SPATIO-TEMPORAL ANALYSIS OF TRAFFIC FLOW ON SARGODHA-JHANG ROAD (PUNJAB) PAKISTAN

M. A. Sial[1], M. Mohsin[2*], A. Rehman[3]

[1]Department of Geography, Govt. PST Graduate College Kamalia, Toba Tek Singh, Punjab, Pakistan
[2]Department of Geography, Govt. Sadiq Egerton Graduate College, Bahawalpur, Punjab, Pakistan
[3]Department of Earth Sciences, University of Sargodha, Sargodha, Pakistan
[*]Corresponding author Email: mohsinshahzad10@yahoo.com

ABSTRACT: Traffic flow in Pakistan has become more complex in recent years due to rapid population growth and rapidly generating economic activities. The main objective of this research was to explore the various factors and attributes related to road network configuration contributing to an irregular traffic flow and congestion at second class inter-district national highway section Sargodha-Jhang road, Punjab, Pakistan. It is a national highway road section in central Punjab extending 124 km. Primary data related to traffic flow and volume was collected manually in mode of time and space while secondary data about annual volume of traffic (3 years) gathered from Punjab highway department, southern highway Zone Lahore. Global positioning system (GPS) was used to mark the different locations of collecting samples with latitude, longitude and elevation. The analysis was performed in MS Excel by applying descriptive statistics and analytical tendencies and results were geographically presented by various graphs and maps prepared by using ArcGIS 10.5 software. Traffic flow was analyzed on hourly, weekly and yearly basis by comparing spatial and temporal average and variance. Results determined the hourly fluctuations as peak from 8:00AM – 9:00AM (1,103 vehicles) and 2:00PM - 3:00PM (1,215 vehicles), medium from 11:00AM – 12:00AM (1,000 vehicles), and low hours from 5:00PM – 6:00PM (800 vehicles). Thursday and Saturday were the busiest days in a weekly flow of the traffic while the Friday was least busy day regarding the weekly flow of traffic. Likewise, the yearly results of traffic flow also shown slight increase in volume of traffic vehicles over the last three years. Lastly few suggestions were proposed to bring the regularity, road safety, less traffic jam and congestion and to avoid the traffic accidents in the study area.

Keywords: Spatio-temporal Analysis; Road Network; Traffic Flow; Jhang-Sargodha Road; Pakistan.

(Received   07.04.2023   Accepted 25.08.2023)

INTRODUCTION

Cities around the world are facing emerging challenges for better system of transportation as the population is growing particularly in developing countries (Tariq *et al*., 2021). A road network is a combination of various features and attributes which enables a route path for smooth and safe using of vehicles and road users. Traffic flow and volume are two core quantitative attributes of a traffic stream on a road network. The study of the crossings is considered very essential for the betterment and development of the efficacy of highway intersections in urban areas by the transportation engineers and policy makers (Candappa *et al*., 2015). In Pakistan, the national highway (N-5) is the longest and busiest initiating from the biggest and hub city of Karachi to Torkham with a length of 1,756 km (Farooq and Akram, 2018). Pakistan is one of the highest countries with the problems of road safety and with an eight times greater accident share than that of many developed countries i.e. USA (Batool *et al*., 2012). It is one of the rising global as well as regional issues in countries like Pakistan where the traffic congestion creates many problems like traffic jam, long queues, saturation of flow rate of traffic and crashes. Road crashes contribute significantly in the disability, injury and causality and thus one of the more common economic and social problems of the masses (Nazeer *et al*., 2021; Heydari, 2013). This is more common on highway interactions in developing countries cities like Pakistan where increasing number of automobiles, buses, rickshaws and flow of pedestrians hurry to reach their destinations (Yumlu *et al*., 2014; Farooq and Akram, 2018). The concept of road traffic impedance as a road section, traffic load and travel time is an important aspect regarding the traveling interval on highways (Shao, 2004). There is wide range of factors and involvements which affect the traffic flow on inter cities roads in Pakistan (Imran, 2009). Traffic volume is defined as the vehicle distance which travelled on a selected road segment. It may be implied to traffic pressure and occupancy on certain road section, which is used in detection of traffic exposure and travel gradient. So, traffic volume is measured in vehicle per mile, equal to

the total figure of vehicles travelling one mile. Therefore, it depends upon density, speed and time with reference to road length (Helbing, 2002). In order to measure and analyze the network of highway road covering many impeding links and points affecting by their link roads, travel time is considered a key factor (He *et al*., 2016; Xu *et al.,* 2016). Daily fluctuations in traffic volume and flow are categorized into three ranking hours as follows, Peak hours, Medium hours, and Low hours (Karlaftis, 2002). Notably, during the peak hours the traffic congestion is enhanced which not only influence the flow of traffic but also indirectly the health and economy of the commuters (Farooq and Akram, 2018). The highways have crossed the desired limit of traffic during the peak hours due to mushroom growth in vehicular population while no sufficient counter measures are been made in terms of road infrastructure up-gradation to an acceptable level and converting the road user from own cars to public transport system by providing a quality transport system (Naeem *et al*., 2018). That is why, many roads across the rural-urban connection faced congestion at certain road points called critical traffic points especially in peak hours (Chauhan *et al.,* 2017; Mahona *et al.,* 2019). The main objective of this research was to explore the various factors and attributes related to road network configuration contributing to an irregular traffic flow and congestion at second class inter-district national highway section Sargodha-Jhang road, Punjab, Pakistan.

