Ethiopian Journal of Business and Social Science

DOI: https://doi.org/10.59122/164F53to

Volume: 7 Number: 1 , 2024 , Pages: 53~83

ISSN:2707-2770

Assessing the Contributing Factors and Distributions of Road Traffic Accident in Arba Minch Town, Gamo Zone, South Ethiopia

Lideta Alemu Ayalew[1], Abera Uncha Utallo[1], and Thomas Toma Tora[1]

[1]Department of Geography and Environmental Studies, College of Social Science and Humanities, Arba Minch University, Arba Minch, Ethiopia

Article Info

Accepted on March, 2024

Published on: June, 2024

Abstract

Road traffic accidents pose a persistent global challenge, with their frequency increasing. This study examines the contributing factors and spatial-temporal patterns of road traffic accidents in Arba Minch town, South Ethiopia. Utilizing a mixed-method approach, the research employed descriptive research design for data collection and analysis. Data was gathered through field observations, key informant interviews (with 5 traffic police officers, 3 transport experts and 30 drivers), focus group discussions (with road users), and supplemented by road traffic accident records from Gamo Zone and Arba Minch Town Transport and Traffic Police Office. Both probability (stratified) and non-probability (purposive) sampling methods were used to select drivers and traffic police officers. Spatial analysis techniques such as interpolation, kernel density estimation, and point pattern analysis were employed to assess the distribution of accidents and identify hot spot areas. The findings reveal a high incidence of road traffic accidents in Arba Minch town, with 207 incidents recorded between July 2018 and June 2023. These accidents were primarily attributed to drivers aged 18-30 with 2-10 years of driving experience, occurring predominantly during daytime hours and on Mondays, Thursdays, and Saturdays. The identified hot spot areas include Shecha Daget, around Arba Minch Textile Factory, Arba Minch University main campus, Arba Minch stadium, in front of Shecha Square-Rafael Church Road, Nechsar Addisu Mesgid, and Sikela around Gamo Square. The study underscores the urgent need for targeted traffic law enforcement measures in these identified areas to mitigate the risk of accidents in Arba Minch town.

Keywords: *Black Spots/Hotspots, Distance Weighted Road Traffic Accident, Geographic Information System, Inverse, Kernel Density Estimation*

1. INTRODUCTION

Roads serve as crucial arteries for the development of nations and societies, fostering connectivity between regions and facilitating the movement of people and goods. This significance amplifies, particularly in countries with expansive territories, where alternative modes of transportation such as railways and waterways are limited, a common scenario in developing nations. However, the proliferations of urban populations, transportation infrastructure, and subsequent travel distances have precipitated adverse consequences, notably Road Traffic Accidents (RTAs) and environmental degradation (Endalkachew, 2020). RTAs encompass collisions between vehicles, pedestrians, animals, road debris, or stationary objects like trees or utility poles (Afolayan et al., 2022).

Globally, RTAs have exhibited periodic escalation. Recent statistics indicate approximately 1.35 million annual fatalities and 50 million injuries attributable to preventable accidents. A road traffic accident is the eighth leading cause of death in all age groups and the primary cause among those aged 5 to 29. Economic losses due to RTAs can reach up to 3% of a country's gross domestic product, escalating to 5% in low- and middle-income nations. This alarming trend is exacerbated by the burgeoning vehicular population. Projections suggest RTAs may cause 13 million deaths and 500 million injuries worldwide over the next decade (WHO, 2021). Road safety improvement is imperative in low and middle-income countries, given the disproportionately high incidence, magnitude, and repercussions of RTAs in these regions. Despite fewer registered vehicles, over 90% of road fatalities occur in developing nations, where the mortality rate surpasses that of high-income countries by over threefold (Weldemarium, 2022).

In Africa, RTAs stand as the foremost cause of fatalities and disabilities, particularly afflicting individuals aged 5 to 29. The continent harbors the highest annual traffic fatality rate globally, at 27 per 100,000 individuals, despite possessing only 2.3% of the world's vehicles. Africa contributes to 20% of global road traffic deaths. With ongoing rapid economic expansion and motorization, the problem may exacerbate in the forthcoming decades. Presently, RTAs rank among the leading causes of death in sub-Saharan African nations, with half of all fatalities concentrated in Nigeria, Ethiopia, South Africa, and Sudan (Endalkachew, 2020).

Ethiopia, like many African countries, grapples with several road safety challenges. According to the Ethiopian Federal Police Commission (2021), thousands of road users succumb to accidents annually. In the 2021/2022 fiscal year, 15,034 road accidents were recorded, claiming 4,161 lives, inflicting significant physical injuries on 5,763 individuals, and causing minor injuries to 5,110 others. Additionally, 31,643 accidents resulted in property damage exceeding 2.28 million Birr. This alarming trend escalates annually, driven by rapid population growth and vehicle proliferation.

Arba Minch, situated in Southern Ethiopia, epitomizes a town grappling with heightened levels of traffic accidents. Recently, road traffic crashes, particularly those involving pedestrians, have emerged as a formidable challenge within the town (Jemal et al., 2017). According to the Arba Minch town traffic police office, the town witnessed over 207 traffic accidents between July 2018 and June 2023, resulting in 56 fatal injuries, 56 serious injuries, 43 minor injuries, and 52 accidents causing property damage only.

Given the spatially distributed nature of RTAs, Geographic Information System (GIS) offers a potent toolset for data storage, retrieval, comparison, and spatial visualization. Globally, accident hotspots can be pinpointed using various techniques, including accident density, frequency, rate, and severity indexes. GIS, leveraging spatial attributes and geostatistical analysis, has emerged as a pivotal tool in road safety endeavors, particularly in identifying black spot sites (Robel, 2020).

However previous studies are based on the report data analysis without mapping and identifying the spatial location of the accident site for example, Jemal et al. (2017) studied the cause and trend of accidents and develop a multiple non-linear regression equation for evaluating the rate of accidents in Arba Minch town. Direslgne et al. (2017) identified the magnitude and its associated factors of RTA, and Tesfahun (2017) studied determinants that lead drivers into traffic accidents. All of them are concentrated on assessing trends, magnitude and its associated factors of RTA as well as application of some models. So, this study fills this gap by identifying hotspot areas by utilizing GIS methodologies. Therefore, the aim of this study was to assess the contributing factors and spatiotemporal distributions of traffic accident and identify accident hotspot areas in Arba Minch town.

2. MATERIALS AND METHODS

Description of the Study Area

Arba Minch Town serves as the administrative hub of the Gamo Zone, situated within the South Ethiopia region. Geographically, Arba Minch town spans between 5°57'58''N to 6°06'52''N latitude and 37°31'45''E to 37°36'15''E longitudes. Encompassing an area of 55.19 km2, the town boasts elevations ranging from 1,154 to 1,522 meters above sea level. Its road infrastructure spans a total length of 151 kilometers, comprising asphalt (43 km), cobblestone (72 km), and gravel (36 km) surfaces. As of the latest records from the Arba Minch town transport office (2023), the town hosts a total of 3,299 registered vehicles, including 1,741 motorcycles, 61 taxis, 185 trucks (with loads exceeding 35 quintals), 62 trucks (with loads ranging from 5-10 quintals), 1,100 three-wheel vehicles, and 150 passenger vehicles.

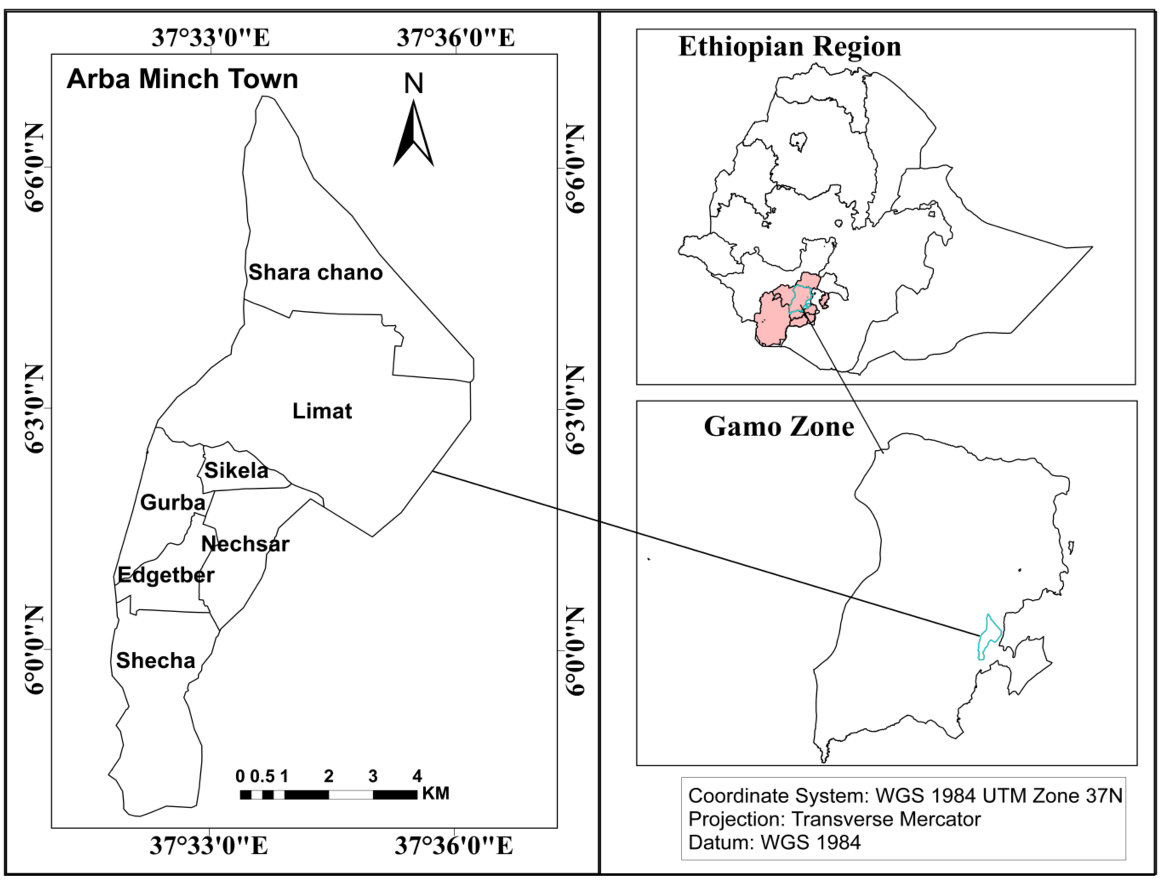

Figure 1: Map of the study area

Research Design and Approach

To meet the study's goal, this study used a descriptive research design. To capture the trends and details of the situation the researchers used a mixed-method (a combination of both quantitative and qualitative) approach for data collection and analysis to yield a more complete analysis. The spatial and non-spatial data collection and process were done using Geospatial technology like GPS and GIS software and Excel.

