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Evaluating Traffic Congestion at DHA Phase-I Roundabout

Level of Service Assessment and Development of Simulation Models Using PTV Vissim Software

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Abstract

Most junctions, especially multilane roundabouts, are facing traffic congestion due to an increase in the number of vehicles traveling through Islamabad, Pakistan. This occurs when the amount of traffic demands more space than is available. In light of Pakistan's diverse driving conditions, the topic of effective vehicular traffic modelling is still heavily contested. Improving the traffic capacity of multilane roundabout is of great significance in solving the urban traffic problems. Considering the DHA Phase 1 roundabout situated at GT Road, this study aims to present a detailed analysis of the traffic delay at this roundabout. Highway Capacity Manual (HCM) and microscopic traffic simulation software PTV Vissim were used to analyze the traffic flow. Traffic Congestion Analysis of DHA Islamabad Phase-I roundabout was carried out by determining the Level of Service and developing a simulation model using PTV Vissim software. It was observed that LOS was improved from F to D. Delay was reduced by 94.18% at Fauji Foundation Hospital, 76.09% at DHA road, 70.85% at Kacheri road and 42.11% at Bahria road. Queue Length was reduced by 100% at Fauji Foundation Hospital, 73.75% at Bahria, 68.07% at DHA and 51.42% at Kacheri road. Moreover, a solution was proposed to decrease the traffic congestion and the LOS was significantly improved.

Keywords

traffic congestion, roundabout, level of service, queue length, delay analysis, PTV Vissim

1 Introduction

Traffic congestion refers to the condition in which the volume of vehicles on a road or transportation network surpasses its ability, bringing about reduced speeds, longer travel times, and expanded queuing. It is a typical issue in urban regions and is brought about by different variables. We should investigate these causes exhaustively, upheld by references. Accidents, breakdowns, and other traffic occurrences can upset the ordinary progression of vehicles, causing congestion. At the point when a mishap happens, it frequently prompts path terminations or reduced road capacity, driving different vehicles to dial back or redirect, bringing about congestion. A review led by the Texas Transportation Foundation gauges that traffic episodes represent almost 25% of total congestion in the US. In order to determine the best practical and long-term solution to reduce traffic, this study evaluated Pakistan's current urban and transportation infrastructure. Vehicles (Inactive, Private) at signalized convergences have brought about increased fuel utilization, congestion, and harmful gas emissions, which were analyzed by Medapati et al. (2022). A process duration increment of 132 s (green) and 95 s (red) diminished fuel utilization by 41% at four signalized crossing points. Flyover can likewise be proposed.

Traffic flows through roundabouts and a method for figuring out how to get as much traffic as possible into a roundabout were analyzed by Kabanga et al. (2022). This tactic might be put into practice by selecting an appropriate roundabout geometry for a particular intersection and taking into account the effects of various parameters on traffic speeds. Our macroscopic model was created to solve the issue of traffic congestion at un-signalized roundabouts, which a thorough investigation has shown to be one of the

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major contributors to traffic congestion in the majority of African cities. The goal is to choose the ideal roundabout layout for a specific intersection. It comprises of two sections: one is the numerical model and the subsequent one is based on the parameters. The fundamental goal of this work was to analyze how the sweep (r), angle of the turning development (θ) and the quantity of lanes (n) influence throughput velocities in the roundabout.

The intent of evaluating the consequences of BRT system operating in a turbo roundabout, both in normal and congested conditions, in terms of environmental impact was studied by Severino et al. (2022). This study compares six turbo roundabout scenarios that were modeled using a microsimulation tool with and without reserved lanes. This study analyzes a variety of carriageway configurations, including those with and without reserved lanes that are positioned symmetrically and asymmetrically with regard to the geometric center of the roundabout, taking into account a vehicle flow equivalent to 80% of the maximum value of the particular intersections. Due to this circumstance, severe traffic scenarios with the same mix of traffic can be evaluated as a function of the viability. Bus rapid transit (BRT) is present or absent in a turbo roundabout, and the findings of employing Vissim and VERSIT + micro through EnViVer also demonstrate a difference in emissions.

The fast expansion of vehicles in Pardubice, Czech Republic, brought about congestion, environmental impact, social government assistance, and governance, which were studied by Kučera and Chocholáč (2021). The specific solution to the traffic issue involved using the current roundabout and possibly reconstructing it with the bypass. The usage of PTV Vissim software provides the potential for further academic publications, such as numerous operational scenarios prior to their application in real life in other transportation situations in city logistics.

Traffic congestion has a few impacts like upkeep of highway, mishaps, land utilization, environmental impacts and is a significant issue in Johannesburg. They were studied by Olayode et al. (2020). Big data will be helpful for the efficient management of traffic congestion at signalized and un-signalized road crossings. Establishing a smart surveillance center in Johannesburg, where a massive monitor is placed at the observation center to show the whole road network and information on all cars travelling through signalized and un-signalized road intersections in real time. This will support effective city vehicular operations. The entire city is scanned by surveillance systems, which promptly identify and take action to stop illegal automobile navigation and maneuvering.

