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Identifying the Hot Spot Areas of Road Traffic Accidents

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ABSTRACT

The road traffic accident is caused by several factors associated with the traffic system: road users, road environment and vehicles. This study was carried out to analyze the road traffic accidents by applying GIS to identify hot spot sites of road traffic accidents along Bahir Dar to Gondar road. The accident data for the years 2008-2011 were collected from pertinent police stations along the routes. A total of 460 reported accidents were collected. Google Earth and digital maps were used to fix accident locations. Twenty five accident hot spot sites were identified in traffic accident analysis using Kernel Density estimation method, a 10-m Lixel length and 50-m search width. Around Bahir Dar, on average, one hot spot site was found for 1.3 km road length. On the other hand, around Libokemkem, on average, one hot spot site was found for 38.1 km road length. This was the safest portion of the Bahir Dar to Gondar route. The findings have indicated that pedestrians were by far subjected to the highest number of casualties represented in killed or seriously injured persons, followed by passengers and drivers. The most productive age was more vulnerable to traffic accidents for the past three years

KEYWORDS: Road traffic accident, Hot spot site, Pedestrians, Passengers, Drivers.

INTRODUCTION

Transportation systems are designed to move people, goods and services efficiently, economically and safely from one place to another. Despite this, there are many accidents that are commonly encountered at a variety of spatial and temporal scales. The road transport safety is influenced by human factors (including driver ability, performance, knowledge and awareness), environmental factors and vehicle characteristics. The road design is another factor which also has a tangible impact on safety (AASHTO, 2004). But, the most important factors are driver behavior, vehicle characteristics and roadway design. The primary indicator used in ranking the severity of the road safety situation is the number of fatalities per 10,000 registered vehicles (Traffic Safety Bureau, 2005). In developing countries, accident number and type are mainly registered for the drivers to be the cause of accidents regardless of the real cause of the accident.

According to McCarthy (2001), small speed limit changes on non-limited-access roads will have a little effect on speed distribution and highway safety unless complemented with speed-reducing actions. Similarly, Mungnimit (2001) and Bener (2005) explored the pattern of road traffic accidents and their causes in developing countries. Results of their research showed that the major cause of traffic accidents was careless driving (71%). The majority of accident victims (53%)

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were among the most productive class in the society; i.e., age group 10 to 40 years. Road traffic accidents were the third leading cause of death after the diseases of the circulatory system and cancer.

Contributing factors associated with the driver include error, speeding, experience and blood-alcohol level (Osterom and Eriksson, 2002). Factors associated with the vehicle include its type, condition and center of gravity. Environmental factors include the quality of the infrastructure, weather and obstacles (Osterom and Eriksson, 2002). Dramatic increases in the proportion and absolute number of traffic facilities have been witnessed in a number of developing countries, while they decreased by more than 20% in industrialized nations (Ross et al., 1991). African and Asian countries, with relatively low vehicle densities, are experiencing substantially higher fatality rates per 10,000 vehicles than the industrialized European and North American States (Atubi, 2009b). Human error is estimated to account for between 64% and 95% of all causes of traffic crashes in developing countries (TRL, 1990; Atubi, 2009b). The road accident is caused by different factors, such as road geometry, congestion, weather condition… etc. One group of factors influencing accidents is the road geometry. Road geometry can directly influence the probability of an accident, but it can also be a cause of congestion which also influences the accident probability. Road geometry is, for instance, the length of weaving sections at on and off ramps, the number of lanes, the lane markings, the curvature of the road,… etc. (Knoop et al., 2008).

Similarly, World Health Organization (WHO) stated that over 1.2 million people die each year on the world's roads, and between 20 and 50 million people suffer non-fatal injuries (WHO, 2009).The report also assessed 178 countries and presented that low-income and middle-income countries have higher road traffic fatality rates than more developed countries. Over 90% of the world's fatalities on the roads occur in low-income and middle-income countries, which have only 48% of the world's registered vehicles (WHO, 2009). Road accidents appear to occur regularly at some flash points such as sharp bends, potholes and curved sections of the highways. At such points, overspeeding drivers usually find it difficult to control their vehicles, which then results in fatal and other types of traffic accidents (Atubi, 2009b).