METHODOLOGY

Study area: The study area Sargodha-Jhang is an inter district road in central Punjab. It is 124 km long provincial highway and is located between 32.07°75′81″N to 31.28°86′07″N latitude and 72.69°80′83″E to 72.31°90′33″E longitude. The directional gradient of the road is north east to south west from Sargodha towards Jhang and both of these terminal cities are gradually Divisional and District headquarters in central Punjab region (Figure 1). Federal capital and the biggest port city of a country are two important pillars of a state and 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. It also connects Lahore-Islamabad Motorway (M-2) to region of southern Punjab with a shortest travel route. The study area belongs to medium category in its quality and structure. Overall, the study area belongs to a less developed road network even in advance transportation need of time. The proposed study will offer keen interest in up-gradation of Sargodha-Jhang road which also boost the development of this region.

Figure 1: Map of the study area

Data collection: It is empirical evidence that traffic always occurs in mode of time and space. So primary data was collected for road conditions, infrastructure and network, daily fluctuation of flow, weekly volume, and secondary data was used for studying annual volume and flow. Primary data related to traffic flow and volume was collected manually in mode of time and space while secondary data about annual volume of traffic gathered from Punjab highway department, southern Zone Lahore. However, road conditions and containing standard were classified into 4 categories for every section of road as follows:

Average Annual Daily Traffic (AADT): It is the average 24-hours traffic volume at a given location over a year, compiled by the total number of vehicles passing a particular location in a year divided by 365.

Average Annual Weekly Traffic (AAWT): It refers to average 24-hours volume occurring on week day over a full year, computed by total weekday volume for the year divided by 260.

Average Daily Traffic (ADT): It is also 24-hour average volume for a specific period of time, such as a day, a month, a season, a week or more than a day.

Average Weekly Traffic (AWT): It is also 24-hour average volume on week days for any specific period of time less than one year.

Data analysis and presentation: Traffic volume was calculated into four categories of temporal variations mode of Geo-spatial distribution in the study area as, Hourly flow and volume from 7 spatial points, Daily flow and volume from 7 locations also, Weekly flow from one official station and Annual flow and volume from 2 stations**.** Manual counts for vehicles flow were used for the calculations of traffic volume on the road. Any source

of automated sensor or video data recording device was not yet installed on Sargodha-Jhang road at the time of the study. Self-collected traffic counts were done in one hour standard duration for determining the hourly fluctuation as peak, medium and low hours. Manual counts on 8:00AM – 9:00AM and again 2:00PM - 3:00PM represented peak hours of traffic flow. The counts on 11:00AM – 12:00AM reflected medium hours of traffic flow. However 5:00PM – 6:00PM counts showed low hours. For hourly counts the vehicles were classified into 9 groups according to mode of vehicles. This primary data was collected with 16 hours standard durations during a day. Annual volume represented by AADTs of last 3 years compiled by Punjab highway department, planning and development wing, southern highway Zone Lahore. Global positioning system (GPS) was used to mark the different locations of collecting samples with latitude, longitude and elevation. The analysis was performed in MS Excel by applying descriptive statistics and analytical tendencies and results were geographically presented by various graphs, cartograms and maps prepared by using ArcGIS 10.5 software. Traffic flow was analyzed on hourly, weekly and yearly basis by comparing spatial and temporal average and variance. Road sections, surface conditions and network features were directly presented with reference to location by network maps.

RESULTS AND DISCUSSION

Sectioning of road: As traffic flow always occurs in the mode of time and space in all types of traffic patterns. Therefore, all the parameters, attributes, and variables related to road network and traffic flow were measured in time and space. Length, width of the sections measured separately for all sections (Figure 2).
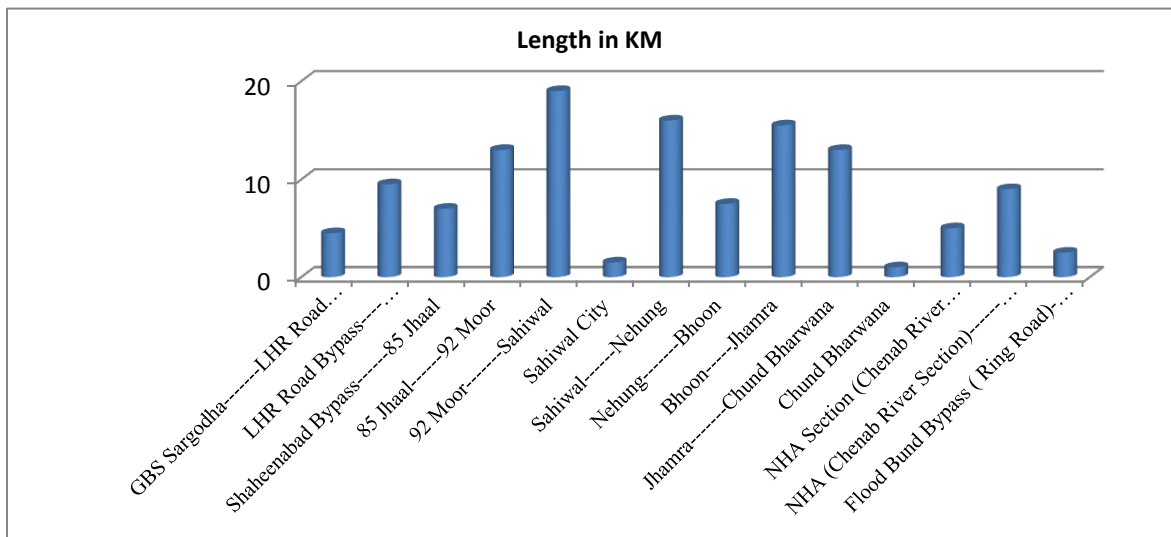
Figure 2: Sectioning of the road

