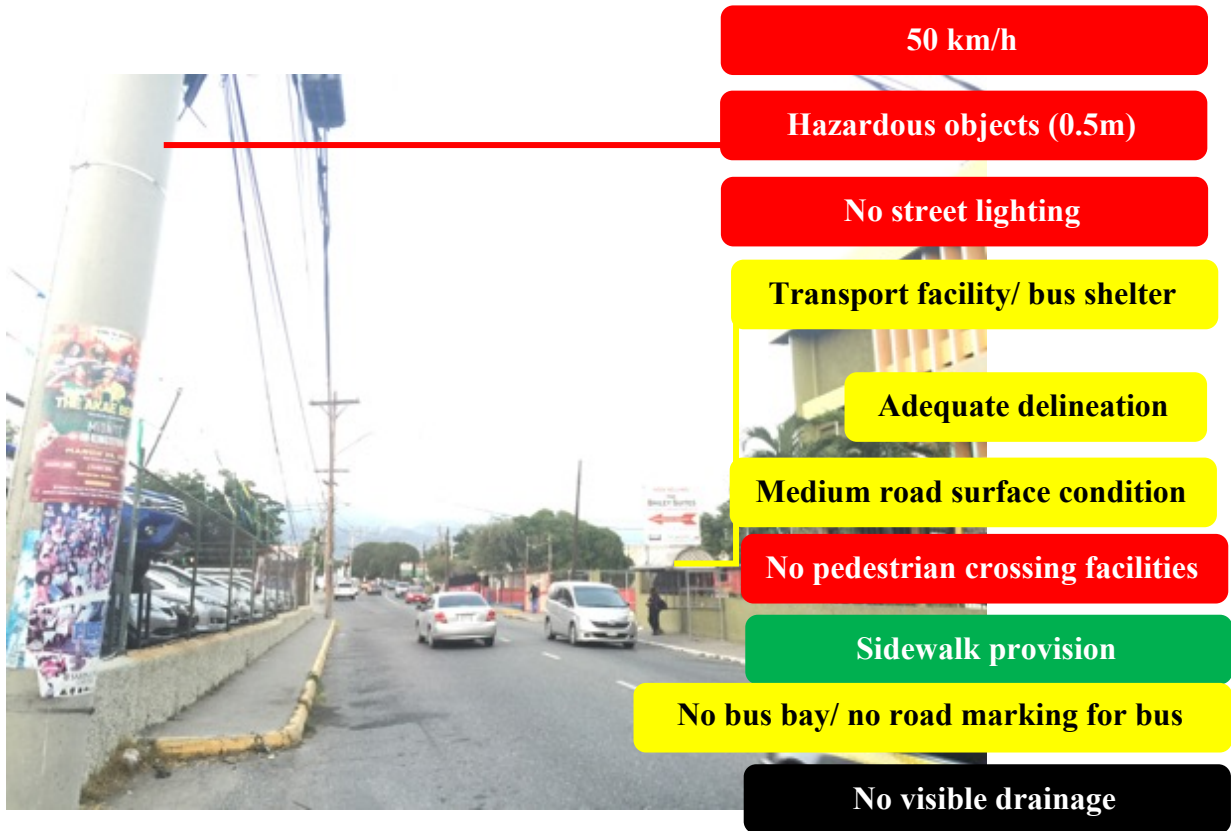
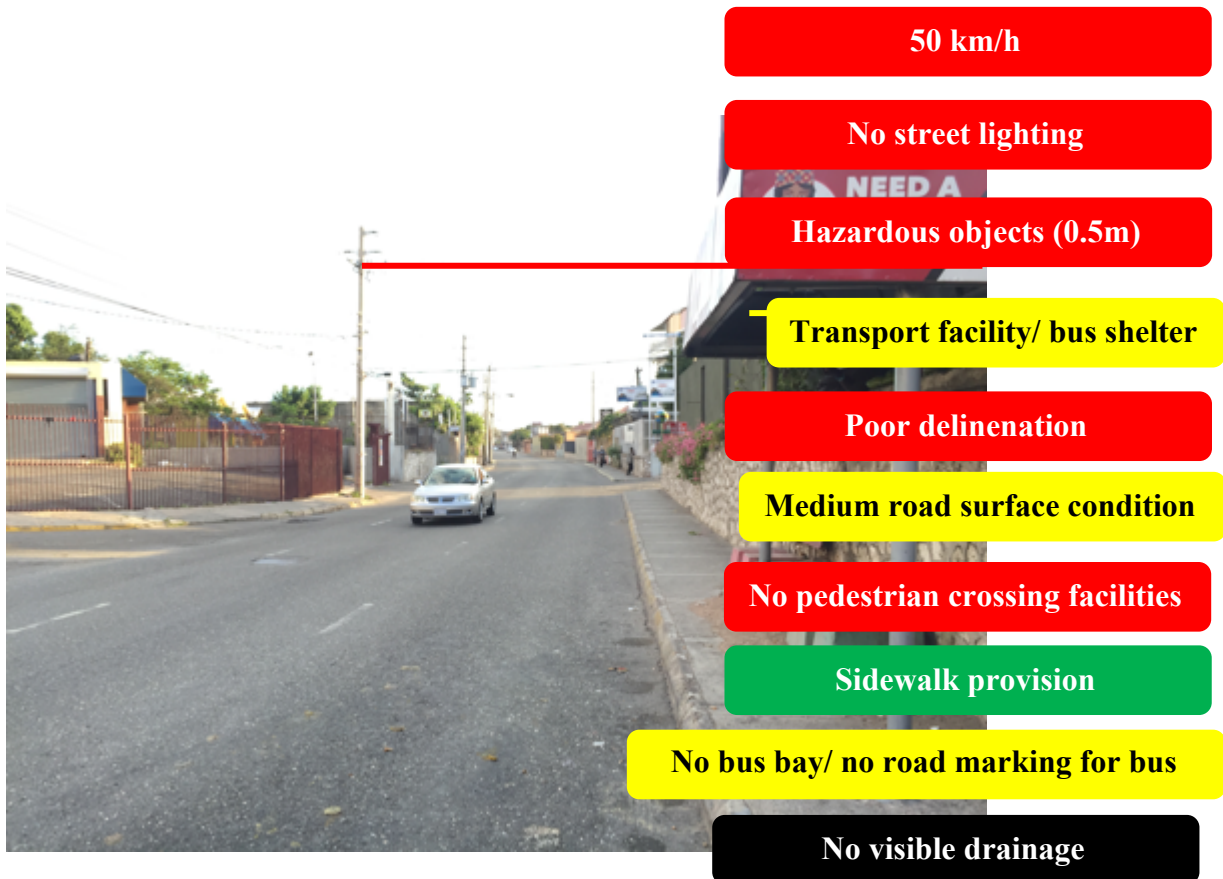


