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Roadway Safety Assessment and Test Application of iRAP along National Highway 3 in Haiti

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ROADWAY SAFETY ASSESSMENT AND TEST APPLICATION OF IRAP ALONG NATIONAL HIGHWAY 3 IN HAITI

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by
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ABSTRACT

More than 3,500 deaths and thousands of injuries occur every day on roads all over the world. The International Road Assessment Program (iRAP) states, “Currently 90% of the world’s 1.25 million road fatalities per annum are in low and middle income countries, and by 2020 the number of road fatalities in these countries is expected to grow by 50%.” The compound problem in developing nations stems from roads which are rapidly constructed without much regard to proper design or safety, a lack of attention to vulnerable road users, and the absence of road safety culture (i.e., safe behaviors, vehicle safety regulations, road safety policy, road safety assessment, and enforcement).

In Haiti, the road safety problem is exacerbated by the lack of data related to roadway crashes and the resulting fatalities and injuries. In numerous international road safety reports by organizations such as the World Health Organization, World Bank, and others, Haiti is one of the few Latin American Countries (LACs) that is not represented with national road safety and fatality statistics due to the limited availability of safety data. Some of the data issues can be attributed to the 2010 earthquake that destroyed much of the capital city of Port-au-Prince, Haiti. The Inter-American Development Bank released a project statement in 2010 that contained a glimpse at road safety in Haiti. According to the documentation, the Office d’Assurance Vehicules Contre Tiers (OAVCT) indicated only 108 fatalities in all of Haiti. This limited data is likely a function of limited insurance coverage among motorists in Haiti. Conversely, an NGO, INGO, operating a medical facility in Haiti noted 52 fatalities and 376 injuries in only 55 days on a 20 km section of National Highway 2 between Léogâne and Gran d Goâve. Given that there are a total of

6045 km of National Highways in Haiti; a fatality rate similar to this for the rest of the country would indicate roughly 15700 deaths due to roadway crashes. Some number between 108 and 15700 is likely the true answer. INGO also indicated that in 32 cases where occupants survived amputations were necessary, leaving crash victims with lifelong disabilities. Meta-analysis of similar reports indicate that approximately 50% of the trauma cases seen in the Haiti hospitals are related to transport crashes. These issues will only get worse with OAVCT reporting growth in motorization of roughly 10% per year. To combat these road safety issues, this research is undertaken in conjunction with the International Road Assessment Program (iRAP), whose goal is "a world free of high-risk roads." While the long-term goal of this project is to create an iRAP presence across Haiti by assessing road and safety conditions through road analysis programs, this thesis covers the initial setup, training, implementation, and coding evaluation. Road video data and GPS data were collected along National Route 3, from Port-au-Prince to Cange in addition to gathering speed data in Domond and video data of pedestrian traffic in Cange. This data, gathered in areas that were deemed to be high-risk, were used to provide an idea concerning t traffic in the area. The data was processed and analyzed using FPZ, an iRAP road analysis program developed by University of Zagreb in Croatia, where the videos were processed along the route and road centerlines were created and segmented with respect to the video files for each segment. Data analysis was followed by iRAP road coding, for all the road sections based on 52 different road attributes. QA check of the coded data generated numerous errors prompting the need to develop a Haiti-specific iRAP coding manual to train the raters involved in this project. Inter-rater reliability tests were carried along with Cohen's

Kappa statistic to assess the agreement among the raters and accuracy with respect to iRAP coding standards. These tests and the assessment of reliability helped the raters to understand the coding process better, and get a good grasp of roadside attributes present along the project route in Haiti. This lays a good foundation for future research and further assessment of the route, which involves generating star-ratings of the road sections upon successful road coding. This report and its implementation greatly assisted the team involved with this project in learning the intricacies of the correct iRAP coding techniques, which has laid the foundation to go further with the ultimate goal of obtaining star ratings of the sections, indicating the high, medium and low risk road sections.

DEDICATION

To my beloved parents and family to whom my life belongs

ACKNOWLEDGMENTS

Words would not be sufficient to express my gratitude towards all the people who provided immense support and motivation for me to accomplish this project as a whole. However, I would make an attempt to thank some of them who have been my pillar of strength for the entire course of this project.

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I would like to thank the Southeastern Transportation Center and Clemson University for their financial support for the entire duration of this project. This project is a successful culmination of our efforts and all the people whose dedicated contribution helped in its completion.

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CHAPTER 1

INTRODUCTION

Road safety is of immense importance towards well-being of road users as well the economy of a nation. But more than that, in today's world, it is a big issue, the lack of which is contributing to millions of fatalities all over the world. The World Health Organization reports around 1.25 million fatalities and 50 million injuries a year due to road-related accidents alone. This is approximately equal to 3500 deaths every day. The compound problem in developing nations stems from roads which are rapidly constructed without much regard to proper design or safety, a lack of attention to vulnerable road users, and the absence of road safety culture (i.e., safe behaviors, vehicle safety regulations, road safety policy, road safety assessment, and enforcement).

If no changes are made in safety policies, behavioral safety, or infrastructure safety, the WHO predicts that there will be 1.9 million fatalities in 2020 (WHO n.d.). The major factors for this increasing figure would be negligence towards essential infrastructure, lack of awareness on safety-related topics and low investment by institutions. Considering this ever growing number, road-related accidents will be a greater issue than diseases like malaria, and may soon eclipse the number of fatalities from HIV/AIDS and Tuberculosis (TB). Moreover, the most frightening fact is that 90% of these deaths and injuries are concentrated in developing nations or low/middle income countries (LMICs). Of these, 46% of the fatalities are related to vulnerable road users (pedestrians and bicyclists) (WHO n.d.). This problem will only magnify in the future as these nations industrialize and motor usage spikes even more. According to several other World Health Organization surveys, road accidents are already the leading cause of deaths among young people, 15-24 years of age. This would result in a severe economic burden on nations with higher road accident rates involving the youth.

In Haiti, the road safety problem is exacerbated by the lack of data related to roadway crashes and the resulting fatalities and injuries. In numerous international road safety reports by organizations such as the World Health Organization, World Bank, and others, Haiti is one of the few Latin American Countries (LACs) that is not represented with national road safety and fatality statistics due to the limited representation and availability of safety data. Some of the data issues can be attributed to the 2010 earthquake that destroyed much of the capital city of Port-au-Prince, Haiti and the data systems residing therein. The Inter-American Development Bank released a project statement in 2010 that contained a glimpse at road safety in Haiti. According to the documentation, the Office d'Assurance Vehicules Contre Tiers (OAVCT) indicated only 108 fatalities in all of Haiti. This limited data is likely a function of inadequate data collection functions and limited insurance coverage among motorists in Haiti.

Conversely, an NGO, INGO, operating a medical facility in Haiti noted 52 fatalities and 376 injuries in only 55 days on a 20 km section of National Highway 2 between Léogâne and Gran d Goâve. Given that there are a total of 6045 km of National Highways in Haiti; a fatality rate similar to this for the rest of the country would indicate roughly 15700 deaths due to roadway crashes. Some number between 108 and 15700 is likely the true answer. INGO also indicated that in 32 cases where occupants survived amputations were necessary, leaving crash victims with lifelong disabilities. Meta-analysis of similar reports indicate that approximately 50% of the trauma cases seen in the Haiti hospitals are related to transport crashes. These issues will only get worse with OAVCT reporting growth in motorization of roughly 10% per year. To combat these road safety issues, research is undertaken in conjunction with the International Road Assessment Program (iRAP), whose goal is "a world free of high-risk roads." While the long-term vision of this project is to create an iRAP presence across Haiti by assessing road and safety conditions through road analysis programs, this thesis covers the initial setup, training, implementation, and coding evaluation. The International Road Assessment Programme (iRAP) is a Non-Profit registered charity organization dedicated and working towards making roads safer worldwide and saving lives in the process. They have had tremendous success all over the world in pursuit of their vision of *'Creating a World Free of High Risk roads'* (iRAP n.d.). The International Road Assessment Programme works hand-in-hand with government and non-government organizations (NGOs), providing them with tools and training for road assessment studies in more than 70 countries. Some of the activities in this process include the following:

- Inspecting high-risk roads, developing Star Ratings, Risk maps and Safer Roads Investment Plans
- Providing training, technology, and support to build and sustain national, regional and local capability
- Tracking road safety performance, in order for the funding agencies to assess the benefits of their investments and efforts

iRAP is also a member of the United Nations Road Safety Collaboration. It also serves as the umbrella organization for AusRAP, EuroRAP, ChinaRAP, usRAP and KiwiRAP, with Road Assessment Programmes now active in more than 70 nations across Europe, Asia pacific, North America, South America, Central America and Africa (House n.d.). This research seeks to assess an initial implementation of iRAP in Haiti using student coders. Road safety is a problem of unknown magnitude in Haiti. Limited road development and maintenance facilities contributes towards this issue. In collaboration with iRAP and EuroRAP, this project is an attempt to assess the road safety situation in Haiti with the following goals:

- To reduce and ultimately prevent traffic-related deaths and injuries
- To make roads in Haiti safer for pedestrians and vehicles

These goals also serve as motivation for this project and to indicate scope for future analysis to achieve them. With the help of iRAP and EuroRAP, this project utilized their tools, equipment and the FPZ software (iRAP's online road analysis interface, University of Zagreb), to help carry out the data analysis and coding of the road sections in Haiti from Port-Au-Prince to Cange, a total of 44 miles of roadway. The following goals were set for this project with the intention of achieving the.

- Prepare a Haiti-specific iRAP road coding training module
- Improve coding accuracy and rater-agreement

The objectives of this project were to:

- Assess the safety of National Highway 3 in Haiti, based on roadway and roadside infrastructure elements (Road Attributes)

- Test an application of iRAP data collection and data coding for potential expansion across Haiti
- Develop and evaluate an Inter-Rater Reliability training course and examination for ensuring agreement among the raters and checking accuracy against iRAP expert coding standards

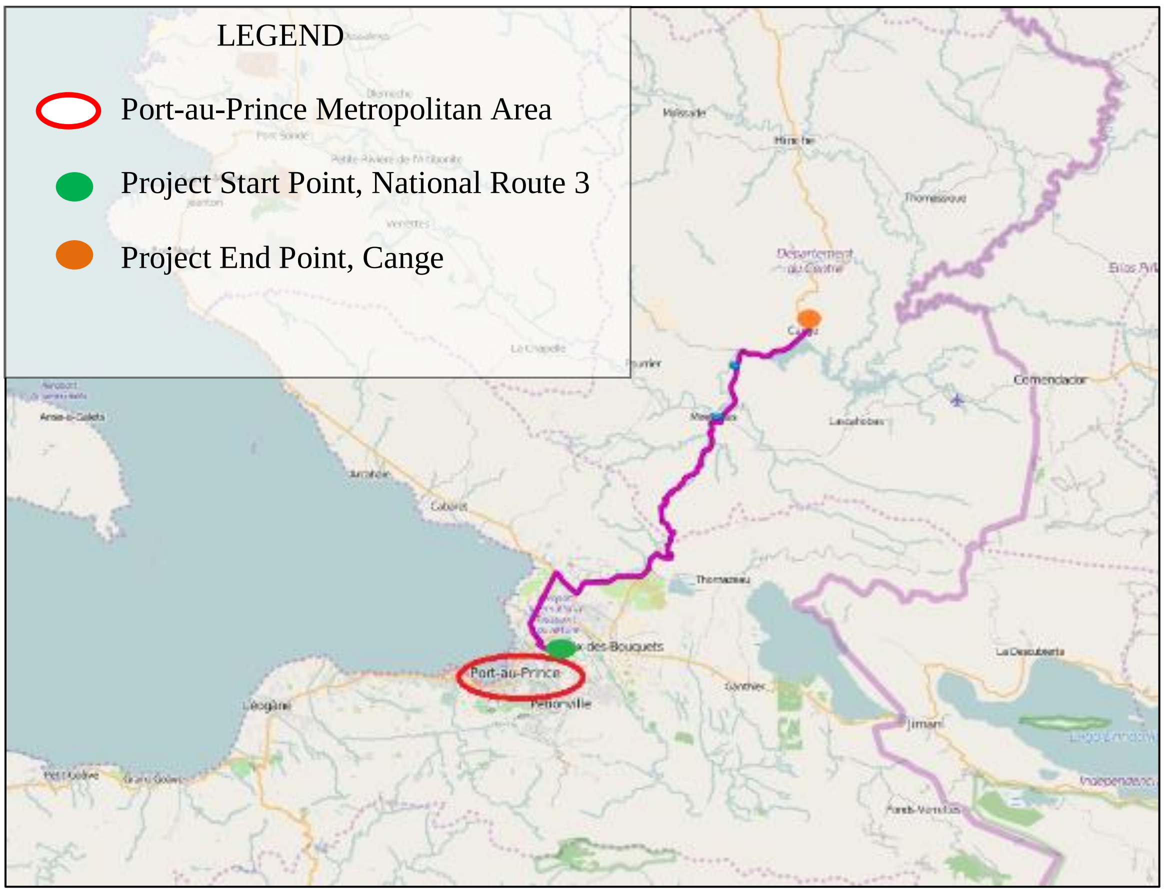


Figure 1.1: Project Location in Haiti

Chapter 2 of this report gives an overview of past road assessment studies done by iRAP in different countries, and an introduction to Star ratings, Risk Maps and Safer Road Investment Plan. It also covers some background information on Haiti, and the road safety situation there. Chapters 3 and 4 discuss the equipment used for this project, the data collection, data preparation and the data analysis processes. Chapter 5 summarizes the results obtained from the analysis, including several suggestions for the identified roadway issues and further improvement needed in the road sections observed. Chapter 6 includes the overall project summary, with a detailed discussion on the conclusionand future recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

By any measure, crashes due to road-related incidents pose a massive health and rehabilitation problem. Roads all over the world have a distressing number of deaths and injuries. This level of road trauma is not an inevitable consequence of rapid development - it is indeed preventable (iRAP 2015). Road-related crashes contribute to well over a million fatalities per year, with approximately 90% in developing nations. Most of these crashes are result of bad maintenance of existing road networks, lack of development of new roads, lack of awareness of road safety, poor roadway infrastructure, etc. Roadway infrastructure and roadside attributes play crucial roles in gauging the safety level of roads, and proper analysis of these attributes can help identify problems in roads sections to provide suggestions for improvement and make roads safer for pedestrians and vehicles. On-road infrastructure basically involves availability of speed limit signs, roadside barriers, and other traffic signs; quality of pavements, intersections, horizontal curvature; presence of adequate vehicle lanes, separate bike and motorcycle lanes, shoulders, sidewalks; adequate lighting, sight distance, grades, safety barriers, traffic signals and control devices, pedestrian crossings, etc. Inadequacy of these attributes among other issues can have negative impacts on road user safety. The following sections of the literature review will cover a broad overview of road safety in the Americas, recent safety studies in Haiti, past iRAP studies, star-ratings, risk maps, safer roads investment plans and inter-rater reliability tests.

2.2 Road Safety in the Americas

In the Americas, road-related injuries are the main cause of fatalities among children (5-14 years of age) and the youth (15-44 years of age). There were more than 142,000 fatalities in the region of the Americas due to road and traffic accidents in 2007 (PAHO 2009). In 2010, this number rose close to 150,000. For this entire region as a whole, average fatality rate due to road accidents and injuries was 16.1 per 100,000 people.

