Identification of Road Traffic Accident Hotspots on Sargodha-Jhang Road (Punjab) Pakistan

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Abstract

Globally, road traffic accidents must be addressed even in an advanced transportation system. However, accident frequency can be reduced by the improvement of a road network and infrastructure. The main objective of this study was to explore the various tendencies and attributes of road traffic accidents (RTAs) frequency and intensity related to weak infrastructure and non-systemized traffic patterns on a second-class inter-district road (Sargodha-Jhang) in the region of central Punjab. Secondary data of RTAs collected from Rescue 1122 for the last 3 years (2021, 2022, and 2023) and used to detect hotspots in the study area. Data analysis was carried out in SPSS 17 software by applying the mode of time and space by the latest Tucky method corresponding to the analysis of variance (ANOVA) with a fitted mean. Accident rates were found to be fatal and statistically significant at a 99% significance level with a p-value (of 0.000). The base map of the road obtained from the Survey of Pakistan published the Road Network Map of Pakistan. A total of 14 locations were pointed out using the Global Positioning System (GPS), and mapping was done in the ArcGIS 10.5 environment using on-screen digitization and geo-referencing. Some conditional and critical attributes like 50% poor road conditions and weak infrastructure, the vacuum of safety measures, the rate of accidents, and total traffic exposure contributed to the frequency and intensity of RTAs.

Keywords: Fatal and Non-Fatal Accidents, GIS Mapping, Accidents Hotspot, Accident Density.

Introduction

A road traffic accident (RTA) is an unanticipated and non-deliberated event that is unexpected with no obvious cause. These crashes are now emerging as the leading public health concern in many developing countries with poor and blighted road infrastructure and violation of traffic rules and laws, i.e., Pakistan. Road traffic accidents are the 10th leading cause of death worldwide. It is suspected to increase gradually till it becomes the third leading cause of disability and adjusted

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life. Injuries of various categories related to RTAs were the world's biggest threat and challenge from 2010 to upcoming years. 90% of global road accidents consequent to death occur in middle and low-income countries, where 85% of the world population lives. Therefore, RTAs seem to be the 7th foremost reason for death by 2030 (Ahmed et al., 2023). It is further anticipated that RTAs cause death to vulnerable road users because more than half (54%) of the individuals killed on the roads are cyclists, motorcyclists, and pedestrians (Ahmed et al., 2023). Therefore, RTAs can now be perceived as the foremost reason for causalities and injuries on regional and global levels (Mohsin & Nazeer, 2024).

A better and less risky transportation system is now an emerging challenge in many developing regions of the world due to the rapidly growing population (Tariq et al., 2021). There are considerable involvements and a wide range of factors that affect the traffic patterns on inter-city roads in Pakistan. Traffic accidents on these roads can be attributed to one or a combination of various factors. Weak infrastructure and network irritants may ultimately cause horrible accidents on the road (Jenelius, 2006). A study undertaken in Abu Dhabi city (UAE) also explores that careless driving is a chief reason for city road accidents, and the drivers' age led to more accident chances. Experience drivers have less probability of being involved in road accidents (Alkaabi, 2023). Pedestrians and two-wheeler motorized vehicle users bear the leading proportion of total accidents as an abundant number of deaths in adolescents and young adults. They both constitute the most vulnerable group among road users. A positive linear relationship is also reviewed between Pakistan's increasing population, vehicles, and accidents (Nasr, 2009). Carelessness (42.22% in 2015 and 43.10% in 2019), over speeding (39.92% in 2015 and 33.89% in 2019), overtaking, and violation of traffic rules were the major causes of RTAs in Bahawalpur City (Mohsin & Nazeer, 2024). Thus, over speeding, Overloading, Carelessness, Vehicle Design, Vehicle fitness, Teenage driving, Driving fatigue, Disobeying traffic rules, Use of cell phones, Road conditions, inward hurdles, Use of drugs, and high beams are frequent reasons for road accidents in Pakistan (Khan & Fatmi, 2014). Any accidents are merely clashes that might be avoided. Logically, an accident can be described as a misfortune event. A lot of parameters and attributes affect the rate of accidents. The occurrence and involvement of crashes mostly vary in different modes of vehicles. Therefore, road accidents are 100% preventable (Khan, 2012).