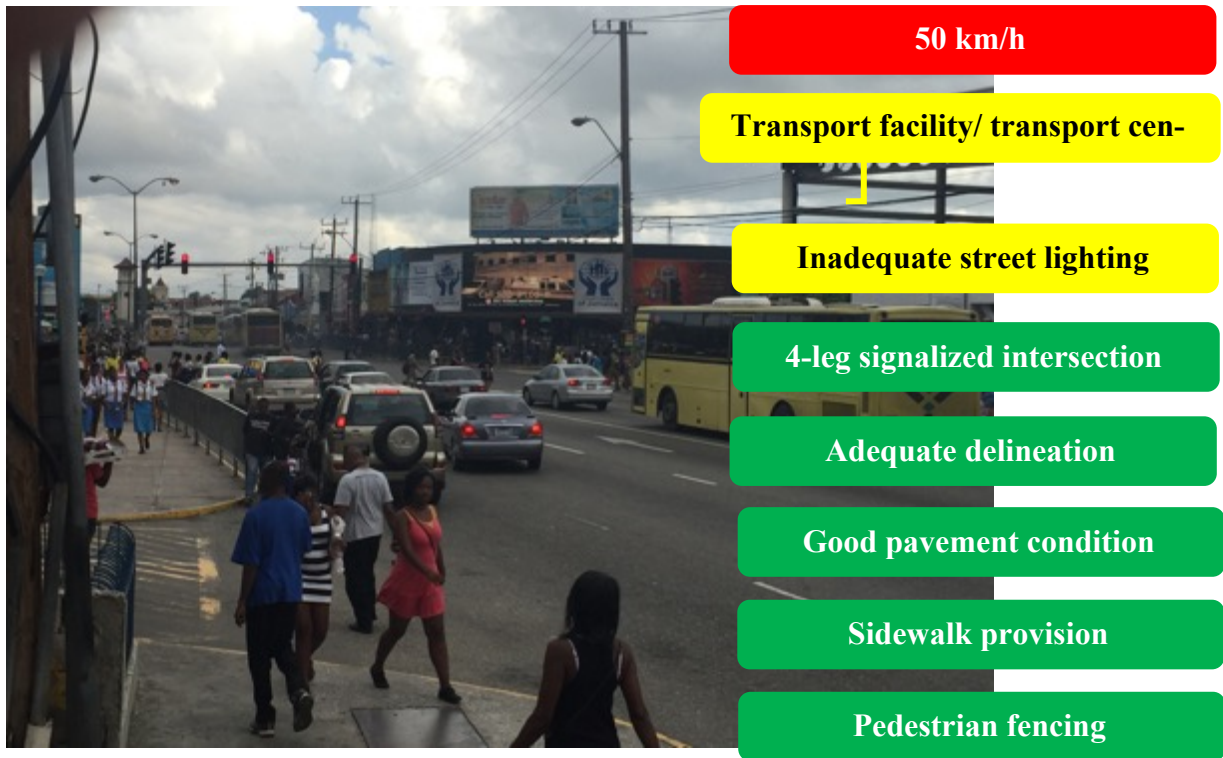
Figure E.1 Image of Old Hope Road, Kingston and St. Andrew road network: Study area

Appendix E



**Figure E.2 Image of Eastwood Park Road, Kingston and St. Andrew road network:
Study area**

Appendix E



**Figure E.3 Image of Constant Spring Road, Kingston and St. Andrew road network:
Study area**

APPENDIX F

Appendix F

Table F.1 Accident report form

Accident Report

Jamaica Constabulary

Division n°				Station n°				Accident n°								
Investigator n°				Rank				Severity		F	S	M	D			
Name																
Date and time	Da	Mont	Yea	Hou	Mi-	Days of week										
	y	h	r	r	minute	Su	Mn	Ts	W	T	Fr	Sat				
Accident Place,(street address/ landmark/offset distance)																
Parish		Road class		Main	Parochial	Farm	Private	Estate	Other							
SPEED LIMIT 30 km <input type="checkbox"/> 50 km <input type="checkbox"/> 70 km <input type="checkbox"/> 80 km <input type="checkbox"/> 110 km <input type="checkbox"/> Not posted <input type="checkbox"/>																
Coordinates				X				Y								
Node 1				Node 2				Distance to Node 1								
Traffic element				Types of element												
N°	Type	Registra- tion No		1 Car		7 Mini bus < 15 seater		13 Tractor		18 Other						
1				2 Station Wagon		8 15<Bus <32 seater		14 Animal drawn								
2				3 Pickup		9 Motorcycle		15 SUV								
3				4 Van		10 Bicycle		16 JUTC Bus								
4				5 Truck medium < 7 ton at time of crash		11 Pedestrian		17 Bus/Coach >32 seater								
5				6 Truck heavy > 7 ton at time of crash		12 Push cart		18 Tractor Trailer								
Accident Char- act.		Number of vehicles involved						Fire resulted		Y	N					
Type	Main Code	Tourist involved		Fuel spillage		Y	N	Stolen vehicle		Y	N					
		Y	N	N known		Hit & Run		Y	N	Private Prop.		Y	N			