Approaches for quantifying traffic congestion have been widely studied. At the moment, magnetic loops, pneumatic road tubes, and piezoelectric sensors are examples of classic "in-situ" technologies used in traffic counts. Non-invasive techniques used all around the world include manual counts, microwave radar, passive and active acoustic, passive magnetic, passive and active infrared, and video image detection methods. In Pakistan, the majority of these techniques are not workable or economical. Counting cars by hand with tally sheets or mechanical or electronic counters is the most efficient way for Pakistan. Both a manual count and a video recording of traffic was done at the DHA Phase-I roundabout in Islamabad, Pakistan (Figs. 1 and 2). This study additionally identifies strategies to alleviate the issues that exist under the existing circumstances.

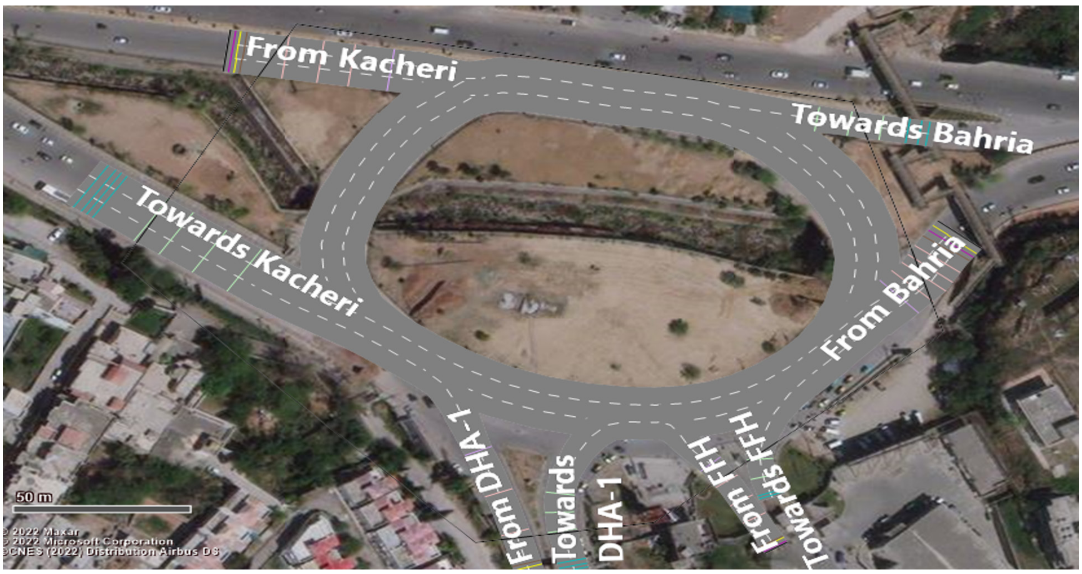


Fig. 1 Location of project

Fig. 2 Traffic congestion situation at DHA Phase-I Islamabad

Objectives of our paper are:

- To evaluate the traffic flow at DHA Phase-I, Islamabad roundabout.
- To perform a capacity analysis for assessing the level of service of existing traffic flow.
- Development of a simulation model using PTV Vissim software (PTV Planung Transport Verkehr GmbH, online) to reduce traffic congestion.

2 Methodology

2.1 Manual traffic count

The flow of traffic on the roundabout was manually counted during peak hours, which are from 2:00 pm to 4:00 pm, seven days a week. This time was selected because existing literature was also collected on peak hours. In the current study the above-mentioned time was selected as it consistently represents the highest traffic volumes, largely due to office closing hours, school and college closure, hospital visits in case of emergencies and routine check-ups, commercial activity, and public transport. Each type of vehicle was counted separately including automobiles, bikes, truck with one and two axles and other vehicles. Additionally, approach study was carried out as opposed to counting movements. Fig. 3 shows the methodology.

PTV Vissim software (PTV Planung Transport Verkehr GmbH, online) was used for the micro-simulation models to check the traffic congestion as well as to mitigate the traffic congestion. Also, traffic count is represented graphically in Fig. 4.