Secure traveling is considered very important for the sound transportation system in a country to meet the basic needs of travel (Hammad et al., 2019). In this regard, road safety measures are a combination of components. It approaches that contain equilibrium in the balanced interaction of road users, vehicles, and network infrastructure on a section of the road. This combination bears qualitative and quantitative attributes installed on a road network to cope with and minimize the risk factors (Ferreira, 2013). That is why the main objective of this paper was to identify weak infrastructure of class two-way inter-district roads in central Punjab, where the road environment is contributing to cumulating more RTA hotspots, and to analyze the rate of tendency and occurrence of accidents concerning the involvement of vehicles, variety of causes and intensity of crashes.

Background of Hotspots Identification of RTAs

In Transportation geography, a hotspot is a location on the way where there are maximum chances of an accident. It may be a point or a segment of the road. In traffic engineering, it is defined as a road location or segment where the expected number of accidents is higher than similar locations on that road (Elvik et al., 2009). Therefore, the data about the mapping and modeling for RTAs is essential to know about the possible causes and consequences of these road traffic accidents

(Bokaba et al., 2022). Al-Aamri et al. (2021) asserted that road intersections (roundabouts, crosses, and bridges) represent a higher risk of causing RTAs than other road geometric features, as found in Muscat Governorate (Sultanate of Oman). Hence, these are the most risky locations and segments of RTAs. Various terms are used to describe these, i.e., hazardous road locations, high-risk locations, accident-prone locations, black spots, hot spots, hot zones, black zones, sites with promise and priority investigation locations (Montella, 2010; Choudhary et al., 2015; Yao et al.,2018).

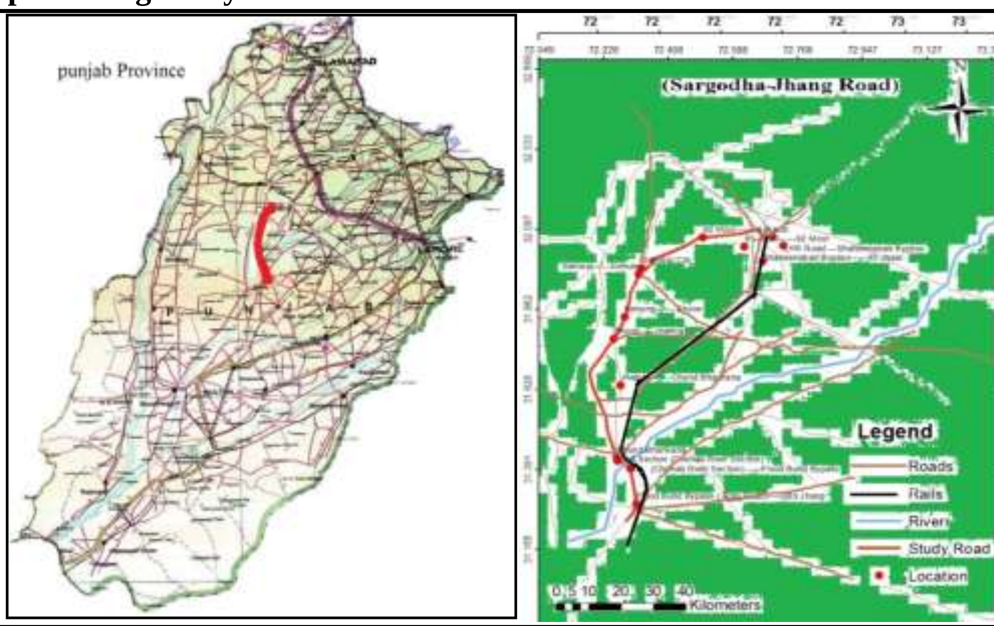
Several approaches are used to determine/ identify accidental hotspots spatially and temporally. For instance, Shariff et al. (2017) employed Nearest Neighborhood Hierarchical (NNH) Clustering and Spatial-Temporal Clustering (STC) in Crimestat and ArcGIS to identify hotspots of traffic accidents in North-South Expressway (NSE) from Sungai Petani to Bukit Lanjan (Malaysia). Alkaabi (2023) used the Getis-Ord Gi* statistic approach in ArcGIS to effectively mark the hotspots of high-density vehicle accidents near the central city of Abu Dhabi (UAE). Bokaba et al. (2022) used multiple machine learning classifiers (random forest, support vector machine, naïve Bayes, k-nearest neighbor, logistic regression, etc.) to analyze the RTAs in Gauteng, South Africa. They found the random forest is useful for empirically analyzing the RTA's hotspot.