The study area is classified into 14 sections upon dynamic nature. It is found that 55% road was unimproved in which 20% was intensively broken, 35% road belonged to medium and rough category. Only 45% road segment was improved with strong infrastructure in the whole study area. Wherein 5 Km long well improved section including Shah Jewna River Bridge in jurisdiction of National Highway Authority (NHA) was entitled as Tolled road, otherwise whole road network was found as

Toll free. It is noted that 45% improved road segments were spaced on discrete locations in the study area. Maximum proportion of improved road section found at central part of Jhang-Sargodha road particularly in Jhang district. Two short sections comprising 9 km length each were found in Sargodha district, from which, one was urban section and other was sub-urban section in Sargodha district of 2.5 km long, one-way road segment has also found within this location.
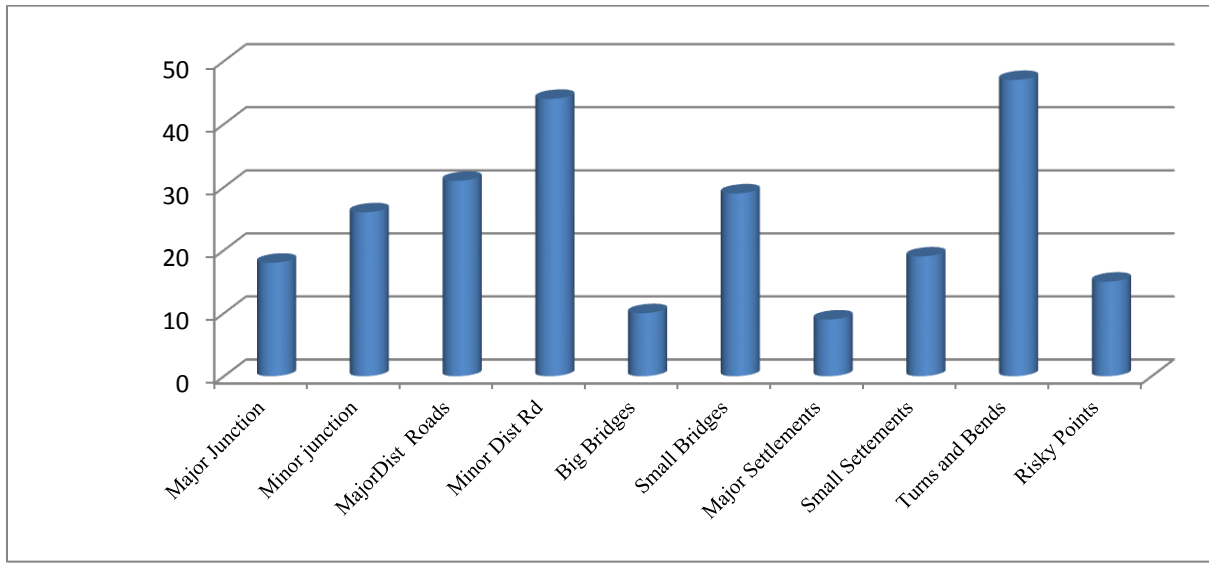
Figure 3: Road features of the study area

Road network and surface conditions were weak and covered an unimproved infrastructure over 50% of study area. Almost 15 locations on the road were found as risky points. Traffic volume and flow was found as heterogeneous mixture of the traffic in mode of time and space in the study area. Weekly flow has not attained any remarkable change with time and space. Days of the week have a slight change in total volume. Any systemized monitoring regarding traffic flow with fixed speed limits on changing network was not found anywhere in the study area. For this purpose, a long term policy could be helpful for the infrastructure of the roads conditions, repairing and timely maintenance of roads in the city excessively used roads (Nazeer *et al*., 2021). Additionally, the intersections, bus stops and saturation density have progressive impacts on unit of travel time as find in a study conducted at Dalian roads, China (He and Zhao, 2013). The process of traffic is a constant link between the three main factors: road users' behavior, protection of road setup and characteristics and vehicles (Georgiev *et al*., 2014).