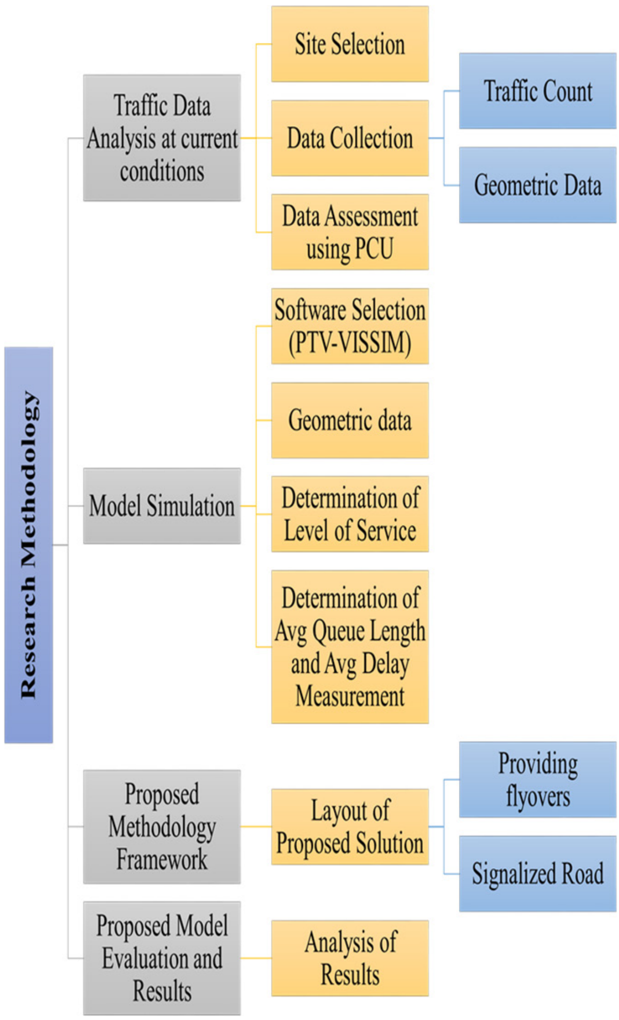


Fig. 3 Methodology

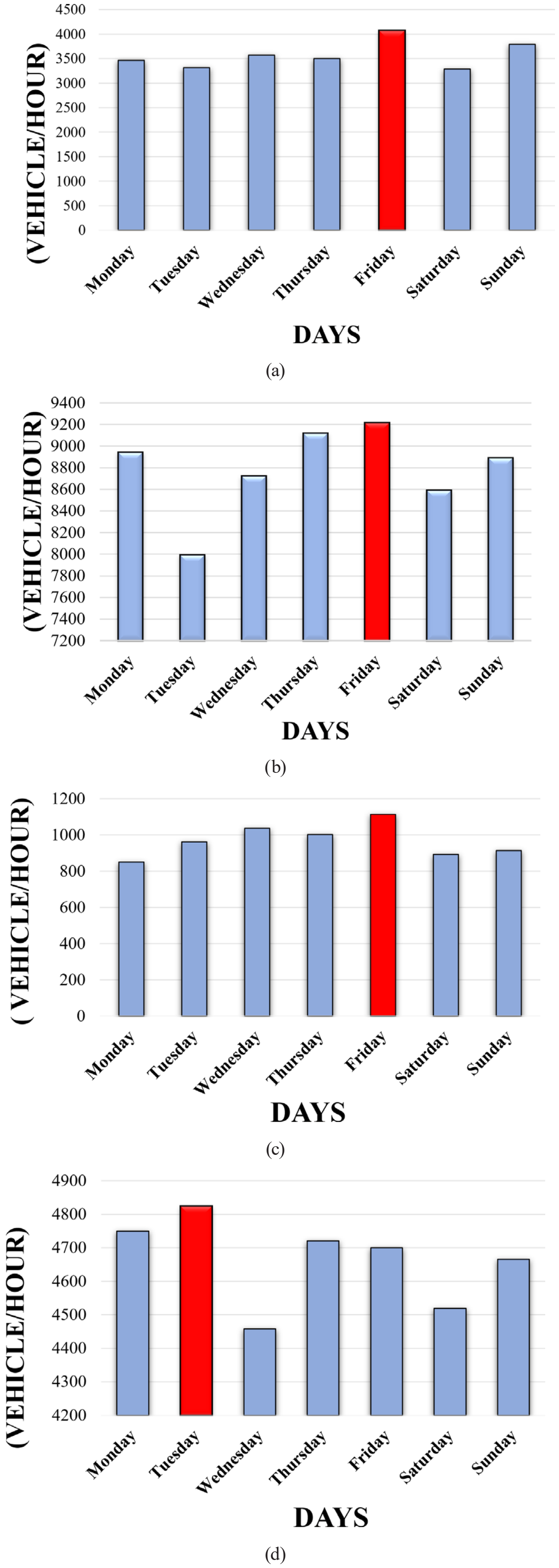


Fig. 4 Traffic count at roundabout on various road: (a) From Kacheri, (b) From Bahria, (c) From Fauji Foundation Hospital, (d) From DHA

To perform traffic congestion analysis, the site was selected. Traffic count was carried out both manually and using video cameras. Geometric data of the roundabout i.e. lane width, lateral clearance, median type etc. was measured. Determination of Level of Service (LOS) was measured at current conditions both manually and using PTV Vissim software (PTV Planung Transport Verkehr GmbH, online). Queue length, delay and LOS was measured at current conditions. Simulation models were prepared and a solution was proposed to address the traffic congestion at DHA Phase-I roundabout, Islamabad. Signals were provided at the two most congested roads and two flyovers were proposed to reduce the traffic congestion and improve the LOS from F to D causing smoother traffic flow and reduced travel delays during peak hours.