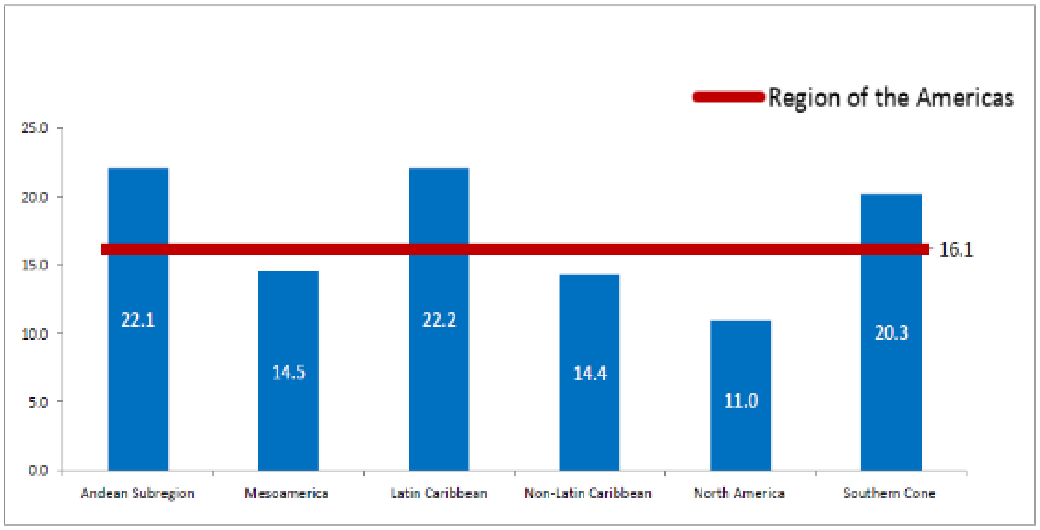


Figure 2.1: Road Traffic Death Rates per 100,000 population in the Region of Americas, by sub-region, 2010 (Source: Rodrigues 2013, Global Status Report on Road Safety 2013)

*Note: Countries by sub-region: **North America**: Canada, USA; **Latin Caribbean**: Cuba, Dominican Republic, Haiti; **Non-Latin Caribbean**: Bahamas, Barbados, Dominica, Guyana, Jamaica, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago; **Southern Cone**: Argentina, Brazil, Chile, Paraguay, Uruguay; **Mesoamerica**: Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama; **Andean South Region**: Bolivia, Colombia, Ecuador, Peru, Venezuela. Mortality rate of Antigua and Barbuda, Grenada, Haiti and Puerto Rico from the World Health Organization database.*

From Figure 2.1, it is observed that the average fatality rates range from 11.0 in North America to 22.2 in the Latin Caribbean, among the sub-regions. Average death rates in the Andean and Latin Caribbean regions are the highest among all sub-regions. The Pan American Health Organization has been making good efforts towards resolving this critical issue. They declared a Plan of Action on Road Safety in 2011 including guidelines, for the member nations (Pan Amercian Health Organization, 51st Directing Council 2011).This plan is an attempt to aid the nations in the Americas to achieve the goals of the Global Decade of Action for Road Safety 2011-2020, stated in 2010 by the United Nations, with a vision to decrease and stabilize road-related fatalities on a global level (United Nations General Assembly, Resolution 64/255 2010).

In the sub-regions of the Americas, majority of the victims of road and traffic accidents are motocyclists, bicyclists and pedestrians, with the exception of North America, where vehicle/car drivers are the primary sufferers. Vulnerable road users like motocyclists, bicyclists and pedestrians constitute 15%, 3% and 23% of road fatalities, respectively. From figure 2.2, it is observed that the Latin Caribbean region has the highest road traffic death rates among all other sub-regions. This can be attributed to a number of factors including: unsafe roadway conditions, lack of vehicle maintenance and safety hardware, risky behavior of road users, lack of adequate law enforcement and regulations. Two-wheeled and three-wheeled vehicles are very common in this area, constituting around 47% of vehicle fleet in the region. One of the most disturbing statistics is that approximately 44.5% of total deaths occur among two-wheeled and three-wheeled vehicle users in the Latin Caribbean region (Rodrigues 2013). Another notable reason for such high death rates in the region of the Americas is lack of safety legislations in many countries. Only 5 of 14 countries have proper and acceptable comprehensive legislation on speed and drunk-driving, respectively. Out of 32 nations, only 12 have dedicated annual budget programs towards National Strategy on Road Safety (PAHO 2009).

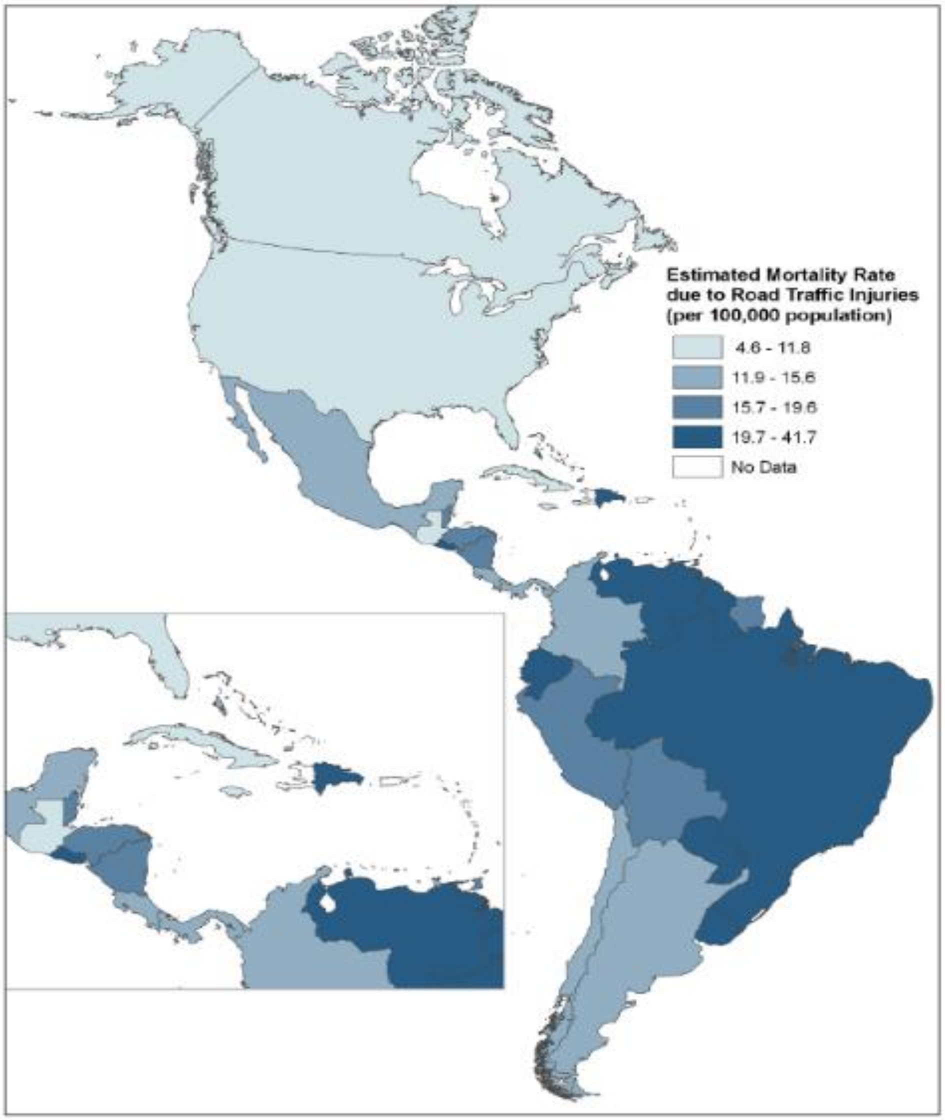


Figure 2.2: Road Death Rates estimated per 100,000 population in the Region of Americas 2010, by country (Source: Rodrigues 2013)

Projected death/mortality rates due to road-related injuries and incidents fluctuate among the different countries in the sub-regions. In 2010, approximately 150,000 road-related deaths were estimated in the Region of Americas. The rate of road-related deaths and number of registered vehicles might not necessarily be connected, however, it is interesting to have an idea about vehicle ownership trends among the sub-regions, which gives an idea about types of vehicles owned, vehicle safety standards, etc. (Rodrigues 2013).

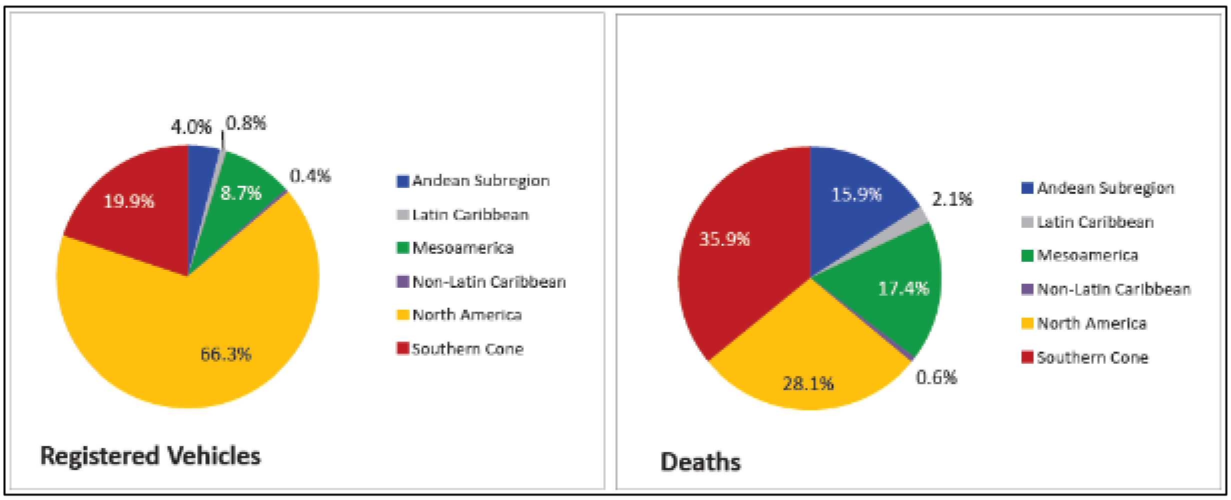


Figure 2.3: Comparison between registered vehicles and road-traffic deaths in the Region of Americas in 2010, by sub-region (Source: World Health Organization, Global Status Report on Road Safety 2013, Geneva 2013)

In a study conducted by the World Health Organization on correlation between affect of registered vehicles on road-related deaths in the Region of Americas, it was observed that the presumed correlation is inconsistent among the sub-regions. Arund 66% of the registered vehicles are in North America, but the road death share in this region is less compared to the number of vehicles registered. On the contrary, the Southern Cone region has only a 20% share of registered vehicles, but has the highest share (~36%) of road deaths among all other sub-regions (Pan Amercian Health Organization, 51st Directing Council 2011) (Rodrigues 2013).

2.3 Recent Safety Studies in Haiti

In Haiti, road safety is a critical issue. The road safety problem is aggravated by severe lack of data on roadway crashes, injuries and fatalities. One of the main reasons for this is the devastating earthquake that occurred on January 12, 2010, resulting in thousands of fatalities, and contributing towards major loss of data throughout the country. Numerous road safety reports by international organizations such as the World Health Organization and World Bank among others, indicate that Haiti is one of the few Latin American Countries (LACs) not represented with the national road safety and fatality statistics due to limited safety resources.

The 2010 Haiti earthquake had a magnitude of 7.1 on the Richter scale, and was the worst recorded in 200 years. The metropolitan area of Port-au-Prince was severly affected, resulting in extensive infrastructure damage, as it was near the epicentre of the earthquake (Near Léogâne). The lack of a life safety building code and relatively low quality building materials in Haiti ensured complete collapse of the majority of buildings in and around Port-au-Prince. Unfortunately, Haiti was already in state of despair before the earthquake (approximately 67% of the population were surviving on less than $2 (USD) per day) (HIB 2011-2013).

As per estimations by the World Health Organization, approximately 50% of the fatalities per year due to road crashes are motorcyclists, cyclists and pedestrians. Almost 25% of all deaths occur from road and traffic injuries. Latin American countries account for 9% of the global population, however around 13% of the road crash deaths occur in this region, with crash data available in 25 of the 33 nations in the region (World Health Organization, Global Status Report on Road Safety 2013, Geneva 2013). Lack of crash data is one of the major problems in Haiti, and it is not included in the WHO Global Status Report due to this reason. In a 2010 Death Estimates report by the WHO and Department of Measurement and Health Information, Haiti is reported to have some fatality and injury data, but this is again indicated as 'incomplete' due to dearth of relevant crash data (WHO 2010). Nonetheless, the data indicates 3000 deaths related to road traffic accidents for all age ranges as shown in Table 2.1.

Table 2.1: WHO Death Estimates 2010

World Health Organization
Organisation Mondiale de la Santé
Department of
Measurement and Health Information
April 2011

Estimated total deaths ('000), by cause, sex and WHO Member State, 2008 (a)

Sex	GBD code	GBD cause (b)	Guatemala	Guinea	Guinea-Bissau	Guyana	Haiti	Honduras	Hungary
		WHO Country code	2250	1190	1192	2260	2270	2280	4150
Persons		*Population ('000) (e)*	*5,781*	*4,223*	*672*	*230*	*3,629*	*2,781*	*1,438*
Persons	145	2. Periodontal disease	-	0.0	0.0	-	-	-	-
Persons	146	3. Edentulism	-	-	-	-	-	-	-
Persons	148	*III. Injuries*	*1.5*	*2.0*	*0.4*	*0.1*	*1.1*	*0.6*	*0.1*
Persons	149	**A. Unintentional injuries**	**1.2**	**1.8**	**0.4**	**0.1**	**1.1**	**0.5**	**0.1**
Persons	150	1. Road traffic accidents	0.2	0.6	0.1	0.0	0.1	0.2	0.0
Persons	151	2. Poisonings	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Persons	152	3. Falls	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Persons	153	4. Fires	0.0	0.4	0.1	0.0	0.0	0.0	0.0
Persons	154	5. Drownings	0.1	0.3	0.0	0.0	0.0	0.1	0.0
Persons	155	6. Other unintentional injuries	0.8	0.4	0.2	0.0	0.9	0.2	0.0
Persons	156	**B. Intentional injuries**	**0.4**	**0.1**	**0.0**	**0.0**	**0.1**	**0.1**	**0.0**
Persons	157	1. Self-inflicted injuries	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Persons	158	2. Violence	0.3	0.1	0.0	0.0	0.0	0.0	0.0
Persons	159	3. War	-	-	-	-	0.1	-	-

a) Age Group: 0-14

World Health Organization
Organisation Mondiale de la Santé
Department of
Measurement and Health Information
April 2011

Total deaths ('000), by cause, sex and WHO Member State, 2008 (a)

Sex	GBD code	GBD cause (b)	Guinea	Guinea-Bissau	Guyana	Haiti	Honduras	Hungary
		WHO Country code	1190	1192	2260	2270	2280	4150
Persons		*Population ('000) (e)*	*5,107*	*818*	*465*	*5,615*	*4,097*	*6,322*
Persons	146	3. Edentulism	-	-	-	-	-	-
Persons	148	*III. Injuries*	*7.1*	*0.9*	*0.6*	*2.6*	*2.5*	*3.6*
Persons	149	**A. Unintentional injuries**	**4.4**	**0.6**	**0.3**	**1.4**	**0.9**	**1.9**
Persons	150	1. Road traffic accidents	1.7	0.2	0.1	0.3	0.4	0.8
Persons	151	2. Poisonings	0.5	0.0	0.0	0.0	0.0	0.1
Persons	152	3. Falls	0.2	0.0	0.0	0.0	0.0	0.3
Persons	153	4. Fires	0.2	0.0	0.0	0.0	0.0	0.1
Persons	154	5. Drownings	0.3	0.0	0.0	0.1	0.1	0.1
Persons	155	6. Other unintentional injuries	1.5	0.2	0.1	0.9	0.3	0.5
Persons	156	**B. Intentional injuries**	**2.6**	**0.3**	**0.4**	**1.2**	**1.6**	**1.6**
Persons	157	1. Self-inflicted injuries	0.7	0.1	0.2	0.1	0.4	1.5
Persons	158	2. Violence	2.0	0.3	0.2	0.4	1.2	0.1
Persons	159	3. War	-	-	-	0.8	-	-

b) Age Group: 15-59

World Health Organization
Organisation Mondiale de la Santé
Department of
Measurement and Health Information
April 2011

Total deaths ('000), by cause, sex and WHO Member State, 2008 (a)

Sex	GBD code	GBD cause (b)	Guinea	Guinea-Bissau	Guyana	Haiti	Honduras	Hungary
		WHO Country code	1190	1192	2260	2270	2280	4150
Persons		*Population ('000) (e)*	*503*	*85*	*68*	*633*	*441*	*2,192*
Persons	144	1. Dental caries	0.0	0.0	-	-	-	-
Persons	145	2. Periodontal disease	0.0	0.0	-	-	0.0	-
Persons	146	3. Edentulism	-	-	-	-	-	-
Persons	148	*III. Injuries*	*0.9*	*0.2*	*0.1*	*0.7*	*0.6*	*3.5*
Persons	149	**A. Unintentional injuries**	**0.7**	**0.1**	**0.1**	**0.5**	**0.4**	**2.5**
Persons	150	1. Road traffic accidents	0.2	0.1	0.0	0.1	0.1	0.3
Persons	151	2. Poisonings	0.1	0.0	-	0.0	0.0	0.0
Persons	152	3. Falls	0.1	0.0	0.0	0.0	0.0	1.6
Persons	153	4. Fires	0.1	0.0	-	0.0	0.0	0.1
Persons	154	5. Drownings	0.0	0.0	0.0	0.0	0.0	0.0
Persons	155	6. Other unintentional injuries	0.2	0.0	0.0	0.3	0.2	0.4
Persons	156	**B. Intentional injuries**	**0.2**	**0.0**	**0.0**	**0.2**	**0.2**	**1.0**
Persons	157	1. Self-inflicted injuries	0.1	0.0	0.0	0.0	0.0	0.9
Persons	158	2. Violence	0.1	0.0	0.0	0.1	0.2	0.1
Persons	159	3. War	-	-	-	0.1	-	-

c) Age Group: 60+

Color Code refers to Incomplete Death Data

(Source: www.who.int/healthinfo/global_burden_disease/estimates_country/en)

The Office d'Assurance Vehicules Contre Tiers (OAVCT) is the mandatory third party insurance provider (The Office of Vehicle Insurance Against Third). This office provides some data on registered vehicles, and covers only traffic accidents. In the statistics for registered vehicles, it is not clear if it includes all types of vehicles or just vehicles with 4 wheels. Table 2.2 provides 10 years of data leading up to the year of the earthquake in Haiti and projects just under 350,000 vehicle registrations.