Road features: The study area has a large variety of spatial distribution and areal variation in network features. Network features bear a large variety containing discrete and non-systemized configuration as shown in

figure 3. Eighteen major and 26 minor junctions have noted in the study area. Thirty-one major distributaries roads and 44 minor distributaries roads as main configuration of whole network founded on the road. Ten main bridges on the road from which a newly constructed river bridge prominently associated to road network and entire traffic pattern found in the study area. Nine main settlements and 29 small settlements situated on and along the road. Apart from both marginal cities as district head quarter and divisional head quarter cities, one Tehsil head quarter city and 3 other towns are main significances of network. Directional gradient of the route not founded as well as aligned. Therefore, 47 bends and turns were found in the study area. Some bends observed as road irritants as well as risky points. In this regards 15 locations on the road were found as dangerous points, may also act as an irritant inward smooth flow of the traffic. As the result, an unbanned road network with weak infrastructure is concluded in the study area. It is finds in a study that poorly constructed road curves and relevant infrastructures would result in an extremely high accident rate and grave accident severities on curves (Shi, 2018).

Average hourly flow: The most significant variation of traffic volume with time is hour to hour flow. A daily

fluctuation is categorized into three ranking hours as, Peak hours, Medium hours and Low hours. Daily traffic flow observed at seven prominent locations on Sargodha-Jhang road. Peak hours are the most important as a main significance of traffic pattern, which is taken by two times during a day at important break points on the road, Average figure taken from all ranking hours during a day are accounted to compare the daily flow in the study area as shown in table 1 and figure 4.

It is noted that the flow sharply increased at peak hours along both city sections in the study area. Qainchi Moor in Sargodha City and Aadhiwal Chowk in Jhang city have abundant average flow of vehicles as compared to other sections. Peripheral sections of both cities also contained much traffic as compared to central

sections of the road. 85 Jhaal is very prominent junction as peripheral section of Jhang city. Daily flow again increased at Sahiwal city, but quite low than Sargodha. All other spatial locations contain low traffic even during peak hours. Time is considered a main factor of road traffic flow frequency (Shao, 2004).

A significant change in daily flow is reflected at Qainchi moor and 85 Jhaal during the whole day. Daily spatial variation is decreased as the distance increased from the main cities. Daily fluctuation in traffic flow is found very low at 92 moor, Jhamra and Shah Jewna Bridge. No significant change found in daily flow beyond the city centers. Saturated flow was concluded in the urban locations, stable flow on peripheral segments and free flow beyond the cities.