In Fig. 4, graphical representation indicates the volume of traffic on various roads of the roundabout throughout the week. The traffic count was carried out during peak hours so that maximum traffic could be counted. Moreover, the red bar in the graph indicates the maximum traffic counted on a single day among seven days of the week.

2.2 Video analysis

Video analysis provides a visual perspective that allows for a detailed examination of traffic patterns and behaviors, facilitating the development of targeted countermeasures to improve traffic management and road safety (Tsuboi, 2021). We installed traffic observing video cameras at all specified directions and recorded real-time footage on DHA phase-I roundabout. Traffic observing video cameras were installed during the period from December 5, 2022 to December 11, 2022. And the exact time of recording was 2 pm to 4 pm because that is the peak hour period.

Then from the video analysis, we counted each vehicle manually. We considered the time of the year because in the selected period, all the universities and the schools and offices remained open and weather condition was almost normal (mostly sunny with average temperature 20–30 °C). This method enabled us to observe the traffic patterns, identify the bottlenecks, and understand the primary cause of congestion at the DHA phase-I roundabout.

2.3 Traffic analysis

The collected data were analyzed to identify the traffic trends, types of violations and factors involved which cause traffic congestion. Traffic engineering techniques were also utilized to assess the traffic congestion, LOS, queue length and delay issues of the road network.

The equations in Fig. 5 were used to find LOS based on Highway Capacity Manual (Transportation Research Board, 2000).

2.4 LOS/Queue/Delay results at current conditions

Simulation models at current conditions were developed using PTV Vissim software (PTV Planung Transport Verkehr GmbH, online). The most congested junctions are highlighted in Fig. 6. Simulation models in PTV Vissim software (PTV Planung Transport Verkehr GmbH, online) were used to check the LOS (Table 1), queue length and delay (Table 2). LOS of this roundabout was F. All the roads were highly congested at peak hours.

Maximum queue length and delay occurs on the road i.e. from Kacheri as shown in Fig. 7. Queue length at Kacheri road is 36.99 m and the shortest queue length is at FFH road i.e. 18.79 m. Highest delay measurement was recorded at Kacheri road i.e. 160 s and the smaller delay was at DHA road i.e. 69.07 s.

Free Flow Speed

$$FFS = BFFS - flw - flc - fm - fa$$

Lane Width (m)	Reduction in FFS (km/h)
3.6	0.0
3.5	1.0
3.4	2.1
3.3	3.1
3.2	5.6
3.1	8.1
3.0	10.6

FLw

Access Points/Kilometer	Reduction in FFS (km/h)
0	0.0
6	4.0
12	8.0
18	12.0
≥ 24	16.0

Fa

Flow Rate

$$vp = \frac{V}{PHF * N * F_{HV} * fp}$$

$$\text{Where; } fhv = \frac{1}{1 + PT(ET-1) + \Pr(Er-1)}$$

$$\text{Density} = \frac{Vp}{FFS}$$

Four-Lane Highways		Six-Lane Highways	
Total Lateral Clearance[a] (m)	Reduction in FFS (km/h)	Total Lateral Clearance[a] (m)	Reduction in FFS (km/h)
3.6	0.0	3.6	0.0
3.0	0.6	3.0	0.6
2.4	1.5	2.4	1.5
1.8	2.1	1.8	2.1
1.2	3.0	1.2	2.7
0.6	5.8	0.6	4.5
0.0	8.7	0.0	6.3

