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Application of GIS to Improve the Efficiency of Road Traffic Accident Data Collection and Analysis: A Case Study in Wolaita Sodo

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ABSTRACT

Currently, road traffic accident data management is affected by manual referencing and inappropriate handling which can lead to inaccuracy in data collection, difficult to retrieve and inflexibility in the data analysis system, of which this study was conceptualized to apply GIS to improve the efficiency of road traffic accident data collection, specifically in Wolaita Sodo area. The accident data (2014 to 2018) was collected from traffic police and with the help of GPS and then transferred into GIS database to establish accident features along the road network. Out of 181 accidents collected, 167 accidents were scattered over different sections of the road network. The data shows that most of the accidents were occurred in the daytime (79%) rather than at night-time (21%). An investigation indicates that the speeding, limited sight distance, lack of traffic signs, poor pedestrian infrastructure, illegal crossing of pedestrian, and poor road alignment was identified as contributing factors at the blackspots. So, appropriate counter measures should be implemented for the selected areas immediately and accordingly. In conclusion, the study discovered that integrating GPS and GIS can improve the accuracy in the accident data collection, provides flexible database and analysis platform.

Keyword: GPS and GIS, KDE, Road Traffic Accident

1. INTRODUCTION

Road traffic accidents on the world's road network have claimed the lives of millions each year. Global status report on road safety indicates that deaths from road traffic crashes have increased to 1.35 million a year and it causes up to 50 million injuries. In developing countries, the fatality is 27.5 per 100,000 populations, whereas in developed countries, it is 8.3 in average [1]. This status tells us that the loss of life has been increased as compared to previous years, even if the road safety programs are implemented in majority of part of the world. The greater portion of the accident took place in developing countries, that is, mostly from Africa. Why road traffic accident did occur three times more in developing countries than developed countries? It is not because of: more portions of vehicles, larger population size and lack of road safety policies in developing countries.

Study indicated that Ethiopia has one of the highest fatality rates per vehicle in the world. It is in excess of 100 fatalities per 10,000 vehicles. Ethiopia loses about $65million annually due to traffic accidents. In addition, the victims are mainly public transport travellers in the working age group (18 to 30 years) [2]. About 10,000 vehicles in United Kingdom killed two people a year whereas in Ethiopia it is 100 persons and the question is why that much difference? Main reasons are the road condition, vehicle condition, awareness of the users about traffic, law enforcement and policies.

Road safety policy makers need to implement means such as: road rules, law enforcement, education, or by applying local traffic control and geometric improvements in order to achieve the road safety [3]. Importantly: road rules, law enforcements, awareness education and traffic measures should be implemented in an appropriate manner in order to save millions of people from killing by a motor-vehicle. Those rules and policies should be based on after investigating the exact situation of the traffic on the road network. Any gap of understanding the exact problem in the ground makes the traffic situation on a road network more complex. If the road safety measures and policies are implemented in a precise way to an appropriate place, it can ensure the safety of traffic in the road network.

In Ethiopia, crashes frequently occur in mid blocks or roadways with majority of collisions occurring between motor vehicles and pedestrians. Importantly, more than half of the fatalities in road accident involve pedestrians. Therefore, it is important to identify the high priority areas for the implementation of effective programs, policies and countermeasures focused on reducing pedestrian crashes. Crash frequency and severity varies by time of the day and day of the week [4]. Most road crashes in Ethiopia involve various vehicle types, commonly: Trucks, Mini-buses and motor-cycles. Prohibiting priority to pedestrian at a road crossing and speeding are common causes of crashes as reported by the traffic police. Interviews and questionnaire for road users and the traffic police report are the basic sources of information related to traffic accidents. Ensuring the quality of sources of information related to the road traffic accident influences analysis of accident that in turn affects the traffic measures and policies to be formulated. The researcher identified that current accident analysis in Ethiopia is limited to the standard tables produced by the Regional Traffic Police departments. Individual accidents are not computerized and thus the analysis is limited. For instance, it is not possible to sort out children's accident and analysis for any patterns with time or month(s) of the year. A more flexible database with location details would be necessary if road safety priorities are going to be more accurately identified and remedial measures to be implemented to combat the problem.

The current Accident data management of Wolaita Sodo are based on hard copy at police stations. This manual work has influenced restricting easy access to the data, missing of data and hence resulting in poor data management. Using GPS for data collection (location identification), creating accident database on GIS and performing analysis on it gives a flexible accident database management, a good time management for the use of collecting data, a better spatial analysis of accidents. Visualization of accident pattern is also important to prioritize locations in a road network for the implementation of traffic measures. Visualization helps to understand spatial patterns but often further investigation is needed to describe or explain these patterns. Temporal analysis of accident data establishes features to describe patterns in road traffic accident distribution based on time, like; at night and daytime, winter and summer, daily, hourly etc. GIS also supports a more specific analysis: different types of accident collision: vehicle-to-vehicle, vehicle-to-pedestrian, vehicle rollover etc., which helps the concerned body to develop measures specifically. And, unlike manual methods that were currently used to identify blackspots, GIS provides KDE tool can evaluate and describe the accident density distribution over the road network so that based on those results the researcher can effectively prioritize, with good visualization, the segments of the road which require immediate traffic safety measures implementation.