Table 2.2: Registered Vehicles in Haiti 2009 (Source: OAVCT)

Registered Vehicles in Haiti			
Year	**Vehicles**	**Annual Increase**	**Growth Rate %**
2000	157,206	N/A	N/A
2001	170,526	13,320	8.5
2002	185,278	14,752	8.7
2003	197,099	11,821	6.4
2004	227,820	30,721	15.6
2005	256,116	28,296	12.4
2006	280,994	24,878	9.7
2007	306,729	25,735	9.2
2008	330,313	23,584	7.7
2009	348,431	18,118	5.5

The Inter-American Development Bank released a project statement in 2010 that contained a glimpse of road safety in Haiti. As per that document, the OAVCT reports only 108 fatalities in Haiti in 2010, due to lack of crash data. This limited data is likely due to the earthquake that wiped out most of the data resources in Haiti. Conversely, an NGO, INGO, operating a medical facility noted 52 fatalities and 376 injuries in only 55 days on a 20 km section of National Route 2 between Léogâne and Grand Goâve (Figures reported by Samatarian's Purse, which works in the area) (HIB 2011-2013). There are a total of 6045 km of National Highways in Haiti, and considering the data from this research by INGO, there would be approximately 15700 fatalities with respect to the entire length of highways in Haiti. This shows the level of negligence on road safety in Haiti and how big a role extensive crash data would play in broadening the scope of this project. INGO also reported that amputations were necessary in 32 cases, leaving crash victims with lifelong disabilities. Meta-analysis of comparable reports show that around 50% of the trauma cases in hospitals relate to traffic accidents. Data on type of crashes in Haiti is also not adequately known, although some studies indicate that a lot of crashes and road accidents involve public transit vehicles which are mostly overloaded and in mechanical and technical states. Pedestrians are often the main victims of such incidents. United Nations Stabilization Mission in Haiti (MINUTSAH) provides some vague crash data and information centered on 21 road crashes over a 7-day period (HIB 2011-2013):

- 8 Fatalities, 60 Injuries
- 0.4 Fatalities per crash
- 50% of victims were pedestrians
- 5 Hit and Run cases

In general, approximately 20% of the emergencies are related to road-related accidents. Some data received from the Departement Artibonite (Table 2.3) regarding road crashes and trauma cases near Saint-Marc (leading towards National Route 1) show that the portion of road-related crashes and injuries is much higher (50%) than the trauma cases reported (HIB 2011-2013). These issues are only estimated to get worse with OAVCT reporting growth in motorization of around 10% per year.

Table 2.3: Departement Artibonite Emergencies (Source: HIB 2011-2013)

		Road Accidents	Work Accidents	Domestic Accidents	Trauma	Non-Trauma	Total Emergencies
2010 Jan-Mar	**Cases**	1212	382	789	2383	4717	7100
	% of Trauma	50.9	16	33.1	100	--	--
	% of emergencies	17.1	5.4	11.1	33.6	66.4	100
2009	**Cases**	5017	1989	2947	9953	11904	21857
	% of Trauma	50.4	20	29.6	100		
	% of emergencies	23	9.1	13.5	45.5	54.5	100

From all of these reports on the status of road safety in Haiti, it is clear that there are two combative problems: 1) there is an awareness of an existing road safety problem as expressed from random reports of medical trauma cases; and 2) there is an inherent lack of data from which to begin addressing these problems. Thus, the first step in this process can rely on established infrastructure assessment methods developed by iRAP and used in many other developing countries as described in the next section

2.4 iRAP Safety Assessments

The International Road Assessment Program (iRAP) is a charitable non-government organization (NGO) dedicated to improving roadway safety around the world. Their vision is to create a world free of high risk roads. Assessing and improving road safety standards are the important factors in achieving this goal. They have assisted in carrying out numerous road safety inspection and assessment studies, generating star ratings and risk maps in more than 70 nations, thus helping those nations improve their safety standards and achieve a star rating of at least 3 or more for the roads.

iRAP's focus is centered on a 'Safe System' (see Figure 2.4), based on complementary actions on roads, vehicles and behavior (Bradford 2016). Adhering to seat belt laws and speed limits, curbing drunk driving, active & passive protection of both the driver and vehicle, and self-explaining and forgiving road systems, all work towards this safe system.

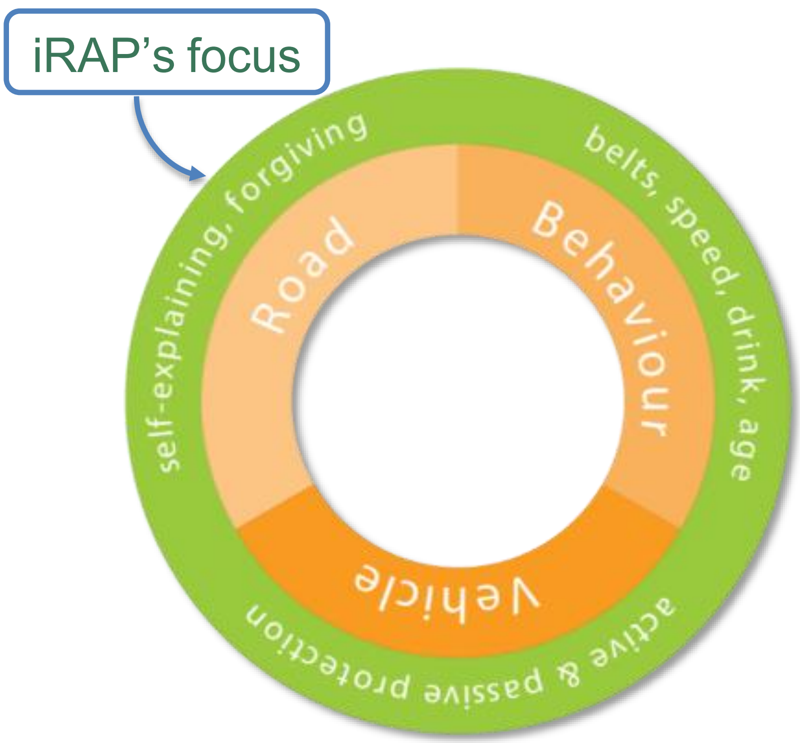


Figure 2.4: The iRAP Safe System (Source: Bradford 2016)

iRAP has conducted star rating assessment programs in many countries like India, Colombia, Brazil, China, Moldova, etc. A brief discussion of the summary report from

India provides a good example of their assessment capability to obtain the highest level of efficiency in improving road safety standards.

In collaboration with the World Bank Global Road Safety Facility (GRSF), Ministry of Road Transport and Highways (MoRTH), Public Works departments of the 10 Indian states, local engineering firms and research institutes, iRAP assessed the safety of a sample of roadway sections in 10 states in India. The sections of roads for the states of Andhra Pradesh, Assam, Gujarat, Karnataka, Haryana, Kerala, Tamil Nadu, Rajasthan, Telangana and Uttar Pradesh were assessed from 2010-2014. The initial findings showed that most of the road sections were rated 1 or 2 stars with respect to safety, with approximately 76,000 fatalities and injuries occurring on those roads per year, at an expense of around USD 2.8 billion (INR 182.2 billion). One of the major reasons for this grave situation is that 97% of the roads have no formal sidewalks/footpaths (iRAP 2015) (iRAP n.d.). The Safer Roads Investment Plans created after the star rating results provides feasible solutions with an adequate economic case. For example, new sidewalks/footpaths on a 440km stretch of road in Kerala can avoid around 4600 fatalities and injuries on a 20 year period and help save approximately USD 52.3 million (INR 3.4 million) in expenses related to crashes.

The first step in the iRAP process was to inspect the road network and carry out surveys of the road sections. Detailed and in-depth surveys of road attributes were conducted on 10,446 km of roads for the 10 states. Road attributes included things such as the cross section of road, markings and signs, intersection design and type, pavement condition, roadside severity/hazards, presence of sidewalks for vulnerable road users, etc.

(iRAP 2015) (iRAP n.d.). Road inspections were carried out through a survey vehicle equipped with video cameras, GPS, distance measuring devices and survey software used by analysts to register more than 50 different attributes (road infrastructure elements) for each 100 m road segment (iRAP 2015).

Table 2.4: Road Project List and Lengths (Source: iRAP India 2015)

Project	**State**	**Year of Survey**	**Length of Road (km)**
Lucknow-Muzaffarpur NH1 Project	Haryana	2010	120
Andhra Pradesh Road Project	Andhra Pradesh	2011	431
	Telangana		
Assam State Roads Project	Assam	2011	446
NHIIP	Andhra Pradesh	2012	1632
	Karnataka		
	Rajasthan		
	Telangana		
Gujarat State Highway Project II	Gujarat	2011-2012	2261
2nd Karnataka State Highway Improvement Project	Karnataka	2011	908
2nd Kerala State Transport Project	Kerala	2012	623
Tamil Nadu Road Project	Tamil Nadu	2014	2007
UP Core Road Development Program	Uttar Pradesh	2014	2018
Total			**10,446**

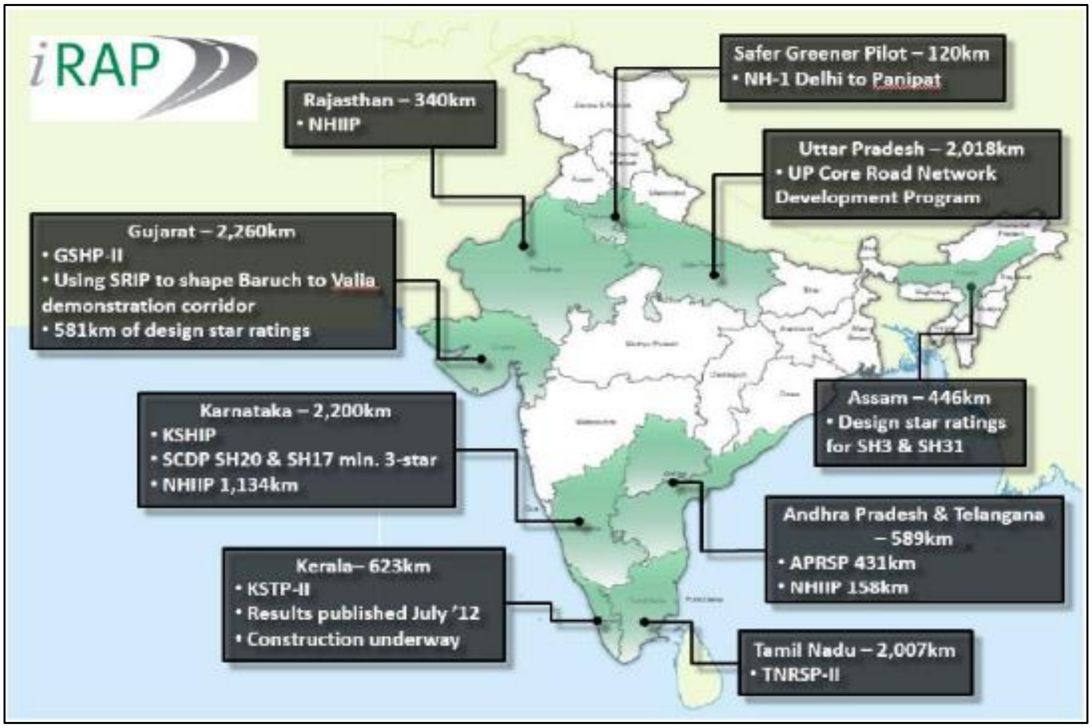


Figure 2.5: iRAP India Road Projects by State (Source: iRAP 2015)

Some key road infrastructure elements/attributes were inspected to determine the risk factors present and to investigate deficiencies in the road network and design that lead to crashes and injuries, and result in road trauma. Approximately 97% of the roads with speeds equal to or more than 40 km/h have no sidewalks; almost all the roads surveyed with speeds equal to or more than 40 km/h, used by bicyclists and motorcyclists, have no bicycle or motorcycle facilities. Around 93% of the road sections with traffic speeds of 80 km/h and more are single undivided carriageways. Nearly 77% of the roadway curves with speed 80 km/h or more have unsafe roadsides, increasing the roadside severity for both drivers and pedestrians. Additionally, crash statistics for these 10 states in India were collected from the Ministry of Road Transport and Highways, and the latest official figure indicate around 139,680 fatalities and nearly 500,000 serious injuries reported from road/traffic crashes (Ministry of Road Transport and Highways 2014). Star ratings on a scale of 1-5 (1 being worst, 5 being best) were then developed for all the sections of roads under consideration for the 10 states. Each different mode of travel (vehicle, motorcycle, pedestrian and bicycle) receives a star rating, with respect to iRAP Star Rating Scores depending upon risk factors of the roadway and roadside infrastructure elements.

Figures 2.6-2.8 show the star ratings of all the road sections and for all transportation modes, including lengths of the section for each star rating. A star rating map for vehicle occupants only, and a star rating chart showing the distribution of star ratings for each mode of travel are also provided.

	Vehicle Occupant		Motorcyclist		Pedestrian		Bicyclist	
Star Ratings	Length (kms)	Percent	Length (kms)	Percent	Length (kms)	Percent	Length (kms)	Percent
5 Stars	17.00	0%	4.30	0%	0.00	0%	4.80	0%
4 Stars	343.00	3%	173.80	2%	56.00	1%	61.30	1%
3 Stars	2,214.00	21%	1,654.00	16%	897.50	9%	1,357.70	13%
2 Stars	4,000.20	38%	2,975.60	28%	2,118.60	20%	1,965.00	19%
1 Star	3,817.80	37%	5,584.30	53%	6,742.10	65%	5,523.80	53%
Not applicable	51.60	0%	51.60	0%	629.40	6%	1,531.00	15%
Totals	10,443.60	100%	10,443.60	100%	10,443.60	100%	10,443.60	100%

Figure 2.6: Star Ratings iRAP India (Source: iRAP 2015, www.irap.org)

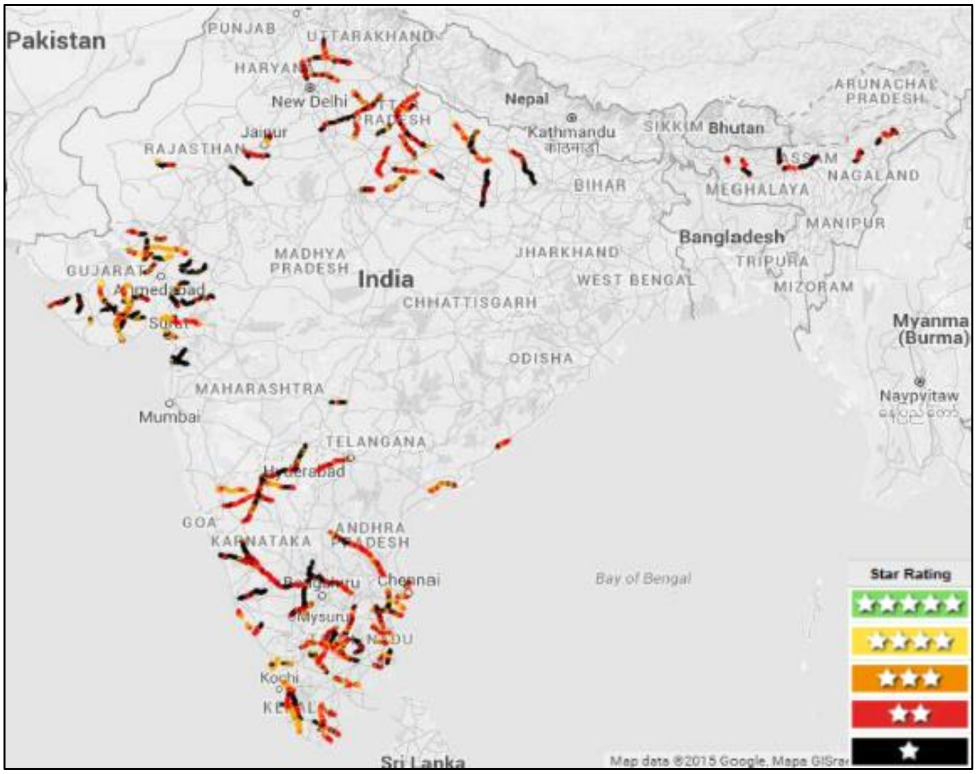


Figure 2.7: Star Rating Map- Vehicle Occupants (Source: www.irap.org)