Material and Methods

Study Area

The study area Sargodha-Jhang road is an inter-district 2nd class provincial highway extending 124 km long in central Punjab (Figure 1). This region is an irrigated agricultural plain of central Punjab. Sargodha-Jhang road is located geographically between 32.07°75′81″N to 31.28°86′07″N latitudes and 72.69°80′83″E to 72.31°90′33″E longitudes. Both terminal cities are gradually becoming divisional and district headquarters in the central Punjab region. One Tehsil headquarters city, 3 main towns, 5 prominent junctions, 7 intersections, and 8 other main breakpoints are located on and along the road.

Figure 1: Map Showing Study Area



The study area is very important in context of road network in the country. Federal capital and the biggest port city of a country are two important pillars of a state configuration along with socio-economic as well as Geo-political activities of a country. Sargodha-Jhang road provides a shortest route distance between Islamabad and Karachi. So, this section leads as a bypass between Islamabad and Karachi via Sargodha and Jhang. Sargodha-Jhang road belongs to a second class provincial highway road, falling in medium category in its quality and structure. Road layout is not quite straight. The salient aim and objective of this research is to analyze the rate of tendency and occurrence of accidents with reference to Fatal and non-fatal accidents, density and growth of crashes. These tendencies may capable of determining of Hotspots and modes of their treatment with reference to road safety measures.

Data Collection

Road traffic accident secondary data in the study area formulated by Punjab Rescue 1122 Emergency Service Sargodha and Jhang is used in this study for past three years viz. 2021, 2022 and 2023. This data was belonged to the total accidents occurred in the study area, total victims, crash density/km, and victims density/km. On the basis of loss and causalities, the crashes may be grouped as follows;

- Fatal accidents------------- killed persons
- Non-fatal accidents--------injured persons
- Financial loss accidents---monetary grievances

Data Analysis

All the data is analyzed in mode of time and space by a latest Tucky method corresponding to analysis of variance (ANOVA) with a fitted mean processed in the SPSS 17 software. Accident rates are measured by total traffic exposure on a road segment as total number of accidents during a year/ Annual traffic exposure demoted as;

$(R) = N/ V L$

Consequences and severity of accidents is rated upon, number of fatal and non-fatal accident killed and injured persons, total victims, total vehicles involved, temporal rates and growth. Rate of occurrence of accident on a road segment is calculated by number of crashes with time period over total accidents in a year (Anderson, 2009) are devoted as, accident frequency calculated by; Number of crashes x Time period / Total accidents

RTAs Hotspot Identification and Mapping

A base map of the study area is collected from road network map of Pakistan by Survey of Pakistan and digitized and geo-referenced in ArcGIS 10.5 software. The study area map is finalized with its main network features by GIS configuration. Geographic positioning system (GPS) is used to mark the different locations of collecting samples from the study area with latitude, longitude and elevation. The study area is classified into 14 sections according to the discrete and heterogeneous nature of road configuration. Road conditions are tabulated into 4 standards according to ground facts.

Identification of hotspot is a very difficult as well as longer process. However, there is not an approved universal mode of detecting hotspot, yet applicable to 2nd class provincial highways. Therefore, hotspots are detected by using some critical attributes as, lack of safety measures, poor road condition, weak infrastructure, macroscopic parameters and microscopic parameters.

Results and Discussion

The road condition always acts as coefficient of an independent variable in accident study. The better road conditions, the less likelihood of a fatal accident. However, it is analyzed that major and severe accidents are more and common than minor clashes as exposed with group A with 99% confidence level displayed in table 1. The road sections having maximum risk of fatal accidents are highly significant with fatality and number of sections exposed to traffic crashes.