Table 1: Average hourly flow of traffic

Location	Peak Hour (8--9)AM	Peak Hour (2---3)PM	Medium Hour (11---12)AM	Low Hour (5---6) PM
Qainchi Moor	271	303	256	233
85 Jhaal	239	266	191	159
92 Moor	71	80	75	62
Sahiwal City	148	166	133	112
Jhamra	30	35	27	22
Shah Jewna Bridge	37	43	32	23
Aadhiwal Chowk	307	322	286	269
Total	**1,103**	**1,215**	**1,000**	**880**
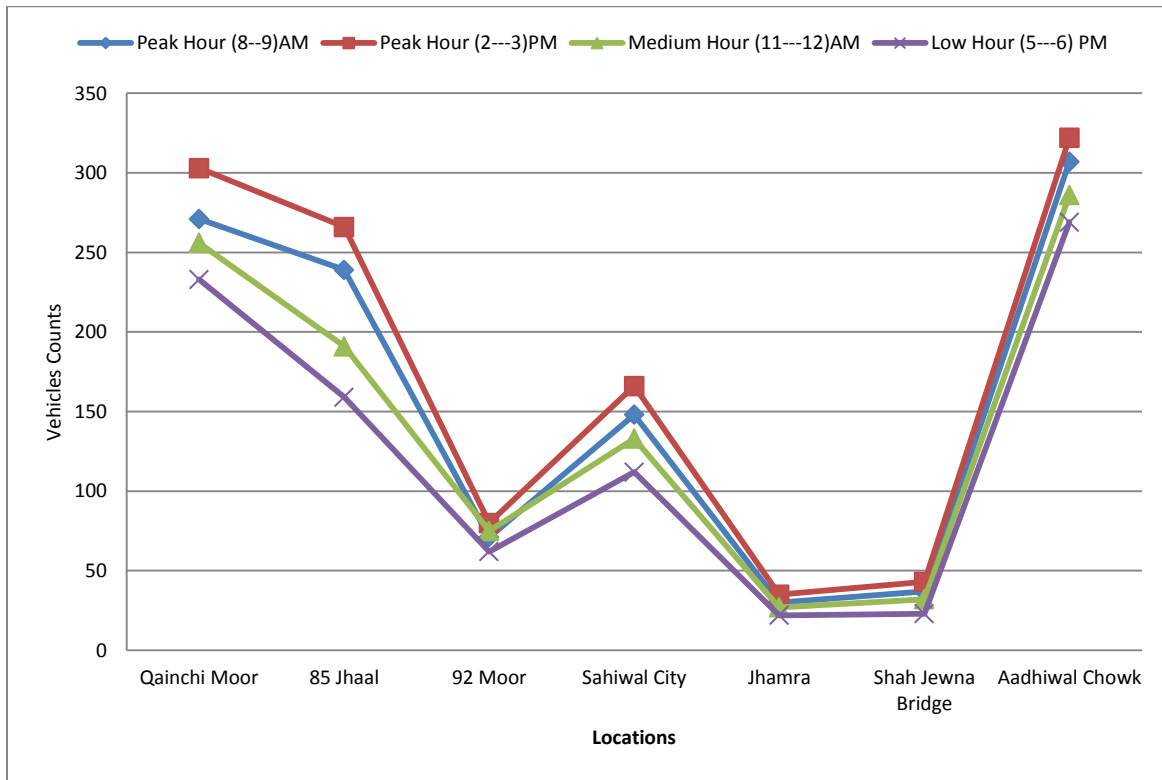
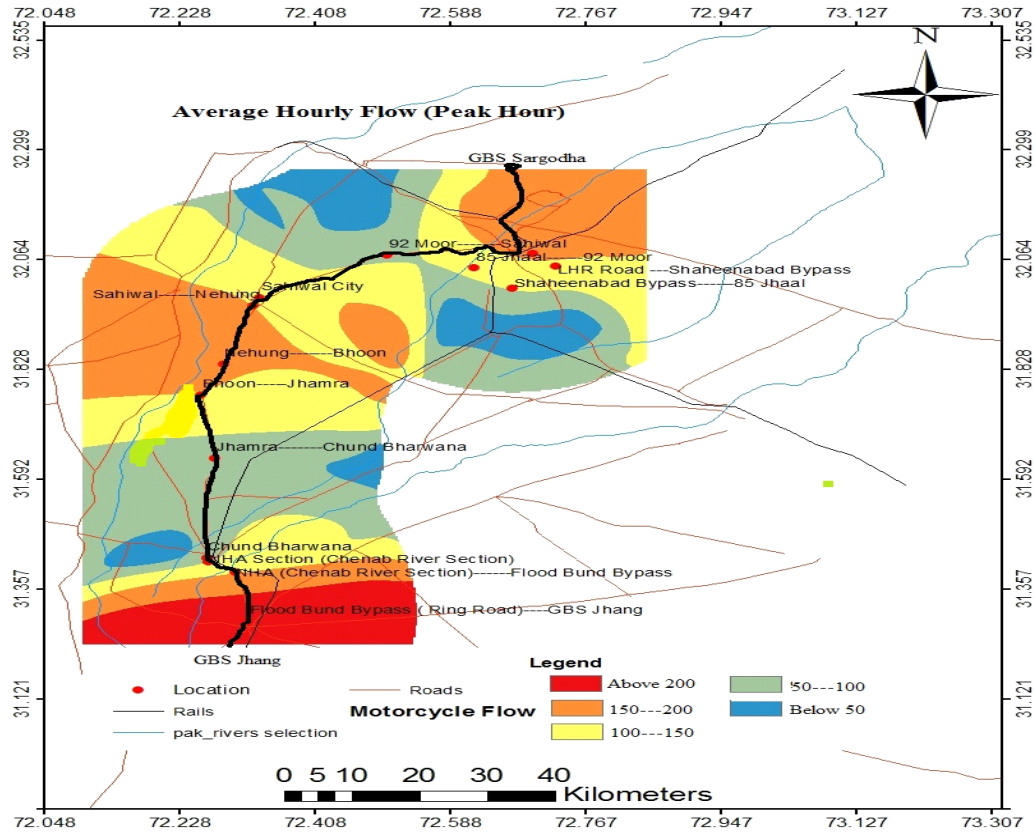**Figure 4: Comparison of hourly flow of traffic**

Figure 5: Average hourly flow of traffic

Figure 5 represented the spatial dimension of motorcycle flow in the study area. Maximum flow remains exposed at urban locations. Sargodha city has more city outlet roads as compared to Jhang city because Sargodha road is the only city outlet road in northern side due to a flood region. So, maximum flow of motorcycles found on urban, sub-urban and peripheral section of Jhang city. Urban locations on the way also found very significant flow of motorcycles in the study area. Central part of the study area is resulted as very significant flow of two-wheeler traffic on Sargodha-Jhang road as reflection of yellow colour in the figure 5.

Weekly flow: Weekly traffic flow has taken by using a primary form of manually counted data from Shah Jewna Toll Plaza, 13 km from Jhang. Manual traffic counts with consecutive recordings have taken for 24 hours period for a day. Only toll paid vehicles were recorded in manually count Performa at the tool plaza. Therefore, two to three wheeler mini vehicles, which do not paid toll, also counted to conclude weekly flow of all vehicles as shown in table 2.
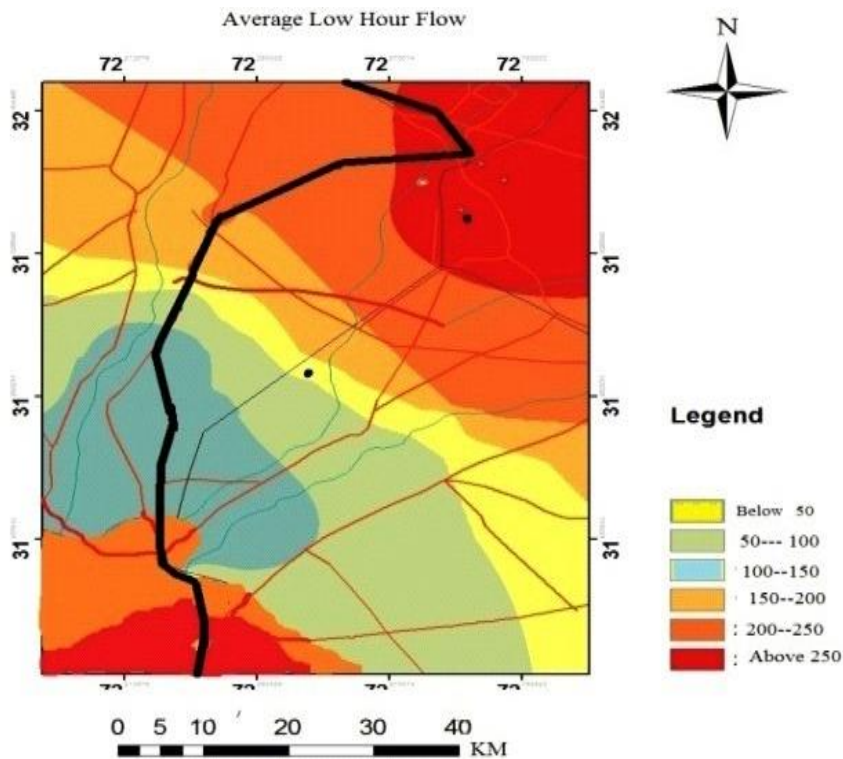
Table 2: Weekly flow of traffic

