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EVALUATION OF OPTIMAL DESIGN SOLUTION FOR INTERSECTION THROUGH TRAFFIC ASSESSMENT DATA: A CASE STUDY

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ABSTRACT

Satisfaction of the commuters on the road depends upon the traffic conditions of the road. If the built-in road facility is accomplishing the travel needs, it means that road facility has maintained its supply demand equilibrium. However, if the demands of the road are more than it can bear, the existing facility fails in providing the acceptable level of service to the commuter and as result it instigate all traffic problems. Kula Dher intersection is located at Mardan-Charsadda/Ghani Khan Road. In its current condition, it is failing to provide the acceptable level of service. Commuters use the said intersection while reaching 4 major districts that is Peshawar, Mardan, Charsadda and Swat. In its peak hour, the intersection becomes unserviceable due to immense traffic causing traffic delays, congestion, and pollution. This study evaluates the current traffic condition of Kula Dher intersection by collecting traffic data by direct field survey. The traffic data was then analyzed with 20 years projection. An effort has been made to provide a methodology framework in choosing the optimal solution for traffic congestion at intersection through traffic assessment study.

Keyword's

Traffic Data, Traffic Congestion, Intersection, Traffic Assessment Study, Recommendation

I. INTRODUCTION

Prior to reaching any design solution in engineering field one has to count all the criteria involved in decision making for best possible solution. In the same way while proposing a construction of new facility, or rehabilitating it, engineers carry out various studies such as geotechnical investigation, environmental assessment, traffic assessment, geological information, and others. Like others studies traffic assessment study is the key criteria to evaluate the best possible design for highway facility. In this paper we will be evaluating the highway facility of intersection at Kula Dher through traffic assessment study and present an optimum design solution.

Much research has highlighted the issue of congestion in intersection. To understand the traffic system at an intersection; traffic data needs to be assessed to know the performance of the existing facility (Farooq and Akram, 2017). Traffic data can be collected manually where a traffic counter personnel visually count the numbers of vehicles passing by the highway facility and other is automatic method where the traffic is recorded by means of mechanical recorder. (Policepatil, Vishal, Roopa, Suresh, Shrishail, Inganakal, 2018)

Atomode (2013) worked on traffic delay causes at a signalized intersection and proposed signalized intersection and emphasized that parking should be prohibited in the vicinity of the road intersection.

Corrierea and Guerrieri (2012) researched the analytical model on the turbo roundabout that is the channelized multilane intersection that helps in diminishing vehicular accidents when using roundabout. Their study deduced that vehicular delays is the result of single lane capacities, conflicting flow, circulating flow, user interacting with the road facility, and traffic demand.

Lal. G., Divya L. G., Nithin K.J., Mathew. S and Kuriakose. B. (2012) carried out work on the traffic problems and the sustainable improvement of the road intersection at ETTumanorr, India. Study shows that design was insufficient to accommodate the current traffic demand. Furthermore, the absence of signals at the intersection and unlawful parking at the intersection were the other causes of congestion at the study intersection. The study proposed to install signal system at the intersection in order to provide the best level of service.

Cantisani. G., Loprencipe. G and Primieri. F. (2012) worked on the geometric design of an intersection taking functional testing and economic analysis into consideration and proposed the optimal solution of roundabout using Sidra Software.

Research has been done either discussing the causes of the traffic congestion at the intersection and or it focuses on the solution. There is very limited amount of literature that emphasized both on the causes and solution. An effort is being made in this paper by taking an over capacitated Kula Dher intersection as a case study. Existing traffic data and traffic forecast data is assessed and the optimal solution to the congestion problem at the intersection is proposed.

STUDY AREA

The intersection is located at Mardan-Charsadda/ Ghani Khan Road. Its channelized traffic to Charsadda in the west, Mardan in the East, Nissatta Interchange, and Motorway 1 (M1) in the South that leads to Peshawar and Islamabad and District Swat in the North. At peak hour, the facility is over capacitated and hence causing traffic delays and congestion.

II. RESEARCH METHODOLOGY

This paper will describe the methodology and results of the traffic operations assessment. The Study Area is shown in Figure 1. The scope of the Study is as follows:

• Conduct and review the field data of a.m. mid-day, and p.m. peak hour turning movement counts at the intersection Kula Dher Road

• Identify and assess the existing traffic conditions within the Study Area.

• Using conservatively 5% growth annually for traffic forecasts and assesses the transportation network performance for the Study Area for the 2029 and 2039 future horizon year.

• Identify the need for improvements within the Study Area to accommodate the future traffic forecasts.

• Develop and assess traffic forecasts for alternative network improvement scenarios.