Appendix F

Traffic element	Manoeuvre	Direction	Code 1	Code 2	Code 3
1					
2					
3					
4					

Weather		Road surface		Light conditions		Road character		Roadway Configuration		Area	
1	Fine	1	Wet + Asphalt	1	Daylight	1	Straight road	1	Two Way undivided	1	Sub-Urban
2	Cloudy	2	Dry + Asphalt	2	Darkness	2	Curve left 1 st vehicle	2	Two Way divided	2	Urban
3	Rain/Hail	3	Oily + Asphalt	3	Dusk	3	Curve right 1 st vehicle	3	Dual Carriageway	3	Rural
4	Fog/Mist	4	Wet + Unpaved	4	Dawn	4	Hill up 1 st vehicle				
		5	Dry + Unpaved	5	Night/Light	5	Hill down 1 st vehicle				
		6	Oily + Unpaved			6	Hump bridge/ Hill crest				
		7	Concrete			7	Blind bend left 1 st vehicle				
						8	Blind bend right 1 st vehicle				
						9	Crest				
						10	Sag				

Road Marking Unbroken Broken Offset Marking Not known Missing/faded indeterminable under accident conditions Not visible

Type of junction		Pedestrian crossing		Control		Roadway Defects		Sidewalk Presence	
1	3-leg, T <input type="checkbox"/> , Y <input type="checkbox"/>	1	Police-controlled	1	Police	1	None	1	Yes
2	4-leg	2	Uncontrolled flashing	2	Traffic warden	2	Ruts	2	No
3	> 4-leg	3	Uncontrolled non-flashing	3	Traffic light	3	Bumps	3	Soft shoulder

Appendix F

4	Roundabout 3-leg	4	Within 50m Police controlled	4	4-Way Stop sign	4	Potholes		
5	Roundabout 4-leg	5	Within 50m Uncontrolled flashing	5	Stop sign	5	Loose material		
6	Roundabout > 4-leg	6	Within 50m uncontrolled Non-flashing	6	Slow sign				
7	Private Entrance	7	Not within 50m of crossing	7	Give way sign				
8	Railroad X	8	Within 50m of over-head crossing	8	Pedestrian crossing				
9	Stop major /minor			9	No control				
10	All way stop								
11	Traffic signal								
12	Yield								

PERSON INJURED		Name: Mr/Mrs/Ms										
Address												
Occupation										Tel. No.		
Nature of injury:												
Traffic element no	PMC Driver <input type="checkbox"/> CMC Driver <input type="checkbox"/> PPV Driver <input type="checkbox"/>				Conductor		Motorcyclist <input type="checkbox"/> Pillion <input type="checkbox"/> Pedalcyclist <input type="checkbox"/>					
	PMC Passenger <input type="checkbox"/> CMC Passenger <input type="checkbox"/> PPV Passenger <input type="checkbox"/> Front Seat <input type="checkbox"/> Back Seat <input type="checkbox"/>				Pedestrian		Died on spot <input type="checkbox"/> Died at hospital <input type="checkbox"/> Work for pay <input type="checkbox"/> Not working for pay <input type="checkbox"/>					
DOB	Day	Month	Year	Sex		Child 5-15 years	Y	N	Type of injury	F	S	M
				M	F							
Safety belt				Helmet		Child restraint						
Worn	Not Worn	Not available		Worn	Not Worn	Worn	Not worn		Not available			
School attended:												
.....												
.....												

Appendix F

Next of kin to be informed:

.....
.....

Name:

.....
.....

Address:

.....
.....

Injured person conveyed to:

.....
.....

B Y:	Police	Ambulance	Helicopter	Private vehi- cle	Not trans- ported	Unknown
---------	--------	-----------	------------	----------------------	----------------------	---------

Statement:

.....
.....
.....
.....

Appendix F

VEHICLE N ^o		Registration N ^o :				HP/CC:	
Seating Capacity: _____		Unladen weight: _____ Kg		Gross weight prior to crash _____ Kg		Load/Goods being transported _____	
Make				Model			
Class			Year		RH D	LH D	
Chassis Number							
Vehicle licence correct				Y	N	Date of issue	Day
Disc n ^o							
Issued by:				Date of expiry		Month	Year
Colour of vehicle							
Drivers name		Mr/Mrs/Ms				Sex	M
						F	
Occupation							
Drivers Licence issue date							
Divers Address							
SEAT BELT: Worn <input type="checkbox"/> Not worn <input type="checkbox"/> Not available <input type="checkbox"/> HELMET: Worn <input type="checkbox"/> Not worn <input type="checkbox"/>							
DOB	Da y	Mont h	Yea r	Badge N ^o		Type of licence	
Driver's li- cence		Number			Provisional/Motorcycle/Private/General		
Operating contrary to driver's licence Yes <input type="checkbox"/> No <input type="checkbox"/>							
Issued by				Date of ex- pire	Day	Month	Year
Tinted Yes <input type="checkbox"/> No <input type="checkbox"/> Dark <input type="checkbox"/>							
Light <input type="checkbox"/>							
Em- ployee	Y	N	Ticket	Y	N	Number	Change code
Insurance cert N ^o				Date of issue	Day	Month	Year
Issued by							
Breath Y <input type="checkbox"/> N <input type="checkbox"/> Result Neg. <input type="checkbox"/>				Date of expiry	Day	Month	Year
Pos. <input type="checkbox"/>							
Refused <input type="checkbox"/> Reading							

