

Analysis of Road Traffic Accident Related of Geometric Design Parameters in Alamata-Mehoni- Hewane Section

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Abstract— Geometric design deficiencies on existing roads would lead to a potential accident, such as an accident happens at the sharp curves, layered pavement conditions, and slippery pavement surface. Road traffic accident has been increasing in the Southern Region of Tigray, of which this area was shown to have alarming rates. According to the Southern Tigray Regional Police, the high figure of road traffic accidents was recorded in Alamata, Mehoni and Hewane districts. This research study focused on the analysis of traffic accidents related to geometric design parameters of the existing asphalt road. While the data for the analysis covered route data, traffic accident report from the police station containing some injuries, crashes, and damage to properties, as well as interviews and questionnaire surveys to people who are directly involved in road travels, are considered. The primary data have mainly covered the geometry of the road which was measured during the site survey, road safety audit using the checklist, interview, and questionnaire survey. On the other hand, the secondary data collected from the traffic management office in the district offices. On this, the results presented in the form of line graphs, pie charts, figures for road traffic accident and sketch for the suggested improvement in the road design problem. Based on the results of the study in the year 2010 to the year 2015, it found out that there were 866 Road Traffic Accidents have been occurring in the vicinity of the survey road sections. From this figure, the road traffic accident and damaged to properties expressed as an equivalent amount of about 33,565,122.00 Birr. It revealed that the primary cause of road traffic accidents in the study area emanated from the road design elements due to some geometric deficiencies at the traffic accident prone areas. Therefore, this study concluded that the frequency of occurrence of road traffic accidents and the figure of casualties is significantly increasing. This road accident would persist if the concerned agencies do not adequately address the malady.

Index Terms— Asphalt Road, Casualties, Geometric design parameters, Road design elements, Road safety audit, Traffic Accident, Traffic management.

1 INTRODUCTION

Road traffic accidents, deaths, and injuries occur worldwide. The estimated figure comprised of about over 1.2 million people died each year on the world roads as a consequence of road traffic accidents. According to the study by WHO, more than 3,200 people get dead and over 130 000 injured in traffic every day around the globe. Besides, nearly half of all fatal accidents involve pedestrians, cyclists, and power two wheelers collectively called vulnerable road users [1]. When considering the population figures into account, developing nations in Sub-Saharan Africa bears the highest frequency of various accidents worldwide [2].

Currently, developing countries contribute to over 90% of the world's road traffic fatalities and overall road injury, disability-adjusted life year (DALYs) increased by 2.5% between 1990 and 2010, with pedestrian injury DALYs increasing by 12.9%, more than any other category [3]. In Africa over 80% of commodities and people are transported by roads while in Ethiopia road transport accounts for over 90% of all the interurban freight and passenger movements in the nation [4]. Road traffic crashes pose a substantial burden in Ethiopia, as is the case for other developing countries' because Ethiopia was one of the developing countries in the world and road is the major transport scheme. Car ownership has grown rapidly at approximately 7.0% per annum on average [5].

A post-crash approach was the method used in this paper to determine the relationships between road geometry parameters and crash rate. Furthermore, the analysis examines the cases of collapses that most influenced by the critical road parameters. The road traffic accident hazard is believed to be much higher than the indicated statistics by the traffic police record because of under-reporting. The report of road traffic accident showed the occurrence of correct frequency in the study area was high from the other districts. The survey tracked the major road of Addis Ababa to Mekelle passing the three districts of Alamata, Mehoni and Hewane. The length of the path is about 116.24km. In addition to the traffic accident related to geometric design, this project also focused on assessing the general characteristics of road traffic accident, major causes and factors contributory to traffic accidents, its effect, and its countermeasures to reduce the severity of road traffic accident.