Existing Condition

The Charsadda-Mardan Road two lanes divided corridor, run east-west, currently functions as a significant link between two cities Charsadda cities in the west and Mardan city in the east.
The characteristics of the Study Area road network are as follows:

- Charsadda-Mardan Road is two-lanes divided corridor, run east-west with a posted speed limit of 60 km/h.
- Ghani Khan/Canal Road is two lane un-divided corridors, run north-south with a speed limit of 50 km/hr.

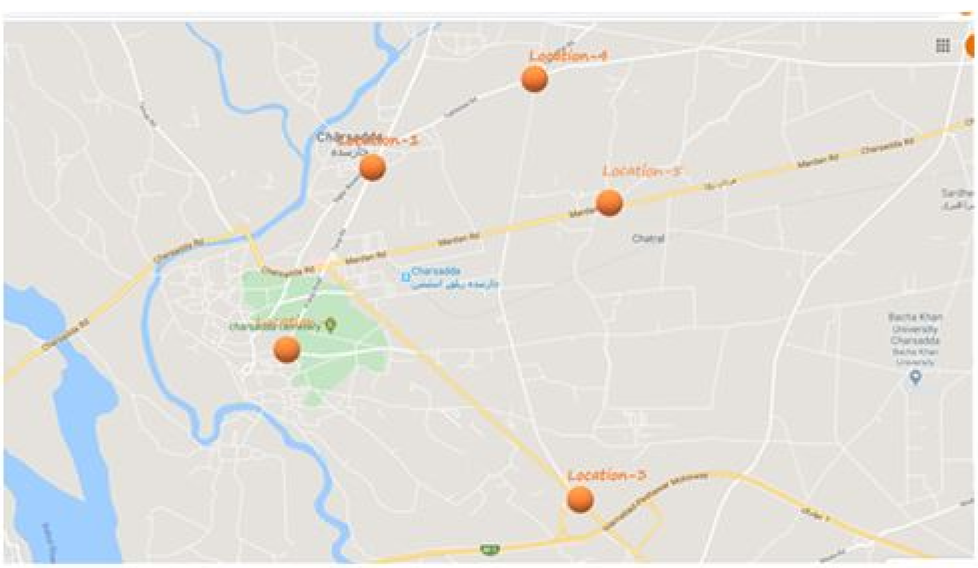

Fig.1 Study area of research

Traffic Data

The traffic turning movement counts were conducted on November 29th, 30th and December 2nd, 2019 at Kula Dher intersection. The three-day traffic data was compared, and the highest traffic count was chosen which was observed on Friday, 29th November 2019. The morning peak 60- minute segment for the intersection occurs between 7:30 - 8:30 a.m., and the mid-day peak 60- minute segment for the intersection occurs between 1:00 pm to 2:00 p.m., while the evening peak 60-minute segment occurs between 4:15 p.m., and 5:15 p.m.

An origin-destination (O-D) study was conducted on Friday, Saturday, and Monday the November 29th, 30th and December 2nd, 2019. Complete day data was collected for travel within the corridor.

III. Results

The results are shown below in Table 1.

Table 1 Origin- destination Survey Results

ORIGIN-DESTINATION SURVEY RESUTS			
Peak Hour	**Origin**	**Destination**	**Percentage**
AM	SB on Ghani Khan Road	Peshawar	65%
		Mardan	13%
		Charsadda	20%
		Nowshera	2%
	NB on Ghani Khan Road	Swat	32%
		Charsadda	49%
		Mardan	19%
	WB on Ghani Khan Road	Swat	1%
		Charsadda	75%
		Peshawar	23%
		Nowshera	2%
	EB on Ghani Khan Road	Mardan	13%
		Nowshera	6%
		Peshawar	81%
PM	SB on Ghani Khan Road	Peshawar	73%
		Mardan	6%
		Charsadda	20%
		Nowshera	1%
	NB on Ghani Khan Road	Swat	50%
		Charsadda	42%
		Mardan	7%
	WB on Ghani Khan Road	Swat	4%
		Charsadda	67%
		Peshawar	28%
		Nowshera	2%
	EB on Ghani Khan Road	Mardan	16%

		Nowshera	7%
		Peshawar	77%

The majority of traffic from the west (eastbound) on Kula Dher Road is destined to take right turn on Ghani Khan Road in both the a.m. and p.m. peak hours.

Traffic Operations

The two key ingredients to assess the quality of traffic operation at intersection is Level of Service (LOS) and volume to capacity (v/c) ratio. Average delay per vehicle correlates with Level of Service. This delay can be instigated by vehicles slowing down. Time spent while stopping at the intersection and waiting in queue. Furthermore, the delay caused by the final acceleration delay also adds up to total delay. Hourly rate of the traffic is attributed to the capacity. This is represented by demand flow rate to capacity ratio. The capacity condition is represented by a v/c ratio of 1.00 (i.e., volume demand equals capacity). The criteria for LOS are presented in **Table 2**.