Appendix F

Cell phone use	Yes <input type="checkbox"/> No <input type="checkbox"/> Not know <input type="checkbox"/>						
If PPV/CMC	PP V	CM C	Carriers Road Licence N°				
Owner's name Mr/Mrs/Ms							
Address					Tel. No		
Damage to vehicle n°		Previous Defects					
Memo served/warned that licence/insurance be produced at: Police stn.							

APPENDIX G

Appendix G

Crash data for roads selected from study area: National Works Agency

Table G.1 Red Hills Road Kingston and St. Andrew study area crash data

Modified by Uter (2018) and obtained from: National Works Agency (2019)

Years	(Multiple years)																		
Street name	(Multiple items)																		
Red Hills Road																			
Count of Accident type	Column labels																		
Row labels	Bicycle accident	Crossing accident	Head-on accident	Other accident	Overtaking accident	Pedestrian accident	Rear end accident	Single accident	Turning accident	Grand Total									
Fatal accident			1							1									
Minor accident		15	4	2	2	3	9	3	7	45									
Property damage only		102	29	51	50		165	5	55	457									
Serious accident	2	2				2	1	2	1	10									
Grand total	2	119	34	53	52	5	175	10	63	513									

Appendix G

Table G.2 Eastwood Park Road Kingston and St. Andrew study area crash data

Modified by Uter (2018) and obtained from: National Works Agency (2019)

Years	(Multiple Items)							
Street name	(Multiple Items)							
Eastwood Park Road								
Count of Accident type	Column labels							
Row labels	Crossing accident	Other accident	Overtaking accident	Pedestrian accident	Rear end accident	Turning accident	Grand Total	
Minor accident	3	8		3	2		16	
Property damage only	32	80	1		41	12	166	
Serious accident	1	3		2	1	1	8	
Grand Total	36	91	1	5	44	13	190	

Appendix G

Table G.3 Constant Spring Road Kingston and St. Andrew study area crash data

Modified by Uter (2018) and obtained from: National Works Agency (2019)

Count of Accident type	Column Labels	Crossing accident	Head-on accident	Other accident	Overtaking accident	Pedestrian accident	Rear end accident	Single accident	Turning accident	Grand Total
Years	(Multiple Items)									
Street name	(Multiple Items)									
Constant Spring Road										
Fatal accident	1					2				3
Minor accident	1	10	9	6	8	10	33	4	18	99
Property damage only		124	26	200	144	4	360	5	81	944
Serious accident	1	1		2		10	4		2	20
Grand Total	3	135	35	208	152	26	397	9	101	1066

Appendix G

Table G.5 Half-Way- Tree Road Kingston and St. Andrew study area crash data

Modified by Uter (2018) and obtained from: National Works Agency (2019)

Years	(Multiple items)	1																	
Street name	(Multiple items)	1																	
Half-Way- Tree Road																			
Count of Accident type	Column labels	1																	
Row labels	1	Bicycle accident	Crossing accident	Head-on accident	Other accident	Overtaking accident	Pedestrian accident	Rear end accident	Single accident	Turning accident	Grand Total								
Fatal accident	1							1			1								3
Minor accident			5	1	2	1	4	6			5								24
Property damage only			38		99	11		79			38								265
Serious accident	1		2				6			1	4								14
Grand Total	2	45	1	101	12	11	85	1	49	306									

Appendix G

**Table G.7 Old Hope Road Kingston and St. Andrew study area crash data
Modified by Uter (2018) and obtained from: National Works Agency
(2019)**

Years	(Multiple Items)																		
Street name	(Multiple Items)																		
Old Hope Road																			
Count of Accident type	Column labels																		
Row labels	▼ bicycle accident	Crossing accident	Head-on accident	Other accident	Overtaking accident	Pedestrian accident	Rear end accident	Turning accident	Grand Total										
Fatal accident				1				3	4										
Minor accident	1	3	2	1	1	4	5	3	20										
Property damage only		59	3	76	14		86	27	265										
Serious accident		2				1		1	4										
Grand Total	1	64	5	78	15	8	91	31	293										

APPENDIX H

Appendix H

Table H.1 Road Crash Fatality data for Jamaica 2002 to 2017

Modified by Uter (2018) and obtained from: Road safety unit of Jamaica (2019)