Table 1: Analysis of Fatality of Accidents (Analysis of Variance)

Source	DF	SS	MS	F	P
Fatal or Not	1	3458.58	3458.58	153.39	0.000*
Name of section	13	3828.73	294.52	13.06	0.000*
Fatal or Not*section	13	968.92	74.53	3.31	0.001*
Error	56	1262.67	22.55		
Total	83	9518.89			

S = 4.74843   R-Sq = 86.74%   R-Sq (adj) = 80.34%

*significant at 99% confidence level

The grouping of fatal and non-fatal accidents is shown in table 2. The higher mean value of 22.4 demonstrated the greater risk of fatal road accidents of various sections of the road with ‘A’ grouping. The details of these sections with anticipated severity of fatal/ non-fatal road traffic accidents is given in table 3 with groupings of A (fatal/ highly dangerous), and B (non-fatal/ less dangerous). While the C and D represent minute chance of the road traffic crashes.

Table 2: Grouping Information of Fatal and Non-Fatal Accidents

Fatal or Not	N	Mean	Grouping
Fatal	42	22.4	A
Non-Fatal	42	9.5	B

Means that do not share a letter are significantly different (Tukey, 1993).

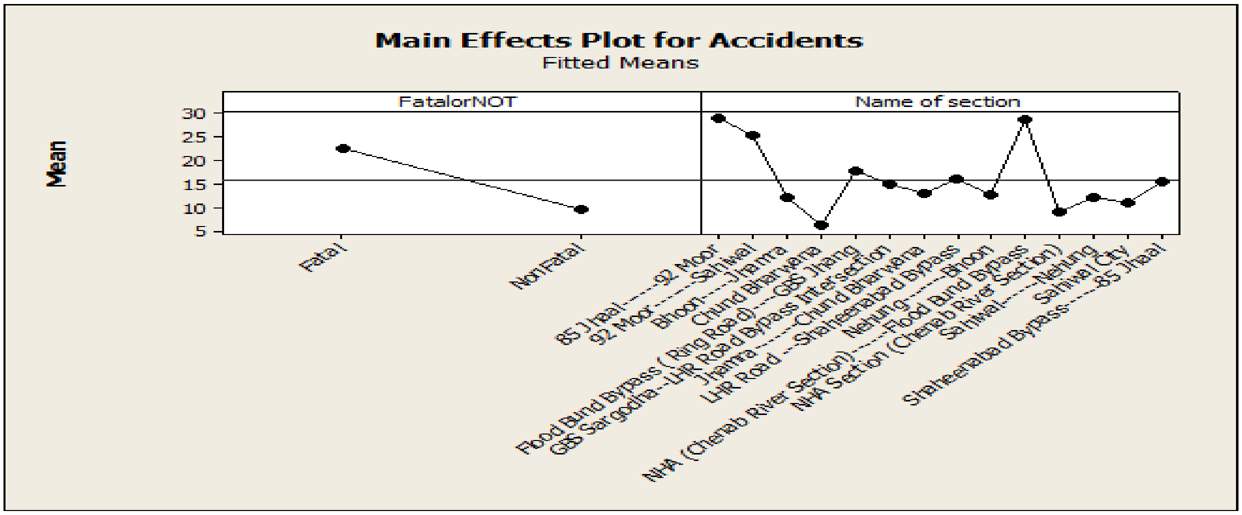
Table 3: Spatial Grouping of Road Sections of Sargodha-Jhang Road

Name of section	N	Mean	Grouping
85 Jhaal------92 Moor	6	29.0	A
NHA (Chenab Section)--Flood Spur	6	28.7	A
92 Moor-------Sahiwal	6	25.3	A B
Flood Bund Bypass--GBS Jhang	6	17.8	B C
LHR Road ---Shaheenabad Bypass	6	16.0	B C
Shaheenabad Bypass------85 Jhaal	6	15.5	C D
GBS Sargodha--LHR Road Bypass	6	15.0	C D
Jhamra-------Chund Bharwana	6	12.8	C D
Nehung-------Bhoon	6	12.7	C D
Bhoon-----Jhamra	6	12.2	C D
Sahiwal------Nehung	6	12.0	C D
Sahiwal City	6	11.0	C D
NHA Section (Chenab Section)	6	9.2	C D
Chund Bharwana	6	6.3	D

Means that do not share a letter are significantly different (Tukey, 1993).