Data Source

In order to address the objectives, the researcher used both primary and secondary data sources. The primary data were generated from field observation, key informant interviews with road transport experts, drivers and traffic police officers and focus group discussion with local peoples. The secondary data were obtained from various published and unpublished sources such as; books, journals, internet sources, research reports, articles, documents and records. The researcher was collecting both spatial (accident coordinates, using GPS instrument) and non-spatial data (from Gamo zone and Arba Minch Town Traffic Police Department, and Transport Authority) of RTAs. Road network of the town was extracted from Google Earth.

Sampling Techniques

The instruments utilized for data collection vary based on the nature of the respondent group. Four distinct respondent categories are identified: traffic police officers, drivers, road transport experts, and road users. Traffic police officers, drivers and road transport experts were engaged through key informant interviews and local peoples participate in focus group discussions, with two groups formed through random participant selection. Each group has eight members.

The study employed purposive sampling techniques to select Arba Minch town because Arba Minch town is one of the leading towns in terms of RTA in Southern Ethiopia region (Jemal et al., 2017). 5 traffic police officers and 3 road transport experts were selected purposively based on their working experience for interview. To ensure representativeness, the researcher has used stratified method to select sample drivers from each vehicle type. The population is divided into six strata by the type of vehicles they drive.

After dividing the population into strata, the next step is to determine the sample size for each stratum. A total sample size of 30 is desired. The formula for calculating the sample size for each stratum in stratified sampling is as follows:

$$n_h = \frac{N_h}{N} \times n$$

Where: n_h is sample size for stratum h, N_h is population size of stratum h, N is total population size, and n is total sample size desired.

Using this formula, 30 drivers were selected for key informant interview.

Table 1

Sample frame and sample size

No.	Vehicle type	Number of drivers	Sample size	Percent (%)
1	Motorcycles	1,741	15	53
2	Three-wheel vehicles	1,100	9	33
3	Taxi	61	1	2
4	Passenger vehicles	150	2	5
5	Trucks loading above 35 quintals	185	2	6
6	Trucks loading 5-10 quintals	62	1	2
7	Total	3,299	30	100

Source: Arba Minch Town Transport Office, 2023

Data Processing and Analysis Techniques

Data collected from both primary and secondary sources were analyzed and presented through the quantitative and qualitative methods of data analysis. RTA data collected from Arba Minch town traffic police department and Gamo zone transport and traffic police office has been analyzed by descriptive statistics (frequency, mean, and percentage) in Excel software and presented in table, chart, and column bar graphs. Discussion and key informant interviews held with road users, transport experts, drivers, and selected traffic police officers were also analyzed descriptively. The spatiotemporal distribution of RTAs was processed in Arc GIS 10.8 software and presented on maps using graduated symbols. To identify and rank RTA hotspot areas, GIS techniques such as kernel density estimation, inverse distance weighted, and a point pattern technique have been used.

Accident data referencing

An accurate accident coordinates (latitude and longitude) were recorded at the place where an accident occurred by using GPS instruments. Google Earth with the support of senior traffic police officers were also used to extracts road data of the town. After GPS survey, all accident data were Geocoded with its accident locations by using code number and location name in Excel for spatial analysis and saved as CSV format to do so in Arc GIS software.

Establishment of GIS database

The database in GIS can be used to establish the spatial features of the accidents on the road network. To create a GIS-based database for recording and storing accident spatial and attribute data, two fundamental steps are required in order to transfer both tables to the GIS platform. The spatial data table should contain object identity which is unique for each feature. Attribute data table also should contain object identity that matches with the object identity in spatial data table. Using join tool in ArcGIS both tables can be joined based on the object identity. After RTA database is created in the GIS platform, Geocoded RTAs data of Arba Minch town were exported into ArcGIS 10.8 software as a point shape file.

Identification of Hotspot Areas

Identification of hot spot locations is a process to detect high density crash locations within a road network. The evaluation of hotspot areas aims to assist in identifying locations with a high concentration of crash incidents. The time interval used in processing of black spot identification is neither long nor short. If longtime data is used, traffic conditions can cause changes based on the pattern of accidents; and if it is short time data, it will enable early action to be taken at locations where there have been unexpected increases in the number or severity of accidents. Therefore, it is often considered that 3-5 years is a reasonable period for analysis.

The applications of GIS such as Inverse Distance Weight (IDW) and Kernel Density Estimation (KDE) were used to produce a continuous surface that visualizes the magnitude of RTA hot spots over space and point pattern technique was applied for selection of top seven hot spot locations. For this analysis, the hot spots are places or a location where at least 1 RTAs with injuries occurred within 1 year or at least 5 road accidents with injuries or fatal of the same type occurred within 5 years. The frequency of accident was the criterion used to plot the hot spot areas in Arba Minch town.

Ranking of hot spot areas: After the top seven hot spot locations identified, the RTAs hotspots ranking processes were undergo by using crash severity index of each hot spot. The crash severity index of each hot spot can be computed by Geurts et al. (2004) ranking schemes by giving values of 5, 3 and 1 for fatal, serious injury and slight injury, respectively. The equation is as follows:

$$SI = X + 3Y + 5Z$$

Where:

SI = severity index,

X = total number of minor injuries within each RTAs hotspot,

Y = total number of major injuries within each RTAs hotspot, and

Z = total number of fatalities within each RTAs hotspot.

3. RESULTS AND DISCUSSIONS

3.1 Contributing Factors of RTA

i. Driver Characteristics and RTA

Driver characteristics significantly influence the occurrence of RTAs, including age, sex, and driving experience. Understanding these factors is essential for enhancing road safety measures. This research highlights the following driver characteristics:

Age plays a crucial role in RTAs. As depicted in Figure 2, drivers aged 18–30 are prominently involved, constituting 46% of incidents (95 accidents). The age group of 31–50 follows closely, representing 33% of RTAs (69 accidents). Drivers above 51 contribute to 13% of accidents (27 incidents). Those under 18 were involved in 3% of accidents during the study, while 4% had unknown or unrecorded ages.

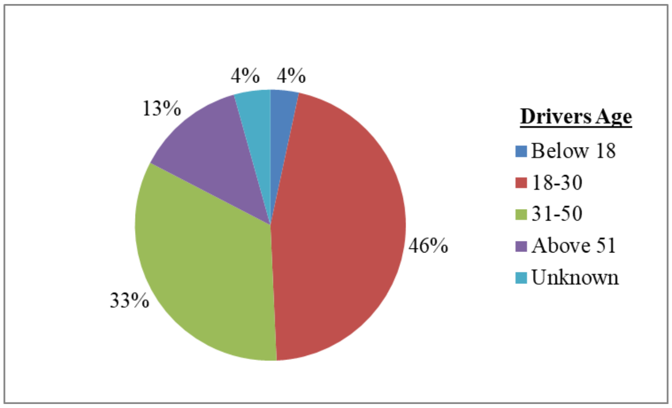

Figure 2: RTA by drivers' age

The age of drivers significantly influences the occurrence of RTAs due to its impact on driving behavior, concentration, responsibility, and patience. Findings indicate that drivers aged 18 to 30 are more frequently involved in road crashes compared to those above 30. Key informants attribute this trend to factors such as inexperience, poor judgment, and impulsivity, commonly observed in younger drivers. A study in Ethiopia by Teferi and Samson (2019) further supports this, highlighting young drivers aged 18-30 as the primary contributors to RTAs compared to other age groups.

As to the drivers' sex, male drivers account for nearly all casualties in the town, comprising 99.5% of total accidents with 206 reported incidents. Conversely, female drivers contribute minimally, representing only 0.5% of RTAs, with just 1 recorded accident. Traffic police officers attribute this gender gap to higher male involvement in driving activities. Melaku (2020) supports this observation, noting lower female engagement in outdoor activities in developing countries like Ethiopia, potentially reducing their susceptibility to RTAs. Driving experience significantly influences accident risk. As depicted in Figure 3, drivers with 1 day to 10 years of experience are most involved in RTAs, constituting 55% of incidents with 114 accidents reported. Those with 11–20 years of experience share 22% of incidents. Additionally, 11% of RTAs involve drivers with 21 to 30 years of experience. There were 8 accidents where the driver's experience level was unknown, representing 4% of total RTAs.

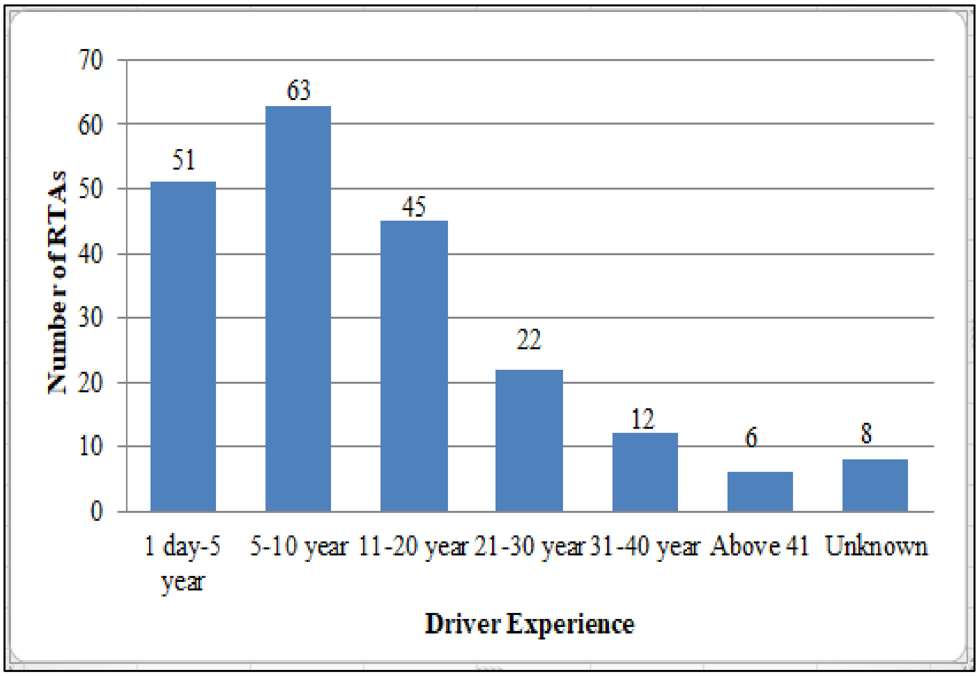

Figure 3: RTA by drivers' experience

The incidence of road crashes in Arba Minch town is influenced by driving experience. As drivers accumulate experience, there is a noticeable decline in RTAs within the town. This trend is attributed to the development of better hazard perception skills, decision-making abilities, and overall driving competence among experienced drivers, thereby reducing accident risks. Similarly, studies by Melaku (2020) and Bener et al. (2017) have highlighted less experienced drivers as the primary contributors to RTAs compared to experienced ones. Additionally, a study conducted in Abu Dhabi by Alkaabi (2023) corroborated that the risk of traffic accidents diminishes with increasing driving experience.

ii. Vehicle Characteristics and RTA

Vehicle Service Age

The vehicle service age determines the rate at which the vehicle will be engaged in RTA crashes. The RTA data collected from Arba Minch town traffic office, as shown in Table 2, reveals that the vehicle service age determines the variation in the distribution of RTA throughout the study period.