Transport engineers need a quality accident data in order to have an accurate understanding of the traffic accident condition in the road network so that they can develop remedies and policies accordingly. Accident data contain a lot of information: location of an accident is one of the data that is recorded using some temporary features in the location where an accident occurs as identification for referencing of the accident point. This referencing system lacks permanency and accuracy in giving the exact spot location of an accident. Accident data is recorded as a text format using a hard copy. The data written in a text format and stored in hard copy would make the analysis difficult, time consuming and inflexible [5]. Currently, policy makers in transport field are limited with an accurate information update that is caused by the methods they have adopted for accident data management. Traffic engineers need a database that is easy and flexible to use with a platform that allows speedy updating of accident analyses. The data stored in hard copy and report generated from takes time and lacks flexibility. While GPS supports an accurate referencing of accident data, GIS gives both database (storage) and flexible analysis platform of a road traffic accident.

Study indicates that transportation is vital tool in transportation industry because it helps to perform different tasks. Actually, there are various ways that GIS is being implemented in the transportation industry. Most commonly, GIS is used as the tool to analyze accidents so that questions like which intersections have the most collisions, which kind of collisions occur most frequently at a location, and what time of day collisions usually occur at a location can be solved [6].

Understanding the spatial patterns of traffic accidents gives an effective way to mitigate accident [7]. Knowing where and when traffic accidents usually occur, law enforcement can conduct more efficient patrols and highway departments can spread the critical information about roadway conditions to drivers more effectively.

In 1994, the GPS system was declared to be fully operational. GPS can be used to identify location or geo-referencing purposes. It gives accurate location of objects, in this case road traffic accident. So, Collecting data with GPS instrument and importing it in GIS is the key step in developing an operational data collection and data management system [8].

In Ethiopia, GIS has not been used in transportation field yet [9].. It provides a platform where data can be stored, retrieved, analyzed and also visualized which can facilitate the decision-making process with quality maps. While recording and reporting accident event were involved in the first phase, the second phase carries data storage, data retrieval, data analysis, and information distribution. To facilitate the accident data management system, integration of GPS and GIS is vital.

Storing data in hard copies, recording locations with poor mapping and referencing are the old practices. It is also time-consuming process and even lacks accuracy. However, GIS have revolutionized the whole framework of an accident data management system [10]. Similarly, the road accident analysis in Ethiopia and specifically in Wolaita Sodo were based on the non-computerized databases were accident's locations recorded on the road segments and temporarily features on the area of an accident.

KDE is one of the most popular spatial data analysis tools. It is used to analyze road traffic crashes due to its simple implementation and easy understanding [9]. It identifies the segment of the road with higher density of traffic crash so that improvement measures can be implemented on the identified segments.

KDE involves placing a symmetrical surface over each point and then, evaluating the distance from the point to a reference location based on a mathematical function and then summing the value for all the surfaces for that reference location [11]. The function of KDE is,

$$f(x,y) = \frac{1}{nh^2}\sum_{i=1}^{n} K\left(\frac{d_i}{h}\right)$$

Where, f (x, y) is the density estimate at the location (x, y), n is the number of observations, h is the bandwidth or kernel size, K is the kernel function and di is the distance between the location (x, y) and the location of the observation.

KDE analysis considers the surrounding of the spot as more risky and less risky when distance between surrounding and the spot is narrower and wider respectively [13]. As one of the spatial analysis tools in GIS, it can be used to determine blackspot locations of the road network.

The study indicates that the successful integration GPS and GIS is the key step in developing an effective data collection and management system.

2. METHOD AND MATERIAL

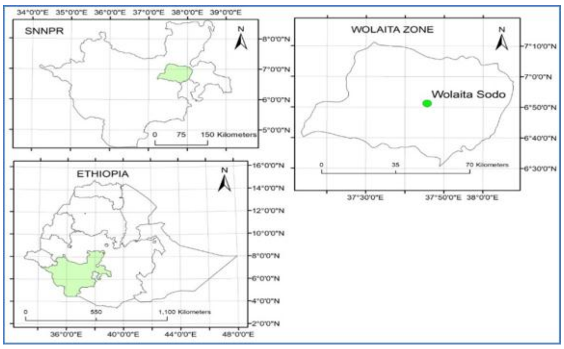
2.1. Study Area

Sodo is a Town in south-central Ethiopia. It has a latitude and longitude of 6° 54' N and 37° 45' E respectively, with an elevation between 1600 and 2100 meters above sea level. Wolaita Sodo is the Second most populous city in South Region after Hawassa. (Source: Free encyclopedia). The map of the Town is shown in figure 1.