Ethiopia with its 79 million (CSA, 2008) people living in a geographical extent of 1.1 million km^2 has a GDP of US $ 6.1 billion, 39% of which is contributed by agriculture, upon which 85% of the population are dependent for living. As per the UN Human Development Index (Estimates for 2010), Ethiopia is ranked 157^{th} and falls under low development country category, with an HDI of 0.328. Over the past 30 years, the *per capita* GDP of Ethiopia has grown from 190 to 398 (USD), while the population rise during this period was alarming (UNHDI, 2010).

Highlights of road traffic accident in Ethiopia depicted that, on average, more than 150 people per10,000 vehicles died due to road accidents in the years 1994 through 2003 (Ethiopia Ministry of Transport and Communication, 2003). The increase in population, motorization and road network expansion coupled with low-level of safety awareness have increased traffic accidents in the country. Researches confirmed that the main causes for these accidents were land use and human factors on road traffic accidents (Omojola, 2004). Pedestrians were other major causes of road accidents as stated by a hospital-based study by Dessie and Larson (1991) accounting for 91% of all traffic casualties in Mekelle.

There is no enough data in the relationship between road characteristics and road traffic accident severity in Ethiopia. However, according to federal police commission report, the death rate due to car accidents is significantly increasing among pedestrians and passengers from time to time in Ethiopia (FDROE, 2007). A total of 25,110 accidents and 3,415 fatalities were recorded in Addis Ababa, the capital, during 2000-2009. The majority of fatalities were pedestrians; 2970 (87%), followed by passengers; 297(9%) and drivers; 148(4%) (Yilma et al., 2010). Among the risky human behaviors is driving over the recommended speed and taking alcohol and driving (Waller et al., 1996; Gururaj et al., 2004). Knowledge, belief and attitude on risky driving behaviors as well as driving experience were also important aspects of risky behaviors identified with evidences (Deus, 2006; Hassen et al., 2011). The accident data obtained from the police report should be used to determine the accident hot spot sites. It is indicated that for the past three years (2008/9-2010/11), a total of 6805 traffic accidents were registered in the region. Shares in percent of the accidents for 2008/9, 2009/10 and 2010/11 were calculated as 30.6, 30.9 and 38.5, respectively. The traffic accident data showed that there was an increase in those shares from year to year in the region (Geurts and Wets, 2003).

Hence, there is a need to identify the hot spot areas along the road with high accidents so as to minimize the risks. Traditionally, traffic accident hot spot site analysis was carried out by different approaches such as: nodal analysis, analysis on link accidents, analysis by accident cost and kilometer-post analysis (Lim and Law, 2005; Nicholas et al., 2009). But, these methods lack exact point location coding systems which could help implement remedial measures from both individual and location level of accidents. The GIS technology can change the whole scope of the conventional techniques by visual dimensions to statistical analysis; GIS can be used for further analysis such as density and trend analysis of crashes. Such analysis can directly help planners understand the nature of the problems, facilitate better design and engineering solutions, and GIS can assist in the development of countermeasures in a short time.

The analysis of traffic accident information is an important element of road planning, analysis and design decisions. Accident information can be used to identify hot spot locations, to set priorities for safety improvements, to support economic analysis, to identify accident patterns and to inform research studies regarding traffic safety. Taking into account the above facts, this study was conducted to analyze traffic accidents by the application of GIS along Bahir Dar to Gondar road. The capability of GIS technology to process both spatial and non-spatial data offers the opportunity for location analysis (Longley et al., 2004; Ferreira et al., 2011). Precise location of data could help guide programs including maintenance, vehicle inspection, emergency medical services and engineering to improve streets and highways. Hence, the main objective of the study was to analyze traffic accidents along Bahir Dar-Gondar road to suggest solutions to the problems.

Study Area and Methodology

Study Area

The study area is a road which lies, from Bahir Dar to Gondar, at a bridge on the Blue Nile in Bahir Dar *(*$11^0$36′ 18″ N and 37 ^{0} 24′ 33″ E*)* to Dashen Beer factory in Gondar town, *(*$12^0$36′ 38″ N and 37^0 26′ 56″ E) with a total length of 155.2 km (Fig.1). To the west of the road, is the largest lake of the country, Lake Tana with an area of over 3,000 km^2. The Fogera plain is located to the east of the road, which is often flooded during the rainy seasons. Due to its diverse landscape, in the vicinity of the road, the area is known to have a wide variety of fauna and flora (ANRS and GEF, 2008).