		National Road Safety Council - Jamaica															
		Road Crash Fatalities by Category 2002 - 2017															
CATEGORY		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
PEDESTRIANS		126	119	96	110	104	108	101	83	115	107	85	89	99	91	84	86
PEDAL CYCLISTS		41	51	46	29	34	28	39	29	26	32	17	26	30	26	32	15
MOTOR CYCLISTS		41	37	29	32	35	27	42	49	39	40	42	56	65	111	96	95
PILLION PASSENGERS		5	4	11	8	6	3	6	4	5	9	3	8	8	8	13	15
PPV PASSENGERS		26	21	19	16	29	16	11	24	6	13	8	17	25	11	18	6
PMC PASSENGERS		68	61	70	60	59	75	52	72	55	47	42	49	36	53	71	35
CMC PASSENGERS		13	12	5	8	12	12	18	6	9	6	4	3	8	6	3	4
PPV DRIVERS		11	10	10	12	14	7	12	11	6	6	6	8	5	5	5	2
PMC DRIVERS		72	67	68	44	70	67	57	60	52	46	49	49	50	66	53	53
CMC DRIVERS		5	9	6	7	8	7	5	9	6	1	4	2	3	4	4	10
OTHER		-	-	-	-	-	-	-	-	-	-	-	-	2	0	0	0
TOTAL		408	391	360	326	371	350	343	347	319	307	260	307	331	382	379	321
MALE		313	315	285	263	295	280	266	292	263	243	213	248	267	332	317	272
FEMALE		95	76	75	63	76	70	77	55	56	64	47	59	64	50	62	49
TOTAL		408	391	360	326	371	350	343	347	319	307	260	307	331	382	379	321
PEDESTRIANS		31%	30%	27%	34%	28%	31%	29%	24%	36%	35%	33%	29%	30%	24%	22%	27%
PEDAL CYCLISTS		10%	13%	13%	9%	9%	8%	11%	8%	8%	10%	7%	8%	9%	7%	8%	5%
MOTOR CYCLISTS		10%	9%	8%	10%	9%	8%	12%	14%	12%	13%	16%	18%	20%	29%	25%	30%
PILLION PASSENGERS		1%	1%	3%	2%	2%	1%	2%	1%	2%	3%	1%	3%	2%	2%	3%	5%
PPV PASSENGERS		6%	5%	5%	5%	8%	5%	3%	7%	2%	4%	3%	6%	8%	3%	5%	2%
PMC PASSENGERS		17%	16%	19%	18%	16%	21%	15%	21%	17%	15%	16%	16%	11%	14%	19%	11%
CMC PASSENGERS		3%	3%	1%	2%	3%	3%	5%	2%	3%	2%	2%	2%	2%	2%	1%	1%
PPV DRIVERS		3%	3%	3%	4%	4%	2%	3%	3%	2%	2%	2%	3%	2%	2%	1%	1%
PMC DRIVERS		18%	17%	19%	13%	19%	19%	17%	17%	16%	15%	19%	16%	15%	17%	14%	17%
CMC DRIVERS		1%	2%	2%	2%	2%	2%	1%	3%	2%	0%	2%	1%	1%	1%	1%	3%
OTHER														1%	0%	0%	0%
TOTAL		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
MALE		77%	81%	79%	81%	80%	80%	78%	84%	82%	79%	82%	81%	81%	87%	84%	85%
FEMALE		23%	19%	21%	19%	20%	20%	22%	16%	18%	21%	18%	19%	19%	13%	16%	15%

10-Jul-2018

Appendix H

Table H.2 Crash data for roads selected from study area: Road safety unit of Jamaica Road crash data as at 2018. Modified by Uter (2018) and obtained from: Road safety unit of Jamaica (2019)

FATAL CRASHES AND FATALITIES

Table 1. Fatalities by quarter, 2003-2018.

Quarter	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January-March	86	81	87	87	91	98	98	82	76	61	64	84	94	107	84	81
April-June	95	94	74	103	103	82	91	68	82	64	77	80	92	81	89	96
July-September	99	81	64	81	85	75	66	78	69	65	89	83	96	106	86	102
October-December	111	104	101	100	71	88	92	91	81	70	77	84	100	85	63	107
Total	391	360	326	371	350	343	347	319	308	260	307	331	382	379	322	386

Table 2a. Projected fatalities by quarter, 2019-2021¹.

Quarter	2019	2020	2021
January-March	81	80	80
April-June	85	84	84
July-September	80	80	80
October-December	85	84	84
Total	331	328	328

Table 2b. Fatality rates per 100,000 populations, 2008-2017².

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Inhabitants	2,676,666	2,686,105	2,695,543	2,704,133	2,707,805	2,714,669	2,720,554	2,725,288	2,728,148	2,728,917
Fatalities	343	347	319	308	260	307	331	382	379	322
Killed/100,000 inhabitants	13	13	12	11	10	11	12	14	14	12

Appendix H

Table H.3 Road Crash Fatality data for Jamaica 2001 to 2013

Modified by Uter (2018) and obtained from: Road safety unit of Jamaica (2019)

FATAL ACCIDENTS AND FATALITIES

Table 1. Fatalities by quarter, 2001-2013.

Quarter	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
January-March	73	94	86	81	87	88	91	98	98	82	76	61	64
April-June	101	103	95	94	74	106	103	82	91	68	82	64	77
July-September	93	84	99	81	64	83	85	75	66	78	69	65	89
October-December	94	127	111	104	101	104	71	88	92	91	81	70	77
Total	361	408	391	360	326	381	350	343	347	319	308	260	307

Table 2. Projected fatalities by quarter, 2014-2016.

Quarter	2015	2016
January-March	75	73
April-June	67	65
July-September	74	72
October-December	66	64
Total	282	274

Table 2a. Fatality rates per 100,000 populations, 2005-2013.

	2005	2006	2007	2008	2009	2010	2011	2012	2013
Inhabitants	2,656,700	2,669,500	2,682,100	2,692,400	2,698,810	2,695,543	2,704,133	2,711,476	2,718,476
Fatalities	325	381	350	343	347	319	308	260	307
Killed/100,000 inhabitants	12.23	14.27	13.05	12.74	12.86	11.83	Screenshot	9.59	11.3

Appendix H

Table H.4 Road Crash Fatality data for Jamaica 2010 to 2015

Modified by Uter (2018) and obtained from: Road safety unit of Jamaica (2019)

Table 4. Fatal accidents and fatalities by month and year, 2010-2015.