2.2. Attribute data

Attribute data collected from the traffic police department were presented using charts, graphs and tables. Attribute data was created by reorganizing secondary data into an Excel sheet as shown in table 1.

2.3. Spatial data



Figue 1. Study area map

In this study the spatial data table consists of only three columns, namely: OBJECT_ID, latitude and longitude. an accurate accident referencing systems known as latitude and longitude can be recorded at the place where an accident happened by using GPS.

2.4. Accident GIS database

Spatial and attribute tables/data were joined using join tool in a GIS. Digitized road network of the town layered using the same coordinate system. Now, the GIS based accident database is created, and it's important to note that this database is edited and additional data: images, numbers, texts can be easily added into the system.

2.5. Data analysis

The database in GIS can be used to establish the spatial features of the accidents on the road network. KDE was used for the identification of accident blackspots along the road network of the town. In this research KDE model was used to identify blackspots based on: Vehicle to pedestrian, vehicle to vehicle and vehicle rollover collision types and, all collision types together.

3. RESULTS AND DISCUSSION

3.1. Accident data collection and referencing

The researcher collected traffic accident data of five years (2014-2018) from Wolaita Sodo Police Department. The data is available with a hard copy record only and kept within an envelope. Every accident was recorded in five pages. Accident location information was described by different points that were filled by the data recorder at the event of an accident. The points are: accident place name, road category name, accident area name, km post reading, accident location's distance in meter from nearest km post, reference landmark, accident location's distance from reference landmark and location map. The researcher found some points were missing: km post reading, accident location's distance in meter from nearest km post, reference landmark, accident location's distance from reference landmark. Without this information it is difficult to find the location of an accident. Again, location map was unclear and improperly sketched for all accident cases being difficult to understand the exact location of an accident. Light pole, house fences, milestone and road intersections are used as reference marks and distance from reference mark is also measured.

References used are temporary, far away from accident point, not exactly, unknown, personal houses and sometimes not even mentioned. Out of 181 accidents, the locations of 14 accidents were not clear and so, they were excluded from further analysis. After proper setup adjustment of the GPS instrument, the location coordinate of 167 accidents were collected using GPS (GARMIN 72H) which has an accepted accuracy level of 5 meters. Different factors affect the signal strength (accuracy level) of GPS: heavy weather, tall buildings and shadow areas are some of those factors and the researcher need to consider those factors [14]. GPS reading gives latitude and longitude of accident location. 167 accidents have been measured and recorded

3.2. Accident Data Collection and Storage

Accident data were recorded in hard copy format and stored on a shelf with a poor handling or arrangement. In fact, selecting the required data from this shelf is time consuming. Each accident is recorded in five pages and, in this study, the researcher collected around 900 pages for five years. The researcher used a high-quality camera to take a shot of 900 pages and copied the information from camera image into excel worksheet.

For road traffic accident there are many characteristics that can be identified and assembled as data, for example: surface finish, road classification, day of accident, time of accident, date of accident, vehicles involved in the accident, vehicle caused accident, accident type, collision type, severity of an accident, cause of an accident and etc. None of these characteristics though are directly related to a point in space; instead, they refer to a road accident and exist as a set of attributes that are independent of location.

The image of vehicles at the time of the accident was not included in the report, but the image of vehicles at the time of an accident can be incorporated into the attribute table as a raster data in GIS database. For different types of Trucks, different types of Bajaj, different types of cars are there and reporting each vehicle type specifically helps to take measures accordingly if necessary.

The image is also important to keep the record of road surface condition at the time of the accident in an accurate way. In pavement engineering road surface defects have categorized like: rutting pothole, longitudinal crack, transverse crack, crocodile crack, raveling, patch, etc. The accident data report showed that the place where all 181 accidents happened the surface condition of the road was reported in a three category namely: good and poor, this reporting system lacks accuracy because it not reports the specific road defect at the location. Additionally, the researcher identified 19 accidents with unknown road surface condition from out of 81. Each type of surface defect has its own impact on the road traffic accident [15].

3.3. GIS-Based Accident Database

To form a GIS-based database for recording accident spatial and attribute data, two basic steps are required in order to transfer both tables to the GIS platform. The spatial data table should contain object_id which is unique for each feature. Attribute data table also should contain object_id that matches with the object_id in spatial data table. Using join tool in ArcGIS both tables can be joined based on the object_id. Now, the road traffic accident database is created in the GIS platform.