The elevation of Bahir Dar to Gondar road varies from 1788 m above sea level at the Blue Nile bridge to 2163 m at Gate of Dashen Beer factory at Gondar. The road stretching from Bahir Dar to Addis Zemen is nearly flat land. The road from Addis Zemen to Gondar traverses mountains, gorges, valleys and small towns. This section of the road consists of main horizontal and vertical curves. Over half of the total area has slopes of less than 8 percent (ANRS and GEF, 2008). The road from Bahir Dar to Gondar traverses five districts (Bahir Dar, Dera, Fogera, Lobo- Kemkem and Gondar-Zuria). The districts are the most populated areas in the region, with an average family size of 4.9 person per household and a population density of 158 persons/km^2 which is higher than the regional average (113 person/km^2). Agriculture is the backbone of the regional economy (ANRS and GEF, 2008).

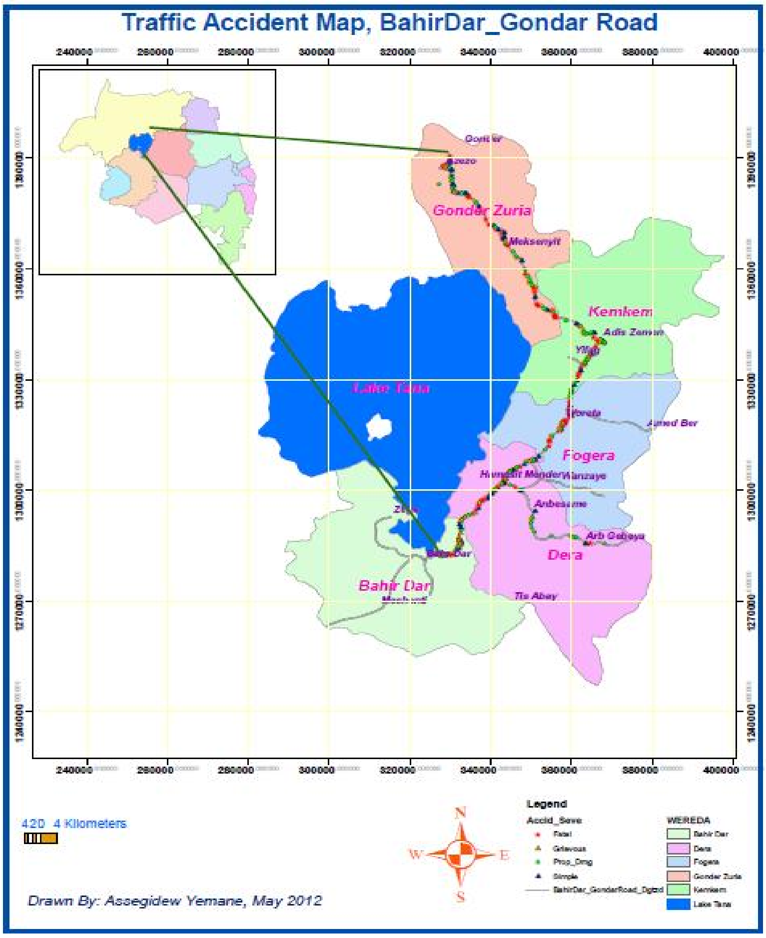

Figure (1): Map of the study area

Data Sources and Methods of Analysis

The methodology and procedure were based on both qualitative and quantitative methods and interviews and a review of secondary data. The concept model chosen for this study was Haddon's matrix (WHO, 2004; Thagesen, 1996). To determine hot spot sections of traffic accident sites, the past three years' data was investigated. A hot spot is a location or a small area within an identifiable boundary showing concentration of incidents (ESRI, 2010). During preliminary survey, it was noticed that police stations were used to keep road traffic accidents independently (apart from other crimes) using predefined format starting from 2008. The three years' traffic accident data (2008-2011) from all police stations along Bahir Dar to Gondar road were collected for this study.

The three major processes involved in the estimation of desired hotspots of accident incidents were: collection of events, mapping of clusters using Google Earth with overlaid maps of each kebele (smaller administrative unit) and fixing geographic coordinates of all accident locations along Bahir Dar to Gondar road for the study period. Collect-event function available with the spatial statistic tool was used for performing the function, which in turn will yield a new weighted point feature class with a field count that indicates the sum of all the accidents that happened in a unique geographic location. This weighted point feature was used as the input for running the hotspot function to identify whether features with high values or features with low values tend to cluster in the study area. This tool works by looking at each feature within the context of neighbouring features. If a feature's value is high, the values for all of its neighbouring features will be also high. The local sum for a feature and its neighbours is compared proportionally to the sum of all features; when the local sum is much different from the expected local sum, that difference is too large to be the result of random chance (Getis and Aldstadt, 2004; ESRI, 2010). The Hot Spot Analysis tool calculates the Getis-Ord Gi* statistic (pronounced G-i-star) for each feature in a dataset. This tool works by looking at each feature within the context of neighboring features. This tool identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots). It creates a new Output Feature Class with a z-score and p-value for each feature in the Input Feature Class. It also returns the z-score and p-value field names as derived output values for potential use in custom models and scripts. The statistical equation for calculating Gi and Gi* can be written as:

$$Gi^*(d) = \frac{\sum j \; W_{ij}(d)\, x_j - W^*_i \overline{x}^*}{s^* \left\{ \left[\left(nS^* 1i \right) - W_i^{*2} \right] / (n-1) \right\}^{1/2}} \quad (1)$$

where W_{ij} (d) is a spatial weight vector with values for all cells 'j' within distance d of target cell i, W_i^* is the sum of weights, S* 1i is the sum of squared weights, S* is the standard deviation of the data in the cells and n is the number of samples of accidents. The Gi* statistic is actually a Z score. For statistically significant positive Z scores, the larger the Z score, the more intense the clustering of high values. Finally, the Kernel density hot spots with the populated field as Gi Z Score were performed with the point density calculator function available with the spatial analyst tool. It calculates the magnitude per unit area from each hot spot features using the populated Gi Z Score field. The output of the Kernel density function is a raster file displaying the areas of high and low clusters of accident occurrence (DeGroote et al., 2008; Zhixiao and Yan, 2008).

The outputs of the above analysis were categorized so that, first, in each site those sites with three or more accidents were selected. Then, a site was considered to be dangerous when its priority value (P), calculated using the following formula, equals 15 or more (Geurts and Wets, 2003; Slinn and Matthews, 2005).

$$P = X + 3*Y + 5*Z \quad (2)$$

where
P =Priority value
X = Total number of light injuries
Y = Total number of serious injuries
Z = Total number of deadly injuries

Map of the Bahir Dar to Gondar road was used to plot traffic accident data. Maps of Bahir Dar to Gondar road including kebeles (smaller admi-+nistrative units) were prepared. The digital maps were overlain on Google Earth. Police officers were introduced about these maps. Taking the name of kebele and specific area of each accident from the data base, Google Earth with digital maps was used to fix each accident location. Location coordinates for each accident were then transferred to the data base.

RESULTS AND DISCUSSION

The traffic accident database of the Bahir Dar to Gondar road which contains all accidents reported by traffic police along the route during the study period of 2008-2011 was established. A total of 474 accidents were collected from pertinent police stations along the route. Among the collected 474 traffic accidents, about 14 accidents (or 3%) were without defined information and were therefore rejected. As a result, the total number of accidents became 460 (Table1). The traffic accident severity shares were 43.5%, 24.0% and 32.5%

for fatal, grievous and simple accidents, respectively. Gondar Zuria district had the leading accident share (31.7%) followed by Dera District (24.3%) in terms of total number of accidents (Table 2). This is followed by Bahir Dar 5th police station and Libo-Kemkem district with 17.6% and 14.3%, respectively. Fogera district police registered the least number of accidents which accounted for a share of 12% along the route in terms of total accidents.

Table 1. Traffic accidents collected, Bahir Dar to Gondar road, (2008-2011)

S.N.	Police Stations	Traffic accidents		
		Collected	Used	% used
1	Bahir Dar 5th Police Station	84	81	96.4
2	Dera (Anbesame) District Police	113	112	99.1
3	Fogera (Wereta) Police	56	55	98.2
4	Libo-Kemkem and Addis Zemen Police	68	66	97.1
5	Gonader Zuria (Maksegnit and Azezo) Police	153	146	95.4
Total		**474**	**460**	**97.0**

Source: Police Stations.

Table 2. Traffic accident severity, Bahir Dar to Gondar road, (2008-2011)

S.N.	Wereda Police	Traffic Accident									
		Fatal		Grievous		Simple		Property Damage		Total	
		Total	%	Total	%	Total	%	Total	%	Total	%
1	Bahir Dar 5th Police Station	15	12.2	16	23.5	25	27.2	25	14.1	81	17.6
2	Dera (Anbesame) Police	24	19.5	23	33.8	18	19.6	47	26.6	112	24.3
3	Fogera (Wereta) Police	27	22.0	7	10.3	7	7.6	14	7.9	55	12.0
4	Libo-Kemekem_Z.Police	17	13.8	9	13.2	10	10.9	30	16.9	66	14.3
5	Gondar Zuria-Police	40	32.5	13	19.1	32	34.8	61	34.5	146	31.7
Grand Total		**123**		**68**		**92**		**177**		460	
Total of Injury				**283**							
Accident Severity Share (%)		**43.5**		**24.0**		**32.5**					

Source: Police Stations.