Table 2

Vehicle service age and RTA

Vehicle service age	RTAs frequency	Percentage (%)
< 1 year	22	10.63
1-2 year	39	18.84
3-5 Year	62	29.95
6-10 year	31	12.56
>10 year	26	14.98
Not stated	27	13.04
Total	207	100

Source: Compiled from Arba Minch town traffic police office RTAs data, 2023

Traffic accident data from July 2018 to June 2023 in Arba Minch town highlights the contribution of vehicles with different service ages to road crashes: vehicles less than 1 year old, 1-2 years old, 3-5 years old, 6–10 years old, and over 10 years old accounted for 10.63%, 18.84%, 29.95%, 12.56%, and 14.98% of RTAs, respectively. As vehicles age, the likelihood of causing accidents decreases, attributed to factors such as reduced speed, driver familiarity, brake system effectiveness, driving comfort, and driver confidence. Similar findings from Efrem (2019a) and Robel (2020) support this trend, indicating a decrease in accident probability with increasing vehicle service age. Notably, the service age of vehicles contributing to 13.04% of traffic accidents was not recorded, as these vehicles were sold after use, making it uncertain how many years they were operated.

RTAs by Vehicle Type

In Arba Minch town (July 2018–June 2023), motorcycles were the primary cause of accidents, accounting for 26%, followed by three-wheel vehicles (Bajaj) and Isuzu trucks at 20% and 12%, respectively. Taxis, Land Cruisers, and Sino trucks each contributed approximately 12%, 7%, and 6% to the accidents, with 24, 14, and 13 incidents, respectively. Buses and minibuses accounted for 4% and 3% of accidents, with 9 and 7 incidents, respectively, while the ambulance and liquid tanker truck each caused 1 accident.

In general, motorcycles and three-wheel vehicles are the primary culprits in causing traffic accidents in the town. This is often attributed to their high numbers and the typically younger and less experienced drivers who operate them. Ashebir and Segni (2020) found similar results in their study conducted in Arsi town, emphasizing motorcycles and Bajaj vehicles as major contributors to accidents. Likewise, a study in Wolaita Zone by Feleke et al. (2015) highlighted motorcycle crashes as the leading cause of RTAs, followed by incidents involving Isuzu Trucks and Bajaj vehicles.

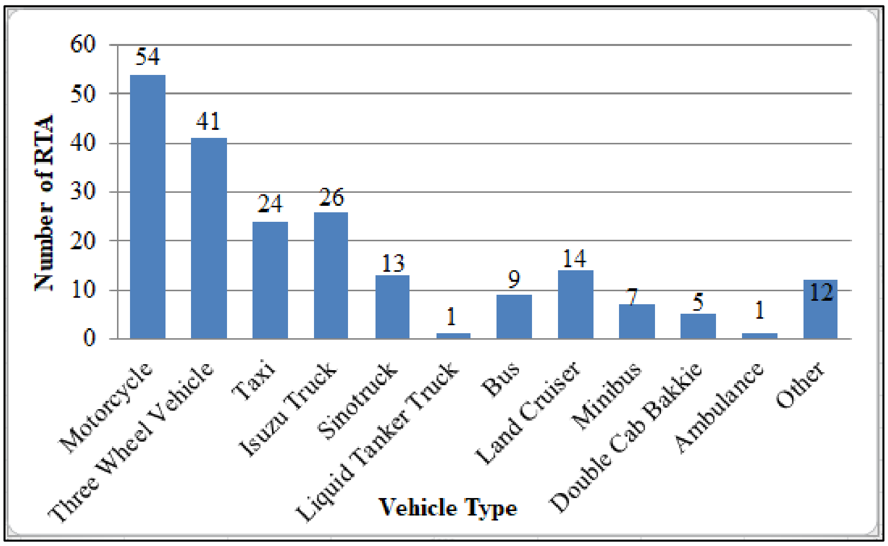

Figure 4: RTA by vehicle type

Source: Compiled from Arba Minch town traffic police office RTAs data, 2023

Road Characteristics and RTA

RTA Condition by Variation of Road Characteristics

Figure 4 shows the characteristics of roads and their corresponding numbers of RTAs. Out of the total number of 207 RTAs, 81 occurred on two-way roads, making up 39% of the total. One-way roads had 76 RTAs, accounting for 37% of the total RTAs. Crossroads experienced 33 RTAs, which is 16% of the total. Lastly, squares had 17 RTAs, representing 8% of the total accidents. One-way roads contribute to 37% of total accidents, highlighting significant traffic issues despite their intended efficiency. Two-way roads, more prevalent and involving more complex vehicle interactions, slightly surpass one-way roads with 39% of accidents, indicating their higher accident rates due to bidirectional traffic flow complexity. This aligns with findings in Addis Ababa, Yeka sub-city, by Robel (2020), emphasizing the high frequency of accidents on both one-way and two-way roads.

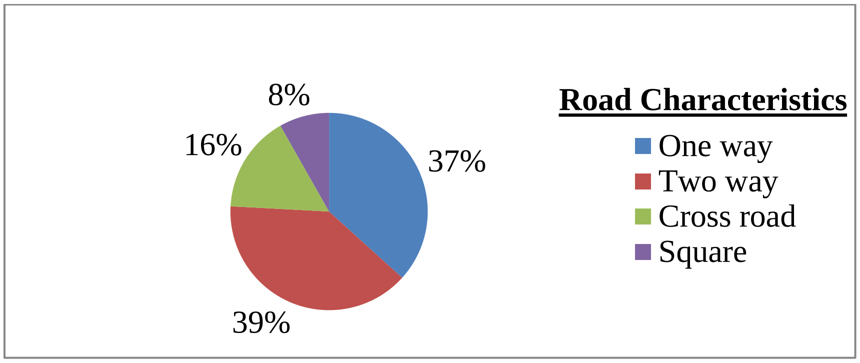

Figure 5: RTA by road characteristics

Source: Compiled from Arba Minch town traffic police office RTAs data, 2023

RTA and Road Surface

Roads paved with asphalt were involved in 162 RTAs, which constitute 78% of the total RTAs. Cobblestone roads and gravel roads contributed 36 (18%) and 9 (4%) from July 2018 to June 2023, respectively. The majority of RTAs were recorded on asphalt surfaces, indicating a higher risk associated with this type of road. Conversely, a smaller proportion of accidents occurred on community roads, particularly those surfaced with cobblestones. This discrepancy may be attributed to the greater traffic density typically observed on main asphalt roads compared to community routes, as well as the tendency for drivers to travel at higher speeds on smoother surfaces like asphalt. Interestingly, drivers exhibit increased caution in areas perceived as hazardous, leading to a lower incidence of accidents in low-hazard locations, which underscores the influence of perceived risk on driver behavior. Supporting this, Aklilu et al. (2021) noted the highest RTA rates on asphalt surfaces in Hawassa city, and Efrem's (2019a) study in Addis Ababa's Kirkos sub-city revealed a higher frequency of accidents on asphalt road pavements compared to other surfaces.

Road Moisture Condition and RTA

Dry, wet, and muddy road moisture conditions contribute 95%, 4%, and 1% of traffic accidents respectively. The data highlights that the vast majority of accidents, totaling 95% of incidents, occurred on dry roads, with 197 accidents recorded. In contrast, wet road conditions accounted for a smaller proportion, representing only 4% of accidents, with 8 reported incidents. Muddy roads experienced the least occurrence of accidents, contributing to just 1% of the total, with 2 reported incidents. Insights gleaned from key informant interviews and focused group discussions indicate that the relatively low percentage of accidents on wet and muddy roads can be attributed to the limited duration of the wet season (with few rainy days per year). Additionally, drivers tend to exercise heightened caution when confronted with adverse weather or road conditions, contributing to the lower incidence of accidents in such circumstances.

Weather Condition and RTAs

The distribution of RTAs based on different weather conditions shows that, good weather conditions constitute 76% of the total accidents. Warm and rainy weather conditions contributed 21% and 3% of RTAs in Arba Minch town respectively.

The data indicates that the majority of accidents occur under good weather conditions, constituting 76% of the total incidents, with 157 reported accidents. Warm weather conditions are associated with a significant but smaller proportion, representing 21% of RTAs, with 44 incidents recorded. In contrast, rainy weather conditions contribute the least to RTAs, accounting for only 3% of the total, with 6 reported incidents. Weather conditions at the time of RTAs play an important role in varying the frequency and risk of road crashes. Climatic and environmental conditions can be factors in RTAs. While experiences show that several crashes occur during conditions of smoke or fog, which reduces visibility, in Arba Minch town, RTAs frequently occur during good weather conditions rather than rainy and warm events. This is due to the high volume of traffic operating during good weather and a perception of reduced risk, leading to less cautious driving behavior.

Spatiotemporal Distribution of RTA in Arba Minch Town

Temporal Distribution of RTA

The time of day significantly impacts the frequency and severity of RTAs. According to Figure 6, which presents the distribution of RTAs based on the time of day, most accidents occur during the day (73%) compared to night (27%). Specifically, the late afternoon period from 3:01 pm to 6:00 pm has the highest occurrence of RTAs, constituting 23% of the total incidents, with 47 accidents reported. The midday hours from 12:01 pm to 3:00 pm contribute 19%, and the morning hours from

9:01 am to 12:00 pm represent 16% of RTAs. During the nighttime, accidents are more frequent from 6:01 pm to 9:00 pm, accounting for 18% of accidents.