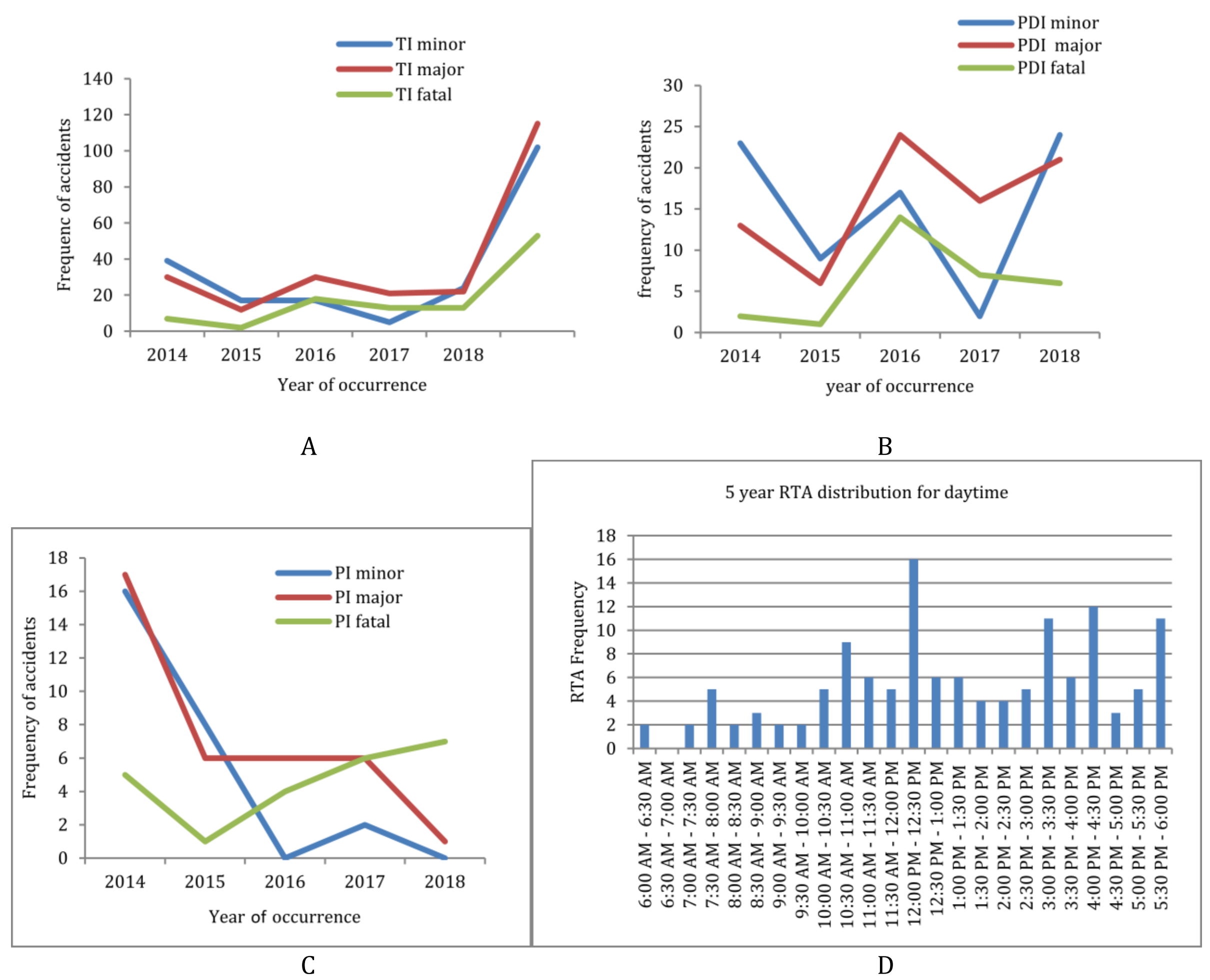


Figure 2. A) Accident's characteristics in each year B) Passenger and driver accidents trend C) Severity characteristics of pedestrian accidents D) Accident's frequency per 30 minutes in daytime

3.4. Accident Analysis

Accident characteristics is presented as shown in (figure 2. A, B, C and D).

The frequency of major injury of PDI showed a 61% rise in rate from 2014-2018 while it was decreased by 94% for PI. The rate of minor injury accident was constant for PDI, and for PI, it was decreased by 100% from 2014 to 2018. For the last three years (2016-2018), the death rate of PDI has decreased by 57%, while for PI it showed a 75% increment indicating that the pedestrian-related crash was increased in recent years. The distribution RTA based on time indicated that most of the accidents were happening in the daytime, which take 79% of total accidents while the remaining (21%) happens at night time. In daytime distributions, accidents were frequent in the morning from 10:30 AM to 12:30 PM and in the afternoon it is from 3:00 PM - 6:00 PM, while as in other cases, it is comparatively low. This varying distribution of accident along time is caused by different factors accordingly, for example, the Ethiopian lunchtime (12:00-12:30 PM) showed the highest (12%) accident number as compared the other times with minimum (2%) frequency distributions which can be related with traffic and pedestrian crowd time. In the morning, breakfast time (7:30 AM – 8:00 AM) showed higher accident frequency (4%) in comparison to other times with minimum frequency (2%).