In Ethiopia, road traffic accident is a perennial problem, specifically in Alamata-Mehoni-Hewane road section. This incidence has long been affected the people and damages vast amount of property threatening the social - economic impact to the surrounding region in the country. In this research study, it was set out to assess the road traffic accident spatially and temporally considering its relevance to

planners, policy makers, stakeholders and the community as a whole. □

Therefore; the research had been used differently engineering techniques and design to ensure the geometric design and construction of road safety would become reliable.

2 RESEARCH METHODOLOGY

2.1 Study Area

The study area is located in the Southern Zone of Tigray Regional State in Northern Ethiopia, about 783 kilometers north of the capital Addis Ababa. The entire distance of the asphalt road is approximately 119.24 kilometers. The terrain features of the area are mountainous and escarpment. The road sections under the study, traverse three districts namely, Alamata Mehoni Hewane, a road from the main route between Addis Ababa and Mekelle consisting of a two-lane two-way highway.

2.2 Sample size & sampling technique

The sample size was gathered using purposive sampling. The area which is very vulnerable to the traffic accident, characterized by dense vehicle, pedestrian movement, mountainous and Escarpment terrain characteristic, road design problem, and improper construction of roads.

The purposive sampling has been used different techniques and procedures to fulfill the objective of the research. The various methods are used:

- The general characteristics of road traffic accident using post road traffic accident data from a southern zone and selected district, which rated off road traffic accident. □
- After selecting the location which was vulnerable by the road accident, interview, and distribution of the questioner, for the driver, pedestrian and traffic police were undertaken randomly.
- During the site survey, recording of the existing road geometric design elements were conducted to compare with the Ethiopian Road Authority Standard. The study concentrated on the issue of the road geometric design element on road traffic accident. These high concentrations of activities along the main roads resulted in a large number of road traffic accidents. Thus, accidents on the highways related to geometric design elements are critical issues of concern in this research study.

2.3 Data Collection Methods

The traffic accident data provided by the traffic police office, only the rural road from 2010-2015 collected from the Tigray Region Traffic Police of the three districts (i.e., Alamata Mehoni and crash). The main Road Traffic Accident (RTA)

input data collected from the daily records file in the Tigray Region Traffic Office which includes the following variables.

- Accident reason
- Accident type
- Accident year
- Estimated accident cost in Birr



Figure 2.1 Observations on Existing Road and Interview Survey

2.4 Methods of Data Analysis

The accident features were analyzed using variables for hazardous road selection criteria along with collected geometrical features and environmental factors through literature review.

2.4.1 Road Traffic Accident Data

Road traffic accident data, which are classified into four degrees of severity (i.e. Fatal, serious, slight, and damage to properties) obtained from the Traffic Police Department. From here, the number of casualties was into three degrees of severity such as the fatality, serious injury, and slight injury. The data collection format was developed in an Excel document which enables the researcher to collect, separate and edit the required variables for the survey. Traffic accident data was processed using descriptive statistics like tables, graphs, and figures to show variations of traffic accidents by year. These data served as the method to know the characteristics of the accidents.

2.4.2 Road Geometric Data

The factors investigated in the geometric design of existing road, include cross-sectional elements, such as road condition, road environment and checking the road geometry (e.g. Road cross-sectional features like width of road, width of shoulder, road barrier, width of median, sight distance, road marking, road light), horizontal and vertical curves. It was done using Safety Audit Checklist of Existing Road of Ethiopian Road Authority Standard. All data obtained from the field observations recorded on the Safety Audit Checklists and

forms prepared in a particular format as illustrated in the subsequent sections. Below are the instances of some features noted during the field survey.

- Locations in which shoulder widths are inadequate
- Markings that are not in existence or in a compound condition (i.e. Old and new markings mix each other)
- Problematic roadside zones include delicate features which can create particular danger within the clear zone width (i.e. Trees, utility poles).
- Improper placement of the bus stops and Nonprovisional of guardrail at curved sections
- Improper information signs, design median and drainage structures.

Audit on existing roads started after certain information about the road sections are obtained and inspected for both traffic directions. However, one project site was not enough to collect audit information and its evaluation. Two or more auditing studies had been conducted, while at least one survey was taken at night time to gather sufficient data for the research study.