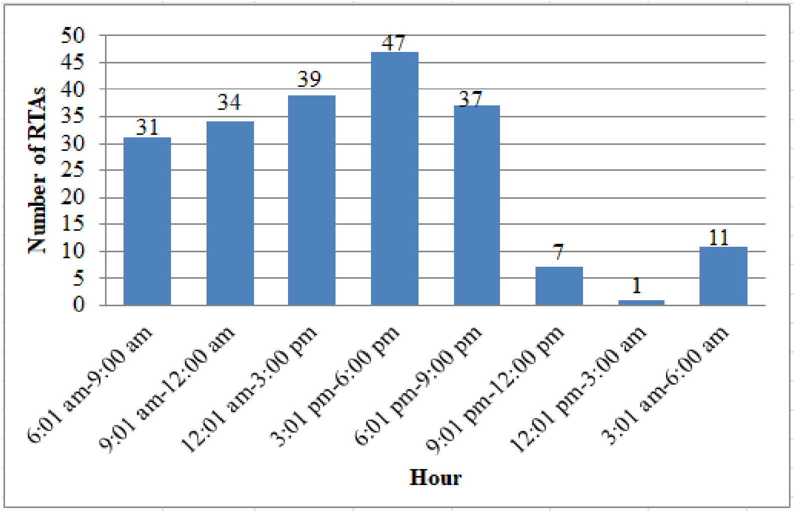

Figure 6: Hourly variation of RTAs

The results reveal that the peak hours for RTAs in Arba Minch town are the midday hours from 12:01 am to 3:00 pm and the late afternoon from 3:01 pm to 6:00 pm. These periods likely correspond to rush hours when more vehicles are on the road, as civil servants go to their offices and children go to school in the morning and return home in the afternoon. Additionally, from 6:01 pm to 9:00 pm, accidents are frequent due to reduced traffic control and drivers transgressing traffic rules. Similarly, there is a disparity in RTA frequencies between the days of the week, as shown in Figure 8 Monday, Thursday, Saturday, and Sunday account for 23%, 21%, 16%, and 13% of the total incidents, with 48, 43, 34, and 27 accidents, respectively. The remaining accidents occurred on Friday (11%), Tuesday (9%), and Wednesday (7%), with 22, 18, and 15 accidents, respectively.

The high number of RTAs on Monday, Thursday, and Saturday is primarily due to these days being market days when the town becomes crowded, resulting in more traffic accidents. This finding is supported by studies from Debela (2019) and Teferi and Samson (2019), which also indicate that RTAs frequently occur on market days due to high traffic volumes. Additionally, the frequency of RTAs on Sunday is notable, as Arba Minch town, with its many tourist attractions and entertainment venues, experiences high congestion of people and vehicles on this day off, chosen by locals and tourists for relaxation.

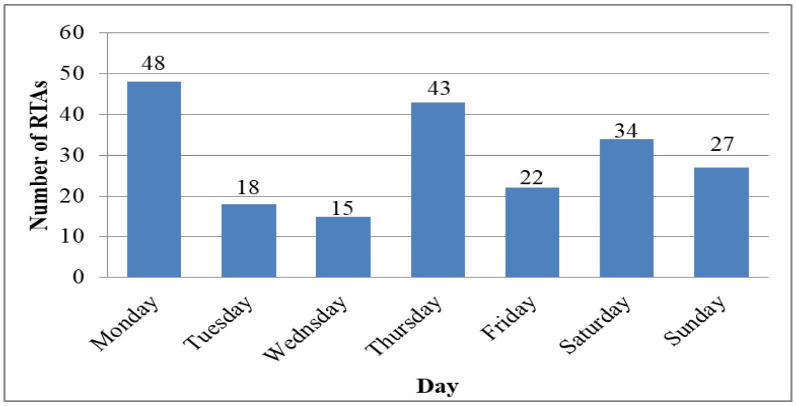

Figure 7 Daily variations of RTAs

RTA in Arba Minch Town from 2018/19-2022/23

The occurrence of RTAs varies with time due to several factors, including the number and quality of vehicles, road quality, physical road characteristics, weather conditions, population size, and the level of awareness among road users. As shown in Figure 9, a total of 207 RTA occurrences have been recorded on the roads of Arba Minch town from July 2018 to June 2023. The data indicates that 16%, 15%, 18%, 27%, and 24% of accidents occurred in 2018/19, 2019/20, 2020/21, 2021/22, and 2022/23, respectively. The highest number of accidents happened in the years 2021/22 and 2022/23, accounting for 55 accidents (27%) and 49 accidents (24%), respectively. Overall, the trend of RTAs in the town has been increasing over time.

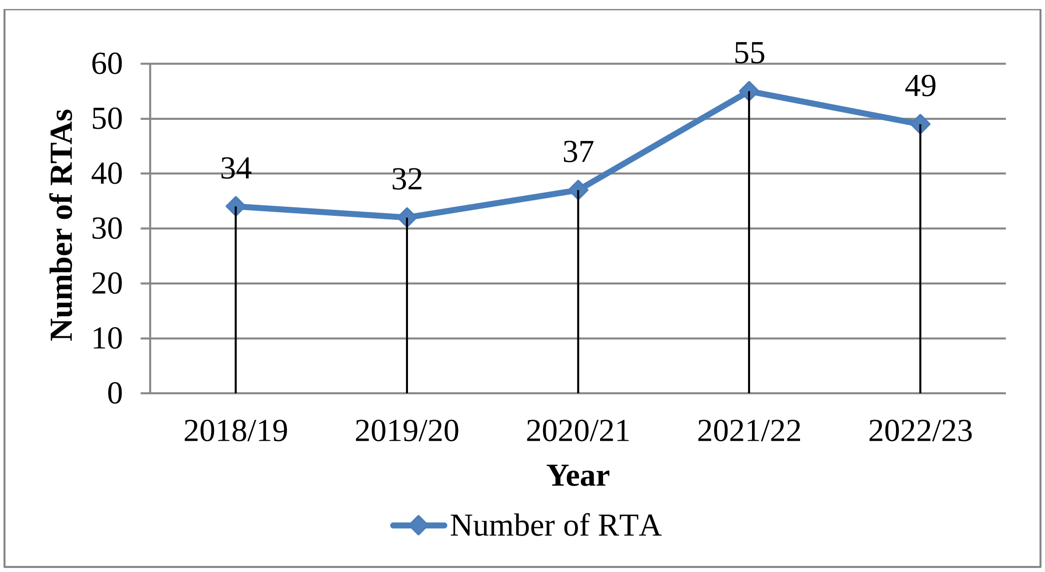

Figure 8: RTAs from July 2018-June 2023 in Arba Minch town

The spatial distribution of traffic accidents in Arba Minch town varies due to factors such as topography, land use, settlement distribution, road quality, and traffic volume. From July 2018 to June 2023, 207 RTAs were recorded, with 196 included in the spatial analysis as the exact locations of 11 accidents were unknown.

In 2018/19, the highest frequency (3) of RTAs was recorded in Sikela sub-town around the bus station and in Nechsar sub-town (Mehal Ketema, Addisu Mesgid). The bus station area typically experiences high traffic volume due to the large number of vehicles and pedestrians. The road around Addisu Mesgid is a crossroad where multiple vehicles converge from four directions, contributing to the high accident rate. In 2019/20, the RTA frequency was high in Shecha (Shecha Daget), Limat (around Arba Minch textile factory), and Sikela (around Arba Minch stadium) sub-towns. Figure 8 illustrates these spatial variations in RTA occurrences.

Spatial Distribution of RTA

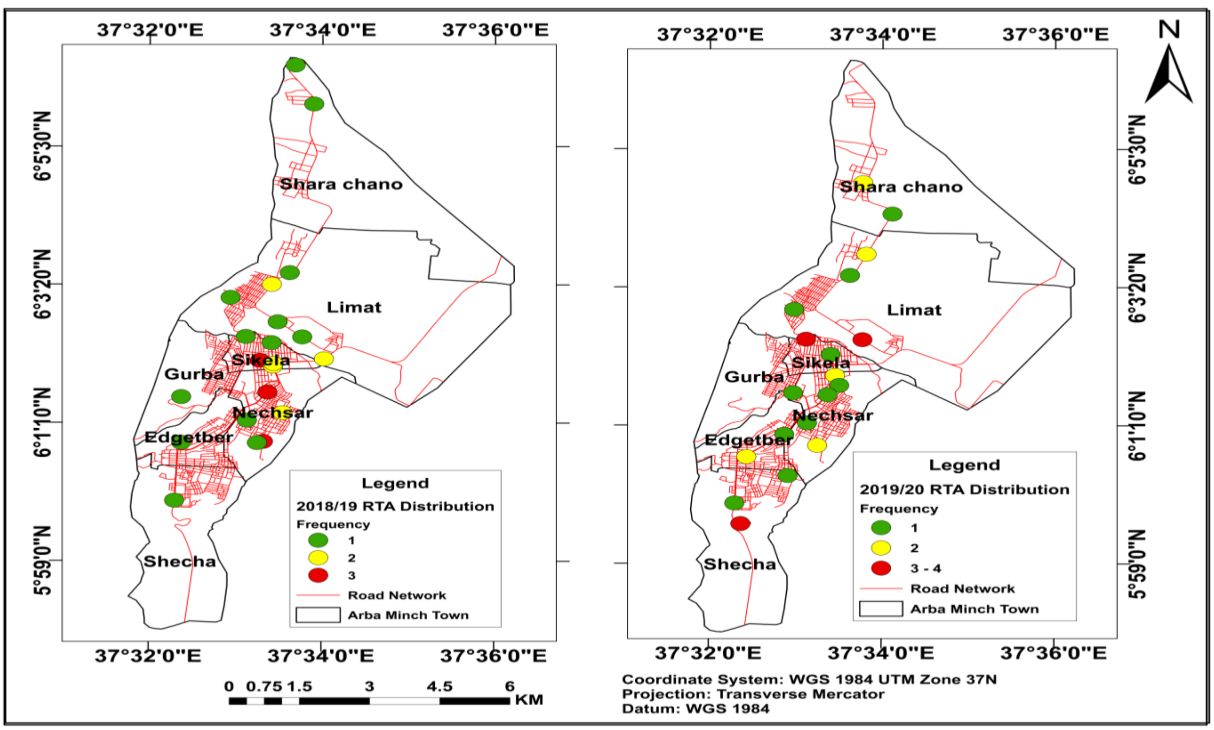

Figure 9: Spatial distribution and frequency of RTA in 2018/19 and 2019/20

Source: RTA data Mapped by the researcher, 2023

In 2020/21, the highest RTA frequency (3) occurred in *Sikela* around *Addisu Gebeya*, near to Shecha Market, and around Konso Square. In 2021/22, the highest RTA frequencies (3, 3, and 4) were occurred in *Shecha Daget*, around Lemlem Square and Gamo Square, respectively (Figure 10).