3.5. Spatial Distribution of Accidents

After the digitized road network has been added to GIS database, accidents spatial distribution then established as shown in figure 3. The result

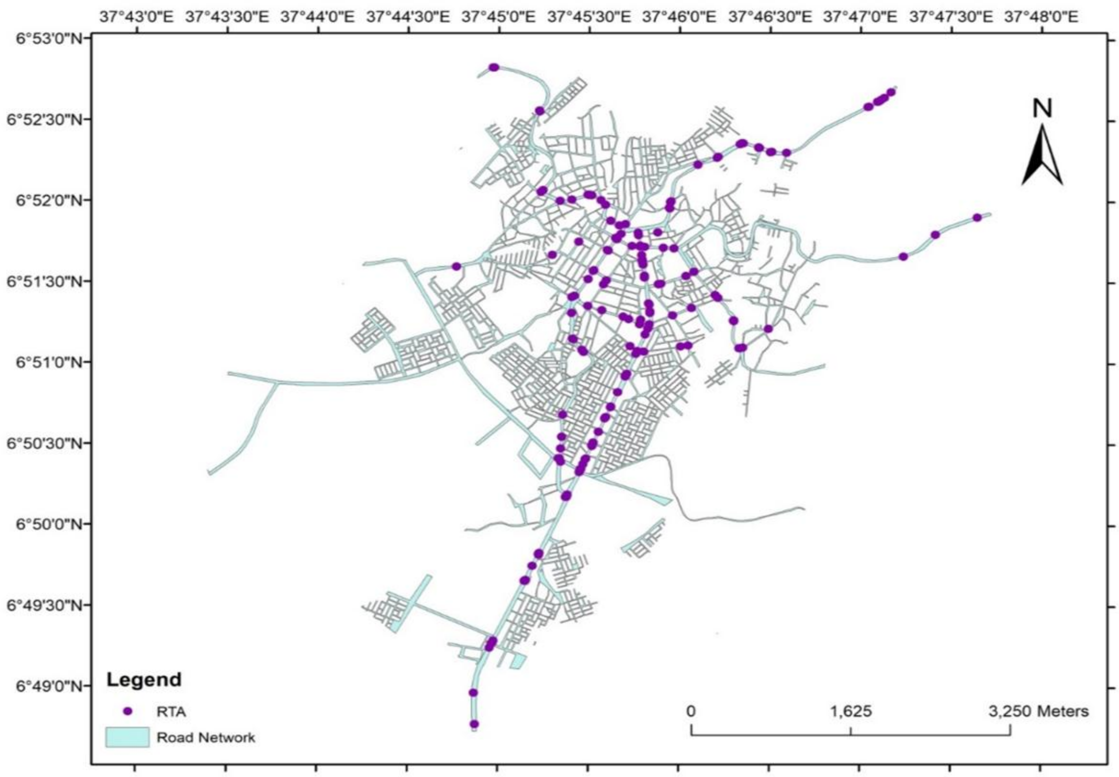


Figure 3. Road traffic accidents - in GIS

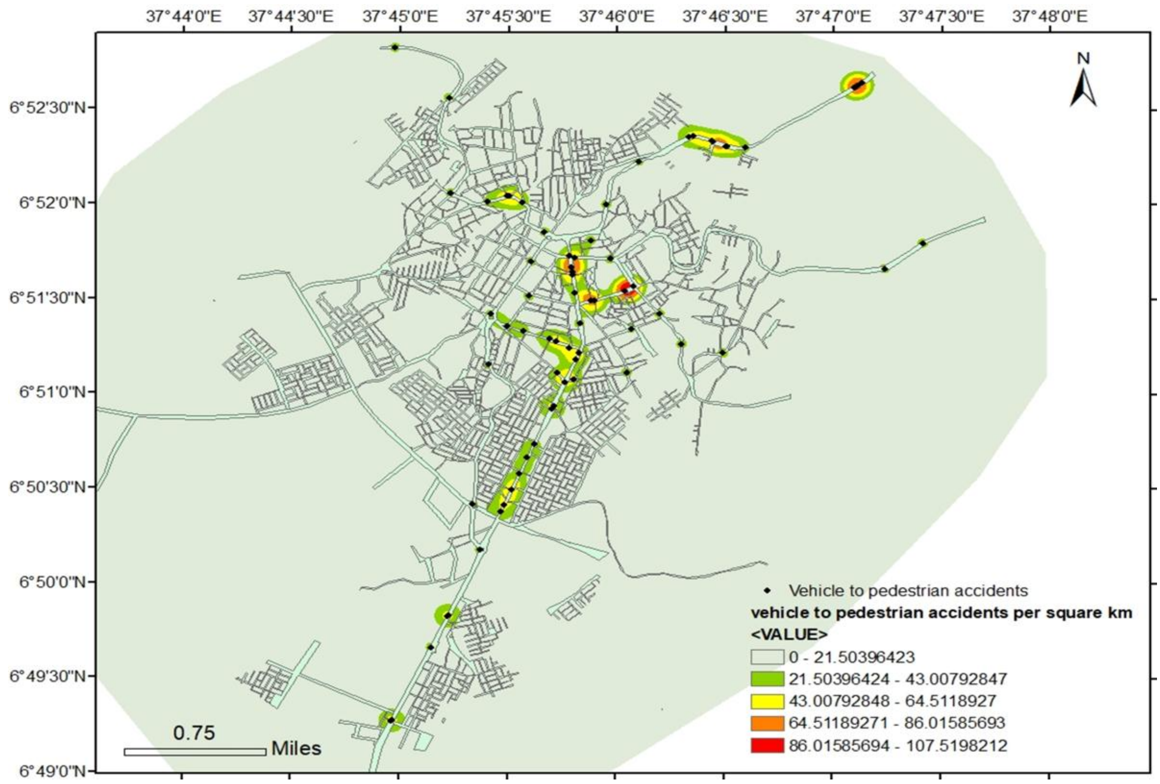


Figure 4. Vehicle to Pedestrian accidents – KDE