Casualties by Road Users

Road users include drivers, vehicles, pedestrians and passengers. Pedestrians had the largest share of accidents (80.3%) followed by passengers with 18.8% and drivers with 0.9% (Table 3). Drivers on Bahir Dar to Gondar road performed better compared to the number of pedestrian and passenger casualties (0.9%). As indicated in the responses, within the pedestrians' casualties, the younger age (14-30 years) was more vulnerable (33.6%). Passengers' casualties had a similar pattern to pedestrians' casualties. The most productive age (18-30 years) was more vulnerable (46.1%). Similar pattern of vulnerability is manifested in fatal accidents; i.e., the younger age (14-30 years) was more vulnerable to fatal accidents in both pedestrians and passengers. It was possible to say that most productive age was more vulnerable to traffic accidents for the years 2008/9-2010/11 along Bahir Dar to Gondar road. This finding is similar to those of the study conducted by Atubi (2009b) and that conducted by Dessie and Larson (1991) which attribute the problem to human error. Because of lack of awareness about the road traffic accidents, pedestrians were the second most important factor on causes of accidents in the study area.

Table 3. Accident casualties by road users, Bahir Dar to Gondar road, (2008-2011)

S.N.	Casualty	Age	Traffic Accident				% Within Casualties	% by Casualty Group
			Fatal	**Grievous**	**Simple**	**Total**		
1	**Drivers**	Below 18 Yrs.				0		
		18-30 Yrs.	1	1	1	3		
		31-50 Yrs.				0		
		Above 51 Yrs.				0		
	Sub-Total		**1**	**1**	**1**			
	% Severity within Drivers		***33.3***	***33.3***	***33.3***	**3**		***0.9***
2	**Pedestrians**	Below 18 Yrs.	11	5	1	7	**2.6**	
		7-13 Yrs.	5	6	3	14	**5.2**	
		14-17 Yrs.	5	6	5	16	**5.9**	
		18-30 Yrs.	24	18	32	74	**27.5**	
		31-50 Yrs.	20	11	19	50	**18.6**	
		Above 51 Yrs.	12	7	13	32	**11.9**	
		Unknown	38	20	18	76	**28.3**	
	Sub-Total		**105**	**73**	**91**			
	% Severity within Pedestrians		***39.0***	***27.1***	***33.8***	**269**		***80.3***
3	**Passengers**	Below 7 Yrs.	0	0	0	0	**0.0**	
		7-13 Yrs.	0	1	0	1	**1.6**	
		14-17 Yrs.	1	0	1	2	**3.2**	
		18-30 Yrs.	13	9	5	27	**42.9**	
		31-50 Yrs.	4	0	3	7	**11.1**	***18.8***
		Above 51 Yrs.	0	1	1	2	**3.2**	
		Unknown	7	14	3	24	**38.1**	
	Sub-Total		**25**	**25**	**13**	**63**		
	% Severity within Passengers		***39.7***	***39.7***	***20.6***			
Grand Total			**131**	**99**	**105**	**335**		
% Severity of All Casualties			***39.1***	***29.6***	***31.3***			

Source: Police Stations.

Accident Variation by District

Accidents are usually dispersed along the road. The traffic accidents vary along Bahir Dar to Gondar road. Gondar Zuria district is leading with 31.7% by the total accidents along the route, followed by Dera, Bahir Dar 5th Police Station, Libo-Kemkem and Fogera district with 24.3%, 17.6%, 14.3% and 12.0%, respectively (Fig. 2 and Fig. 3). On the other hand, in terms of the fatality share in each district, Wereta was found to be leading with about 49.1%. Total traffic accident number in each district was divided by the road length in each district. Bahir Dar 5th police station had 81 traffic accidents for a road length of 11.8 km, followed by Dera district that registered 112 accidents for 30.5 km road length. Fogera district had 55 accidents for 17.8 km road length. Libo-Kemkem had 66 accidents for 38.1 km road length. Gondar Zuria district registered 146 accidents for 57 km road length (Fig. 2). The ratio of traffic accidents to road length for each district was found to be 6.9, 3.7, 3.1, 2.6 and 1.7 for Bahir Dar 5th police station, Dera, Fogera, Gondar Zuria and Libo-Kemkem districts, respectively (Table 4 and Fig. 2). This confirms that road accidents appear to occur regularly at some flash points where there are sharp bends, potholes and bad sections of the highways (Atubi, 2009b).