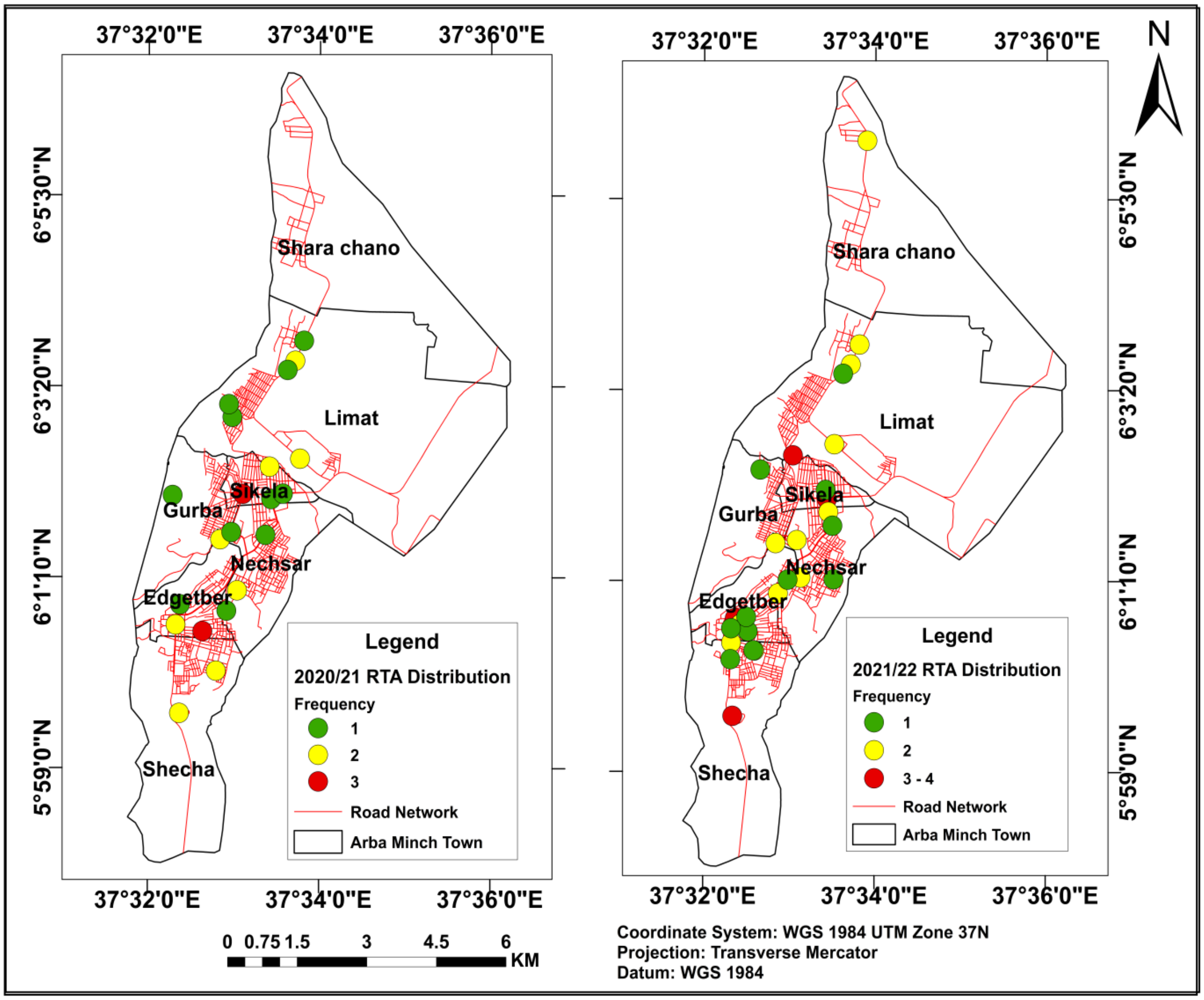

Figure 10: Spatial distribution and frequency of RTA in 2020/21 and 2021/22

Source: RTA data Mapped by the researcher, 2023

The map below shows that in 2022/23, a high RTA occurrence was recorded around Total in Nechsar sub-town and in front of Rafael Church in Shecha sub-town. Over the five-year period from 2018/19 to 2022/23, the frequency of RTAs was notably high in specific locations: Shecha Daget (9), around Arba Minch textile factory (7), Nechsar Addisu Mesgid (6), around Arba Minch stadium (6), Gamo Square (5), the road in front of Arba Minch University main campus (5), and Shecha

Rafael Church (5). This analysis highlights critical hotspots within Arba Minch town where road safety measures should be prioritized to reduce the frequency of RTAs.

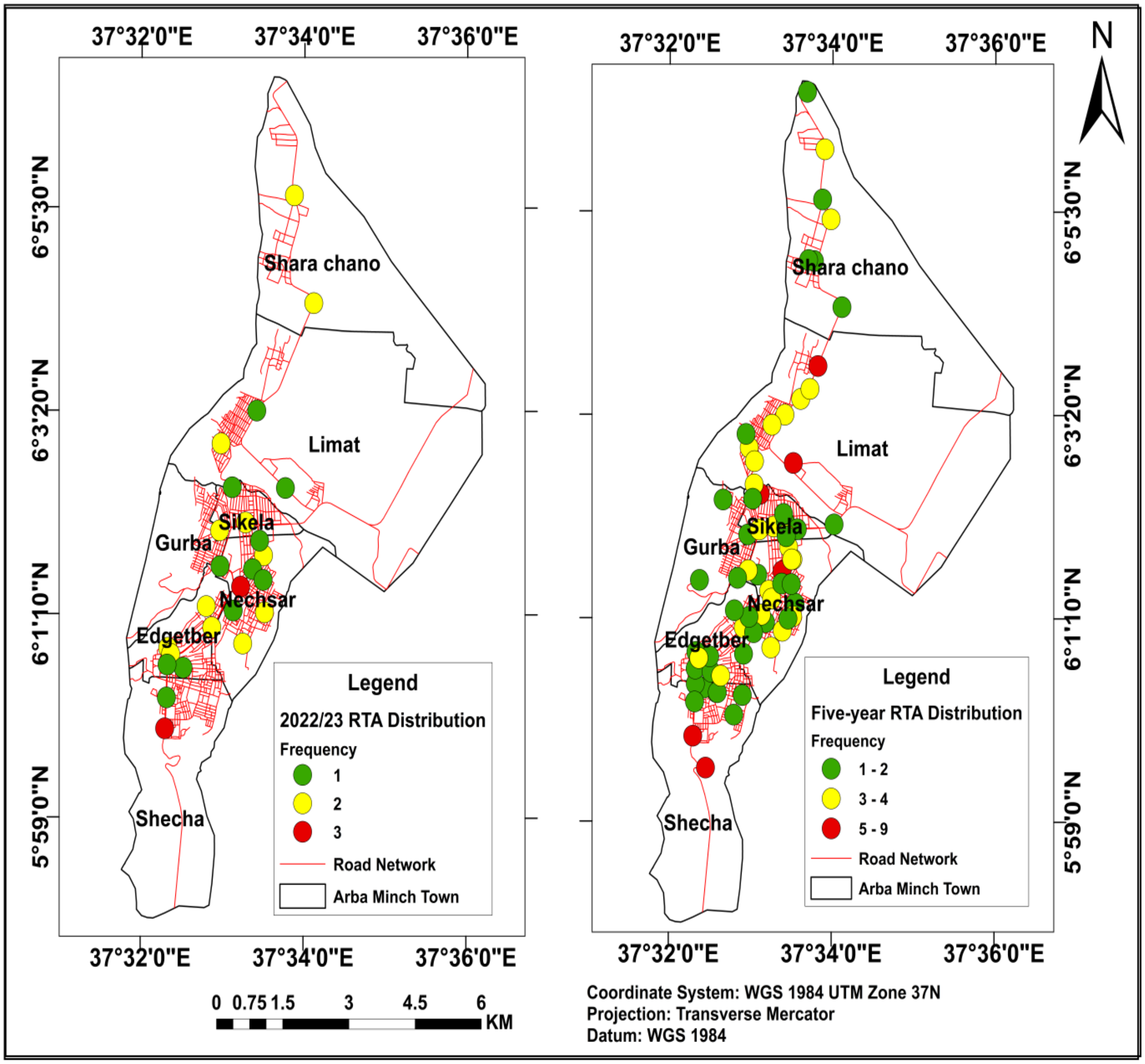

Figure 11: Spatial distribution and frequency of RTA in 2022/23 and 2018/19-2022/23

Source: RTA data Mapped by the researcher, 2023

Distribution of RTA by Place of Occurrence

Figure 12 below illustrates the spatial distribution of RTAs at various locations in Arba Minch town. Business areas contributed significantly to the high frequency of RTAs due to the high volume of goods exchange and roadside trade. Educational institutions also saw a high incidence of accidents, likely due to the high population density in these areas. The map shows accident areas buffered by different distances, indicating that most RTAs in Arba Minch town occurred within a 300-meter radius of educational institutions, market areas, health centers, squares, religious areas, and the bus station.