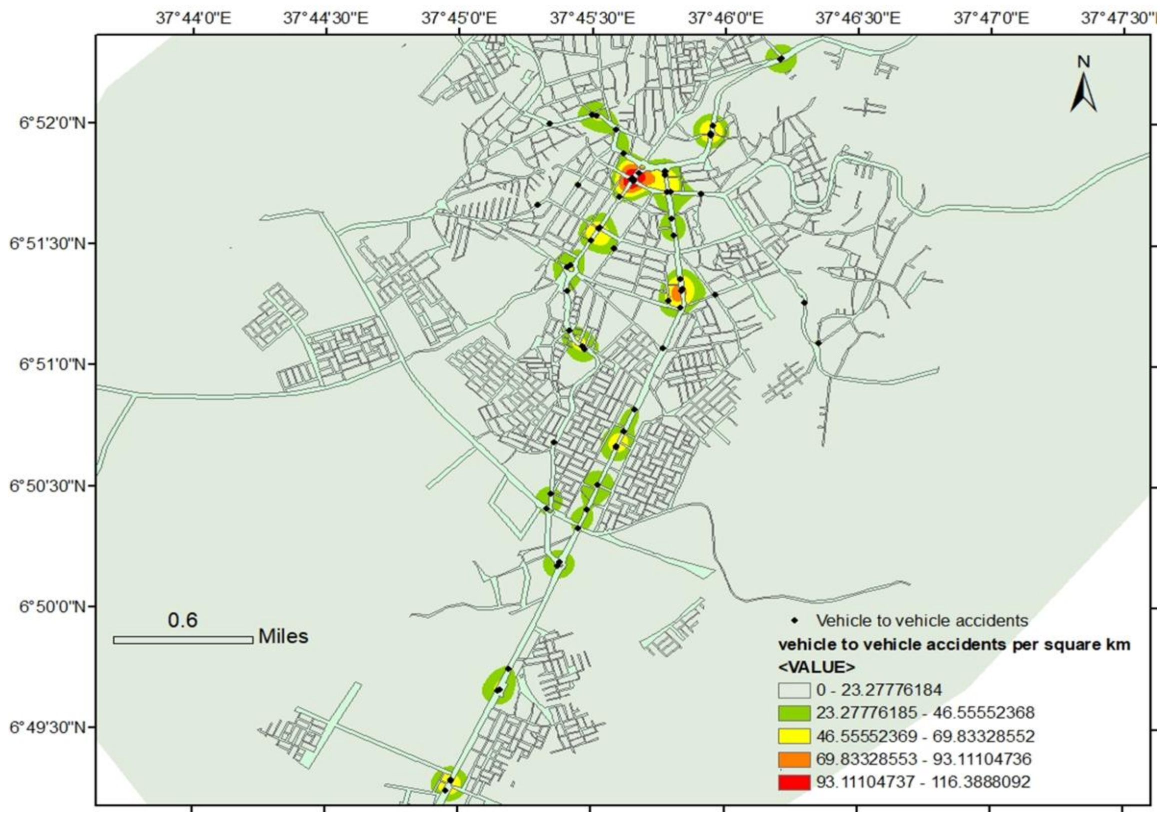


Figure 5. Vehicle to Vehicle accidents – KDE

from the spatial distribution of accidents indicates that accidents were more frequent at road junctions, horizontal curves, CBD areas, pedestrian crossings and midblock areas with poor pedestrian facility along with the road network of the town.