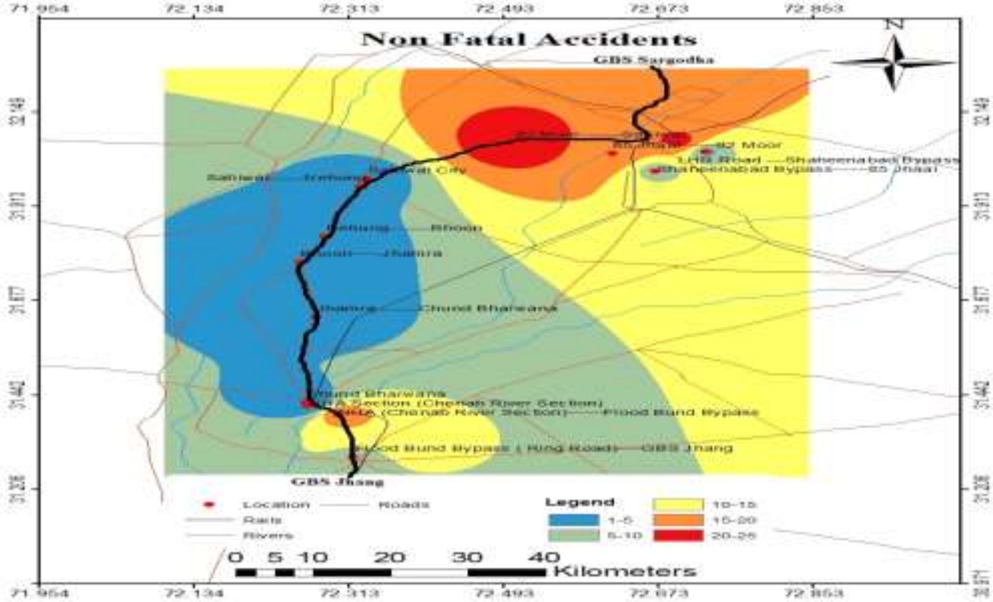
The peripheral sections of both main cities are found with peak tendency of fatal accidents. The 92 Moor---Sahiwal section adjacent to peripheral section of Sargodha city also exposed higher ratio of severe crashes. All other sections located far from cities are found with low intensity of intensive accidents as lying below fitted average in figure 2.

Figure 2: Spatial Distribution of Fatal and Non-Fatal Accidents



The gradient of killed persons is fortunately quite low in the study area. Each category is also increasing with the passage of time from 2021-2023 but fortunately best fitted average is not concluded very high. The rate of increasing gradient of fatal accident is proved as similar as decreasing rate of non-fatal accidents. However, injured group bears an abundant figure of crashes and victims. Previously it is found in a study that about 15 road sections of Jhang-Sargodha road have irritants and bends and thus dangerous and risky with notable rise in hourly (morning and afternoon), and weekly (Thursday and Saturday) traffic flow with increasing volume of vehicular traffic over the past few years (Sial et al., 2023).