3 RESULTS AND DISCUSSION

3.1 General Characteristics of RTA in Alamata-Mehoni- Helene Road Section

The occurrence of Road Traffic Accident (RTA) within the study area significantly increased at alarming rates. According to Region Traffic Police commutation report, from The year 2010 to 2015, Alamata-Mehoni exhibited the occurrence of spatially identified road traffic accident unevenly distributed throughout the rural and suburban area administration.

Table 3.1: Variations of Road Traffic Accident Frequency

District	Road Traffic Accident per Year						Total	(%) Share
	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15		
Alamata	35	36	51	45	28	62	257	27
Mehoni	47	49	65	49	43	61	314	33
Hewane	51	54	67	70	45	87	374	40
Total	133	139	183	164	116	210	945	100

A comparison was made based on the road traffic accident occurrences between the three districts of Alamata, Mehoni and Hewane. Based on the findings of this research study, Hewane district has dominated the event of accident among the districts as shown in Table 3.1. There were 374 (40%) out of 945 accidents occurred in Hewane and its extension from 2010/11 to 2014/15. Mehoni and Alamata districts had shared 314 (33%) and 257 (27%) of accidents during the study period, respectively. The road safety audit report revealed that the

most vulnerable area of road traffic accidents happened in the mountainous and escarpment due to road design problems such as insufficient sight distance, sharp curve, missing narrow lane and shoulder, deficient and damaged road pavement marking.

3.1.1 Variations of RTA by Severity Classes in Alamata-Mehoni - Hewane Road Section

This method called for listing each accident occurring at a site under one of the following Severity levels: Fatal accident, Serious injury, Slight Injury, and Property Damage (PD). Based on the road traffic accident police report in 2010-2015, the percentage distribution of severity class comprised of about 22.8% of the fatal accident, 18.6% serious injury, 13.8% slight injury, and 44.6% property damage, respectively (Table 3.2).

Table 3. 2: Reported Road Traffic Accidents by Severity Class (2010-2015)

Severity Class	Total Road Traffic Accidents						Total	(%) Share
	2010	2011	2012	2013	2014	2015		
Fatal Accident	16	22	36	31	45	75	225	22.8
Serious Injury	28	10	29	32	30	55	184	18.6
Slight Injury	62	17	16	8	23	10	136	13.8
Property Damage	62	68	46	52	55	157	440	44.6
Total	168	117	127	123	153	297	985	100

3.1.2 Property Damaged and RTA in Alamata, Mehoni and Hewane Districts

Some of the impacts of road traffic accidents had a direct economic effect when it was over a property together with the indirect influence to the pedestrians, animal, and the motorists passing through the route. The estimated total cost of road traffic accidents in the three districts from The year 2010 to 2015, have been reached to 41,199,330.00 Birr as shown in Table 3.3. The highest estimated cost has been recorded at 1,175, 6330 Birr (31%) in 2015 while the lowest was 2,857,065.00 Birr (7.5%) in 2011. It means the three districts have lost 41,199,330 Birr in the last five years due to road traffic accidents. Out of 1,275 road traffic accidents occurred in the previous five years, 954 (74.8%) of the accidents have been accompanied with property damage.

Table 3.3: Estimated cost of Road Traffic Accident in Alamata-Mehoni-Hewane Road sections (2008 -2011)

Accident Year	Number Of Accident Resulting Property Damage	RTA Estimated cost (ETB)	%
2010	159	7109800	18.7
2011	68	2857065	7.5
2012	52	3299229	8.7
2013	72	3064199	8.1
2014	81	13112707	26.0
2015	123	11756330	31.0
Total	555	41199330	100.0



Figure 3.1 Damaged to Property

Source: District traffic office (2015)

3.1.3 Spatial Variation of Road Traffic Accidents

Road traffic accidents are usually taking place in urban and rural areas while their distribution is subject to fluctuation, even if there are places where the accidents often happen times. The type of accidents was highly correlated with the type of itineraries and the nature of user actions.