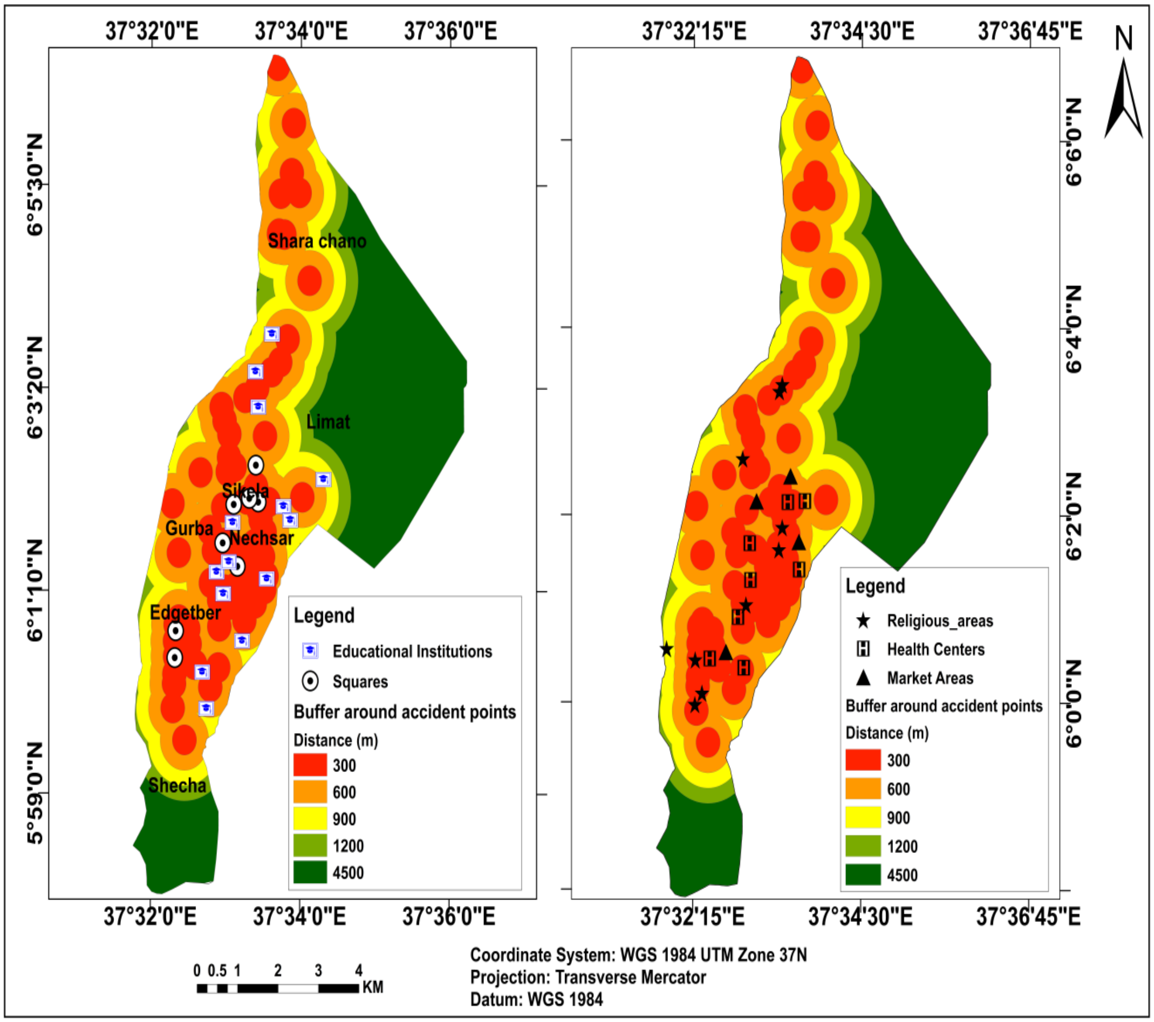

Figure 12: Spatial distribution of RTAs by place of occurrence

Source: Compiled from Arba Minch town traffic police office RTAs data, 2023

This spatial analysis underscores the need for targeted road safety interventions in high-risk areas, such as educational institutions, market areas, and other densely populated zones to mitigate the occurrence of RTAs.

Distribution of RTA by Place of Occurrence

RTA in Sub-towns

Figure 13 shows the distribution of RTAs across various sub-towns within Arba Minch. The red shaded sections represent the sub-towns with the highest RTA concentration, while the dark green shaded areas indicate sub-towns with lower RTA concentration. Gurba sub-town recorded the smallest number of RTAs, with only 7 accidents. Shara Chano and Edgetber followed with 12 and 16 accidents, respectively. Shecha and Nechsar sub-towns had higher numbers, with 49 and 51 RTAs, respectively. Sikela and Limat sub-towns contributed 33 and 37 accidents, respectively.

This distribution indicates significant variation in the number of RTAs across sub-towns, with Shecha and Nechsar having the highest concentration. The highest distribution of RTAs in these sub-towns highlights the need for targeted interventions and improved road safety measures to reduce the occurrence of accidents in Arba Minch town.

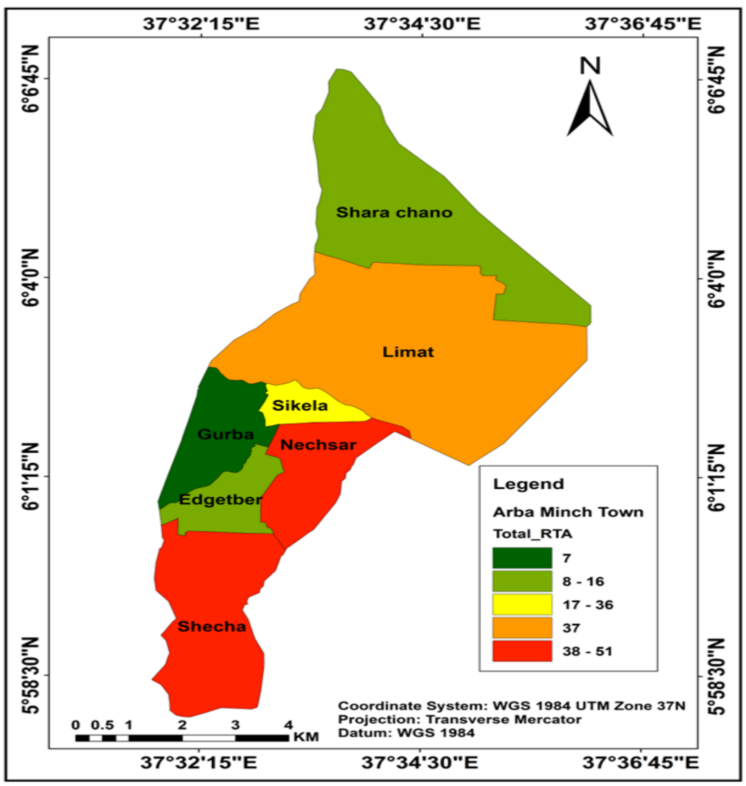

Figure 13: Distribution of RTAs by sub-town

RTA Hotspot Areas in Arba Minch Town

Analyzing Accident Hot Spots Using Kernel Density Estimation

The five-year kernel density estimation map of Arba Minch town's RTA hotspot areas is presented below from Figures 4.17 to 4.19. The map shows the frequency of accidents per square kilometer, with red indicating the highest density of RTAs and light blue indicating the lowest density.

In 2018/19, RTAs were most severe in Sikela and Nechsar sub-towns, while other parts of the study area were relatively safe. In 2019/20, accidents had the highest density around Shecha Daget, Arba Minch stadium, Arba Minch textile factory, Nechsar Addisu Mesgid, the road in front of Arba Minch University main campus, and Arba Minch University Abaya campus (Figure 14).

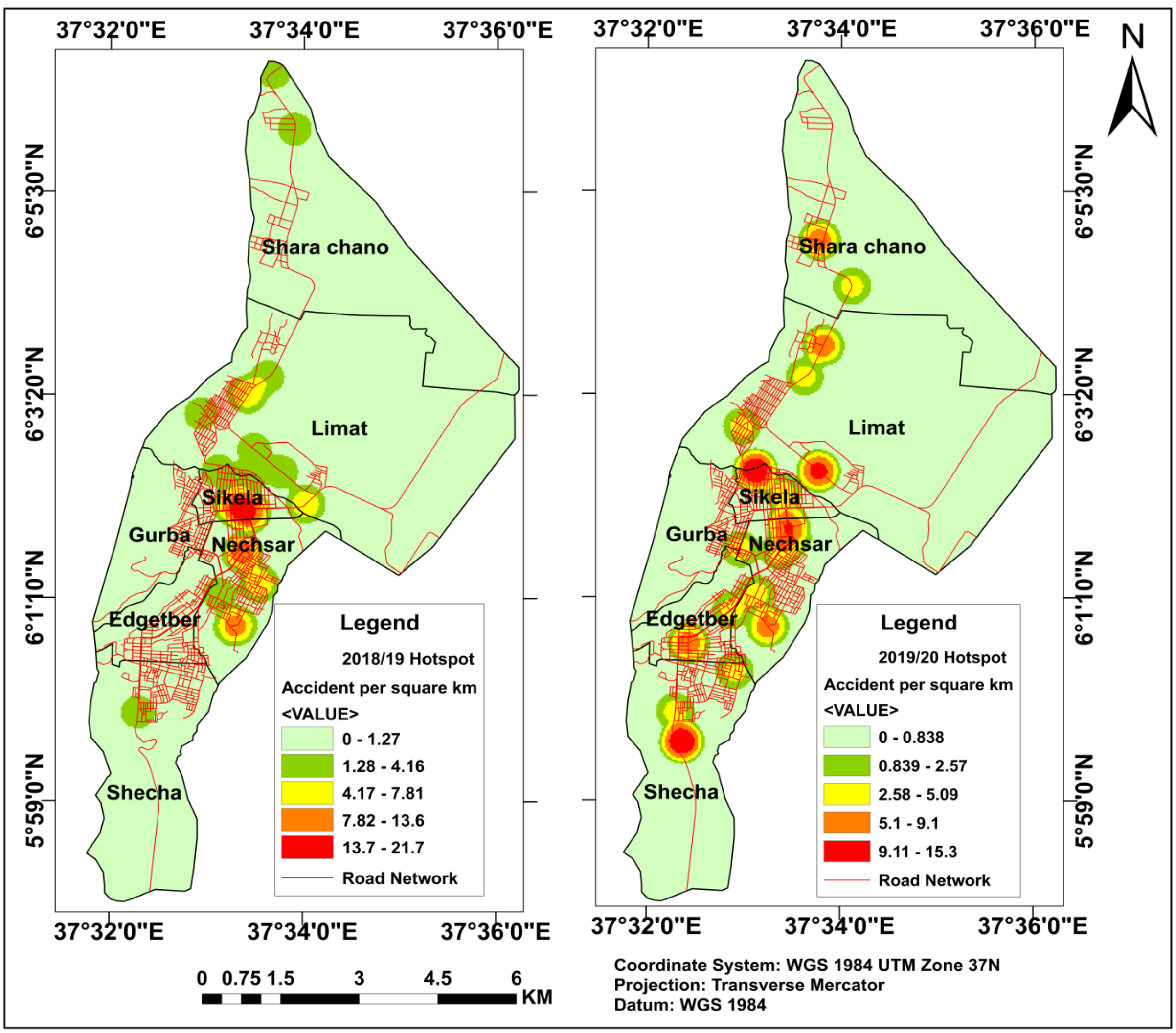

Figure 14: Kernel Density Estimation of RTAs in Arba Minch (2018/19 - 2019/20)

This analysis reveals critical hotspots where RTAs are most frequent, necessitating focused road safety interventions in these high-density areas to mitigate the risk and occurrence of accidents. In the year 2020/21, RTAs showed a high distribution density in Limat sub-town (specifically around Arba Minch University main campus road), Sikela, the southern part of Edgetber, and Shecha (Shecha Daget) sub-towns. Conversely, in 2021/22, the RTA pattern was high in Sikela, Edgetber, and Shecha sub-towns.