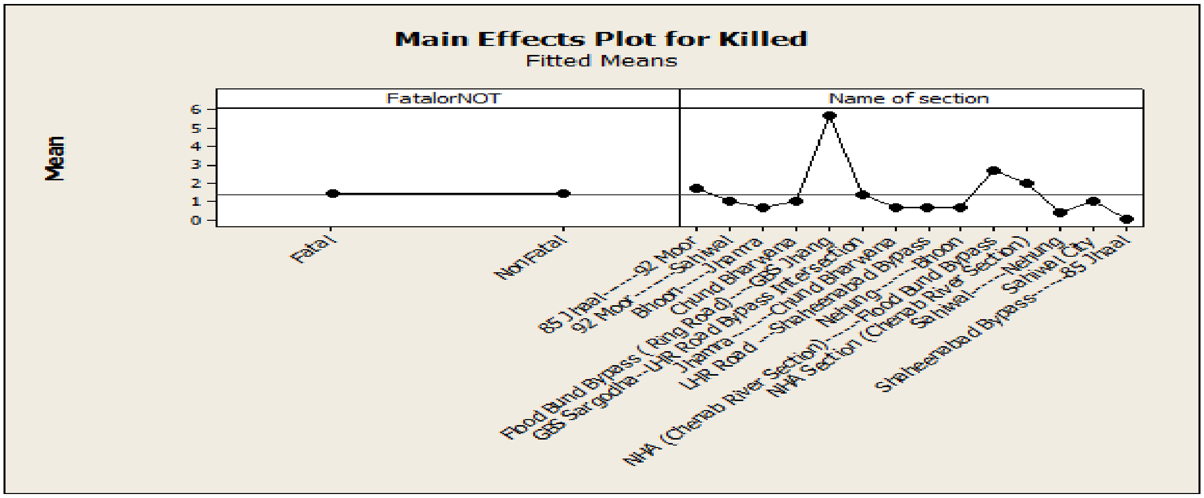
Figure 3: Map of Non-Fatal Accidents



Maximum accidents were found at peripheral sections of both cities. Maximum proportion of road crashes was non-fatal as compared to other tendencies. Minimum values of non-fatal accidents were resulted on central part of the study road where, road conditions are quite improved and traffic pressure is less than other urban and sub-urban sections. Greater tendency of non-fatal accidents near main cities is a true justification of hotspot locations in the study area as presented in the map. In this regards, outlet road segment of Sargodha city has captured maximum non-fatal crashes as compared to other locations in the study area. A recent study conducted in Bahawalpur City also identified that the spatial RTAs hotspots on the cross roads, chowks and inter-city roads like Ahmadpur road, Yazman road, Hasilpur road and Multan road having greater risk of severe road traffic clashes (Mohsin & Nazeer, 2024).

Urban section of Jhang city is attained peak intensity regarding severe accidents in the study area. However fatal and non-fatal crashes are presented as fitted average. Secondly next two consecutive section of Jhang are also found with higher magnitude of intensive accidents. Only peripheral section of Sargodha has attained the score higher than fitted average regarding rate of killed persons. The findings of all other sections related to killed persons are proved low than fitted average as shown in figure 4. This positive reflection urges to all concerned associates to improve poor road network, blight and polluted traffic pattern and weak infrastructure. Nazeer *et al.*, (2021) outlined the main reasons of RTAs in a study conducted in Bahawalpur city including the bike drivers (69.33%), increase in population (62.66%), overtaking of the vehicles (51.33%), over speed and hustle to reach the destination (34.66%) that ultimately resulted in the death of teenage drivers (52%).

Figure 4: Spatial Distribution of Killed Persons



As shown in figure 5, spatial pattern and crash tendency of fatal accidents is significantly similar to non-fatal accidents in the study area. Fatal accidents are found more on cities outlets as compared to other sections. So, spatial presentation of the given map is also a due justification of hotspots locations. Minimum ratio of fatal accidents is resulted on central part of the study road where road condition is quite improved but traffic pressure is significantly low. It is also found in a study that less fatal traffic accidents (~95%) happened on the internal road network in the Irbid Governorate's towns (Jordan) where the highest traffic volume exist (Hazaymeh et al., 2022). It is an obvious fact that considerable ratio of RTAs is happened on roads with excessive volume of heavy vehicular traffic. Traffic congestion is increased during the peak busy traffic and directly affecting the traffic flow as well as indirectly the travellers health and economic situation (Farooq & Akram, 2018). A recent study has identified a total of 22 such heavy vehicle risk segments (HVRSs) and then ranked by crash rate in a highway in Malaysia. The study identify the cluttering of hotspots vulnerable to high risk road traffic crashes based on vehicle type which could be helpful to marking and ordering the segments of the RTAs and to further develop the measures to for these hotspots (Manap et al., 2021).