3.6. Blackspot Analysis Based on Accident Collision Type

Road traffic accident blackspot is identified

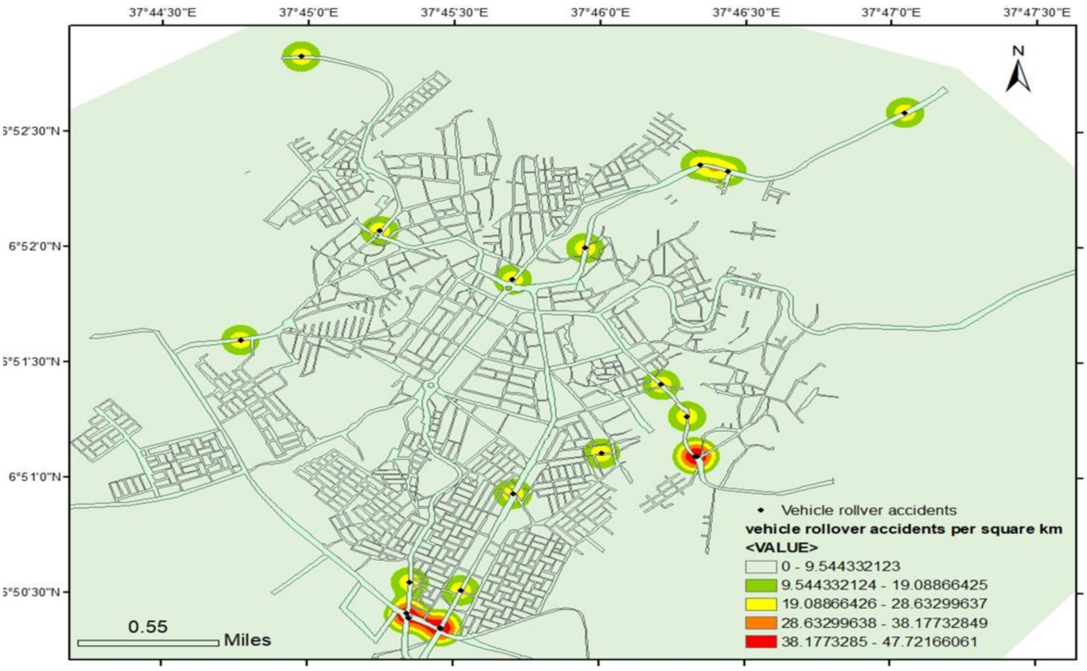


Figure 6. Vehicle rollover accidents – KDE

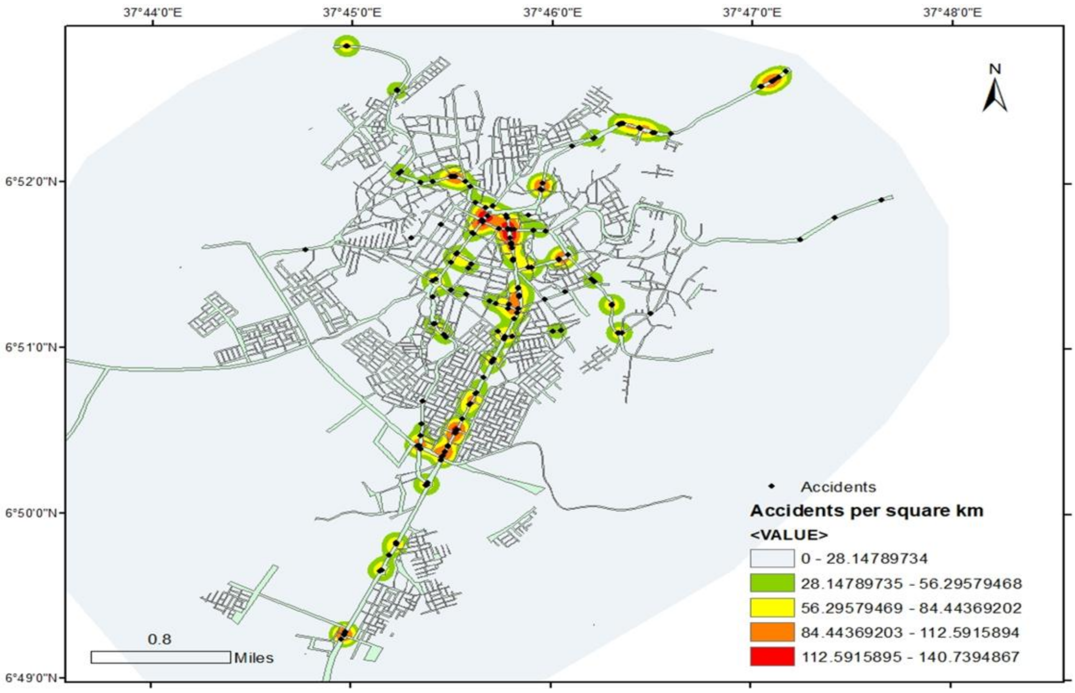


Figure 7. Blackspot for altogether collision

based on the accident collision types: Vehicle to pedestrian, vehicle to vehicle and vehicle rollover is used to identify blackspots. Based on (KDE) modeling: one blackspot from the vehicle-to-vehicle collision, three blackspots from the vehicle-to-pedestrian collision, three blackspots from vehicle rollover collision were identified.