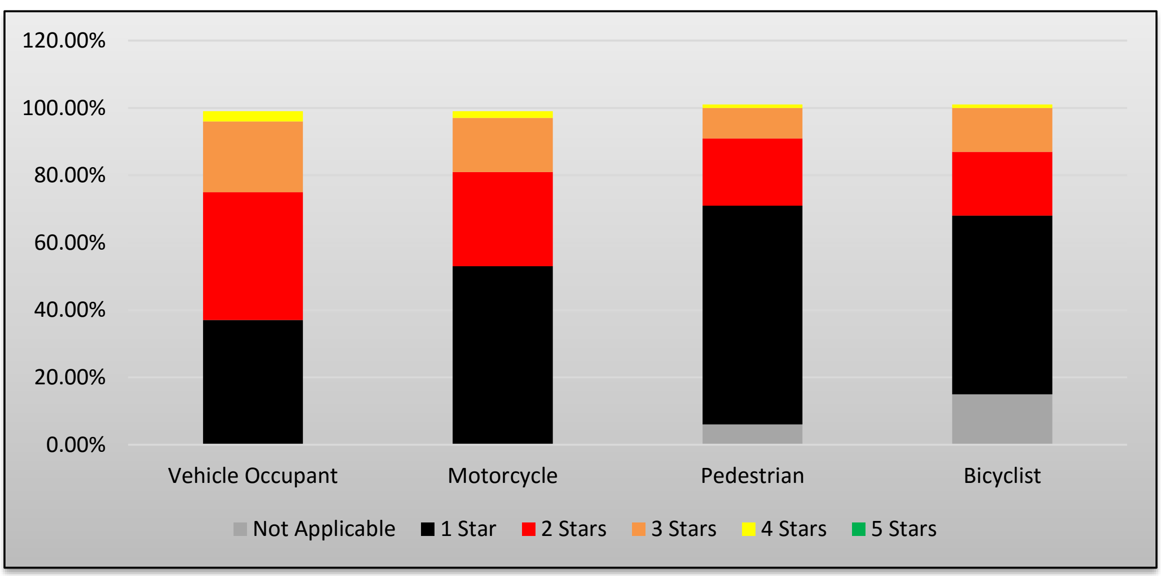


Figure 2.8: Star Rating Chart (Source: www.irap.org)

Safer Roads Investment Plans (SRIP) were then generated to suggest countermeasures and economically feasible solutions to the road safety issues for all the sections, which will be useful in preventing fatalities and injuries in a cost effective manner. The countermeasures and road treatments depicted (in Figure 2.9) propose numerous improvements to road safety that can be implemented in the deficient sections of the road network surveyed. For example, road treatments such as constructing extra lanes creating a double carriageway, designing overtaking lanes with an adequate physical median to avoid head-on collisions, and installing safety barriers will eliminate approximately 223,500 Fatality and Serious Injuries (FSIs) on a 20-year duration, while adequate provision of sidewalks, crosswalks, etc. for pedestrians can prevent around 82,000 Fatality and Serious Injuries (FSIs) for the same time period.

Upgrades on intersections, such as adding protected turn lanes, interchanges, and roundabouts are estimated to save more than 100,000 lives, on a 20-year period.

Figure 2.9: SRIP- Top 8 Countermeasures (Source: www.irap.org)

Using reliable crash data plays a big role in making approximations of fatalities and serious injuries on the surveyed road sections, and estimating the fatalities and injuries that can be avoided, by implementing the road safety improvements suggested and using crash modification factors. Attempts to determine effects of safety improvements in Haiti will be hampered by the lack of available crash data. Alternative means for collecting such data will need to be addressed.

2.5 iRAP Star Rating Methods

Star Ratings from iRAP measure the existing safety level of the road sections in consideration (for vehicle users, motorcyclists, bicyclists and pedestrians), by providing a simple and objective measure of the safety level based on inspected road data (iRAP n.d.). Roads rated 5-stars (in green) are the safest, and roads rated 1-star (in black) are the least safe. The process utilizes video data associated with GPS data to determine location along the road network, which enables users to manually code the road attributes. For star ratings, road sections are assessed every 100 m. The iRAP model is based on crash research from around the world, and the iRAP Global Committee provides technical oversight of the star rating model. Figure 2.12 depicts the star rating process stepwise used by iRAP for road assessment studies (Bradford 2016).

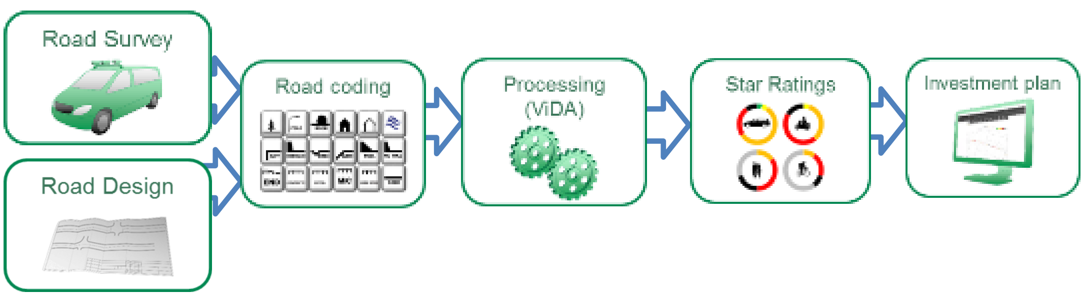


Figure 2.10: General iRAP Star-Rating Process

The first step of this process is to properly inspect the road network by means of survey using GPS devices, video camera and real-time data recording application software (PIP Video Kit app). The data collected would then be converted into 100 m segments after which it is put into the iRAP online coding interface FPZ, where the Road Coding process begins with respect to roadside attributes/infrastructure elements. For the coding process, the road segments are split into 10 m segments and using different road attribute functions available for the coder, the road network is assessed based on existing conditions.

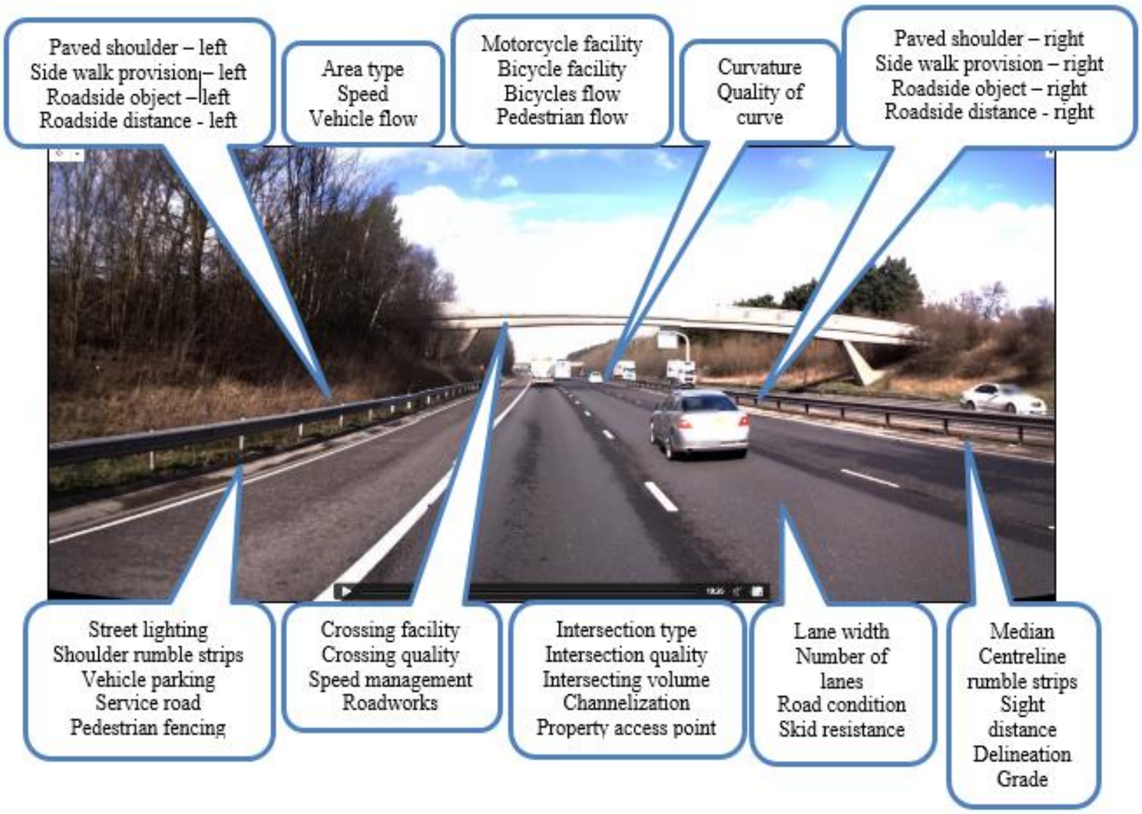


Figure 2.11: Example Road Coding Attributes

Once the coding process is complete, the coded data is checked for quality assurance (QA), to identify any errors and rectify them before converting them into 100m segments for star ratings. After the QA step, the data is uploaded into ViDA which is iRAP's online road analysis program and road safety software platform. The uploaded road data is analyzed to generate detailed and interactive road safety and condition reports, star ratings and risk worms along with Safer Roads Investment Plans for the road network.

ViDA also provides quick results for star ratings for the road network being assessed through the Star Rating Demonstrator.

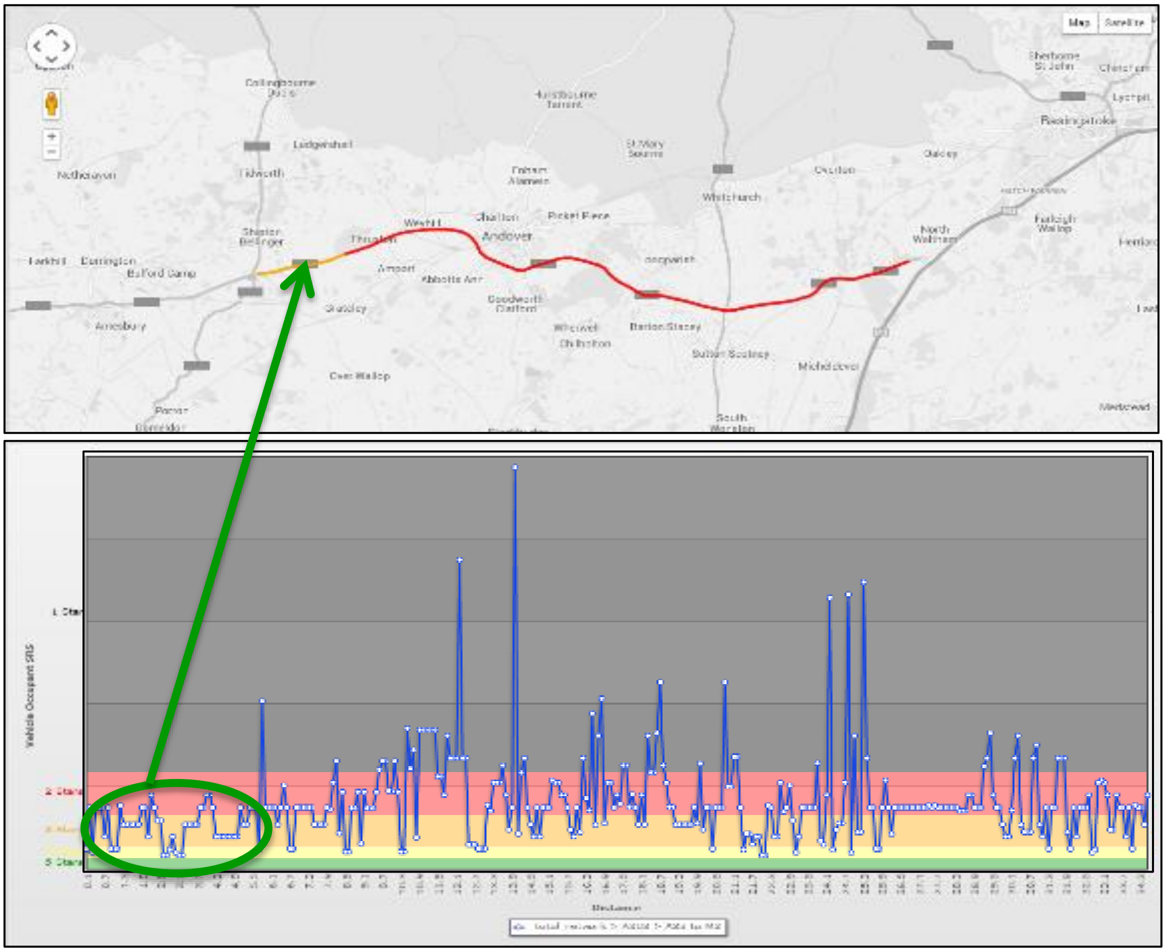


Figure 2.12: Example Star Rating Map with Interactive Risk Worm- ViDA Output (Bradford 2016)

The star rating maps have separate star ratings for each mode of travel. In other words, ViDA can generate road user specific star rating maps based on the coded data, which provides in-depth measure of safety level for all road users (Bradford 2016) (Figure 2.13).

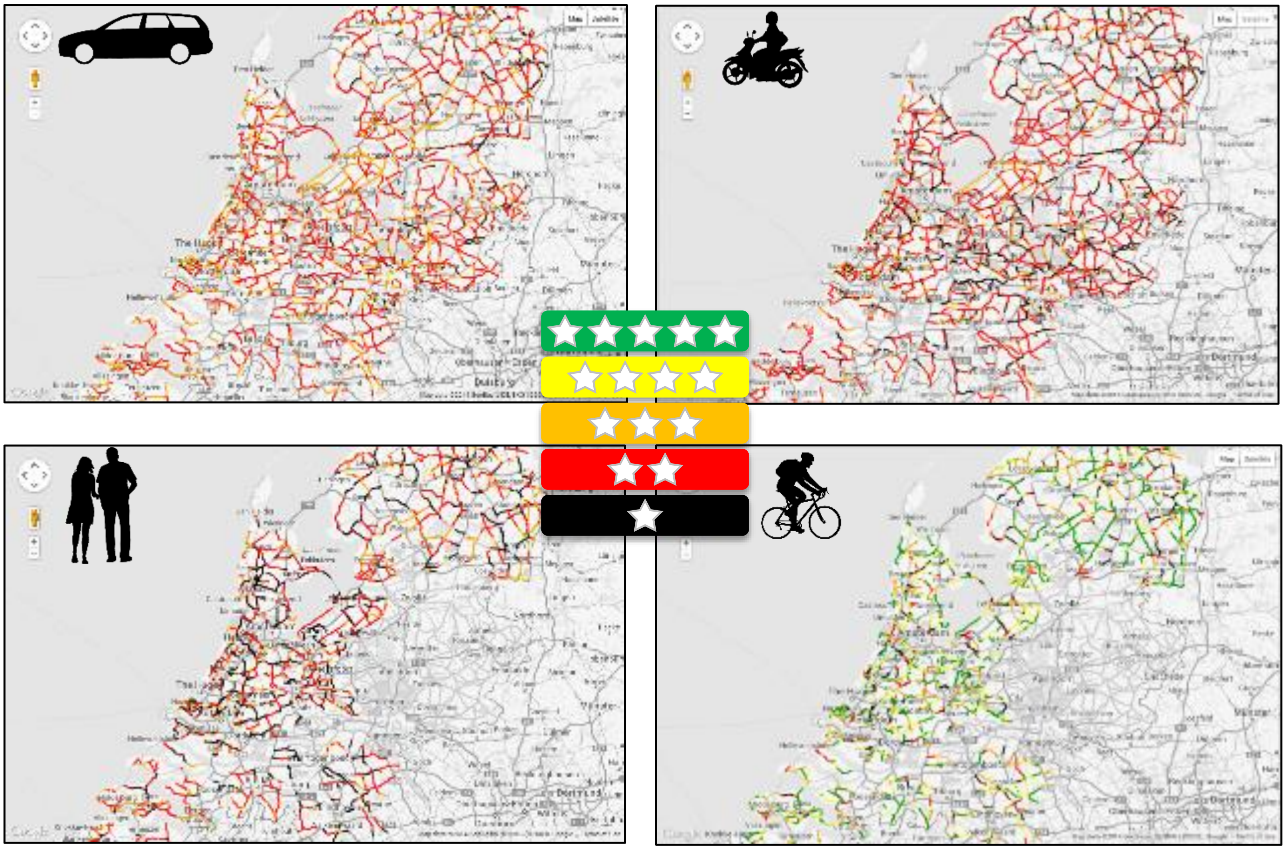


Figure 2.13: Model Road User Specific Maps from ViDA

2.6 Risk Maps

Risk maps are useful tools in iRAP's road assessment studies, indicating genuine fatality and injury figures on road networks being assessed, using ViDA. These are based on historical data, and can be produced for regions with detailed crash data (iRAP n.d.). Adequate crash data also aids defining the crash costs of a road network, and change in those costs after star ratings of a particular road section have been improved. These risk maps attempt to analyze and represent the overall risk due to the contact between vehicles, all road users, and the environment. These maps are very helpful in understanding the areas where likelihood of crashes is highest and to give an unbiased opinion of the likely causes and location of traffic-related crashes and deaths.