Figure 5: Map of Fatal Accidents

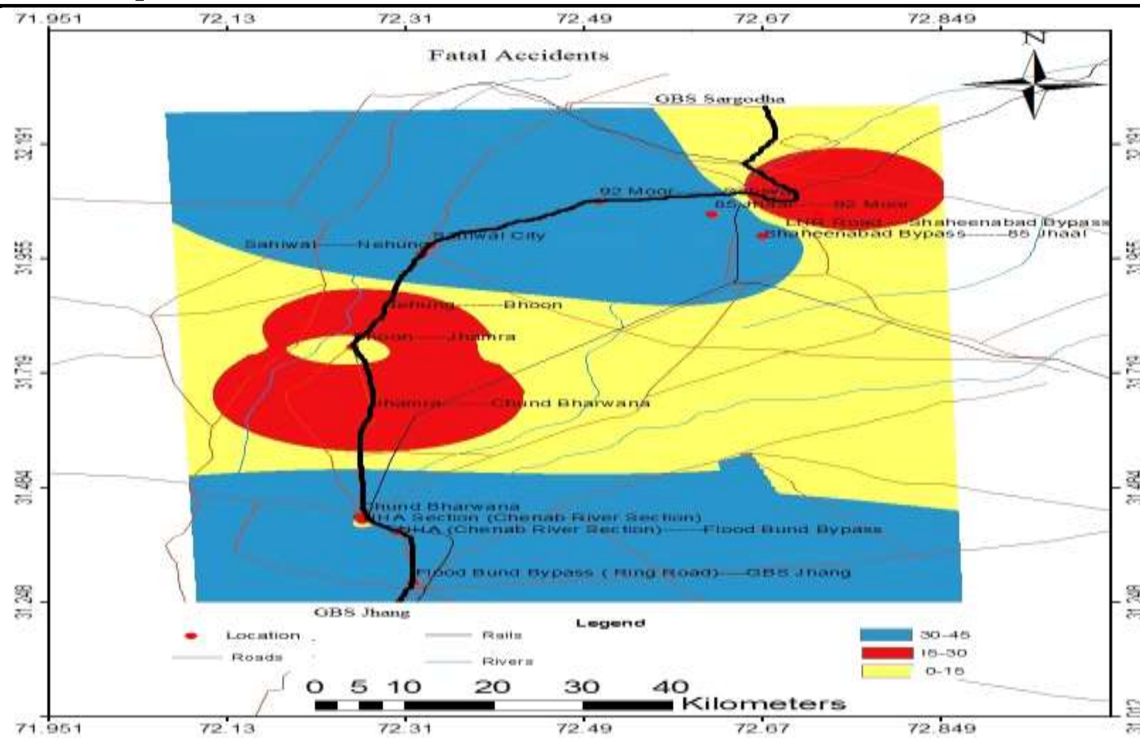


Table 4 signifies that the total number of accidents and total number of victims were increasing with positive correlation with the passage of time since 2021-2023. The approaches towards detection of hotspots vary from country to county. Real time traffic data for a long period of time is inevitable for true detection of hotspot on a road network. Real time crash data with reference to crash locations is suggested to collect for 30 years on a road network for true detection of hotspots. However, short and substantive techniques are probable for detection of hazardous locations in the study area. Mahmood et al., (2022) verified that of RTAs in leading urban centers in Punjab province (Pakistan) are witnessing the massive increment in recent years. By using the RTAs data of 2015-2018 of Lahore, Faisalabad, Gujranwala and Multan an annual increase of 11,153, 3,229, 1,730 and 4,000 respectively were noted.