	2010		2011		2012		2013		2014		2015	
Month	Fatal Acc.	Fatalities	Fatal Acc.	Fatalities	Fatal Acc.	Fatalities	Fatal Acc.	Fatalities	Fatal Acc.	Fatalities	Fatal Acc.	Fatalities
January	26	27	16	25	14	22	18	20	22	22	29	29
February	26	28	22	27	16	16	22	22	24	25	24	26
March	24	26	23	23	21	23	22	22	33	37	29	35
April	17	17	23	27	17	21	22	28	23	26	30	32
May	23	26	25	32	24	25	22	22	22	24	26	27
Total	116	124	109	134	92	107	106	114	124	134	138	149

Table H.5 Road crash data as at 2017

Modified by Uter (2018) and obtained from: Road safety unit of Jamaica (2019)

FATAL CRASHES AND FATALITIES

Table 1. Fatalities by quarter, 2003-2017.

Quarter	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
January-March	86	81	87	87	91	98	98	82	76	61	64	84	94	107	84
April-June	95	94	74	103	103	82	91	68	82	64	77	80	92	81	89
July-September	99	81	64	81	85	75	66	78	69	65	89	83	96	106	86
October-December	111	104	101	100	71	88	92	91	81	70	77	84	100	85	63
Total	391	360	326	371	350	343	347	319	308	260	307	331	382	379	322

Table 2. Projected fatalities by quarter, 2018-2020¹.

Quarter	2018	2019	2020
January-March	81 ^a	79	79
April-June	96 ^a	84	83
July-September	101 ^a	79	79
October-December	94	83	83
Total	372	325	324

Table 2a. Fatality rates per 100,000 populations, 2008-2017².

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Inhabitants	2,676,666	2,686,105	2,695,543	2,704,133	2,707,805	2,714,669	2,720,554	2,725,288	2,729,112	2,728,900
Fatalities	343	347	319	308	260	307	331	382	379	322
Killed/100,000 inhabitants	13	13	12	11	10	11	12	14	14	12

Appendix H

Table H.6 Road crash data as at 2018 by division

Modified by Uter (2018) and obtained from: Road safety unit of Jamaica (2019)

Division	2013		2014		2015		2016		2017		2018	
	Fatal Cra.	Fatalities	Fatal Cra.	Fatalities	Fatal Cra.	Fatalities	Fatal Cra.	Fatalities	Fatal Cra.	Fatalities	Fatal Cra.	Fatalities
Trelawny	8	16	16	17	15	20	11	17	10	12	13	17
St. James	18	22	22	25	21	22	22	24	24	25	16	23
Hanover	18	20	13	14	18	21	19	23	23	25	19	25
Westmoreland	36	40	37	39	55	56	48	54	44	48	40	49
Portland	3	3	11	11	6	7	12	12	4	4	4	5
St. Mary	17	20	7	8	12	12	12	13	13	15	17	18
St. Ann	19	21	24	27	37	40	19	31	22	25	31	34
St. Elizabeth	10	12	16	17	19	19	30	35	16	16	23	23
Manchester	15	20	15	15	16	17	17	19	16	17	21	24
Clarendon	16	17	21	26	33	34	14	16	22	23	19	19
Kingston Central	6	6	2	2	2	2	3	3	2	2	3	4
Kingston Eastern	4	5	5	5	11	11	6	6	9	9	9	9
Kingston Western	8	8	4	4	3	4	2	2	4	4	3	3
St. Andrew Central	15	15	18	20	21	23	15	15	16	16	11	11
St. Andrew South	14	14	13	14	20	24	19	22	11	11	16	16
St. Andrew North	5	5	11	13	11	11	14	14	8	12	15	16
St. Catherine North	33	34	32	34	25	26	34	44	20	24	38	43
St. Catherine South	19	19	28	32	23	23	15	19	22	23	30	32
St. Thomas	5	5	3	3	7	7	6	6	7	9	2	2
Total	269	302	298	326	355	379	318	375	293	320	330	373

Table 5. Fatal crashes and fatalities by division and year, 2013-2018.

APPENDIX I

Appendix I

Table I.1 Worked star rating example for Public transport pedestrian commuters: Model verification: Reference image Appendix J, J.1

Star rating model validation			
Road section: Constant Spring Road			
Road section length: 100m			
Image #: 2790			
Supporting Data			
Attribute	Data/ category		
Vehicle flow (AADT)	18425		
Motorcycle %	0%		
Pedestrian peak hour flow across the road	201 to 300		
Pedestrian peak hour flow along the road driver-side	6 to 25		
Pedestrian peak hour flow along the road passenger-side	101 to 200		
Bicycle peak hour flow	0%		
Speed- 85th percentile	50 to 54 km/h		
Public transport pedestrian commuters at public transport facilities Star rating scores			
Along (drive side)			
Type of risk factor	Category	Risk factor	Score
Road attribute (likelihood)			
Sight distance	Adeuate	1	
Road side object	Present	1	
Road side friction	Present	1	
Lane width	Medium	1.1	
Road condition	Medium	1.2	
Delineation	Poor	1.2	
Speed management/ traffic calming	Not present	1.25	
Vehicle parking	None	1	
Transport facility lighting	Not present	1.25	
Street lighting	Not present	1.25	
Kerb height	0m to < 0.15m	1	
Pedestian fencing	Not present	1.25	
Platform type/ quality (transport facility)	Shared sidewalk/poor	1	
Grade	0 to <7.5%	1	
<i>Product of road attribute (likelihood) risk factors</i>			3.8671875
Road attribute (severity)			
Pedestian fencing quality	Not present	1	
Platform type/ quality (public transport facility)	Shared sidewalk/poor	1	
Speed management/ traffic calming	Not present	1.25	
Sidewalk provision	Non-physical separation 1m to < 3.0m	0.09	
<i>Product of road attribute (severity) risk factors</i>			0.1125
External flow influence	18425 vehicles per day		0.1
Platform/ Sidewalk Traversability	Traversable		1.0
Operating speed	50km/h		0.12
Along (driver side) Star Rating Score			0.0052207