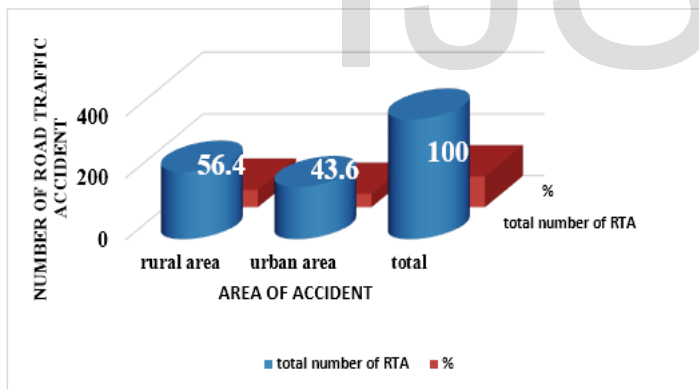


Figure 3.2: Number of RTA within rural & urban areas

Source: District Traffic Offices (2015)

Figure 3.2 showed that the rural area composed of about 56.40% road traffic accident slightly higher than the crash happened in the urban area. This accident was due to some factors such as the section of the roads are almost escarpment and mountainous terrain, narrow road right of way, deficient lane width, eroded shoulder, pavement markings not visible, over speeding and overloading. On the other hand, the traffic accident in the urban area of about 43.6% caused by the too narrow lane width, missing road sign like zebra, ignoring pedestrians and animals, and improper locations by opening roadway medians.

3.1.4 Temporal variation of Road Traffic Accidents (RTA)

The occurrence of road traffic accidents (RTA) may vary within 24 hours of the day. As discussed in the previous sections, different factors like geometric element the availability of light, road pavement marking and road signs, terrain characteristics of the road and the number of pedestrians and animals, would represent a greater impact in the variance of RTA distribution within the day.

The period between 12:00 PM to 6:00 PM revealed the largest proportion of 38% of all the RTA incidents in three districts between the Years 2010 to 2015. The frequency of occurrence of RTAs in the same period exhibited a dramatic increase in figures. In contrast, the time between 12:00 AM to 6:00 AM has contributed only 22% of road traffic accidents based on the records obtained from the three districts. Road traffic accidents in Alamata, Mehoni and Hewane have frequently happened in the night time than in the daylight time (i.e. 12:00 PM to 6:00 PM and 12:00 AM to 6:00 AM). This phenomenon is evident mainly due to the terrain characteristics such as escarpment, sharp curves, steep grades, and insufficient sight distances affecting road safety at night time travel.

3.2 Major Causes of Road Traffic Accident (RTA) in Alamata-Mehoni -Hewane Road Section

Ethiopian traffic police were responsible for completing the road accident data. An accident code developed that contains 30 possible causes of accidents categorized such as drivers, pedestrians, vehicles and road defects. In the figure below, it shows the principal reasons for all accidents that linked to road defects which include alignment effect, cross-sectional effect, and construction of roads. These were considered to be the major road deficiencies causing the majority of the accidents of 47.3% in the three districts.

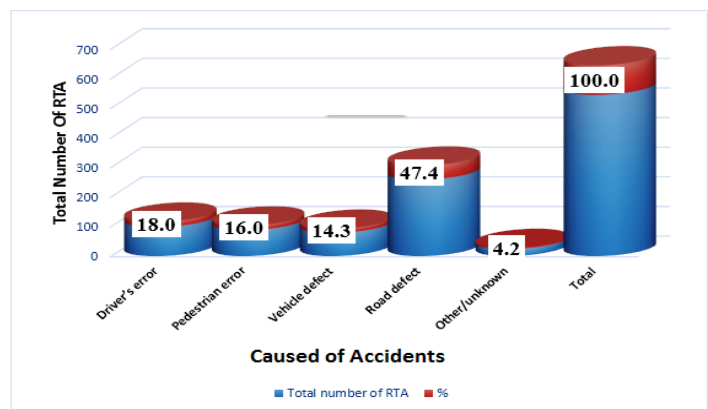


Figure 3.3: Main causes of accidents

Source: District Traffic Offices (2015)