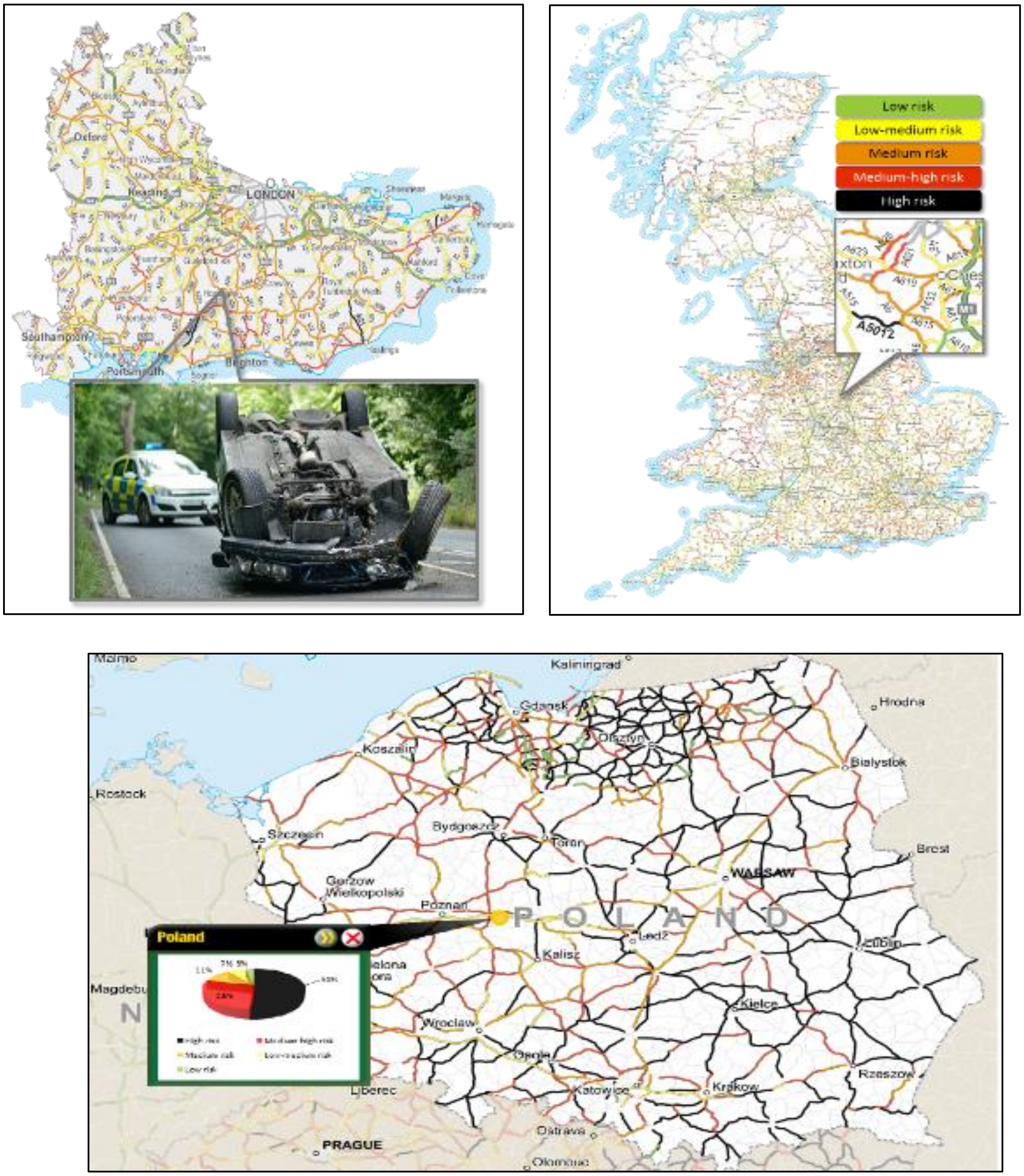


Figure 2.14: Examples of Risk Maps

From risk mapping reports by iRAP, it has been found that there are atleast 3 fatal or serious injuries per mile over a decade, with run-off crashes being the most common cause of fatality. Risk mapping also substantiated that single carriageways and motorways are very similar in terms of crashes per mile, however the former has 7 times more risk than the latter. In our case study in Haiti, however, crash data is extensively limited. Due to this reason, generating risk maps for the road network in Haiti will be dependent upon availability of road crash data at the local level.

2.7 Safer Roads Investment Plans

The Safer Roads Investment Plans (SRIPs) enlist adequate, affordable and economically viable countermeasures to the road safety issues which aid in improving star ratings of a particular road section. When star ratings are improved, this in turn helps prevent deaths and save thousands of lives per year.

More than 90 proven countermeasures and enhancement/upgrade options are considered by iRAP while developing SRIPs, including more than 300 engineering trigger sets that affect road safety. SRIPs help estimate crash costs, and calculate how a certain investment can potentially save lives and cut down on crash costs, with increasing benefits (Bradford 2016). These plans also consider minimum benefit-cost ratio (BCR) criteria set while estimating benefits and costs of an investment and compare it to existing conditions. Figure 2.15 depicts some countermeasures which are suggested in SRIPs. The figure shows an example of a before and after scenario with respect to certain countermeasures for that particular road section. The first figure indicate certain deficiencies on the segment- no roadside barriers or fences and no centerline or road median. The second figure depict the change in the road environment upon implementation of the countermeasures- adequate delineation and centerlines and presence roadside fences, thus improving the safety level of this section.

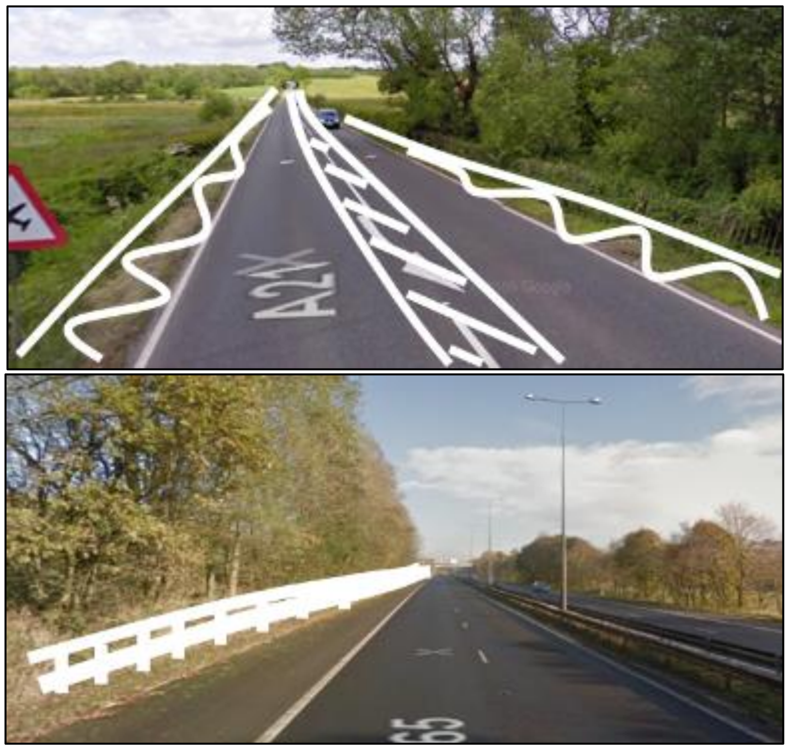


Figure 2.15: Before and After Implementing Countermeasure- An Example

2.8 Inter-Rater Reliability Test

The Inter-Rater Reliability test is helpful in assessing the level of agreement among raters/coders who participate in coding and evaluating alternatives and estimating values of a common attribute, phenomenon or object. Inconsistency in estimation and measurement is a significant issue when a human coder is used, especially if the data being coded can be subjectively assessed. These problems are intensified when more than one rater/coder is involved. If certain estimations comprise of categories and two raters/coders are given the task of checking which observation falls in which category, the percent agreement between the two raters can be obtained. This method works for multiple categories for each observation (RMKB Reliability).

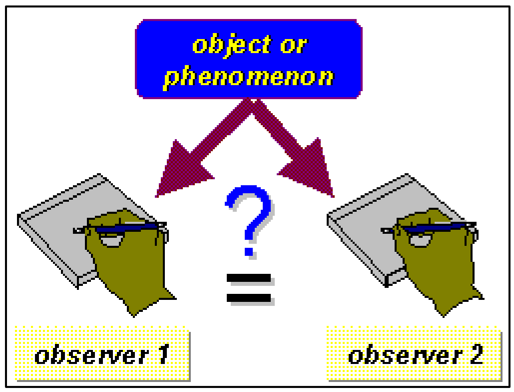


Figure 2.16: Inter-Rater test illustration

Numerous research strategies need the inter-rater reliability (IRR) assessment to check and illustrate agreement and consistency between ratings and values provided by multiple coders (Hallgren 2012). The inter-rater reliability test is very useful in many research projects involving data collection via ratings or attribute values assigned by coders who could be trained or untrained. This test indicates the training that coders might require to further improve their level of agreement on ratings, or to if they are trained enough then to check what the necessary changes need are in the training process in order to obtain a good level of agreement and accuracy with the desired results.

The inter-rater assessment enables researchers to quantify the level of agreement among 2 or more coders, involved in making independent ratings on certain features of a particular set of attributes or subjects (Hallgren 2012). In this research project, the road coding attributes are stressed upon, and coders who were involved in the road coding process will be evaluated in terms of how agreeable they are with respect to each other on the ratings they provided for each attribute. This test has been very useful in further refining the methods and tools provided to researches and/or judges by evaluating if a certain rating scale or attribute value is appropriate and conforming to standards, to estimate a certain condition or variable. From the test, if the raters involved do not agree to certain percentage or degree, either the raters/coders will have to be re-trained or the given coding scale and standards are flawed and need reformations.

CHAPTER 3

EQUIPMENT, SOFTWARE, AND METHODS

3.1 Introduction

For this case study in Haiti, the equipment used was similar to past Safety Assessment studies done by iRAP in other countries. iRAP constantly provided guidance for this project and the first step was to acquire appropriate equipment and software for data collection. For the road network survey and video data along 44 miles of roadway from Port-au-Prince to Cange, the equipment consisted of a Go Pro Camera, a Bluetooth GPS Device, an Android Tablet with the PIP Video Kit App installed for real-time video capture and coordinates (Figure 3.1). The camera and the GPS device were wirelessly connected with the Android App in the tablet. Once data was collected in road network under consideration, the data is used for analysis, coding and processing using iRAP's online coding interface, also known as the FPZ system. A Radar Gun was also used to collect speed data around the local school in Cange, Haiti.

Figure 3.1: Equipment for Data Collection

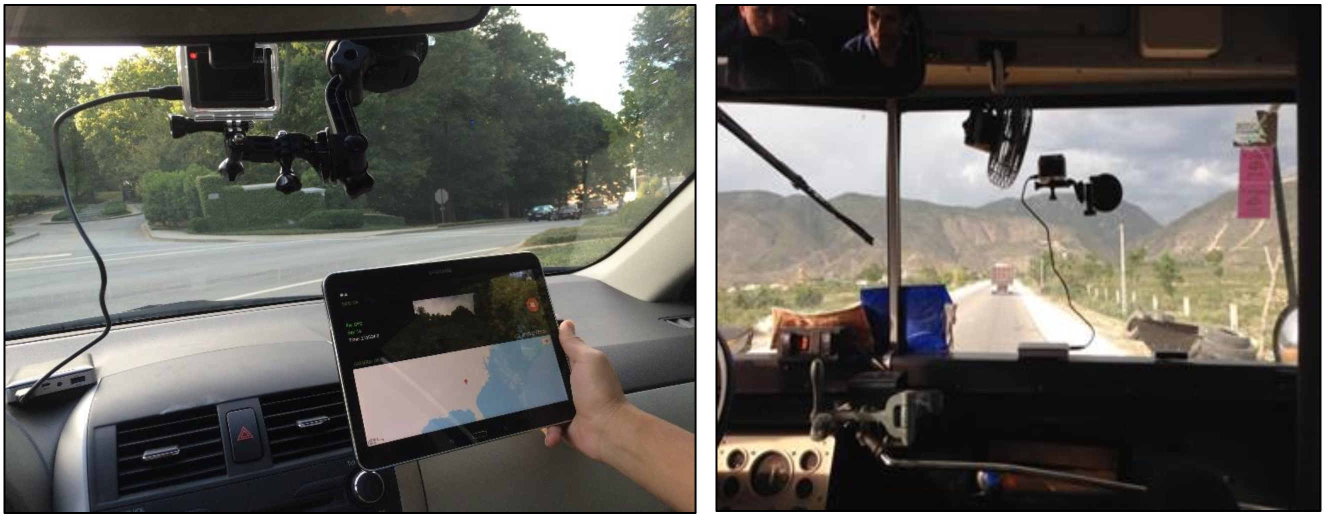


Figure 3.2: (A) Testing the Equipment in Clemson, SC (B) Equipment in Operation in Haiti

3.2 Data Collection

Video data was collected along approximately 44 miles of National Highway 3 in Haiti, from the capital in Port-au-Prince to Cange in the central plateau. The video was used to manually code roadway design and roadside safety features.

Speed data was also collected using a radar gun in and around the local school in Cange in 15-minute intervals, to observe travel/speed behaviors of drivers near the school. Most vehicles had average speeds of 30-39 mph (Figure 3.3), with a mean speed of 35.3 mph and 44 mph as 85th percentile speed, in the small of section of road between Domond and Cange. There were no speed or advance warning signs in the area. No traffic control devices exist to stop or slow vehicles approaching the school during arrival and departure times.

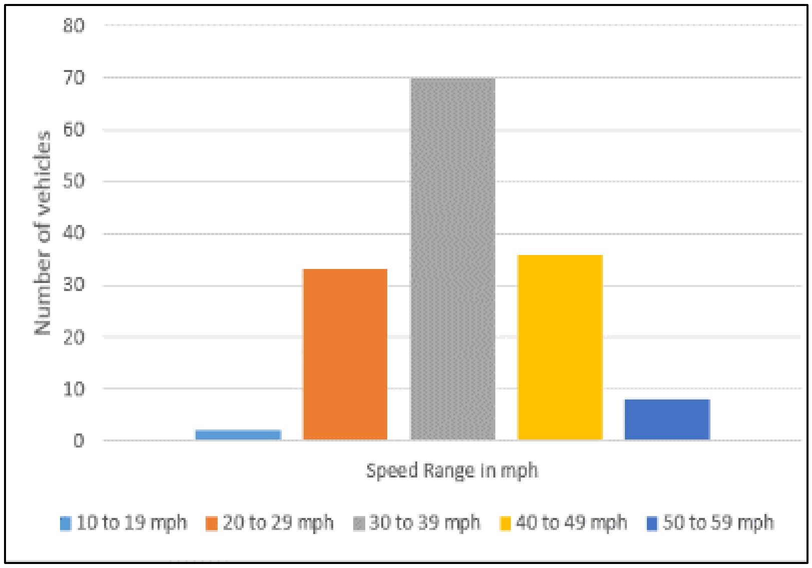


Figure 3.3: Speed Data Chart

3.3 Data Preparation and Methods

After data collection, videos were processed for the entire project route and road centerlines were created using iRAP's coding interface FPZ. After getting access to FPZ through iRAP's and EuroRAP's assistance, Dr. Sevrovic from the University of Zagreb provided tutorials to understand the steps in data processing, which included creating road centerlines, segmenting them and using the video data uploaded in FPZ to start the road coding process. Road centerlines were carefully created using the link creation tools available in the iRAP's online coding interface, from the beginning of the project area (Port-au-Prince) to the end (Cange). Road centerlines were then segmented into 8 road sections to align them with existing video segments along the entire project route (Figure 3.4). Each road section has its own video feed throughout the length of the section, from Port-au-Prince to Cange, Haiti (See Appendix section 1).

Segmenting the road centerlines are important to make all the 8 segments separate entities although they are all part of the same route. This gives the coder more flexibility while coding road attributes for different road segments simultaneously at one time. Once all the road segments were segmented and prepared, the video files embedded in each section were used to start the iRAP road coding process.