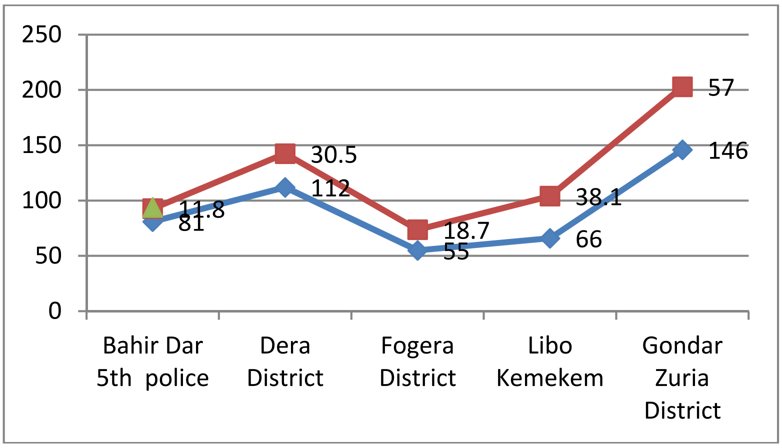

Figure (2): The relationship between the road length and accidents

This implies that Bahir Dar 5th police station had on average 6.9 accidents in 1 km of road length. This is the highest traffic accident density, followed by Dera and Fogera with accident densities of 3.7 and 3.1 accidents in 1 km, respectively (Fig. 2 and Fig. 3). This means that (Bahir Dar 5th police station, Dera and Fogera) had more traffic accidents as compared to the other districts. This is due to the fact that the road geometry along these districts is mostly straight and flat, where drivers move faster and are subjected to severe accidents. Traffic accidents at high speeds along straight and flat geometry are most likely accompanied by fatal casualties. According to Person (2000), the costs of road traffic accidents in Ethiopia for pedestrians and passengers of commercial vehicles were the most vulnerable. These were higher than those in the USA, for instance, where 60% of the fatalities are accounted for by car owners, while in Ethiopia 5% of the fatalities are accounted for by drivers. This implies that in one crash, the number of people killed or injured in Ethiopia is about 30 times higher than in the USA.

The study has indicated that about nine (9) road traffic accident hot spot sites are found around Bahir

Dar which has the least road length share than other hot spot sites. This is due to the fact that most road geometry around Bahir Dar is flat and straight coupled by high traffic movement. The road traffic accidents were related to the volume of car flow rather than to the road geometry. Seven (7) traffic accident hot spot sites were found in Dera district which is the third least in road length share. Similarly, the road geometry in this district is flat and straight, where drivers move faster and are subjected to traffic accidents. In addition, Dera is the nearest district to Bahir Dar along the route and experiences high traffic movement because of its location.

Fogera district has five (5) hot spot sites with the second least road length, and most of its road geometry is flat and straight, where drivers invite themselves to overspeed. Gondar Zuria has three (3) hot spot sites for a long road length unlike its lager share. However, its road geometry along this portion is sloppy and full of curvatures. Due to this, drivers are forced to minimize speed and get the possibility of reducing accidents. Libo-Kemkem district has the least accident hot spot sites as compared to other districts. It has only one hot spot site, but the second largest road length coverage of Bahir Dar to Gondar road. Most of the road geometry along Libo-Kemkem district is sloppy coupled with both horizontal and vertical curves. Drivers remain alert and save life and property from traffic accidents along this portion of Bahir Dar to Gondar road. Therefore, this portion of road (Libo-Kemkem district) of the Bahir Dar to Gondar road was the safest portion of the raod for the years 2008-2011. The three districts (Bahir Dar, Dera and Fogera) have straight and flat road geometry, but with more accident hot spot sites (Fig. 3). This is because straight and flat sections of roads do not have either traffic police or signals (traffic lights), which in turn encourages drivers to drive fast and would definitely result in more traffic accidents. Unlike this study, studies in Ethiopia have shown that the main causes of road crashes were drivers' errors accounting for 81% and problems related to road with 3% of all causes (ERA, 2005).