Table 3.4: Detailed Causes of Traffic Accident

Accident Reason	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	Total	%
Missing	15	34	26	35	54	23	187	12.6
Brake Failure	10	7	5	15	3	34	74	5.0
Failing To Give Way To A Pedestrian	23	24	34	12	23	23	139	9.3
Speeding	20	43	12	54	43	25	197	13.2
Unsafe Loading	13	20	18	14	23	15	103	6.9
Failure To Respect The Right-Hand Rule	27	37	25	34	35	10	168	11.3
Lack Of Experience	34	35	10	8	11	19	117	7.9
Road Defect	47	70	89	101	97	101	505	33.9
Total	189	270	219	273	289	250	1490	100.0

Source: District Traffic Office (2010-2015)

In Table 3.4 shows the different causes of road traffic accident. These crash reasons are the failure to give way for vehicles, speed driving, and failure to give way to pedestrians, road defects, improper turning and failure to respect the right-hand rule had been the leading causes of RTAs in Alamata Mehoni Hewane road in the study period. Road defect was calculated to have 33.90% indicating the road traffic accidents in the mainly characterized sections of the study area.

This incident resulted in a significant property damage and severe consequences in the life of Alamata, Mehoni, Hewane district areas. In addition to this, information collected from some Traffic officers (respondents in this study) has added that road defects, narrow lane width, insufficient sight distances, little awareness of the people nearby about road traffic accidents were the leading causes of accident's occurrences on the road. Also, the traffic officers have further identified other problems like lack of road traffic lights, the insufficient number of road traffic signals, limited numbers, and width of side walkways and inferior quality of the roads had played a critical role in aggravating the occurrence of traffic accidents along the route.

3.3 Effects of existing road geometric design element of the path traffic accident

Existing road geometric design elements which lead to potential accidents, such as curve is too sharp, layered conditions, road pavement that does not meet the minimum requirements (i.e., Too slippery surface) is contributory to the cause of the road traffic accidents in the study area.

3.3.1 Characteristic of Geometric Design Element on Road Traffic Accident

Figure 3.4 presented vehicle collision distributions by roadway alignment. There were 32% collisions occurred in escarpment sections and similarly 24 % at a tangent, 22% of the mountainous terrain, 12% of the rural area and 10% of the urban area. This incidence revealed that the highest collision was happening in the escarpment and followed at the tangent section. Mountain sections were composed of many curves and gradient, which makes difficult to provide a sufficient

road right of way and cut the grade at the desired level. To this point, it has also affected the sharp curves which tend to restrict sight distances and the required superelevation.

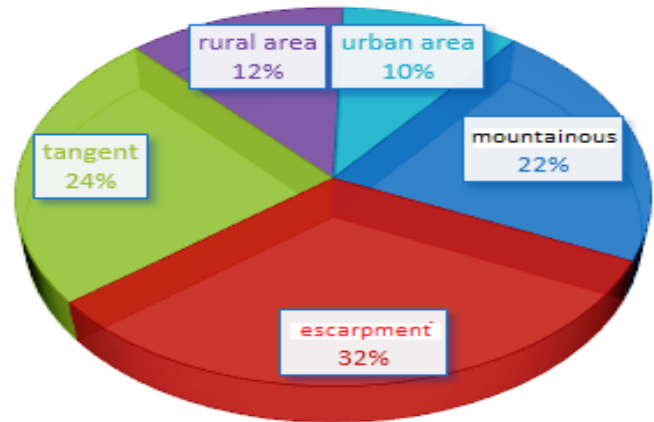


Figure 3.4: Vehicle collision by roadway alignment

3.3.2 Observed effects of existing geometric design parameters on Road Traffic Accidents

A field survey in the study area was conducted for the purpose of determining the general characteristics of road traffic accident, verify the effect of road geometric design elements and for further evaluation. All of the problems, deficiencies, and the hazards recorded on the checklist.