Appendix I

Along (passenger side)			
Type of risk factor	Category	Risk factor	Score
Road attribute (likelihood)			
Sight distance	Adequate	1	
Road side object	Present	1	
Road side friction	Present	1	
Lane width	Medium	1.1	
Road condition	Medium	1.2	
Delineation	Poor	1.2	
Speed management/ traffic calming	Not present	1.25	
Vehicle parking	None	1	
Transport facility lighting	Not present	1.25	
Street lighting	Not present	1.25	
Kerb height	0m to < 0.15m	1	
Pedestian fencing	Not present	1.25	
Platform type/ quality (public transport facility)	Shared sidewalk/poor	1	
Grade	0 to 75%	1	
<i>Product of road attribute (likelihood) risk factors</i>			3.8671875
Road attribute (severity)			
Pedestian fencing quality	Not present	1	
Platform type/ quality (transport facility)	Shared sidewalk/poor	1	
Speed management/ traffic calming	Not present	1.25	
Sidewalk provision	Non-physical separation 1m to < 3.0m	0.09	
<i>Product of road attribute (severity) risk factors</i>			0.1125
External flow influence	18425 vehicles per day		0.1
Platform/ Sidewalk Traversability	Traversable		1.0
Operating speed	50km/h		0.12
Along (passenger side) Star Rating Score			0.0052207

Appendix I

Crossing (transport facility)			
Type of risk factor	Category	Risk factor	Score
Road attribute (likelihood)			
Number of lanes	Two	2.8	
Road side friction	None	1	
Pedestrian crossing facilities (transport facility)	No facility	6.7	
Skid resistance/ grip	Sealed- medium	1.4	
Transport facility lighting	Not present	1.25	
Sight distance	Adequate	1	
Vehicle parking	None	1	
Speed management/ traffic calming	Not present	1.25	
Street lighting	Not present	1.25	
Sidewalk provision	Adjacent to traffic	0.1	
Tactile pavement	Not present	1	
Ramp quality	Not present	1	
Median type	Centre line	3	
Delineation	Poor	1.2	
Intersection type	None	1	
School zone warning	Not applicable	1	
Facilities for public transport	Present/ Shelter	1	
<i>Product of road attribute (likelihood) risk factors</i>			18.466875
Road attribute (severity)			
Speed management/ traffic calming	Not present	1.25	
Pedestrian crossing facility (transport facility)	No facility	90	
<i>Product of road attribute (severity) risk factors</i>			112.5
External flow influence	18425 vehicles per day		0.1
Operating speed	50km/h		0.12
Crossing (transport facility) Star Rating Score			24.930281

Appendix I

Standing/waiting score (Public Transport facility)			
Type of risk factor	Category	Risk factor	Score
Road attribute (likelihood)			
Sidewalk provision	Adjacent to traffic	0.1	
Kerb height	0m to < 0.15m	1	
Quality of curve	Not applicable	1	
Pedestrian fencing	Not present	1.25	
Speed management/ traffic calming	Not present	1.25	
Road condition	Medium	1.2	
Grade	0 to 75%	1	
Sight distance	Adequate	1	
Lane width	wide (>=3.25m)	1	
Facilities for public transport	Present/ Shelter	1	
Platform type/ quality	Not present	1	
Platform type/ quality (transport facility)	Shared sidewalk/poor	1	
Road side friction	None	1	
<i>Product of road attribute (likelihood) risk factors</i>			0.1875
Road attribute (severity)			
Sidewalk provision	Adjacent to traffic	1	
Pedestrian fencing quality	Not present	1.25	
Platform type (transport facility)	Shared sidewalk/poor	1	
<i>Product of road attribute (severity) risk factors</i>			1.25
External flow influence	18425 vehicles per day		0.1
Platform/ Sidewalk Traversability	Traversable		1.0
Operating speed	50km/h		0.12
Standing/waiting score (Public Transport facility) Star Rating Score			0.0028125
Public transport pedestrian commuters at public transport facilities Star rating score and Star Rating			
Crash type	Star Rating Score	Star Rating	
Along (drive side)	0.005220703		
Along (passenger side)	0.005220703		
Along (average of drive and passenger sides)	0.005220703		
Crossing (transport facility)	24.93028125		
Standing/waiting score (Transport facility)	0.0028125		
Total Score / Star Rating	24.93831445	3	

Appendix I

**Table I.2 Worked star rating example for iRAP Pedestrian model:
Model verification: Reference image Appendix J, J.1**

Star rating model validation			
Road section: Constant Spring Road			
Road section length: 100m			
Image #: 2790			
Supporting Data			
Attribute	Data/ category		
Vehicle flow (AADT)	18425		
Motorcycle %	0%		
Pedestrian peak hour flow across the road	201 to 300		
Pedestrian peak hour flow along the road driver-side	6 to 25		
Pedestrian peak hour flow along the road passenger-side	101 to 200		
Bicycle peak hour flow	0%		
Speed- 85th percentile	50 to 54 km/h		
Pedestrian Star rating scores			
Along (drive side)			
Type of risk factor	Category	Risk factor	Score
Road attribute (likelihood)			
Sidewalk - driver-side	Adequate	1	
Curvature	Straight	1	
Quality of curve	Not applicable	1	
Sight distance	Adequate	1	
Lane width	Medium	1.2	
Delineation	Poor	1.2	
Grade	0m to < 7.5%	1	
Road condition	Medium	1.2	
Speed management / traffic calming	Not present	1.25	
Vehicle parking	None	1	
Shoulder rumble strips	Not present	1.25	
Skid resistance / grip	Sealed- medium	1.4	
Street lighting	Not present	1.25	
<i>Product of road attribute (likelihood) risk factors</i>			4.725
Road attribute (severity)			
Sidewalk - driver-side	Adjacent to traffic	1	
<i>Product of road attribute (severity) risk factors</i>			1
External flow influence	18425 vehicles per day		0.1
Operating speed	50km/h		0.12
Along (driver side) Star Rating Score			0.0567