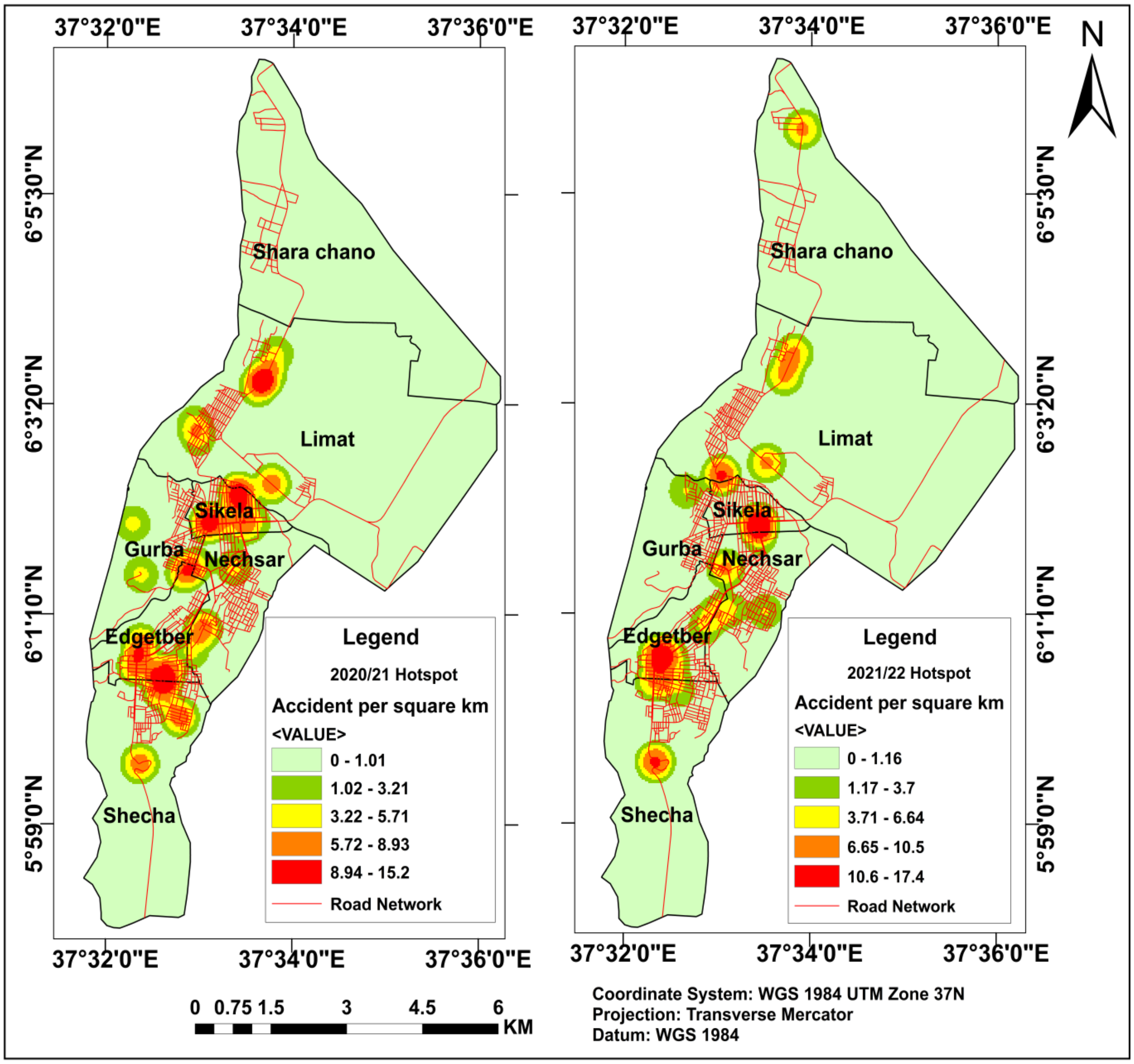

Figure 15: Kernel Density Estimation of RTAs in Arba Minch (2020/21 - 2021/22)

This analysis further underscores the dynamic nature of RTA hotspots, necessitating ongoing monitoring and targeted interventions to address the changing patterns of accidents in Arba Minch town.

In Figure 16 below, the kernel density spatial analysis method identifies the highest (dark red) and lowest (light blue) density of RTAs in the town. RTAs were high in Sikela, Nechsar, the northern part of Shecha, the western part of Limat, and the southern part of Edgetber sub-towns, particularly along the road in front of Arba Minch University Main Campus, Yeshi Madeya, around Arba Minch textile factory, Arba Minch Stadium, Sikela Gamo Square, Nechsar Addisu Mesgid, Shecha Rafael Church, and Shecha Daget. Conversely, in Shara Chano, the southern part of Shecha, Gurba, and the eastern parts of Limat sub-towns, there was a low density of accidents. The main reasons for the low density of accidents in these areas include the availability of forests and agricultural areas and the low population density.

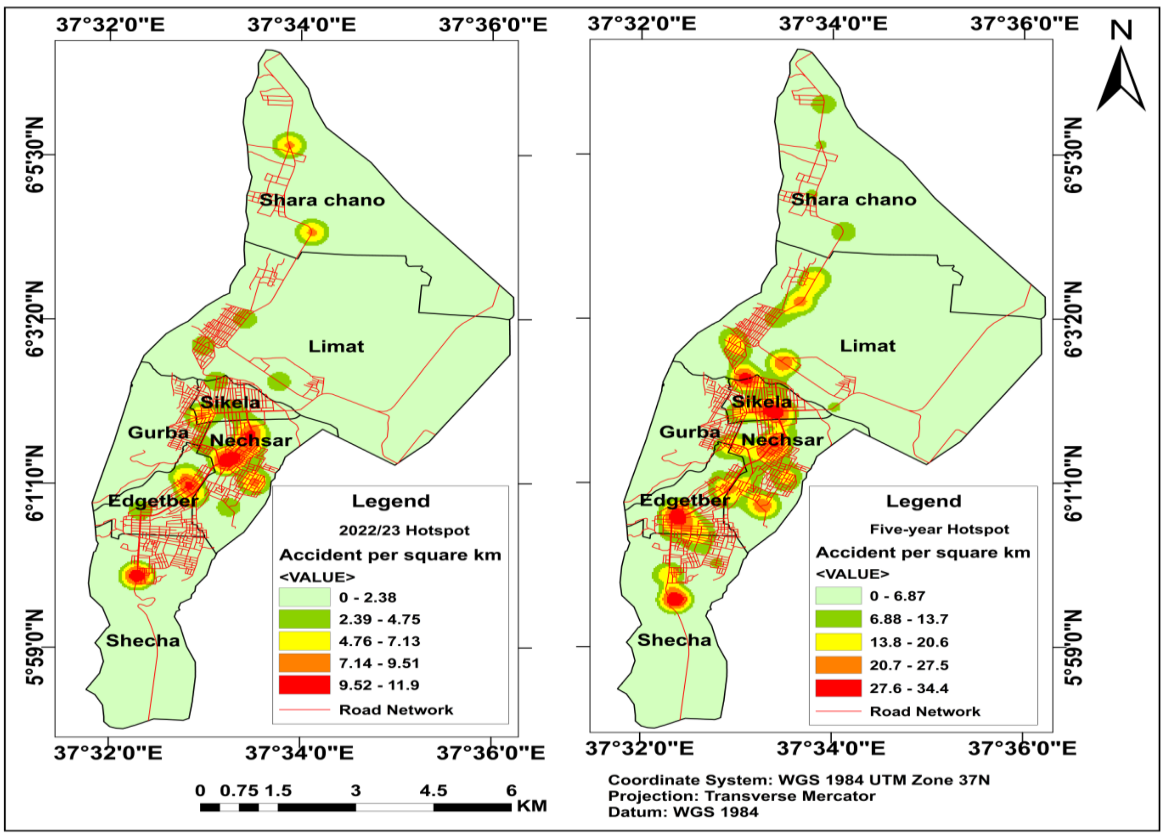

Figure 16: Kernel Density Estimation of RTAs in Arba Minch (Overall)

This comprehensive analysis provides valuable insights into the spatial distribution of RTAs in Arba Minch town, highlighting areas with high accident densities that require targeted interventions to improve road safety.

Analyzing Accident Hot spot Using Inverse Distance Weighted

Inverse Distance Weighted interpolation functions are utilized to create a continuous surface from sampled traffic accident points, enabling the forecasting of unknown values of RTA point data. This method generates a continuous surface representation of RTA magnitudes over space.

The traffic accident hotspot areas in Arba Minch town are depicted in Figure 4.20. The map illustrates that in high accident areas, the frequency of accidents was nine, whereas in low accident areas, it was one. Red and green colors indicate areas with severe and safer accident occurrences, respectively.

In Arba Minch town, RTAs were severe in the central part of Limat, Sikela, Nechsar (Addisu Mesgid), and Shecha (Shecha Daget and Raphael Church) sub-towns. Conversely, Shara Chano, the eastern parts of Limat, Gurba, most of Edgetber, and the southern part of Nechsar sub-towns were relatively safer. However, it's important to note that this doesn't imply these areas are entirely free from accidents.

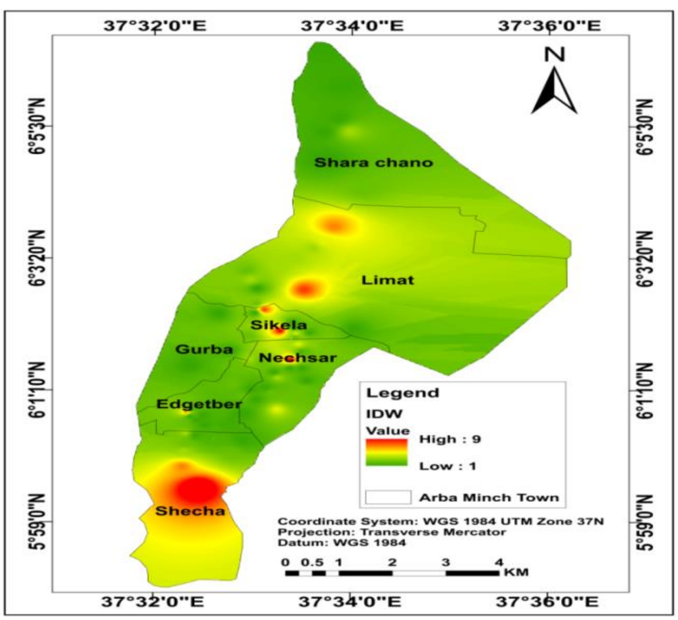

Figure 17: Traffic Accident Hotspot Areas in Arba Minch Town

This analysis provides a comprehensive visualization of RTA hotspots, aiding in the identification of areas requiring targeted interventions to enhance road safety in Arba Minch town.