The list categorized under two main headings. One was road design problem, danger, while the one was the roadside problem risk. When conducting the road safety audit, the safety problems were categorized under these two main headings and recorded accordingly to the respective portion of the checklist

Table 3.5: Road design problem checklist during site visit

A. Road Design Problem	
No.	Observed (Hazard)
1	Shoulder missing
2	Carriageway too narrow
3	Narrow road right of way
4	Shoulder too narrow
5	Improper median opening
6	Limited sight distance
7	Improper pedestrian crossing
8	Too small radius of horizontal curve (Sharp curve)
9	Asphalt defects
10	Improper drain
11	Missing Road Marking
12	Dismantling road signs, No inventory of speed control

Table 3.6: Roadside problem checklist during site visit

B Roadside Hazard	
Number	Observed roadside problem
1	Temporary narrow bridge
2	Missing guardrails
3	Improper culvert design on the roadside
4	Improper bus stop location
5	Missing sign boards

Based on the field survey, it observed that the roads within the three districts jurisdiction were improperly designed such as no provision of road shoulder in case of an emergency situation to be used by vehicles, insufficient sight distances, narrow lane width, limited road right of way, and too sharp curves. In addition to this, the road signs are not installed in the appropriate locations, and most signboards have been thoroughly worn out. Another thing, the horizontal and vertical alignments were not suitable for the design speed of vehicles. Some sections of the pavement surface traced with old patched, and potholes of varying dimensions were believed to be the main contributory of the dramatic increase in traffic accidents.

3.3.3 Comparison with the Standard

The existing geometric dimension of the cross sectional elements of the audit road has been measured and compared with Era Geometric Highway Design Manual (Two-Lane Rural road DC4 Paved) Highway as presented in Table 3.7 below.

Table 3.7 Observed values compared with ERA Standard

No.	Roadway Element	ERA Standard Values	Observed Values
1	Design speed	25-70km/hr depending on terrain	100km/hr
2	Number of lanes	2 lanes	2 lanes
3	Carriageway width	6.5-7m	3-4m
4	Shoulder width	0.5-1.25m depending on the terrain	0.0-1m
5	Roadside clear zone	9m	0.0-9m
6	Minimum bridge clearance	100m	50-70m
7	Bridge width	At least full approach travelledway width or plus 0.6m clearance on each side	2/3 of travelledway width
8	Alignment	Adequate & amooth flowing alignment	Poor alignment
9	Pedestrian crossing	Controlled	Uncontrolled

3.3.4 Safety Audit Checklist of Existing Road

Tables 3.8 below shows the safety audit checklist, with entirely the field observations recorded during the site survey of the asphalt road from Alamata, Mehoni and Hewane road.

Table 3.8: Observed road design problem

Road Location	Observed road design problem Hazard	Comments
1. Alamata District	Missing shoulder, narrow bridge, and right of way ⊗	Dangerous to road users
	Missing shoulder	Increases accident potential
	Dismantling of road marking	
	Improper median opening	Reduces roadway capacity
	Narrow right of way	
	Dangerous pedestrian crossing	Increases accident potential
	Missing of shoulder and narrow right of way	Reduces roadway capacity
Missing road sign	Increases accident potential	
2. Mehoni to Hewane	Missing sign and insufficient sight distance	Reduces road capacity ⊗
	Road signs inventory	Dangerous to road users
	No speed limit	
	Improper median opening	Reduces roadway capacity
3. Hewane to Adikeyih	Dangerous guardrail start and end	Dangerous to road users
	Missing road marking and light	Dangerous to road users
	Insufficient sight distance	Reduce roadway capacity
	Road sign and marking	Dangerous to road users
	Asphalt pavement damage	Dangerous to road users
	Critical fixed objection on the roadway, Insufficient sight distance⊗	Dangerous to road users