Dangerous Hot Spot Sites Along Bahir Dar to Gondar Road

A road site is considered dangerous when its priority value (P) equals 15 or more. Ranking hot spot sites for treatment was accomplished by dividing the priority value by hot spot section length. Accordingly, high priority values over short length hot spot sections should be ranked first. Hamusit k-01 is ranked first for treatment (Table 5). This is due to the fact that a high priority value of (31) is registered over a relatively short length (260 m) hot spot section. Bahir Dar near Ashere and Wereta Kebele-4 occupied the second and third ranks for treatment. Even though Wereta Kebele-4 near Kela had a big priority value of 49, it is ranked third for the fact that the value is spread over a long distance of 800 m. Azezo Lozamariam hot spot site is ranked last as a small priority value is found over a long distance of hot spot section (Table 4).

Table 4. Hot/black spot sites, Bahir Dar to Gondar road, (2008-2011)

S.N.	Name of Identified Scheme (Hot/black spot)	Wereda (Police Station)	Total No. of Accidents	Priority Value from Kern Density
1	Wereta Kebele-4 (Kera)	Fogera	17	49
2	Hamusit K-01	Dera	4	31
3	Zenzelima-4 (Taxi Fermata)	Bahir Dar 5th	10	25
4	Azezo Lozamariam	Gondar-Zuria	10	24
5	Bahir Dar Near Abay Bridge-1	Bahir Dar 5th	13	21
6	Dera-Wenchit-1	Dera	7	18

7	Wereta Kebele-4 Fuel Station	Fogera	5	18
8	Bahir Dar *ASHREFE*	Bahir Dar 5th	3	18
9	Zenzelima 2 (Baynes Got)	Bahir Dar 5th	4	13
10	Fogera-Quhar Kebele	Fogera	3	13
11	Wereta TVET College	Fogera	3	13
12	Dera-Zera Kebele	Dera	5	11
13	Dera-Wenchit -3	Dera	4	11
14	Dera-Wenchit -4	Dera	4	11
15	Makisegnit-Gereno	Gondar-Zuria	4	11
16	Wereta K-2 Elementary School	Fogera	3	8
17	Hamusit K-08	Bahir Dar 5th	3	7
18	Bahir Dar Kella (Abay Bridge-2)	Dera	5	6
19	Dera-Wenchit 2	Dera	4	6
20	Addis Zemen_Matowegera	Libo-Kemkem	4	5
21	Zenzelima-1	Bahir Dar 5th	3	5
22	Bahir Dar Kebele 11 *Gabreiel*	Bahir Dar 5th	3	4
23	Bahir Dar Kebele 11 Addis Alem	Bahir Dar 5th	4	1
24	Zenzelima-3	Bahir Dar 5th	3	1
25	Azezo Lozamariam Kebele 19	Gondar-Zuria	3	0

Source: Police Stations.

Table 5. Dangerous hot/black spot sites, Bahir Dar to Gondar road, (2008-2011)

S.N.	Hot Spot Site	Num. Accidents	Priority Value (P)	Length (m)	Ratio (P:Length)	Rank
1	Hamusit K- 01	4	31	260	0.119	1
2	Bahir Dar near *ASHREF*	3	18	285	0.063	2
3	Wereta Kebele 4 (near Kera)	17	49	800	0.061	3
4	Zenzelima 4 (Taxi Fermata)	10	25	433	0.058	4
5	Bahir Dar, Near Abay Bridge-1	13	21	392	0.054	5
6	Wereta Kebele 4 Fuel Station	5	18	380	0.047	6
7	Dera-Wenchit 1	7	18	389	0.046	7
8	Azezo Lozamariam	10	24	699	0.034	8

Source: Police Stations.