As described in figure 4, vehicle to pedestrian accidents priority areas were selected at three spots and the places were examined by the researcher such that: lack of proper pedestrian facilities, improper parking of vehicles, speeding of vehicles, activities on the walkway & carriageway and sight obstruction and lack of awareness to the public (pedestrian) regarding proper movement of pedestrians are the main causes of the accident on these blackspots. So, properly taking measures on these factors can combat the accidents induced from collision between vehicle and pedestrian.

The investigation carried on the blackspots selected from vehicle rollover accident shows that: speeding of the vehicle at horizontal & vertical curve overlap, limited intersection sight and poor geometric design at T-junction so that improvement should be taken to combat the accident rate at these locations (figure 5).

Vehicle to vehicle collision accident was commonly occurred at the intersection of the which has improper intersection sight distance, lack of either stop or yield signs and non-marked pavement surface which led the vehicles into conflict while crossing, turning to left/right/U (figure 4).

Factors identified from the investigation on altogether collision type accident (figure 6) were pedestrian facility missing, speeding and improper pedestrian crossing so that taking measures on these areas can minimize accident rate in a considerable amount. Table 7 shows blackspots identified along the road network of the town.

4. CONCLUSION

Road traffic accidents on the world's road network have claimed the lives of millions each year. Data quality affects the policy makers' understanding level of accident condition. Currently, the secondary road traffic accident data of Wolaita Zone Traffic police department are recorded on a hard copy and kept in an envelope. It takes time, more effort and also not even accurate to identify accidents data from such a system. Poor data recording system, less standard data storage system and inflexible database establishments were identified as a gap in accident data management system currently. Accident location referencing system also lacks accuracy because references used to locate the accident were temporary, far away from accident point, not exactly, unknown, personal houses and sometimes even not mentioned. For this reason, 14 accidents with unknown location were dropped from the database. So, traditional accident location referencing system should be replaced by better systems.

Data shows the rise in accident rate from 2014 to 2018. For instance: there is a slight drop in major road traffic accidents whereas fatal accidents exhibited a slight rise in the rate from the year 2014-2018. Also, the rates of minor accidents have shown an increment from the year 2014-2017, while in 2018, it was increased. For the years (2016-2018), the death rate of PDI has decreased while for PI it has shown an increment. Based on time, it indicates that most of the accidents were happening in the daytime (79%) rather than at night (21%). In daytime, accidents were frequent in the morning from 10:30 AM to 12:30 PM and in the afternoon it is from 3:00 PM - 6:00 PM and in other cases it is comparatively low, for example: the Ethiopian lunchtime (12:00-12:30 PM) has shown the highest accident number as compared to other thirty minutes distributions and similarly, in the morning the breakfast time (7:00 AM – 8:00 AM) indicated higher accident frequency. The night time accident mostly happened from 6:00 PM – 8:30 PM, which is considered as the dinner time, which experiences a crowd of pedestrians.

The spatial analysis of accidents in ArcMap 10.3 shows that accidents were more frequent at road junctions, horizontal curves, CBD areas, pedestrian crossings and midblock areas with poor pedestrian facility along with the road network of the town.

Accidents blackspot for each collision types: vehicle-vehicle, vehicle-pedestrian and vehicle roll-over helps to develop a more specific solution to the specific problem at a specific location. Based on KDE modeling: one blackspot from the vehicle-to-vehicle collision, three blackspots from the vehicle-to-pedestrian collision, three blackspots from vehicle rollover collision were identified.

Contributing factors are: Speeding, limited sight distance, lack of traffic signs, poor pedestrian infrastructure, illegal crossing of pedestrian, and poor road alignment. Limiting speed, public Education, providing no parking zone near the intersection, provide warning and informative traffic sign at junctions, preventing activities on the shoulder and walkway of the road, removing sight obstruction and providing pedestrian walkway and crossing measures to be implemented by concerned bodies can minimize the rate of road traffic accident. So, the integration of GIS and GPS together improves the platform for collecting, handling and understanding road traffic accident by supporting transport engineers to carry out accurate, timely, flexible and effective analysis of accidents as well as to identify priority locations of the road network for the investigation of accident factors and to develop implementation measures.

5. RECOMMENDATIONS

Based on the findings of the study, the following recommendations are forwarded:

- Digitized data collection, storage and analysis should be implemented and the stakeholders should be trained to use GIS.
- Accident location data collection should be supported with GPS instrument.
- The information regarding pavement condition and vehicles involved in accident should be recorded in an accurate and specified way.
- Road design should be done in consideration of proper pedestrian facility, proper road signs and pavement markings.
- Proper measures should be implemented at the selected blackspots immediately.

6. ACKNOWLEDGEMENT

NA

7. CONFLICT OF INTEREST

The authors have declared that there is no conflict of interest.

8. SOURCE/S OF FUNDING

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