Top Seven Traffic Accident Hot Spot Areas in Arba Minch Town

Figure 18 and Table 3 show top seven RTA hot spot areas of Arba Minch town. Top seven traffic accident hot spot areas of Arba Minch town were *Shecha Daget*, around Arba Minch textile factory, the road in front of AMU Main Campus, around Arba Minch Stadium, in front of Shecha Raphael Church, *Nechsar Addisu Mesgid* and around Gamo Square

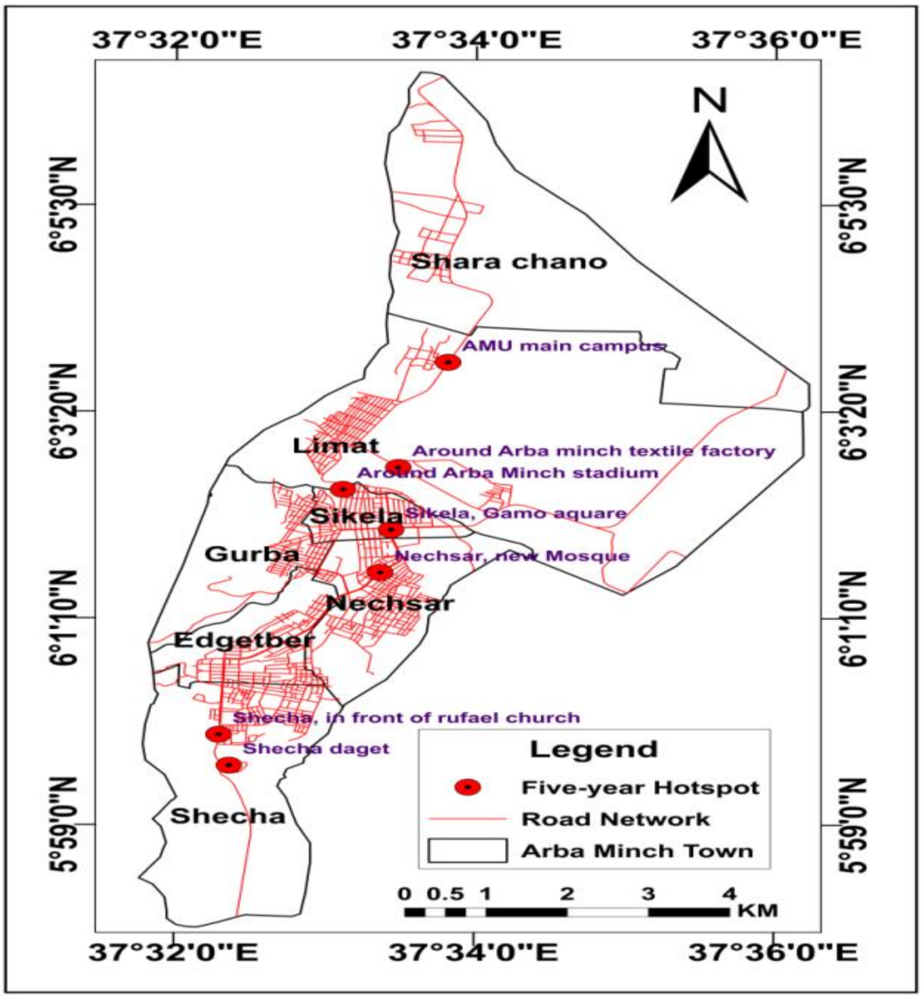

Figure 18: Top seven RTA hotspots

Table 3

Top seven RTA hotspot areas in Arba Minch town

Code	Name of Hot spots	Frequency of RTAs	Severity Value	Rank
26	*Shecha Daget*	9	90	1
03	Around Arba Minch Textile Factory	7	32	2
02	In front of AMU Main Campus	5	31	3
13	Around Arba Minch Stadium	6	27	4
22	*Shecha* Square to Raphael Church Road	5	19	5
43	*Nechsar Addisu Mesgid*	6	17	6
14	*Gamo* Square	5	13	7

Source: Compiled from Arba Minch Town Traffic Police Office RTAs data, 2023

1. Shecha Daget: The road around Shecha Daget is characterized by twists, narrow passages, and potholes, making it inherently risky for drivers (Figure 19). As observed during field observations, these road conditions contribute significantly to the high frequency of RTAs in this area compared to other identified hot spots in the study area.

Figure 19: The road condition in *Shecha Daget*, Field Survey, 2023

2. Around Arba Minch Textile Factory: This is the second most dangerous accident hotspot due to the high number of workers entering and leaving the premises**.** There is an elevated risk of accidents in this area due to the increased traffic flow associated with the textile factory.

3. In front of AMU Main Campus: This area serves as a primary gateway and outlet for various parts of Southern Ethiopia and the capital city of Addis Ababa. It is frequented by cattle, particularly during morning and evening hours, as well as university students and other road users. The presence of congested pedestrians, especially university students, and other road users further adds to the vulnerability to accidents in this area, alongside vehicular traffic.

Figure 20: The road in front of AMU Main campus, photo, 2023

4. Roads around Arba Minch Stadium: These roads experience high foot traffic, particularly during events such as concerts, sports matches, or festivals held at the stadium. The increased pedestrian activity, combined with vehicular traffic, intensifies the risk of accidents in this area.

5. Nechsar Addisu Mesgid: The road around Nechsar Addisu Mesgid is a crossroad characterized by high traffic volume due to the convergence of multiple roads. Drivers at crossroads often have to make quick decisions about their route, leading to potential confusion and dangerous driving behaviors such as failing to yield the right of way or not signaling intentions. Crossroads can also be less visible than other parts of the road, increasing the likelihood of accidents.

6. Shecha Square to Raphael Church Road: Another key RTA hotspot area is the road in front of Shecha Raphael Church, serving as the gateway for various districts of the zone and the South Omo and Konso zones. The road's steep incline, combined with misplaced or poorly visible pedestrian crossings, such as zebra crossings, contributes to accidents. Pedestrians, particularly students of Arba Minch University Chamo Campus, may not use designated crossings, leading to frequent accidents in the area.

7. Gamo Square: Situated near the bus station, Gamo Square serves as a primary route to and from various directions to the bus station and other parts of the town. This area experiences a high frequency of community mobility, with people traveling to markets, bus stations, banks, and other destinations. The significant influx of people and vehicles contributes to congestion, increasing the likelihood of traffic accidents resulting in fatalities, serious injuries, slight injuries, and property damages. The congestion exacerbates the rate of casualties in this area.

Figure 21: Vehicle congestion around Gamo square, photo, 2023

CONCLUSION AND RECOMMENDATION

The findings of this study indicated that most RTAs were caused by drivers aged 18-30 with 1-10 years of driving experience, and almost all of them are male drivers. Motorcycles were the leading vehicles in causing more accidents (26%) followed by three-wheel vehicles (20%) and Isuzu trucks (12%). Therefore, Arba Minch town transport and traffic police department should make special awareness creation programs and develop targeted interventions for identified high-risk groups; especially for young male motorcycle, three-wheel vehicles, and Isuzu truck drivers, considering their high involvement in accidents.

Spatial analysis revealed that accidents were more frequent around market areas, schools, health centers, bus stations, and religious places, with Shecha and Nechsar sub-towns experiencing the highest concentration of accidents. The top seven hot spot areas were identified, including Shecha Daget, around Arba Minch textile factory, and Arba Minch University main campus. The town's transportation sector should strengthen law enforcement efforts, particularly in the identified hotspot areas and expand the public transportation network to reduce traffic congestion.

Furthermore, the study emphasizes the importance of improving data collection and analysis methods, advocating for the integration of GIS and GPS technologies to enhance the accuracy and efficiency of accident data management.

Overall, this study contributes valuable insights for stakeholders aiming to reduce fatalities, injuries, and property damage caused by RTAs in Arba Minch town. It also provides a basis for further research in this area and advocates for the adoption of GIS tools for RTA analysis and prevention strategies.

REFERENCES

Afolayan, A., Easa, S. M., Abiola, O. S., & Alayaki, F. M. (2022). GIS-Based Spatial Analysis of Accident Hotspots : A Nigerian Case Study.

Aklilu Toma., Ashenafi Senbeta., & Anteneh Bezabih. (2021). Spatial distribution of RTA at Hawassa City Administration, Ethiopia. Ethiopian journal of health sciences, 31(4).

Alamiraw Mulugeta., Tamene Adugna., Saathoff, F., & Alemayehu Gebissa. (2021). Severity, spatial pattern and statistical analysis of road traffic crash hot spots in Ethiopia. Applied Sciences, 11(19), 8828.

Alkaabi, K. (2023). Identification of hotspot areas for traffic accidents and analyzing drivers' behaviors and road accidents. Transportation research interdisciplinary perspectives, 22, 100929.

Ashebir Nigussie & Segni Bekele. (2020). Prevalence and Factors Associated with Road Traffic Crash Among Bajaj And Motor Bicycle Drivers In Negelle Arsi Town, Oromia Regional State, South East Ethiopia Int. J. Of Adv. Res. 8 (Jan). 145-153].

Bener, A., Yildirim, E., Özkan, T., & Lajunen, T. (2017). Driver sleepiness, fatigue, careless behavior and risk of motor vehicle crash and injury: Population based case and control study. Journal of Traffic and Transportation engineering (English edition), 4(5), 496-502.

Debela Deme. (2019). Road traffic accident in Ethiopia from 2007/08-2017/18. American International Journal of Sciences and Engineering Research, 2(2), 49-59.

Direslgne Misker., Abayneh Tunje., Achamyelesh Mengistu., Fikeru Abera., Matiyas Yalelet., Misganaw Gebrie., Mohammed Yimam., Sara Ayalew., & Solomon Anemaw. (2017). Magnitude And Factors Associated With RTA Among Traumatized Patients In Arba Minch General Hospital, 2017. Int J Pub Health Safe, 2(127), 2.

Efrem Alebachew. (2019a). GIS Based RTA Black Spot Sites Assessment: A Case Study of Kirkos Sub-City, Addis Ababa, Ethiopia.

Endalkachew Mekonen. (2020). RTA In Ethiopia The Economic Effect of RTAs In Ethiopia : Evidences From Addis Ababa City. ITIHAS The Journal Of Indian Management, May.

Ethiopian Federal Police Commission. (2021). RTA Report: Addis Ababa.

Geurts, K., Wets, G., & Verkeersonveiligheid, O. K. (2003). Black Spot Analysis Methods : Literature Review. Onderzoekslijn Kennis Verkeersonveiligheid.

Jemal Bedane., Sultan Bedane., & Raju Ramesh. (2017). Road Accidents of Arba Minch Town In Ethiopia : An Empirical Study. SSRG International Journal of Civil Engineering, 4(3), 26–30.

Melaku Tadege. (2020). Determinants of fatal car accident risk in Finote Selam town, Northwest Ethiopia. BMC public health, 20, 1-8.

Robel Aychew. (2020). GIS-Based Identifications of RTA Hotspots And Hazardous Bus Stops: A Case Study of Yeka Sub-City, Addis Ababa. Addis Ababa University.

Teferi Abegaz & Samson Gebremedhin. (2019). Magnitude of RTA related injuries and fatalities in Ethiopia. PloS one, 14(1), e0202240.

Tesfahun Zewude. (2017). Determinants That Lead Drivers In to Traffic Accidents: A Case of Arba Minch City, South Ethiopia. Science Journal of Applied Mathematics and Statistics, 5(6), 210. Https://Doi.Org/10.11648/J.Sjams.20170506.13

Weldemarium, T. D. (2022). Reducing RTA : Rapid Evidence Synthesis. In 33rd EPHA Annual Conference.

World Health Organization. (2021). Global Launch: Decade of Action For Road Safety 2011-2020 (No. WHO/NMH/VIP11. 08). World Health Organization.