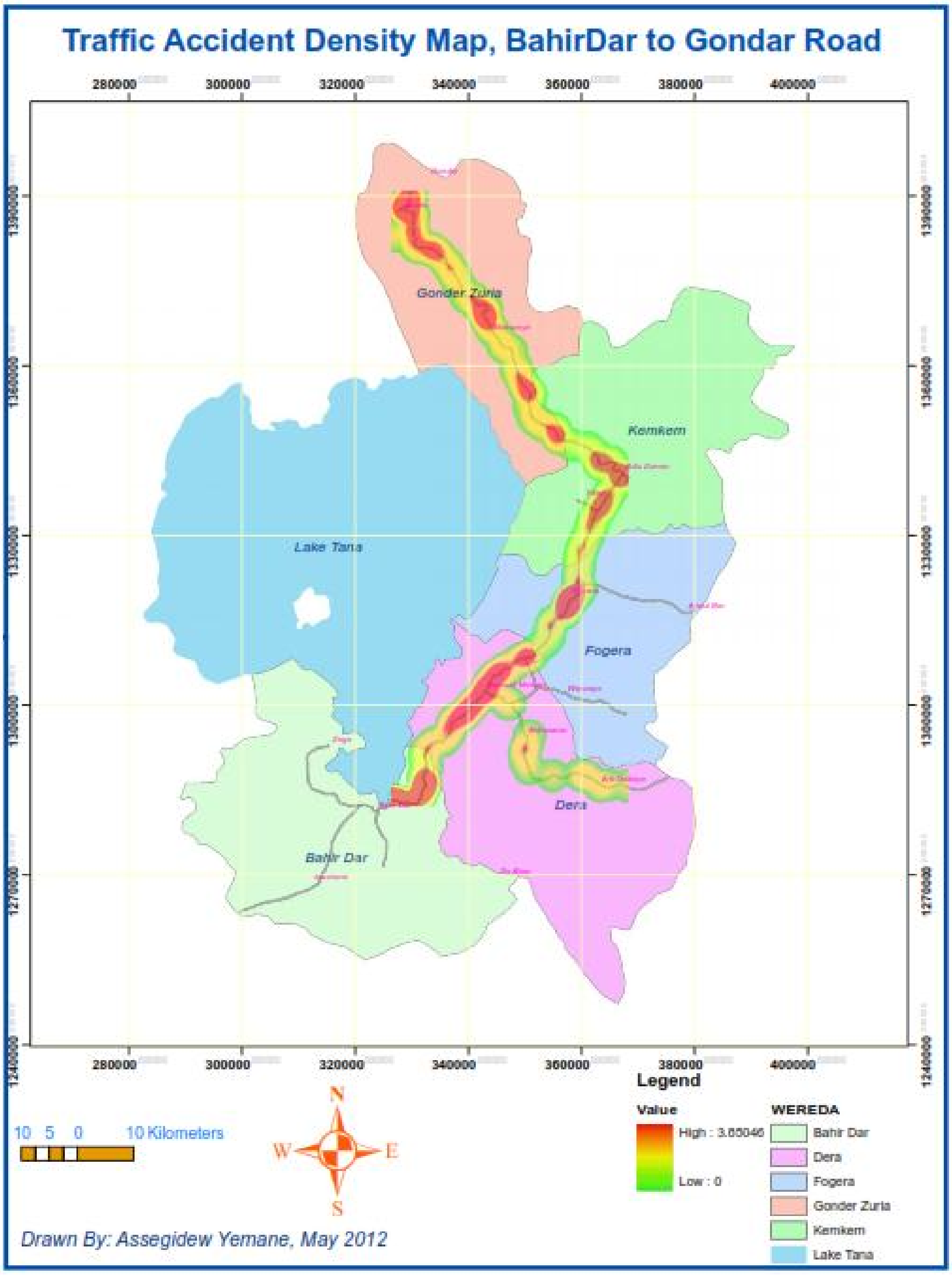

Figure (3): Traffic accident density map, Bahir Dar to Gondar road, (2008-2011)

CONCLUSIONS

The results obtained throughout the assessment of the traffic police data and field survey indicated that road traffic accidents are a serious problem along Bahir Dar to Gondar road. In the GIS output, accidents are represented by their accident reference numbers and there were about 25 traffic accident hot spot sites, identified during the past three years (2008-2011). Around Bahir Dar, on average, one hot spot site is found in 1.3 km road length. On the other hand, around Libo-Kemkem, on average, one hot spot site is found in 38.1 km road length. This shows that road accidents are related to traffic congetions and drivers' behavior. A road site is considered dangerous when its priority value (P) equals 15 or more. Accordingly, Hamusit K-01, Bahir Dar near ASHREF, Wereta Kebele-4 (near Kera), Zenzelima-4 (Taxi Fermata), Bahir Dar near Abay bridge, Wereta k-4 around fuel station, Dera Wenchit-1 and Azezo Lozamariam are found the most dangerous road hot spot sites of the road accidents. This was related to the nature of road, pedestrians' and drivers' problems. Thus, road design and frequent training should be taken into account to manage the road accidents. GIS is a very important tool to analyze road accidents and identify hot spot sites.

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