FLc

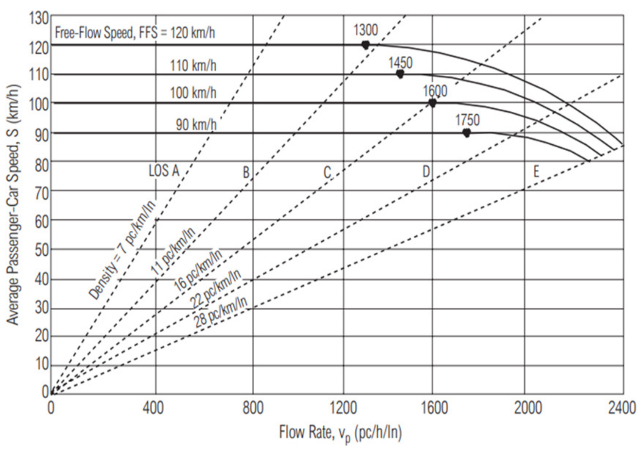


Fig. 5 Governing equations

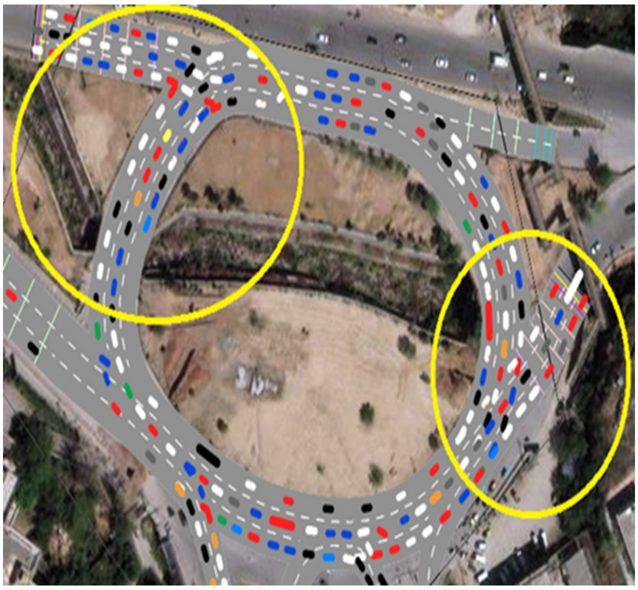


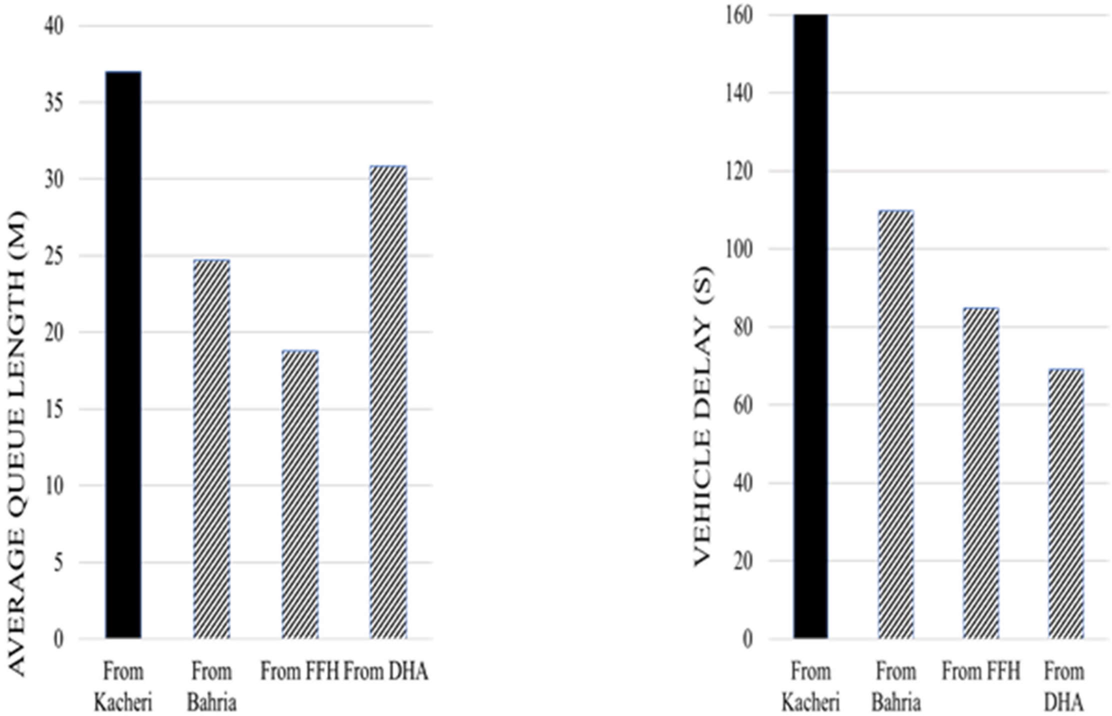
Fig. 6 Traffic congestion situation using PTV Vissim software

Table 1 Manual calculation of LOS

	Level of Service			
Road	FFS	Flow Rate	Density	LOS
From Kacheri	36.4	1,382.95	37.99	F
From Bahria	36.2	3,168.77	87.53	F
From DHA	27.6	555.74	20.13	C
From FFH	31.45	2,426.03	77.13	F

Table 2 Manual calculation of Avg. Queue/Delay

Avg. Queue Length		Avg. Delay	
Road	Avg. Queue Length (m)	Road	Avg. Vehicle Delay (s)
From Kacheri	36.99	From Kacheri	160
From Bahria	24.68	From Bahria	109.68
From FFH	18.79	From FFH	84.78
From DHA	30.82	From DHA	69.07



(a) (b)