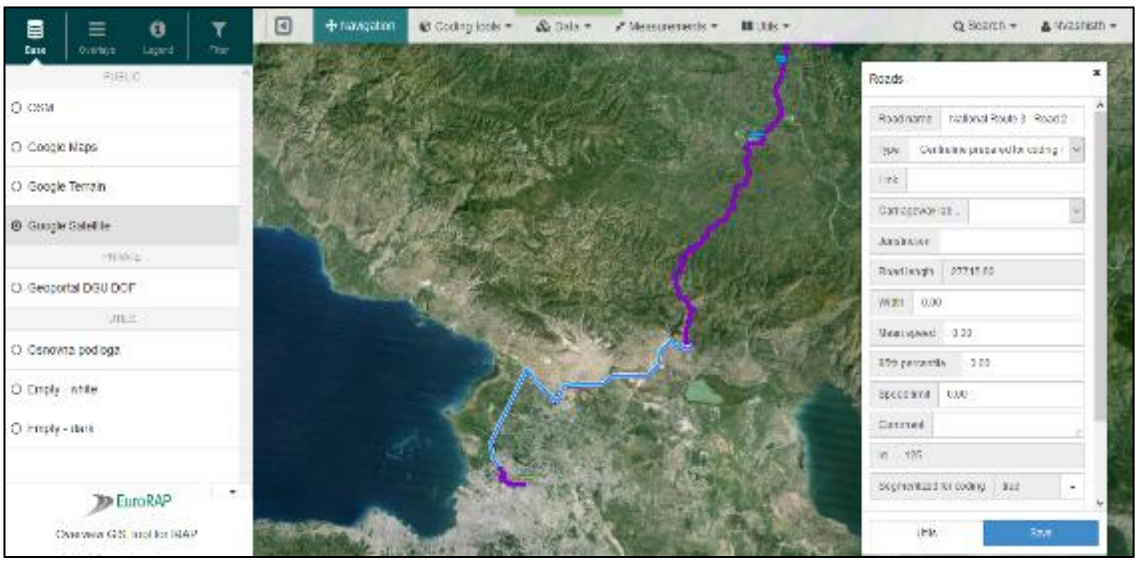


Figure 3.4: Creating and Segmenting Road Centerlines

CHAPTER 4

DATA ANALYSIS

4.1 Introduction

Data analysis consists of analyzing the video files along the entire project route from Port-au-Prince to Cange, coding of all road sections based on roadway attributes available. iRAP's online coding interface takes into consideration 52 different road attributes for coding, which are used in developing star ratings of the sections in 100m segments. For the simplicity of this thesis report, sections 5-8 have been considered for analysis and star ratings, reducing the scope of this report to approximately 22 miles of roadway. After the coding process, the coded data is checked for Quality Assurance, to identify and rectify any errors in road attribute coding, and then uploaded into ViDA which is the online road analysis program. It uses the coding results, and generates Star Ratings of the project road section, Risk Worms and Risk Maps for the project area (depending on detailed crash history data) and ideas for Safer Investment Plans to suggest improvements which could potentially save lives.

Analysis of the video data resulted in many unusual observations and anomalies which were not easily coded using existing codes. For instance, there was a truck on the roadside of a section with most of its parts scavenged, and an empty gas tank on the other side of the road. There were non-traversable ditches along majority of the sections. In a section towards the end of the route, half of the lane was eroded and falling off the hillside into Lake Peligre, which makes it very unsafe for all road users. In many sections of roads, where there are communities and commercial buildings present, part of the metal road barrier has been removed to provide access to the building entrances. In another case, there are no safety barriers of protection in a road section with a very sharp curve, which poses a huge safety risk for vehicles on either side of traffic. Another interesting observation was presence of Tap-Taps, or mini-trucks which are widely prevalent in Haiti and almost always overloaded. There are no official laws or regulations against them (Figure 4.1).

Figure 4.1: Haiti Anomalies

4.2 Coding of Road Attributes

Coding of the project route based on the roadside attributes is the most important element in the data analysis portion and generating star ratings. The video files uploaded into the FPZ system (iRAP's online coding interface) were used to convert the road sections into 10m segments for the coding process. Using the video data of the entire route, road sections were coded with respect to 52 different road attributes present along each road section, in 10m segments. These road attributes are basically the roadway infrastructure elements, and coding of these elements provides the basis of the analysis process. Figure 4.2 shows an example of the coding process for a section of the route in the project area. The buttons available below are the all the road attributes that have been coded for this and all road sections. The attributes shown on the right side of the window indicate the attributes already coded for a section; as we move ahead these change with respect to change in existing roadway elements as observed from the video. For the coding process, the iRAP Star Rating and Investment Plan Coding Manual (International Road Assessment Programme 2014) have been used extensively to learn the intricacies of the attributes and to learn the correct technique to code them in the right scenarios. For example, while coding the number of lanes in a section, only lanes in the direction of travel are considered. If there is just one lane in the direction of travel, the number of lanes is coded as "1"; if there are 2 lanes in the direction of travel and one for the opposing traffic, it is coded as "2&1", and so on.

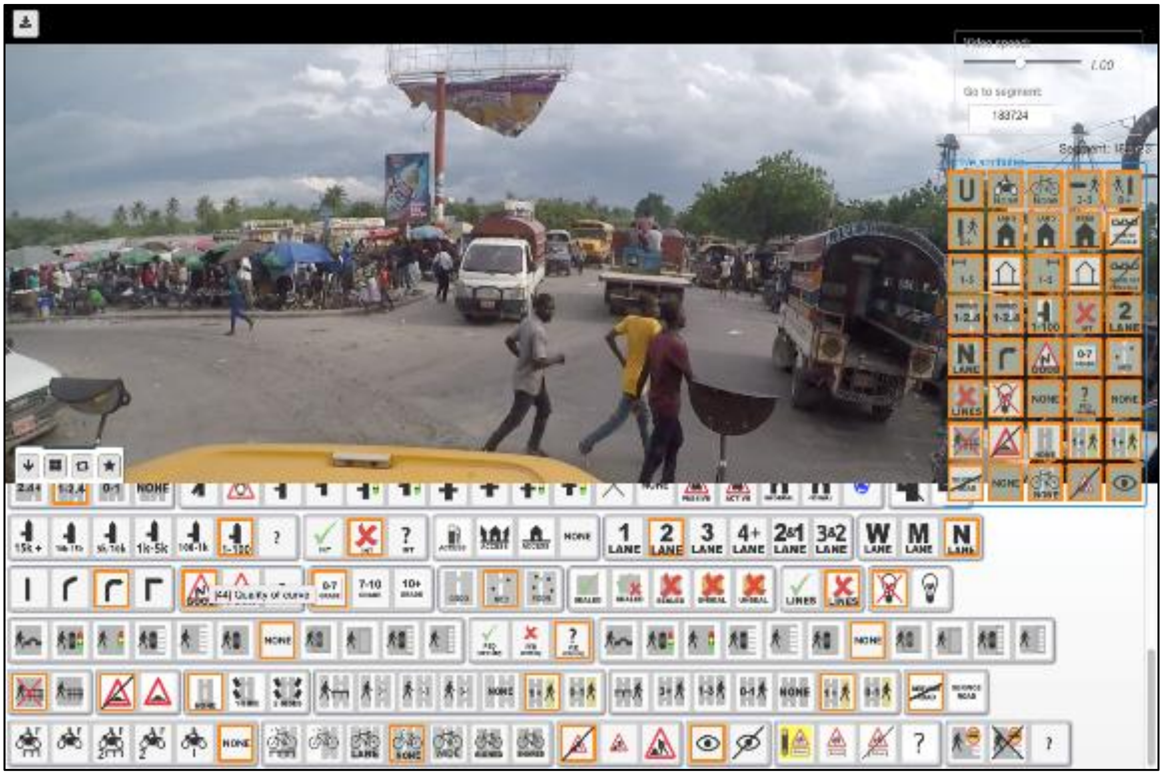


Figure 4.2: Coding of Road Attributes using iRAP's Coding Interface

Quality Assurance (QA) Check:

The road coding process is followed by Quality-Assurance check where the coded data goes through a check for any errors or miscoded data on any section of the route. The QA check was done in collaboration with iRAP and EuroRAP and their assistance in verifying the data brought to surface many errors in coding that needed to be rectified to move ahead with the analysis to obtain star ratings. For instance, in most of the sections, with respect to 'Roadside severity' attribute of the roadway, the most important roadside attributes having a more likelihood of severity were to be considered- if there were trees and light poles, following which there's a cliff, the cliff needs to be coded as the roadside severity attribute for that particular section. In many sections, stone walls along the road were usually completely ignored and objects which are present behind stone walls (cliff, slope, trees etc.) were coded instead. According to the iRAP methodology, these types of stone walls should be coded as non-frangible (rigid objects). When coding roadside severity objects, the object which is located closest to the edge of the road pavement (or edge line) should always be coded. Slope attribute was often incorrectly used instead of cliff attribute. In many cases it was observed that downward slope attribute was incorrectly used on locations where a cliff is obviously present along the road. Deep drainage ditches were often ignored on both sides of the road and objects which are located behind ditch were coded instead. The iRAP coding manual states that when coding the roadside severity attribute group, dangerous objects which is closest to the road edge should always be coded. Another example of an error can pedestrian and motorcycles counts per 100m segments (10m while coding). Number of pedestrians within each 100 meters of the road (10 road segments) should be counted and then appropriate attribute value should be selected and coded from first to the last road segment of the observed 100 meter road section. For example, if 3 pedestrians are counted on the road segments 105, 106 and 109 then in that case, attribute value of 2 to 3 pedestrians along the road should be selected and coded over the whole 100 meter section (from road segment 100 to road segment 109). On road segments 110 value of pedestrian observed attribute should be again selected based on the number of pedestrians counted on the next 100 meter road section (from road segment 110 to road segment 119) and so on. This is as per the manual by iRAP on road coding (International Road Assessment Programme 2014). The figure below shows an example of the QA feedback report as processed by iRAP/EuroRAP.

HAITI_QA_R1-v2

Project file	Video name	Segment	Attribute	Recorded Item	Correction	Notes
		189913				Section start
		189914	Roadside severity - driver side	Frangible	Pole	Pole is more dangerous objects
		189914	Pedestrian observed flow driver side	None	6 to 7	Number of pedestrian within each 100 meters (10 road segments should be counted)
		All Road Segments	Lane width	Narrow	Medium	Recurring issue over the whole video: Lane is more than 2.75 meters in width
		All Road Segments	Paved shoulder passenger and driver side	None	0-1 or 1-2.4 meters (if edge line is present)	Recurring issue: Paved shoulder is always coded as none regardless of the actual paved shoulder width.
		All Road Segments	Road condition	Medium	Good	Recurring issue over the whole video: There is no visible potholes or other deformations on the pavement which could adversely affect the vehicle path
		189914	Roadside severity - passenger side	No object	Slope	Dangerous slope is present
		All Road Segments	Speed limit, Motorcycle speed limit, Truck speed limit, Differential speed limits	NOT CODED		Recurring issue over the whole video: Appropriate speed limit should be coded
		All Road Segments	Property access points	NOT CODED		Property access points are not coded.
		189914	Land use passenger side	Residential	Undeveloped	There are no residential objects present on this segment
		189990 - 189916	Land use passenger and driver side	Commercial	Undeveloped	There are no commercial objects present on this road segments
		189914	Pedestrian observed flow passenger side	2 to 3	1	Only one pedestrian observed within 100 meters

Figure 4.3: QA Feedback for iRAP- Haiti Road Section 5

Inter-Rater Reliability:

One of the many issues faced during the coding process was selecting the correct value/code for many attributes in different sections of the route (from sections 5-8) and meeting iRAP's coding standards. In other words, a test of inter-rater reliability would help the coders/users in learning the coding process more closely and getting closer to achieving the highest coding quality for all attributes, wherein there are minimal or no errors detected when the coding data goes through quality check. Errors identified after the QA check indicated several coding values/attributes coded incorrectly for various sections, due to which coding of all sections (5-8) had to be carefully done again taking care of the errors committed earlier and not repeating them. These caused several delays in moving ahead with the project and obtaining star-ratings. The inter-rater reliability test would be a test for the raters/coders to check the degree of agreement in terms of attribute coding for various road sections. The basic purpose is to judge how close all the coders are to the already established iRAP road coding guidelines/process, and to assess the level of agreement among them with respect to coding attributes for different scenarios. For inter-rater reliability test in this project, the coders, part of the coding process, were allotted a particular set of road sections with certain attributes to code. The iRAP standard coding manual were provided to all the users to ensure transparency, and the test results indicated the degree of agreement between them in regard to selecting appropriate coding values for different road sections and attributes they would be judged based on the closeness of their coded data to the given guidelines.

To better prepare the coders in dealing with the iRAP coding process and reducing delays occurring due to errors in road coding, a set of Do's and Don'ts, as part of iRAP Coding Training, has been prepared, particularly for this project to enable the coders involved to get a better idea about the common errors that were identified from the 2 QA checks (APPENDIX Figures A.1-A.27). The training module covers 14 major attribute categories which had the maximum errors across all sections, especially from section 5 to 8. Along with the iRAP coding manual, this training module was effective for the coders to get a better grip on coding of different road attributes correctly and conforming to iRAP coding standards. This training module and the iRAP coding manual assisted the coders towards two inter-rater reliability (IRR) tests, through which their level of agreement was obtained in terms of road attribute coding along with the percentage of accuracy with the correct coding values from iRAP for the sections in consideration. Adequate levels of agreement are essential to ensure good consistency and accuracy in the assessment, as inadequate levels of agreement and accuracy indicate need for more in-depth training for the coders/raters, to scale the inadequacy and/or to further improve the coding training methods (Wongpakaran et al. 2013) (PCC n.d.). The basic model used to calculate the inter-rater reliability is the percent agreement in the 2-rater model, with the attributes under consideration (PCC n.d.). The ratings were compared to a specific benchmark which indicated if the inter-rater reliability was acceptable or unacceptable.

CHAPTER 5

INTER-RATER RELIABILITY TEST RESULTS

5.1 Introduction

Two Inter-Rater Reliability tests were conducted to assess the agreement between two raters for the coding process of this project, and to check their accuracy with the coding attribute values established by iRAP, for the particular sections used for the two tests. 14 different attributes were used in the tests, which had the most number of errors from two phases of QA checks. To prepare the raters for the tests, a set training modules/slides (See APPENDIX) for coding was prepared to help understand the major errors committed while coding those attributes previously. Each attribute has been divided into multiple scenes in many cases, to give more examples of how to correctly code that specific attribute value for that segment of the road. The percentage agreement was compared to a threshold of 75% minimum agreement.

5.2 Reliability Test 1

The first set of coding reliability test slides provided an idea about the degree of understanding among the raters, indicating improvements in certain aspects of attribute coding and others common errors in different instances. The first test set had 32 scenes of different road segments divided among 14 attribute groups where most errors were identified. These are tabulated in Table 5.1:

Table 5.1: Attribute List for Reliability Tests

ATTRIBUTE	NUMBER
Roadside severity	1
Ped. Observed Flow	2
Motorcycle observed flow	3
Speed limits	4
Lane Width	5
Road condition	6
Skid resistance	7
Land use	8
Upgrade Cost	9
Delineation	10
Paved shoulder width	11
Property access points	12
Sidewalks	13
Traffic Calming/Speed Management	14

From the test, the percentage agreement among the two raters with respect to their agreement on coding a certain attribute was obtained, along with their individual accuracies with the code established by iRAP as well as the average accuracy for both. The test is based on the two-rater model, and ratings were calculated by 0 and 1 notations, 0 for incorrect/disagreement and 1 for correct/agreement.