Days	Vehicle Mediums									
	Motorbike	Rickshaw	Car/Jeep Pickup	Wagon	Van	Bus	Truck	Light Vehicle	Tractor & Trolley	Mean
Mon.	711	613	1,029	396	197	107	729	86	31	396
Tue.	743	621	1,068	456	228	119	757	117	34	423
Wed.	761	636	1,079	467	236	126	795	119	37	432
Thu.	775	642	1,147	429	205	121	783	123	39	435
Fri.	685	593	1,049	368	170	109	639	79	27	385
Sat.	714	659	1,173	438	189	187	647	94	32	435
Sun.	723	648	1,107	370	190	113	677	107	25	410
Total	**5,112**	**4,412**	**7,652**	**2,924**	**1,415**	**882**	**5,027**	**725**	**225**	

Maximum flow rate of all kinds of vehicles found during middle days of a weak as Tuesday to Thursday. A minor variation in flow during middle days was been noted in the study area. A moderate change in traffic volume has concluded throughout the week. As the result, 45% of each traffic volume was observed during 3 middle days of a weak, while other 4 days including weekend days contains 55% traffic volume. Minimum share of the whole traffic was identified on Friday. It is also noted that flow of mini vehicles were increased gradually on Saturday (Figure 6). Overall, no sharp variation found in weekly traffic flow and volume in any mode of vehicles. However, a significant fluctuation had been detected in flow of mini vehicles, particularly, in motorcycles, rickshaws, cars, jeeps and wagons with temporal change during a week. The saturation flow and lost time are considered the most important factors in defining the optimal cycle. The fast increase in the ownership of vehicles in Pakistan in general, and Karachi in particular has geared-up the intensity of the traffic which created various intense problems such as traffic jamming and creating long queues eventually causing more delays and surge in the number of road traffic accidents at various sections on highways (Iqbal, 2009).

Statistical comparison of the traffic conditions for various days showed that traffic flow within core weekdays appears to be highly similar and consistent. Traffic conditions on Fridays differed from core weekdays in each of the measures. Specifically, it appears that the P.M peak on Fridays not be extended further in the day. Traffic conditions on weekends differ from traffic conditions on weekdays, and Saturdays differ in flow from Sundays. Major incidents, such as festivals, strikes and scheduled holidays can cause significant disruptions to the typical weekday traffic conditions.

Figure 6: Average daily low hour flow of traffic

Yearly Flow: Annual traffic volume is identified by using secondary data in annual average daily traffic format, entitled as AADT (Table 3). AADT is the average 24-hours traffic volume at a given location over a year, computed by the total number of vehicles passing a site in a year divided by 365. Traffic figures may be presented as:

Units = thousand vehicle miles.

AADT was collected from planning and development division, southern highway zone Lahore.

These counts were collected by highway department during discrete intervals according to requirement of their services. The flow of mini vehicles was quietly increased form 2013-14 towards direction from Sargodha to Jhang, but the flow of buses and flying coaches was slightly decreased from 2012-13. The growth of trucks was more than increased of any other big vehicles. Common mini vehicles were increased from 2013-14 in traffic volume from Jhang to Sargodha, but the growth was lower than 2012-13. Some other mini vehicles like vans, wagons,

Hiaces (flying coaches), and few Coasters were decreased from 2013-14.

Table 3: Yearly flow (AADT-Both Directions) Sargodha-Jhang

Years	Motorbike/ Rikshaw	Car, Jeep, Pickup	Wagon Coaster	Bus Coach	Truck	Trailers	Tractor trolley	Total
2012	2,304	1,583	562	339	897	84	136	5,905
2013	2,351	1,617	553	332	943	107	149	6,052
2014	2,359	1,634	549	337	957	119	156	6,111

Table 4: Yearly flow (AADT-Both Direction) Jhang-Sargodha

Years	Motorbike/ Rikshaw	Car, Jeep, Pickup	Wagon Coaster	Bus Coach	Truck	Trailers	Tractor trolley	Total
2012	2,221	1,566	543	337	879	95	184	5,825
2013	2,283	1,503	541	330	962	148	204	5,971
2014	2,319	1,517	537	334	997	137	213	6,054

Annual temporal increase and variations in traffic volume was not very significant on Sargodha-Jhang road. Average traffic growth from 2012-13 was slightly greater than growth from 2013-14 in both districts. All mini vehicles were being increased with low proportion form 2012-13. Few buses were decreased from Sargodha to Jhang as in traffic volume from Jhang to Sargodha (Table 4).