Fig. 7 (a) Queue and (b) delay at current conditions

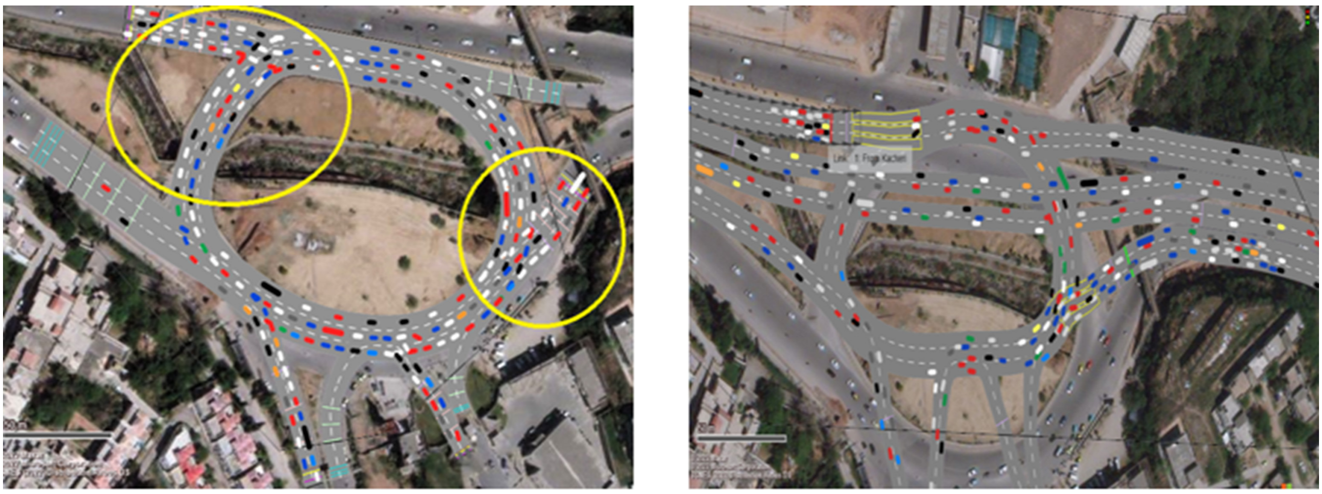
3 Results and discussion

3.1 Comparison of LOS at current and proposed conditions

Two scenarios are given in Fig. 8 which shows the traffic at current and proposed conditions, respectively. LOS was improved from F to D (Table 3). Moreover, it can be seen that traffic congestion can be observed on the roundabout at current conditions but after providing two flyovers and converting it into a signalized roundabout significantly reduces the traffic and the level of service was also improved.

3.2 Comparison of queue/delay at current and proposed conditions

Queue length was increased in the proposed scenario due to the provision of signals while delay was reduced significantly. Queues form when the signal forces vehicles to stop at red light and clear during green light leading to higher maximum queue length even if delays are reduced. So, as a result of signalized roundabout as shown in Fig. 9 traffic congestion was reduced and the LOS of the roundabout was improved.

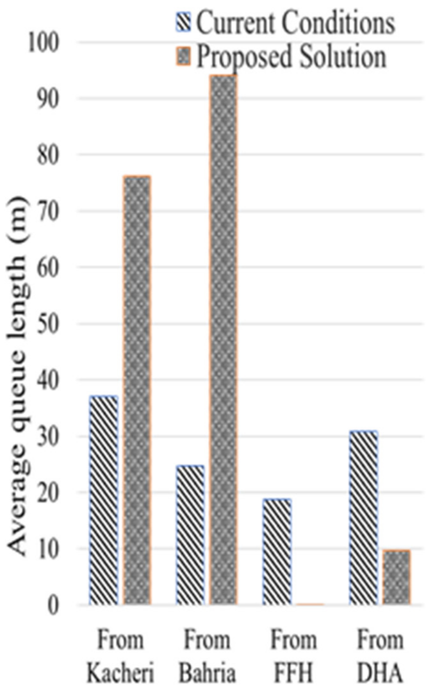


(a) (b)

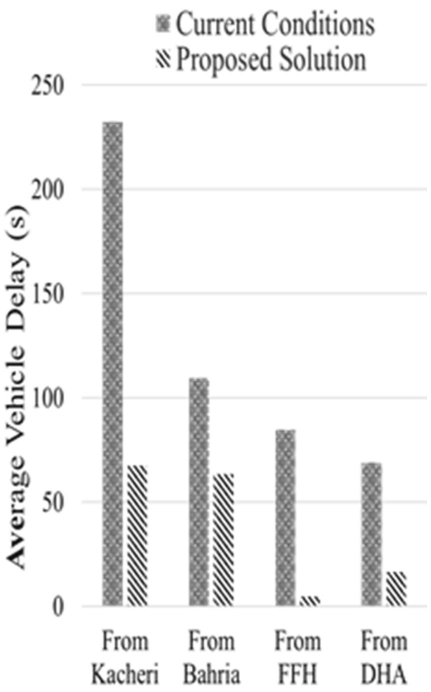
Fig. 8 Traffic at (a) current and (b) proposed conditions

Table 3 LOS at current and proposed conditions

Road	LOS at current	LOS at proposed conditions
From Kacheri	F	D
From Bahria	F	D
From FFH	C	C
From DHA	F	D



(a)



(b)

Fig. 9 (a) Queue and (b) delay at current and proposed conditions

4 Proposed solution

For mitigating these issues, a solution was provided in which the following attributes were checked i.e. LOS, Delay and Queue Measurements. Due to traffic congestion at current conditions, a solution was proposed to overcome the traffic congestion at DHA Phase-I Roundabout, Rawalpindi. Level of Service was F on 3 roads out of 4. So, the roundabout was redesigned and a suitable solution was provided to reduce traffic congestion on the roundabout. In the proposed solution, two flyovers "From Bahria" and "From Kacheri" were provided. They were provided to divert the traffic so that congestion can be reduced. By providing flyovers, traffic moving from Bahria to Kacheri will travel on flyover. Also, traffic moving from Kacheri to Bahria will travel on flyover.