Table 5.2: Reliability Test 1 Responses and Results

ATTRIBUTE NO.	SCENE	CORRECT CODE	CORRECT CODE NO.	RATER 1 CODE	RATER 2 CODE	RATERS' AGREEMENT	RATER 1 ACCURACY	RATER 2 ACCURACY	COMMON ACCURACY
1	1	Pole	12	8	11	0	0	0	0
	2	Slope	9	9	11	0	1	0	0
	3	Deep Drainage Ditch	8	5	5	1	0	0	0
	4	Non-frangible structure	13	2	15	0	0	0	0
	5	Pole	12	12	10	0	1	0	0
	6	Non-frangible structure	13	13	12	0	1	0	0
	7	Deep Drainage Ditch	8	8	8	1	1	1	1
	8	Unprotected Safety barrier end	15	1	1	1	0	0	0
2	1	6 to 7	5	5	5	1	1	1	1
	2	None	1	4	2	0	0	0	0
	3	1	2	2	2	1	1	1	1
3	1	4 to 5	4	3	1	0	0	0	0
4	1	All 60, No differential speed	4	4	4	1	1	1	1
5	1	Wide	1	1	1	1	1	1	1
	2	Medium	2	2	2	1	1	1	1
6	1	Good	1	1	1	1	1	1	1
	2	Good	1	1	1	1	1	1	1
7	1	Sealed- Adequate	1	1	3	0	1	0	0
	2	Sealed- Medium	2	2	2	1	1	1	1
8	1	Undeveloped	1	1	1	1	1	1	1
	2	Residential	3	3	3	1	1	1	1
9	1	High	3	3	3	1	1	1	1
	2	Low	1	1	3	0	1	0	0
10	1	Poor	2	2	2	1	1	1	1
11	1	None	4	4	3	0	1	0	0
	2	None	4	4	3	0	1	0	0
12	1	Residential Access 1 or 2	3	1	1	1	0	0	0
	2	Residential Access 3+	2	2	2	1	1	1	1
13	1	0 to 1 m	4	4	4	1	1	1	1
	2	None	5	7	5	0	0	1	0
14	1	Present	2	2	2	1	1	1	1
	2	Not Present	1	1	1	1	1	1	1
					Ratings	**20/32**	**24/32**	**18/32**	**17/32**
					% Agreeme	**62.50%**	**75.00%**	**56.30%**	**53.13%**

	Raters' Agreement	Rater 1 Accuracy	Rater 2 Accuracy	Common Accuracy
Ratings	20/32	24/32	18/32	17/32
% Agreement	62.50%	75.00%	56.30%	53.13%

Table 5.2 depicts the percentage agreement values among the raters'. The raters' agreed on 62.50% of the responses for the coding values, which is lower than the threshold

of 75%. This depicts that the inter-rater reliability test 1 is unacceptable and the raters require further training on certain attribute coding features. Rater 1 had a much higher correct code accuracy (75%) as compared to Rater 2 (56.30%), with respect to the code established by iRAP for a specific attribute. The overall average accuracy for both the raters with the iRAP code values was 53.13%, which is quite low portraying the need for more training on the errors committed. The results of test 1 were not satisfactory to provide a valid response to the rater reliability for coding. Hence, a second reliability test was conducted to check improvement in the raters' agreement and overall rating for the coding attributes. Test 2 was conducted after another round of training on the correct coding techniques for varying scenarios.

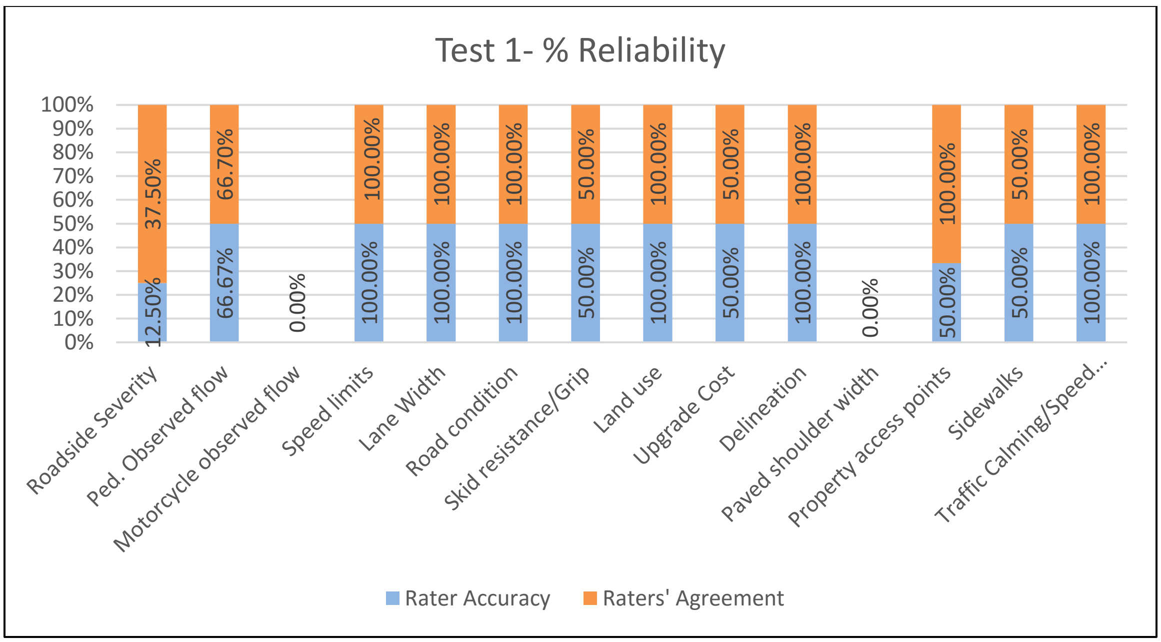


Figure 5.1: Test 1- % Reliability Illustration

Figure 5.1 illustrates the percentage distribution of rater accuracy and raters' agreement from Test 1, with respect to all the 14 attributes used for the two tests. It can be observed that the roadside severity attribute has the least accuracy and agreement, which implies that this attribute category had the maximum errors in coding. Further training on all attributes, focusing more on roadside severity attribute, helped in improving the coding accuracy in the second test.

5.3 Reliability Test 2

The second reliability test set had 31 scenes of different road segments divided among the same 14 attribute groups.

Table 5.2 depicts the percentage agreement values among the raters' from Test 2. The raters' agreed on 80.65% of the responses for the coding values, which is more than the minimum threshold of 75%, and indicates a sharp improvement in coding understanding among the raters. This depicts that the inter-rater reliability Test 2 is acceptable and approximately 81% of the ratings are identical. Rater 1 had a much higher correct code accuracy (90.32%) as compared to Rater 2 (83.87%), with respect to the code established by iRAP for a specific attribute, however this also indicates a sharp increase in accuracy. The overall average accuracy for both the raters with the iRAP code values was 77.42%, which is quite reasonable and satisfactory, portraying no further need for training on the errors committed. Test 2 were satisfactory, with high improvement ratings, and met the minimum benchmark to provide a valid response to the rater reliability for coding.

Table 5.3: Reliability Test 2 Responses and Results

ATTRIBUTE NO.	SCENE	CORRECT CODE	CORRECT CODE NO.	RATER 1 CODE	RATER 2 CODE	RATERS' AGREEMENT	RATER 1 ACCURACY	RATER 2 ACCURACY	COMMON ACCURACY
1	1	Deep Drainage Ditch	8	8	8	1	1	1	1
	2	Non-frangible structure	13	2	2	1	0	0	0
	3	Aggressive Vertical Face	5	5	5	1	1	1	1
	4	Unprotected Safety barrier end	15	15	15	1	1	1	1
	5	Non-frangible structure	13	2	13	0	0	1	0
	6	Pole	12	12	11	0	1	0	0
	7	Pole	12	12	12	1	1	1	1
	8	Unprotected Safety barrier end	15	1	15	0	0	1	0
2	1	4 to 5	4	4	4	1	1	1	1
	2	8+	6	6	6	1	1	1	1
3	1	1	2	2	2	1	1	1	1
4	1	All 40, No differential speed sign	2	2	2	1	1	1	1
5	1	Wide	1	1	2	0	1	0	0
	2	Medium	2	2	2	1	1	1	1
6	1	Poor	3	3	3	1	1	1	1
	2	Good	1	1	1	1	1	1	1
7	1	Sealed- Adequate	1	1	1	1	1	1	1
	2	Sealed- Medium	2	2	2	1	1	1	1
8	1	Undeveloped	1	1	1	1	1	1	1
	2	Residential	3	3	3	1	1	1	1
9	1	High	3	3	3	1	1	1	1
	2	Medium	2	2	1	0	1	0	0
10	1	Poor	2	2	2	1	1	1	1
11	1	0 - 1m (Narrow)	3	3	3	1	1	1	1
	2	None	4	4	4	1	1	1	1
12	1	None	4	4	1	0	1	0	0
	2	Residential Access 1 or 2	3	3	3	1	1	1	1
13	1	None	5	5	5	1	1	1	1
	2	0 - 1m (Non-Physical Separation)	4	4	4	1	1	1	1
14	1	Not Present	1	1	1	1	1	1	1
	2	Present	2	2	2	1	1	1	1
					Ratings	**25/31**	**28/31**	**26/33**	**24/31**
				% Agreement		**80.65%**	**90.32%**	**83.87%**	**77.42%**

	Raters' Agreement	**Rater 1 Accuracy**	**Rater 2 Accuracy**	**Common Accuracy**
Ratings	25/31	28/31	26/33	24/31
% Agreement	80.65%	90.32%	83.87%	77.42%

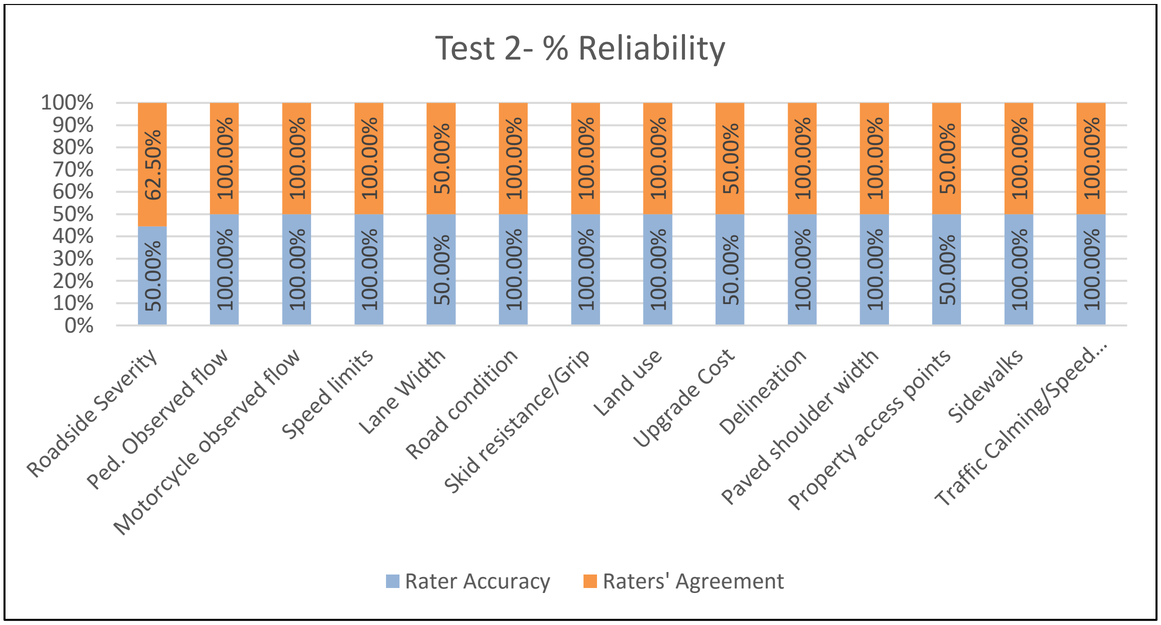


Figure 5.2: Test 2- % Reliability Illustration

Figure 5.2 illustrates the percentage distribution of rater accuracy and raters’ agreement from Test 2, with respect to all the 14 attributes used for the two tests. It can be observed that the % reliability from Test 2 for the roadside severity attribute improved by approximately 67% from that of Test 1, which implies that the training modules helped in improving the coding accuracy for this attribute.

5.4 Coding Reliability Assessment

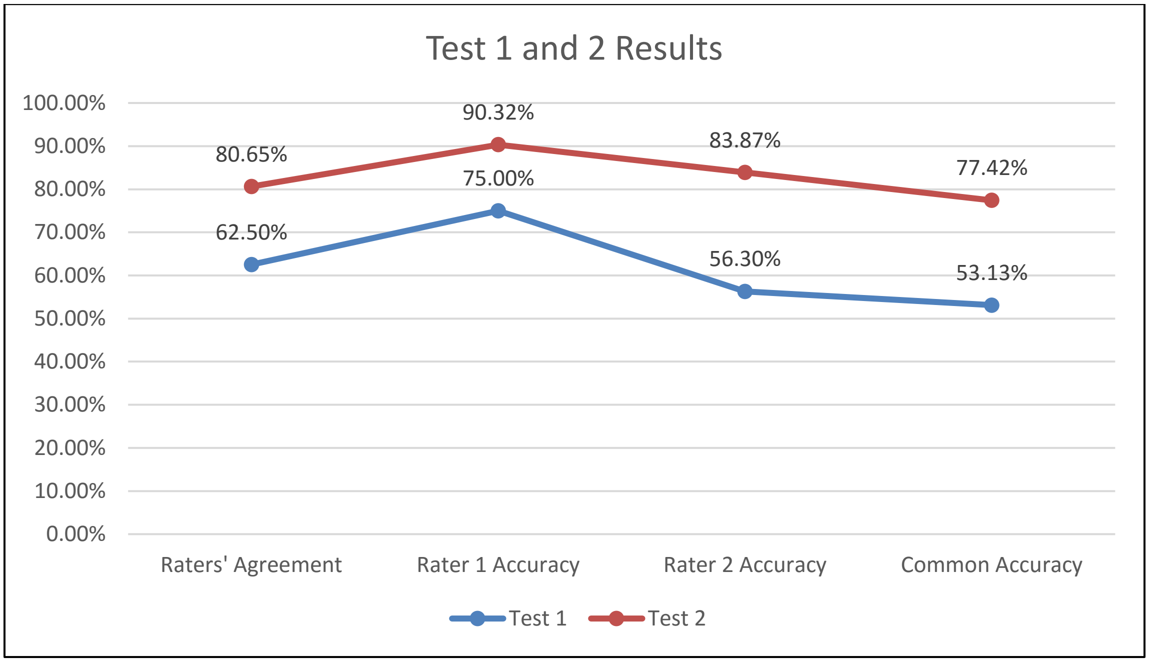


Figure 5.3: % Agreement and Accuracy Comparison from Test 1 and 2

Figure 5.3 depicts the comparison of percentage scores from the two tests with respect to raters' agreement and accuracy. Raters' agreement improved by approximately 29% in Test 2, with almost 46% increase in coding accuracy with respect to the established coding values by iRAP. This indicates the importance of adequate and intensive training requirement for the attribute coding process in this safety assessment.

5.5 Cohen's Kappa Statistic

In addition to the simple 2-rater reliability model or percent-agreement calculation method, Cohen's Kappa coefficient statistic was used to measure inter-rater agreement on a 0 to 1 scale. Cohen's Kappa statistic measures categorical items and is considered to be a more accurate and robust means to evaluate inter-rater agreement, taking both actual agreement and agreement by chance into consideration (Wikipedia n.d.). The two raters involved either agree or disagree in the ratings they provide, without any degrees of disagreement (or no weights). The kappa statistic in this analysis was done in *Microsoft Excel* to test rater reliability. Inter-rater reliability through the kappa statistic is important due to the fact that it depicts the degree to which the responses/data collected in a particular study are correct representations of the attributes measured. The kappa statistic scores can be interpreted in many ways. In this analysis it is interpreted as follows:

Table 5.4: Kappa Score Interpretation

Kappa Scores	**Interpretation**
-1 - 0.21	Poor Agreement
0.21 - 0.40	Fair Agreement
0.41 - 0.60	Moderate Agreement
0.61- 0.80	Substantial Agreement
0.81 - 1.00	Almost Perfect Agreement

Equation 1 shows the mathematical formula to calculate the kappa statistic:

$$k = \frac{[P(a) - P(e)]}{[1 - P(e)]} \quad \text{- Equation 1}$$

Where, *k* = kappa coefficient, varies from -1 to 1

P(a) = Probability of actual agreement

P(e) = Probability of expected/chance agreement

Equations 2 and 3 depicts the formula for standard deviation and standard errors required to calculate the 95% confidence intervals.

$$SD = \sqrt{\frac{P(a)[1 - P(a)]}{[1 - P(e)]^2}} \quad \text{- Equation 2} \qquad SE = \frac{SD}{\sqrt{N}} \quad \text{- Equation 3}$$

Cohen's kappa coefficient was calculated for both the tests with respect to the raters' responses 0 or 1, in comparison with the correct code established by iRAP.

Kappa coefficient for Reliability Test 1:

Table 5.5: Cohen's Kappa Calculation for Test 1

Raters	Response	Rater 1		Sum	Percent
		0	1		
Rater 2	0	7	7	14	43.75%
	1	1	17	18	56.25%
Sum		8	24	32	
Percent		25.00%	75.00%		

$$P(a) = (7 + 17) / 32 = 0.75$$

$$P(e) = (0.25*43.75) + (0.75*56.25) = 0.53$$

Thus, from Equation 1: k = **0.47**

This indicates 'Moderate Agreement' among the raters from test 1, which implies they need more training to improve their agreement/accuracy.