Mini vehicles, like motorbikes, rickshaws, cars, jeeps and mini pickups were increased in average annual flow from 2013-14. Vans, wagons, hiaces (flying coaches) and coasters were rarely decreased form 2013-14 as from 2012-13. Buses and Trucks were slightly increased from 2013-14. Other big and long vehicles were also fewer increased in average annual flow from Sargodha-Jhang from 2013-14. It is found that the traffic growth in total motorized vehicles was not so significant for all three previous years (Figure 7).

The Infrastructural improvements are the key for elegant road security management. Various state to the art techniques like data envelopment analysis (DEA) and geographic information system (GIS) are being utilized to assess the level of risk of choking segments of highways particularly countries like Pakistan (Shah and Ahmad, 2019). Therefore, GIS techniques are widely employed to analyze the spatial distribution of road traffic accidents and accident-prone road networks, including hotspot analysis (Zhang *et al.*, 2021).
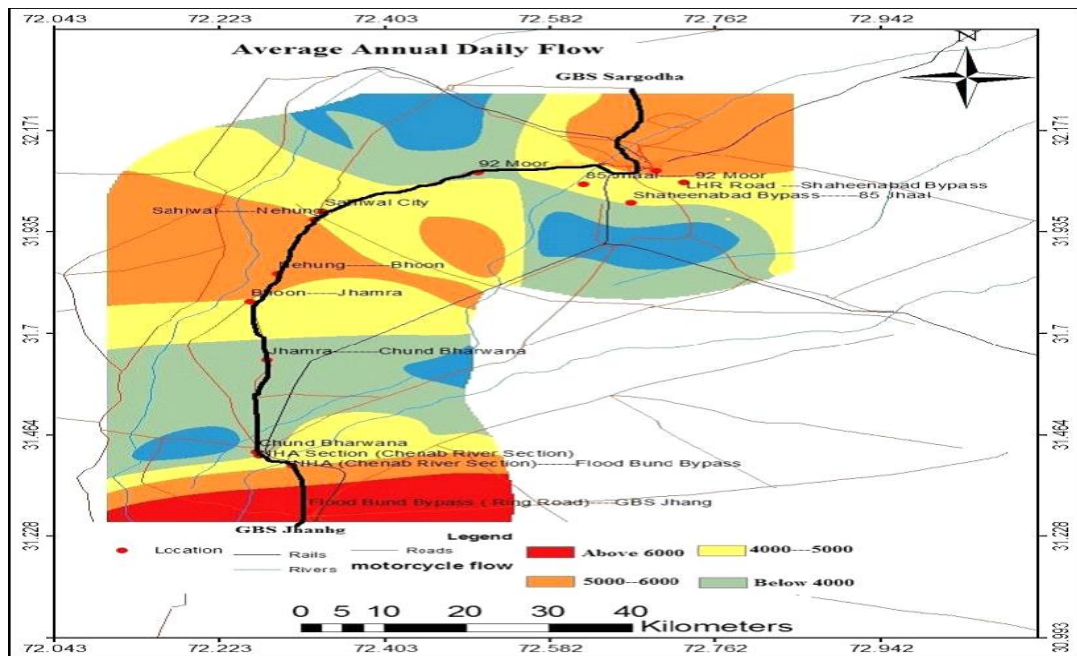
Figure 7: Average annual daily flow of traffic

Conclusion: Traffic flow in Pakistan has become more complex in recent years due to rapid population growth and rapidly generating economic activities. Road transportation and infrastructure is not yet upgraded as the need of time. This research aims to explore the various factors and attributes related to road network configuration contributing to an irregular traffic flow and congestion at second class inter-district national highway Sargodha-Jhang road section extending 124 km, in central Punjab, Pakistan. The analysis of the traffic flow on hourly, weekly and yearly by comparing spatial and temporal basis suggest the irregularity and variations in the traffic flow and volume in study area. The study area has a large variety of spatial distribution and areal variation in network features including 47 bends and turns were found. Some bends were observed as road irritants as well as dangerous points for road traffic accidents and thus 15 locations on the road section were identified as highly unsafe points. Moreover, any source of automated sensor or video data recording device was not yet installed on Sargodha-Jhang road. The peak hourly fluctuation were recorded as peak (8:00AM – 9:00AM and again 2:00PM - 3:00PM), medium (11:00AM – 12:00AM) and low (5:00PM – 6:00PM) hours. Weekly flow showed that the vehicles were increased on Thursday and Saturday while the Friday was least busy day in this regard. Over the past years, the yearly traffic flow and volume were also slightly increased.