By providing two flyovers, Level of Service was not reduced from F. So, in order to reduce the traffic congestion and LOS from F, two signals were provided on the most congested roads so that traffic can move smoothly.

Signals were provided on the road "From Bahria" and "From Kacheri". Signals were provided on these roads so that LOS can be reduced. After running the simulation, it was observed that by providing the two flyovers and two signals at the roundabout, LOS was improved from F to D.

Fig. 10 indicates the solution proposed to mitigate traffic congestion. Two flyovers "From Bahria-Kacheri" and "From Kacheri-Bahria" was proposed. Also two signals were provided in order to reduce the traffic congestion.

Two signals were provided at the two most congested roads i.e. From Bahria and From Kacheri. Signals were provided on the basis of Intergreen Matrices. Intergreen Matrices are defined as the time required to elapse between the green end of a clearing flow and the green start of an

Fig. 10 Proposed solution

entering flow. By keeping the intergreen, it is ensured that the clearing flow does not conflict with the entering flow. Cycle time of the signal was 90 s. Signals provided in the proposed solution was Red-Red/Amber-Green-Amber as shown in Fig. 11.

It was seen that delay measurement was decreased significantly due to providing flyovers and signals. But at the same time, queue length was increased due to signals. When signal turns red, long queues of vehicles were created (Tables 4 and 5, Fig. 12).