The above table illustrates the problem related to road design elements on RTA. This shows the road design elements do not affect the motorist's operational capability on road travel, but merely on the condition of the road. It is varied with the location and terrain features. Based on the data gathered in Alamata district, the effect of road design element which increases the potential of an accident is due to the missing shoulder, narrow lane width, limited road right of way and road sign markings. While the urban sections of Mehoni to Hewane, there were an improper opening of medians, poor

road marking and signs, narrow lane width, missing shoulder width, insufficient sight distance, the absence of lightings.

3.3.5 General Crash Situations and Potential Countermeasures

After a field survey conducted, the observation time compared to ERA Standards. Accordingly, the possible countermeasures are proposed for identifying the road design problems on the hazardous locations.

Table 3.9: General crash situations and potential countermeasures

General Crash Situations (Pedestrian/Vehicle Conflicts)	Possible Countermeasures or Suggested Improvement (Pedestrian/Vehicle Segregation)
<input type="checkbox"/> Loss control	<input type="checkbox"/> Road markings, delineation, speed control device
<input type="checkbox"/> Narrow Bridge	<input type="checkbox"/> Bridge widening
<input type="checkbox"/> Sharp curves	<input type="checkbox"/> Increase the curve radius
<input type="checkbox"/> Limited road right of way	<input type="checkbox"/> Acquire additional road right of way
<input type="checkbox"/> Carriageway too narrow	<input type="checkbox"/> Minimize median width
<input type="checkbox"/> Poor visibility or limited sight distance	<input type="checkbox"/> Proper provision of sight distance
<input type="checkbox"/> Over speeding	<input type="checkbox"/> Provide speed limit

4 CONCLUSION

This research study carried out two critical data, one was road geometric, and the other was a road traffic accident. These data are used to describe the general characteristics of the road traffic accidents, identify the major causes using the collected road traffic accident, and to verify from a wide range of road geometric design elements and its effect on the motorists. Road safety audit on existing roads was conducted using ERA standard checklists to collect factual data in the project area.

Based on the results and discussion, the survey demonstrated that the frequency and occurrence of road traffic accidents in study area revealed dramatic variations because of the impact of various factors such as temporal variation (i.e. Hourly, daily,) alignment effect (i.e. Tangent, mountainous and escarpment areas), driver characteristics. Therefore, the road traffic accidents randomly dispersed in the field of study in terms of time and place.

On the other hand, the primary causes of road traffic accidents based on the traffic police reports and vital information from the pedestrians, car drivers, and traffic officers through questionnaire surveys and interviews; are: road design problems over speeding, failure to give way to vehicles and pedestrians, overtaking in winding horizontal curves, improper turning movements, inability to respect the right-hand rule contributed much to the misery of road crashes in the study area.

Some safety defects observed during the conduct of safety audit such as non-compliance with the typical features of ERA road geometric manual. It can be mentioned a problem on road design elements and improper road construction due to inadequate sight distances, a narrow right of way, shoulder carriageway, improper median opening, not properly position guardrails, deteriorated pavement surface, sharp curves, and no lightings at urban areas in Hewane and Adikeyih road sections. The realization of road safety audits on existing roads has been considered to have great support and guidance for building road safely and improving existing or potential accident which is found to be hazardous locations.

In the study area, there were lack of adequate and proper record of accident data. These data that encompasses along the road sections are the crash severity class (i.e. Fatality, serious injury, minor injury and property damage), accident year, time of occurrence, type of vehicles involved, reasons or accident contributing factors, and the termination of the collision. About this, there was a big problem to identify black spot locations which hinder or limits the possibility of this research study to analyze the accident data and to realize either these hazards were among the crash contributing factors or not, and to pinpoint each risk as traffic related accidents.

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