Appendix I

Along (passenger side)			
Type of risk factor	Category	Risk factor	Score
Road attribute (likelihood)			
Sidewalk - driver-side	Adequate	1	
Curvature	Straight	1	
Quality of curve	Not applicable	1	
Sight distance	Adequate	1	
Lane width	Medium	1.2	
Delineation	Poor	1.2	
Grade	0m to < 7.5%	1	
Road condition	Medium	1.2	
Speed management / traffic calming	Not present	1.25	
Vehicle parking	None	1	
Shoulder rumble strips	Not present	1.25	
Skid resistance / grip	Sealed- medium	1.4	
Street lighting	Not present	1.25	
<i>Product of road attribute (likelihood) risk factors</i>			4.725
Road attribute (severity)			
Sidewalk - passenger- side	Not present	1	
<i>Product of road attribute (severity) risk factors</i>			1
External flow influence	18425 vehicles per day		0.1
Operating speed	50km/h		0.12
Along (passenger side) Star Rating Score			0.0567
Crossing (inspected road)			
Type of risk factor	Category	Risk factor	Score
Road attribute (likelihood)			
Number of lanes	Two	2.8	
Median type	Centre line	3	
Pedestrian crossing facilities- inspected road	No facility	6.7	
Pedestrian crossing quality	Poor	1.5	
Intersection type	Not present	1	
Intersection quality	Not applicable	1	
Pedestrian fencing	Not present	1.25	
Skid resistance / grip	Sealed- medium	1.4	
Street lighting	Not present	1.25	
Sight distance	Adequate	1	
Vehicle parking	None	1	
Speed management / traffic calming	Not present	1.25	
<i>Product of road attribute (likelihood) risk factors</i>			230.835938
Road attribute (severity)			
Pedestrian crossing facility - inspected road	No facility	90	
<i>Product of road attribute (severity) risk factors</i>			90
External flow influence	18425 vehicles per day		0.1
Operating speed	50km/h		0.12
Crossing (inspected road) Star Rating Score			249.302813

Appendix I

Crossing (side road)			
Type of risk factor	Category	Risk factor	Score
Road attribute (likelihood)			
Number of lanes	One	1	
Median type	Not applicable	1	
Pedestrian crossing facilities- inspected road	No facility	6.7	
Pedestrian crossing quality	Not applicable	1	
Intersection type	Not present	1	
Intersection quality	Not applicable	1	
Pedestrian fencing	Not present	1.25	
Skid resistance / grip	Unseal - poor	5.5	
Street lighting	Not present	1.25	
Sight distance	Adequate	1	
Vehicle parking	None	1	
Speed management / traffic calming	Not present	1.25	
<i>Product of road attribute (likelihood) risk factors</i>			57.578125
Road attribute (severity)			
Pedestrian crossing facility - side road		90	
<i>Product of road attribute (severity) risk factors</i>			90
External flow influence	18425 vehicles per day		0.1
Operating speed	50km/h		0.12
Crossing (Side road) Star Rating Score			62.184375
Pedestrian Star rating score and Star Rating			
Crash type	Star Rating Score	Star Rating	
Along (drive side)	0.0567		
Along (passenger side)	0.0567		
Along (average of drive and passenger sides)	0.0567		
Crossing (inspected road)	249.3028125		
Crossing (side road)	62.184375		
Total Score / Star Rating	311.5438875	1	

APPENDIX J

Appendix J



Figure J.1 Image #2790 of Constant Spring Road, Kingston and St. Andrew road network: Study area

APPENDIX K

Appendix K

K.1 Existing road safety management system

Road safety in Jamaica has not received the attention and representation in accordance with international best practices when comparisons are made to the successful and sustainable gains achieved in developed countries, WHO (2004). In Jamaica there are a number of different agencies that play various roles in reducing the number of road crashes on the road network.

This is shown in Table K.1 as follows:

Table K.1 Authorities in Jamaica

Authority	Area of responsibility	Reporting entity
National Works Agency (NWA)	Main roads	Ministry of Economic Growth and Job Creation
Road Safety Unit (RSU)	Data collection/ training	Ministry of Transport and Mining
National Road Safety Council (NRSC)	Advocacy for road safety programmes	Ministry of Transport and Mining
Transport Authority (TA)	Transport regulation/ Revenue protection (primary function)	Ministry of Transport and Mining
Jamaica Constabulary Force (JCF)	Law enforcement/ traffic enforcement and the like	Ministry of Justice
Jamaica Urban Transport Company (JUTC)	Public transportation	Ministry of Transport and Mining
National Road Operating Company (NROC)	Toll roads	Ministry of Economic Growth and Job Creation
Parish Council (PC)	Land use zoning/Local roads	Ministry of Local Government

Appendix K

Authority	Area of responsibility	Reporting entity
Ministry of Agriculture (MoA)	Farm roads	Ministry of Agriculture
Urban Development Corporation (UDC)	Urban planning and development	Ministry of Economic Growth and Job Creation