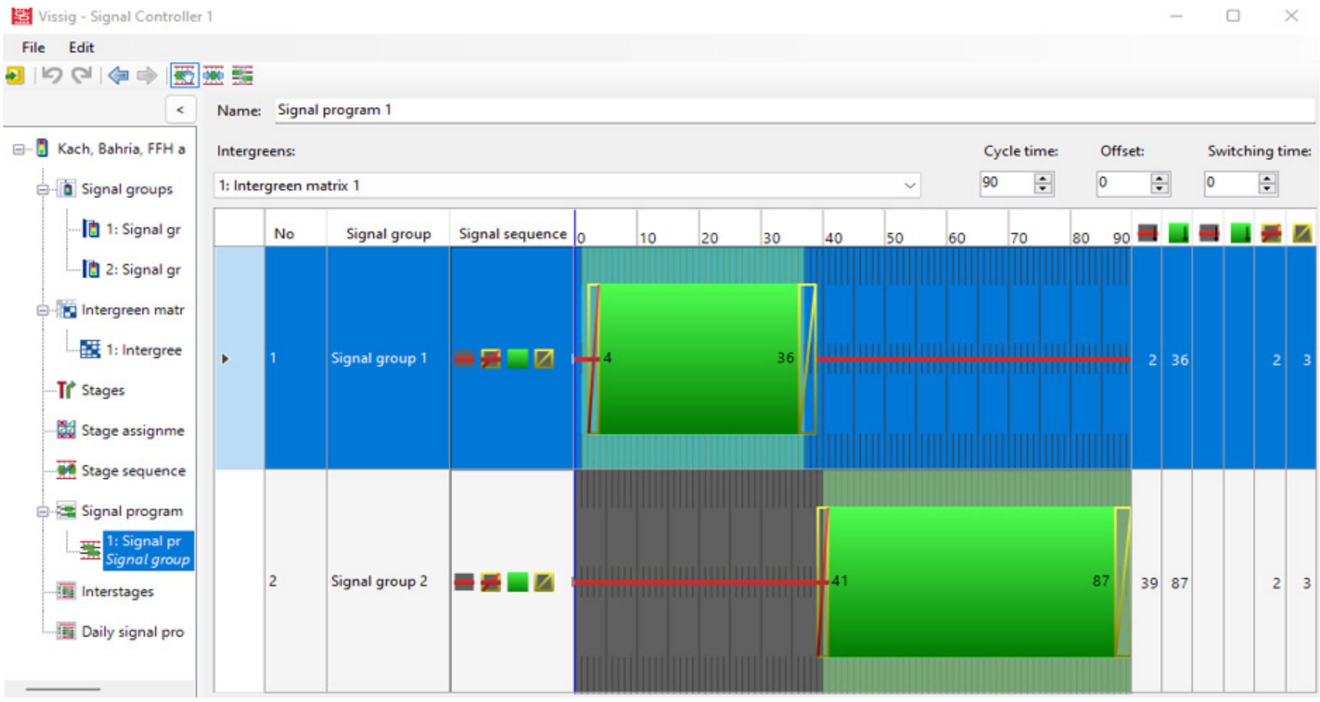


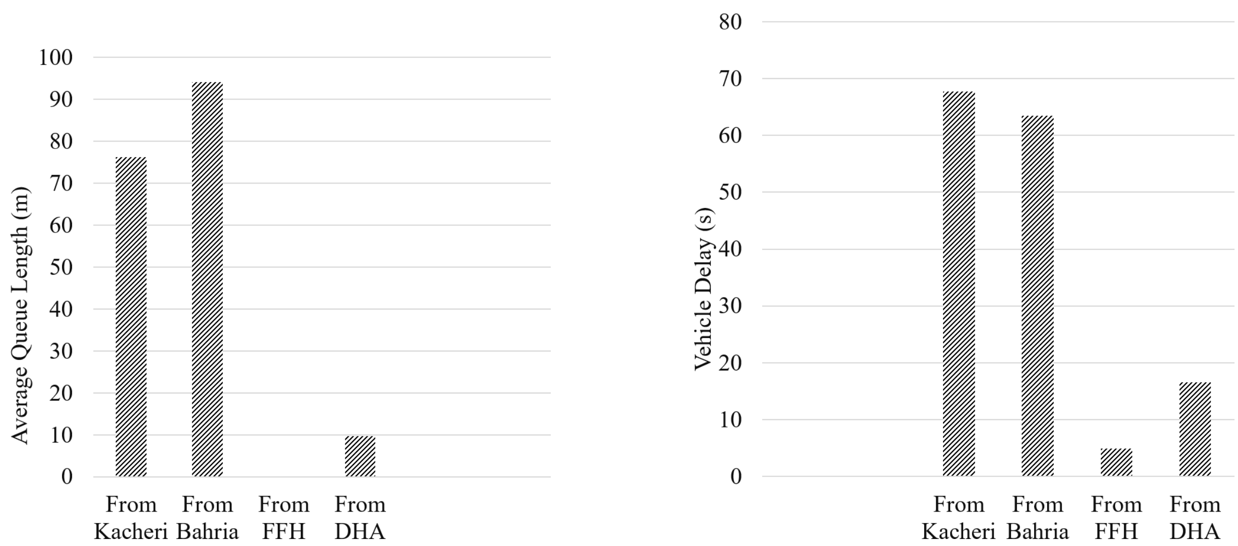
Fig. 11 Signal program

Table 4 LOS at proposed condition

Road	LOS
From Kacheri	D
From Bahria	D
From FFH	C
From DHA	D

Table 5 Avg. Queue Length/Vehicle Delay at proposed conditions

Road	Avg. Queue Length (m)	Avg. Vehicle Delay (s)
From Kacheri	76.15	67.73
From Bahria	94.06	63.49
From FFH	0.00	4.93
From DHA	9.64	16.51



(a) (b)

Fig. 12 (a) Queue length and (b) vehicle delay at proposed solution

5 Limitation and future recommendations

Out of date or manual traffic count could result in unreliable conclusions. Traffic simulation models often make assumptions (e.g. constant speed, homogeneous vehicles) that does not represent the real world nature of mixed traffic flows. PTV Vissim assumes specific parameters (acceleration, lane changes etc.) which does not match the driving style adopted all over the world. High quality data is required for accurate calibrations which is not possible in Pakistan at least. It is due to the fact that modern tools and equipment used for the collection of traffic data are not widely used in the developing world due to lack of resources and poor economy conditions. Amendments in traffic laws or public transport during or after study may not be captured in the model, affecting the accuracy of predictions. The study focuses on one particular roundabout, its findings cannot be implemented on other roundabouts or intersections having different geometry and traffic patterns.

Data collection methods must be improved in the future, such as data collection duration must be extended which covers different times of day, seasons or special events. Advanced traffic data collection equipment, such as real time traffic sensors, GPS data or drone based traffic monitoring, must be carried out for accurate results in future. A detailed study on local driver behavior must be performed in PTV Vissim to get accurate results. Future traffic growth scenarios must be conducted in order to observe the growth in population as well as in vehicles so that roundabouts in future can be designed accordingly. The impact of incidents such as accidents or road blockages must be simulated in PTV Vissim to develop better emergency management strategies. Prediction in traffic simulation must be improved using machine learning algorithms. Autonomous vehicles will be the future of modern transportation systems, simulation models should be developed to assess their influence in traffic congestion and traffic flow at roundabouts.

6 Conclusion

Maximum traffic congestion is observed at the Kacheri and Bahria town Road whereas the minimum traffic congestion is observed at FFH and DHA-1. LOS, delay and queue length were considered as performance parameters to evaluate the traffic condition at the roundabout. The results suggest that worst LOS F was observed at Kacheri and Bahria road followed by the queue length of 232 m and 110 s of delay at Kacheri and Bahria, respectively. Using PTV Vissim software (PTV Planung Transport Verkehr GmbH, online), a proposed model connecting Bahria-Kacheri and Kacheri-Bahria Road via flyover and signalized road is modelled and evaluated based on LOS, queue and delay. The results suggest that by incorporating these solutions, the LOS and delay at all roads gets better. As a result, there was an average improvement of 56.48% in delays at Kacheri and Bahria Road. However, it is observed that the queue length is increased at the Kacheri and Bahria road due to the provision of traffic signals on those roads.

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