From equations 2 and 3:

Std. Dev. = 0.92

Std. Error= 0.162

95% Confidence Interval = ***(0.15, 0.70)***

Kappa coefficient for Reliability Test 2:

Table 5.6: Cohen's Kappa Calculation for Test 2

Raters	Response	Rater 1		Sum	Percent
		0	**1**		
Rater 2	**0**	4	2	6	**19.35%**
	1	1	24	25	**80.65%**
Sum		5	26	31	
Percent		**16.13%**	**83.87%**		

$$P(a) = (4 + 24) / 31 = 0.90$$

$$P(e) = (0.1613*0.1935) + (0.8387*0.8065) = 0.71$$

Thus, from Equation 1: k = **0.67**

This indicates 'Substantial Agreement' among the raters from test 2.

From equations 2 and 3:

Std. Dev. = 1.03

Std. Error= 0.186

*95% Confidence Interval = **(0.30, 1)***

CHAPTER 6

CONCLUSIONS

6.1 Overall Project Summary

The test application of iRAP's road safety assessment methodology in Haiti helped in understanding the safety situation in Haiti better in terms of quality of roadside infrastructure currently present and opened new avenues for more in-depth into Haiti's safety problem. iRAP's process of video analysis and star rating of road sections is effective in evaluating road sections in its current state as well as providing suggestions for improvements based on star ratings. One of the major issues faced during the course of this project was accurate road attribute coding, using iRAP's online analysis software FPZ. The coding process followed once video data was collected for 44 miles of roadway along National Route 3 in Haiti. Road coding, done on 52 different road infrastructure elements/roadside attributes, basically involved processing the video files in iRAP's online interface FPZ and using the various attribute options, each of the 8 road sections were coded. The quality-assurance (QA) check on the coded data resulted into numerous errors in the coding techniques, multiple times. This was in part due to lack of a proper training module on iRAP road coding, and in part due to lack of effective physical guidance on the coding process through iRAP. As the project moved ahead, its objectives branched into many important elements concentrating on improving the quality of coded and reducing errors in numerous attribute groups. The goals set for this project were successfully achieved. Through adequate understanding of all the attribute groups and closely referencing the iRAP Coding Manual, a set of training module/slides were created to assist the coders/raters in getting a firm grip on the correct coding techniques for various scenarios and road segments. This set of training slides helped the raters in being more reliable with the analysis process. Two Inter-Rater Reliability tests were done to evaluate the raters and the understanding on coding, to check the agreement and accuracy with the correct code values as established by iRAP. These tests resulted in interested results; the first test indicating a low level of accuracy (below a minimum agreement benchmark of 75%) which prompted another round of training and a second test. The second test showed a big increase in accuracy and agreement among the raters in terms of 14 major attributes with most coding errors, indicating higher percentages of agreement and meeting the acceptable limit of 75%. The training module, reviewed by a team of iRAP professionals deemed it to be effective in further strengthening the grip on iRAP road assessment coding. The training module helped the team have a very good understanding of all iRAP attributes and the ways in which they are coded, greatly improving the team's coding skills. Test 2 results gave acceptable reliability values implying the raters have sound knowledge of the iRAP coding process as this project moves ahead to obtain star ratings of the road sections in future.

Cohen's kappa coefficient statistic used to evaluate rater reliability is a popular and a robust technique to measure agreement between raters. Kappa statistic for test 1 produced a k value of 0.47, which is in the range of 0.41 – 0.60, indicating a moderate agreement between raters which is less than satisfactory. Kappa statistic for test 2 produced a k value of 0.67, which is within the 0.61 – 0.80 range, indicating a substantial agreement implying a satisfactory rater agreement. The ‘Haiti-specific’ iRAP Coding Training Module prepared to illustrate correct values to 14 attributes with most errors followed by the IRR tests, greatly improved coding reliability among the raters, indicating a Strong grip on iRAP road coding process for different scenarios along the road sections of this project.

The application of iRAP in Haiti is indeed feasible, as almost all data is collected as part of the iRAP process. The tools and software used are relatively user-friendly, with costs of implementation waived for academic interests. Extensive knowledge in traffic safety is not essential for this process, and results can be obtained without historical crash data. However, historical crash would be required to obtain detailed risk worms. The test application of iRAP in Haiti is nearing its completion. Equipment setup and data collection processes went smoothly. Although the initial data processing method was complex, it was completed with adequate support from iRAP and EuroRAP. However, iRAP data coding training was insufficient for many attributes, as their manual is not country-specific, due to which a specific training module for road coding in Haiti was prepared. Additional site data and plans must be executed, along with AADT data to obtain star ratings of the road sections.

6.2 Challenges and Recommendations

This project posed a lot of challenges and issues related to adequate data, validation, historical information and road coding. One of the major issues faced was accurate road coding and conforming to iRAP coding standards. Three phases of coding produced numerous errors in the coded data indicating further need to train the coders and understand the intricacies of iRAP coding. One of the contributing factor here was the iRAP coding manual which is generic and not country-specific. Although this manual was strictly followed, there were many instances as observed from the videos where the manual disagreed with observed information. This prompted the need to prepare a separate iRAP coding manual specifically for Haiti, to better understand its road environment. This Haiti-specific manual was the first step towards assessing coding accuracy and rater-reliability in road coding for Haiti. The next challenge was to reduce the coding errors identified from 3 phases of Quality-Assurance check. In reference to this manual, 2 sets of inter-rater reliability tests were conducted, along with 2 Cohen's Kappa tests to assess the errors made and monitor improvement among the rater through the new manual and the tests.

One of the other big problems encountered were severe lack of road crash data and information on fatalities and victims, which limited this research and hindered further analysis of crash rates and trends over the years. Lack of road data is mainly due to the devastating earthquake that occurred on January 12, 2010 wiping out almost all data sources across Haiti. In addition to this, there is no adequate AADT data available, barring a small section of road between Domond and Cange, which makes it difficult to assess the traffic situation along National Route 3. Another big issue hindering road safety development is lack of road safety awareness among the locals. Interviews conducted with various locals indicated that most of the people are unaware of the basic road safety guidelines, including inadequate implementation of safety laws in the country. Insufficient equipment for blood-alcohol checks, inadequate road signs, speed limits (barring some communities) and lack of effective first aid are some of the other challenges that Haiti and its people are facing currently. In cases of crashes and injuries, lack of trauma and post-crash assistance contributes towards amplifying this problem in Haiti. All these challenges and issues are hindering the nation's progress towards a safer nation and most importantly, sustaining itself economically. This research along National Route 3 attempts to find solutions to some of the problems in Haiti, expand the analysis to other National Routes throughout Haiti, and create road safety awareness programs for the Haitians.

Lack of crash data in Haiti has hindered in-depth analysis of the road and safety situation, however efforts are on to acquire effective data on road and traffic conditions through other alternative means. Surveys involving people living near road sections could be a good way of knowing about crashes and fatalities they might have come across. Based on different visual cues, possible crash sites can be located and mapped on GIS to get a better understanding of where crashes occur the most, although this data might not be very accurate as there could be human errors involved. Other data collection methods for crashes could be installing cameras at important and busy junctions and intersections with high traffic volumes and also in and around certain communities with schools located to compare crash rates. This could be useful in obtaining real-time footage of traffic and observe road related incidents and their frequencies. There have been many NGOs working and making surveys on the road safety condition in Haiti, and connecting with such organizations to help make roads in Haiti safer would be a great initiative in future. Another effective means for data collection could be sending out interns and/or hiring locals in Haiti to observe and make notes of accidents and crashes at specific locations in different areas with varying traffic flow rates.

APPENDIX

iRAP – International Road Assessment Programme

CEDC – Clemson Engineers for Developing Countries

FPZ – Faculty of Transport and Traffic Sciences, University of Zagreb, Croatia

IRR – Inter-Rater Reliability Test

1. **Equipment Setup and Data Collection Steps:**

    i. The Bluetooth GPS and the GoPro camera were wirelessly connected to the Android Tablet using a data collection app called PIP Video Kit. Once the camera and GPS were turned on and paired with the tablet's Bluetooth service, PIP video kit automatically detects these two devices and connects them together to collect real-time video of road sections with coordinates.

    ii. To collect data, a project file is created within the app and automatically saved. This saved project can opened any number of times to collect data along a particular road section.

    iii. The camera is fixed on the inside part of the front mirror of a vehicle, with the GPS device placed on the dashboard, while the app begins recording video data as the vehicle moves ahead.

    iv. Video recording can be stopped by tapping on the 'End video' button on the app, and the data is saved automatically, as soon the entire project route is covered.

    v. The video data along with coordinates are then extracted using the 'extract data' feature within the app, which produces excel sheets of location coordinates in addition to the video files.

    vi. The data is then transferred through a secured FTP managed by iRAP, upon which the data is uploaded into FPZ for analysis.

    vii. The first step in data processing is creating road centerlines in FPZ. This is done by using the 'add line' feature in FPZ under the 'Roads-Edit' tab. The video files are already embedded along the project route and they are indicated by dotted lines along the route in FPZ. Road centerlines are created along the video data lines, from the project start point to the end point.

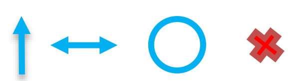
viii. After creating the road centerlines, they are segmented and divided into different sections, in 10m segments. Segments are assigned using the 'Assign segments' feature in FPZ which pops up when a particular road section is selected. The road sections were divided into 8 segments, each with unique attributes.

ix. Under 'Data' tab, the roads are highlighted in blue. The road sections were named as National Route 3- Road 1 to Road 8, respectively. From the search bar, each road section can be found by typing in the name. This feature was used to open each road section and the video project attached to them to start the road coding process. A new window pops up when 'open project' is selected, with an array of coding buttons with a window with the video at the center for a particular road section. A total of 52 road attributes were coded for each road section, using the different attribute categories available in the coding window, under the 'star' tab. The coded values are recorded simultaneously on the right pane of the window with each passing segment.

2. **iRAP Coding Training Module and Steps:**

Key:

Incorrect code value indicators



Correct code value indicators

A#: Attribute number, in figures

Attribute 1: Roadside Severity

Roadside Severity Hierarchy (in descending Order of Severity, as per iRAP Coding Manual):

- Cliff
- Tree >= 10 cm dia.
- Sign, post, pole >= 10 cm dia.

- Unprotected safety barrier end
- Aggressive vertical face
- Upwards slope- Rollover gradient
- Deep drainage ditch
- Downwards slope
- Large boulders >= 20 cm high
- Non-Frangible structure- Rigid structure/bridge or building
- Frangible structure- Semi-rigid structure or building
- Safety barrier- metal
- Safety barrier- wire rope
- Safety barrier- motorcycle friendly
- Upwards slope- No rollover gradient
- No object- within 20 m of the roadside

Attribute 1: Roadside Severity

Driver Side- Scene 1: Segment 185917

Incorrect attribute code: Frangible Structure

Correct attribute code: Non-Frangible Structure

(Vehicles can hit the beginning of stone wall frontally)

Driver Side- Scene 2: Segment 185918

Incorrect attribute code: Frangible Structure

Correct attribute code: Deep Drainage Ditch

(Present in front of the wall)

Passenger Side- Scene 3: Segment 185990

Incorrect attribute code: No Roll ✗

Correct attribute code: Aggressive Vertical Face ✓

(Rockface present)

Passenger Side- Scene 4: Segment 186196

Incorrect attribute code: Non-Frangible Structure ✗

Correct attribute code: Tree (>=10cm dia.) ✓

(Tree present, 5-10m from edgeline)

Passenger Side- Scene 5: Segment 186345

Incorrect attribute code: Tree ✗

Correct attribute code: Cliff ✓

(Cliff present along the road, more dangerous than a tree- as per order of severity)

Passenger Side- Scene 6: Segment 185962

Incorrect attribute code: Deep Drainage Ditch ✗

Correct attribute code: Tree (>=10cm dia.) ✓

(Tree present, 1-5m from edgeline)

Attribute 2: Pedestrian Observed Flow

Driver Side- Scene 1: Segments- 185960-185969 (10)

Driver Side- Scene 1: Segments- 185960-185969 (10)
(Contd.)

Incorrect attribute code: None ✗

Correct attribute code: 1 ✓

[1 Pedestrian observed within 100m (10 road segments)- coded from each '0' to '9'th segment]

Passenger Side- Scene 2: Segments- 189270-189279 (10)

Passenger Side- Scene 2: Segments- 189270-189279 (10)
(Contd.)

Incorrect attribute code: 2 to 3 ✖

Correct attribute code: 1 ✔

[1 Pedestrian observed within 100m (10 road segments)- coded from each '0' to '9'th segment]

Attribute 3: Motorcycle Observed Flow

Scene 1: Segments- 188950-188959 (10)

Scene 1: Segments- 188950-188959 (10)
(Contd.)

Incorrect attribute code: 1 ✗

Correct attribute code: 2 to 3 ✓

[2 Motorcycles observed within 100m (10 road segments)- coded from each '0' to '9'th segment
Do NOT consider parked motorcycles]

*NOTE: if a particular pedestrian or motorcycle was counted in one segment of the video or in one image, and if the same person or motorcycle appears in the next segment of the video or image, do NOT count them again.

Attribute 4: Speed Limits

Scene 1: Segment 188017

Incorrect attribute code: Speed Limit 40, Motorcycle and Truck Speed Limit not coded, Differential Speed Limit attribute not coded ✗

Correct attribute code: Speed Limit 40, Motorcycle Speed Limit 40 and Truck Speed Limit 40, Differential Speed Limit- Not Present ✓

(All Speed Limit groups should be coded)

Attribute 5: Lane Width

Scene 1: Segment 186392

Incorrect attribute code: Narrow (>=0m to <2.75m) ✗

Correct attribute code: Medium (>=2.75m to <3.25m) ✓

Attribute 6: Road Condition

Scene 1: Segment 188956

Incorrect attribute code: Medium ✖

Correct attribute code: Good ✔

(Very few or no visible defects on road)

Scene 2: Segment 189458

Incorrect attribute code: Medium ✖

Correct attribute code: Poor ✔

(Serious defects on road, more likelihood of unpredictable impact on vehicle control)

Attribute 7: Skid Resistance/Grip

Scene 1: Segment 189467

Incorrect attribute code: Sealed- Adequate ✗

Correct attribute code: Sealed- Medium ✓

(Smooth and shiny surfaces visible, some loose gravel/other materials present for up to 20%)

Attribute 8: Land Use

Scene 1: Segment 185947

Incorrect attribute code: Driver Side- Residential
Passenger Side- Commercial ✗

Correct attribute code: Driver Side- Undeveloped Areas
Passenger Side- Residential ✓

Scene 2: Segment 189004

Incorrect attribute code: Driver Side- Undeveloped Areas
Passenger Side- Commercial

Correct attribute code: Driver Side- Industrial and Manufacturing
Passenger Side- Residential

Attribute 9: Upgrade Cost

Scene 1: Segment 185947

Incorrect attribute code: Medium

Correct attribute code: High

(High cost of major works for adding a feature like additional lane, depending on surrounding environment)

Attribute 10: Delineation

Scene 1: Segment 186309

Incorrect attribute code: Adequate ✖

Correct attribute code: Poor ✔

(Central and edge lines are not visible, so delineation quality is poor)

Attribute 11: Paved Shoulder Width

Scene 1: Segment 189473

Incorrect attribute code: Driver Side- Narrow (>=0m to <1m) Passenger Side- None ✖

Correct attribute code: Driver Side- None Passenger Side- Narrow (>=0m to <1m) ✔

(There is no paved shoulder on the driver side. There is a narrow paved shoulder on the passenger side with edgeline present)

Attribute 12: Property Access Points

Scene 1: Segment 189186

Incorrect attribute code: None ✖

Correct attribute code: Residential Access 1 or 2 ✔

(Low-flow tracks/access points for residential properties present. Do NOT include points where vehicles cannot enter or exit the roadway)
(10 road segments- coded from each '0' to '9'th segment)

Scene 2: Segment 185973

Incorrect attribute code: None ✖

Correct attribute code: Residential Access 1 or 2 ✔
Or, Residential Access 3+

(Low-flow tracks/access points for residential properties present. Do NOT include points where vehicles cannot enter or exit the roadway)
(10 road segments- coded from each '0' to '9'th segment)

Attribute 13: Sidewalks

Scene 1: Segment 189186

Incorrect attribute code: Driver Side- 0-1 (Non-physical separation)
Passenger Side- 0-1 (Non-physical separation)

Correct attribute code: Driver Side- None
Passenger Side- None

(No sidewalks present on either side of the road)

Scene 2: Segment 188019

Incorrect attribute code: Driver Side- 1-3 (Non-physical separation)
Passenger Side- 1-3 (Non-physical separation)

Correct attribute code: Driver Side- 0-1 (Non-physical separation)
Passenger Side- 0-1 (Non-physical separation)

(Sidewalks present on either side of the road, 0-1m from the road edge, NOT the width of the sidewalk)

Attribute 14: Traffic Calming/Speed Management

Scene 1: Segment 189443

Incorrect attribute code: Not Present

Correct attribute code: Present

(Speed bump present)

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