Suggestions: Minimizing accidents is the key aim for any highway in the world particularly in developing countries. So in the light of findings, for a better and smooth flow of traffic and maintains its volume in the study area the current study proposed few suggestions;

1- Installment of an overhead bridge for pedestrians is highly recommended to cross acute junction safely i.e. Qainchi Moor in Sargodha City.
2- A permanent traffic police check post should be established at 85 Jhaal Junction.
3- The police stations and patrolling posts on the way must be officially engaged in monitoring and checking of speed limits, speed intervals, overloading and vehicles fitness in the study area.
4- Road occupancy, various irritants, and encroachments should be cleared at Sahiwal city, Nehung and Chund Bharwana.
5- A seven km long road segment, 2 km from Jhang always affected seriously during every flood attack. This must be rebuilt at flood spur as much height than the adjacent to Chenab River.
6- Sixty five km long poor and rough road should also upgraded for smooth flow of traffic.
7- Aadhiwal Chowk is identified as the busiest intersection in Jhang City, where, traffic signs and lightening signals must be installed.

REFERENCES

Candappa, N., D. Logan., N.N. Van and B.F. Corben (2015). An exploration of alternative intersection designs in the context of safe system. Accident Analysis and Prevention, 74: 314-323.

Chauhan, D.K.V., M.K.J. Kansagra and V.K. Prajapati (2017). Review on Estimation of L.O.S through Congestion on Urban Road - A Case Study of Vrundavan Chowkdi - Vadodara City. International Journal of Advance Engineering and Research Development, Special Issue: 1-4.

Farooq, D. and T. Akram (2018). Traffic Flow Analysis and Solutions to Ease Traffic Flow at Unsignalized Taxila Intersection. Periodica Polytechnica Transportation Engineering, 46(2): 101-107.

Georgiev, N., V. Velyova and M. Dimitrova (2014). Road infrastructure and traffic parameters - main factors affecting traffic safety. Scientific Proceedings XXII International Scientific-technical Conference 2014, Trans & Motauto '14; XXII(3): 67-70.

He, H. and S. Zhao (2013). Discussion on Influencing Factors of Free-flow Travel Time in Road Traffic Impedance Function. 13th COTA International Conference of Transportation Professionals (CICTP) 2013, Procedia - Social and Behavioral Sciences, 96: 90-97.

He, F., X. Yan., Y. Liu and L. Ma (2016). A traffic congestion assessment method for urban road networks based on speed performance index. Procedia Engineering, 137: 425-433.

Helbing, D., A. Hennecke., V. Shvetsov and M. Treiber (2002). Micro-and macro-simulation of freeway traffic. Mathematical and Computer Modelling, 35(5): 517-547.

Heydari, S. (2013). Epidemiological characteristics of fatal traffic accidents in Fars province, Iran: A community-based survey. Public Health, 127: 704.

Iqbal M.J. (2009). Estimation of Saturation Flow and Lost Time at Selected Signalized Intersections of Karachi (Pakistan). PhD Thesis, Mehran

University of Engineering & Technology, Jamshoro, Sindh, Pakistan.

Imran, M. (2009). Public transport in Pakistan: A critical overview. Journal of Public Transportation, 12(2): 4.

Karlaftis, M.G. and I. Golias (2002). Effects of road geometry and traffic volumes on rural roadway accident rates. Accident Analysis and Prevention, 34(3): 357-365.

Mahona, J., C. Mhilu., J. Kihedu and H. Bwire (2019). Factors Contributing to traffic flow congestion in heterogenous traffic conditions. International Journal for Traffic and Transport Engineering, 9(2): 238-254.

Naeem, M.M., F. Subhan., M. Hasnain., S. Shah and F. Khan (2018). An Investigation of Factors Affecting Traffic Flow on Urban Highways in Pakistan and their Remdial Measures. International Journal of Scientific & Engineering Research, 9(12): 158-161.

Nazeer, M.A., M. Mohsin and A. Rehman (2021). Measures of Road Traffic Accidents (RTAs) in Bahawalpur City, Pakistan. International Journal of Innovations in Science and Technology, 3(4): 208-217.

Shao, C (2004). Traffic Planning. China Railway Publishing House.

Shah, S.A.R. and N. Ahmad (2019). Road Infrastructure Analysis with Reference to Traffic Stream Characteristics and Accidents: An Application of Benchmarking Based Safety Analysis and Sustainable Decision-Making. Applied Sciences, 9: 2320.

Shi, L (2018). Cask Evaluation Model to Assess Safety in Chinese Rural Roads. Sustainability, 10: 3864.

Tariq, K.A., H.H. Khan, S.Z. Afghan and A. Raza (2021). Evaluation and improvement of major intersection on eastern corridor of Gujranwala, Pakistan using SIDRA. Journal of Engineering and Applied Sciences, 40(1): 1-7.

Xu, C., Z. Li and W. Wang (2016). Short-term traffic flow prediction using a methodology based on autoregressive integrated moving average and genetic programming. Transport, 31(3): 343-358.

Yumlu, C., S. Moridpour and R. Akcelik (2014). Traffic Congestion in Melbourne, Australia: A Case Study. AIPM National Conference 2014, Adelaide: Australia.

Zhang, H., M. Zhang., C. Zhang and L. Hou (2021). Formulating a GIS-based geometric design quality assessment model for Mountain highways. Accident Analysis and Prevention, 157: 106172.