Table 4: Crash Density and Concentration of RTAs

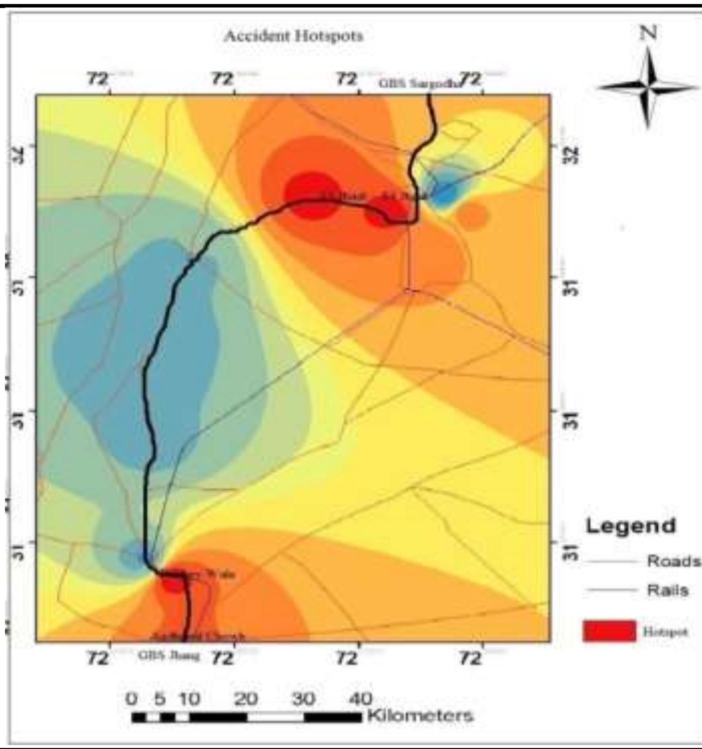
Years	Total Accidents	Total Victims	Crash Density/Km	Victims Density/Km
2021	290	410	2.26	3.2
2022	367	493	2.87	3.85
2023	384	503	3	3.95

Hotspots of RTAs

The identification of the hotspots of RTAs on Jhang-Sargodha road has exposed some conditional and critical attributes studied in the field for close estimation of hotspots (Figure 6). As 50% poor road conditions and weak infrastructure, vacuum of safety measures, rate of accidents and total traffic exposure were contributed in the frequency and intensity of RTAs. Consequently, three locations were identified as hotspot where there is maximum risk of RTAs is observed:

- 85 Jhaal---84 Jhaal: It is 7 km long road segment where rate of accidents is higher than other surrounding sections. This road segment is located on 13 km far from Sargodha. The significances of hotspot characteristics are identified as higher traffic pressure with polluted mixture of different vehicles due to the busiest outlet and peripheral location along Sargodha.
- Pakkey Wala----NHA Junction: Another hotspot location is found around Pakkey Wala, 11 km far from Jhang city. It is a 3 km short road segment which is located in flood prone region very close to Chenab River. This segment also contains poor road condition, 20 feet narrow width but heavy traffic pressure also. The road is constructed on a flood protection Bund with very narrow shoulders and edges. Two long flood dips are also situated on the way. It is also a peripheral section of Jhang city where traffic pressure remained higher during the whole day.
- Aadhiwal Chowk: It is an urban junction near General Bus Stand in Jhang city where tendency of accidents is detected higher than surrounded locations. Two reasons are identified in its ranking as a hotspot. One is the highest traffic pressure because it is the busiest junction between Jhang city and Jhang Sadar. Other reason is found as locational gradient and configuration of the junction because all four distributaries roads are not intersected at a right angle. So, this oblige gradient of distributaries roads always acted as a major irritant inwards smooth flow of traffic.

Figure 6: RTAs Hotspots



Conclusion

Road traffic accidents (RTAs) are considered a major issue of developing world countries with the involvement of numerous intervening factors. The currents study investigated the road traffic accidents/ crashes, their density, victims and the fatal and non-fatal accidents and the identification of the RTAs hotspots on the Jhang-Sargodha road, an inter-district second class highway of

Punjab. Findings of the study revealed that a total 14 locations on the road were found as risky points. Spatial distribution of the crashes is proved, as the distance increases from the cities and other urban locations, accident acceleration is gradually reduced. The accident ratio has slightly increased with the passage of time. Hazardous locations and hotspots were identified on the peripheral segments of the both main cities. Consequently, three locations are identified as hotspots on Sargodha-Jhang road. From which, two were short peripheral road segments and one location is a chowk in urban section of Jhang. The study recommends that a seven km long road segment, 2 km from Jhang must be rebuilt at flood spur height adjacent to Chenab River. Aadhiwal Chowk is identified as the busiest intersection in Jhang city, where, warning signs and lightening signals must be installed. Overall, the Government should work on improvement of weak infrastructure of Sargodha-Jhang road to reduce the ratio of RTAs.

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