Table 2. LOS for Signalized Intersection

LEVEL OF SERVICE CRITERIA	
SIGNALIZED INTERSECTIONS	
Level of Service (LOS)	**Delay (seconds/vehicles**
A	0-10 seconds
B	>10-20 seconds
C	>20-35 seconds
D	>35-55 seconds
E	>55-80 seconds
F	> 80 seconds

Driver perception and reaction time on the unsignalized intersection differs from the one using the signalized intersection. In un-signalized intersection drivers experiences less traffic delays while the signalized is designed to accommodate higher traffic volumes and hence the time spent on the signalized intersection is greater than the unsignalized intersection. The LOS criteria for unsignalized intersection are shown below in **Table 3.**

Table 1: LOS for Unsignalized Intersection

LEVEL OF SERVICE CRITERIA	
UNSIGNALIZED INTERSECTIONS	
Level of Service (LOS)	**Delay (seconds/vehicles**
A	0-10 seconds
B	>10-15 seconds
C	>15-25 seconds
D	>25-35 seconds
E	>35-50 seconds
F	> 50 seconds

To evaluate the level of service LOS C or better is perceived as acceptable while in peak hours LOS D is allotted to both through and right-turn movements and overall intersection. For left turn LOS E is considered to be acceptable. Similarly, v/c is achieved for overall intersection and for the specific movement within the intersection. Conflicting movements that affects the free flow within the un-signalized intersection dictates the level of service. LOS and v/c are determined separately even though they are related. An intersec-tion could provide good level of service though it is over capacitated and vice versa. Therefore, it could be expected that even though the movement is not over capacity it would show LOS F. Similarly, LOS E or better does not mean that the intersection is over capacitated. The results for the existing peak hour traffic in unsignalized intersection were analyzed using Synchro Version 7 Software and shown in **Table 4.**

Table 2: Existing Peak hr LOS Unsignalized Intersection

EXISTING PEAK HOUR LEVEL OF SERVICE											
UNSIGNALIZED INTERSECTION											
Intersection	**Approach/Movement**		**AM Peak Hour**			**Mid-Day Hour**			**PM Peak Hour**		
			LOS	**v/c**	**Delay sec**	**LOS**	**v/c**	**Delay sec**	**LOS**	**v/c**	**Delay sec**
Kula Dher	East	Left/Thru/Right	D	0.93	44.7	F	2.54	92.8	E	0.85	69.4
	WB	Left/Thru/Right	D	0.86	37.0	F	2.16	552.5	E	0.86	69.1
	NB	Left/Thru/Right	E	0.91	57.1	C	0.46	23.4	C	0.49	25.3
	SB	Left/Thru/Right	D	1.28	49.3	D	0.78	35.8	D	0.88	42.1
	Overall Intersection		F	0.93	46.5	F	2.16	265.1	F	0.27	50.6

In the a.m. peak hour, at the Kula Dher intersection, the northbound shared left turn / through / right turn movement and intersections operates at poor levels of service and over capacity. While the capacity and level of service is deemed acceptable for all other movements. All other movements operate within capacity and at acceptable levels of service. In the mid-day peak hour, at the Kula Dher intersection, the east and westbound shared left turn / through / right turn movement and intersections operates at poor levels of service and well above capacity. Only northbound shared left/through/right movements operate within capacity and at acceptable levels of service. In the p.m. peak hour, at the Kula Dher intersection, the east and westbound shared left turn / through /right turn operates at poor levels of service and over capacity. The northbound shared left turn/through/ right turn movement operates at acceptable levels of service within capacity.

Future Conditions: Traffic Forecasts

The future a.m. and p.m. peak hour turning movement forecasts for the 2029 and 2039 horizon year extracted from the data collected on November 21st, 2019 at Kula Dher and apply conservatively 5% annual growth for traffic forecasts. These traffic forecasts served as the base set of traffic volumes for the Do Nothing and various improvement scenarios considered.

Intersection Improvement Scenarios

In order to accommodate the 2039 traffic forecasts, a number of improvements were examined for each intersection and in combination with each other.

These scenarios are defined as follows:

- Scenario 1 – DO Nothing
- Scenario 2 – Roundabout/Conventional– Convert the Kula Dher intersection from an unsignalized intersection to a roundabout.
- Scenario 3 – New Bridge Crossing – Provide a new bridge crossing on Kula Dher to provide uninterrupted flow to Charsadda-Mardan road traffic.

These scenarios are described in greater detail in the following sections. The traffic forecasts prepared for these alternative scenarios have been derived from the data collected at site for a.m., mid-day, and p.m., peak hour travel demand forecasting model. The model was used to determine the growth and distribution in traffic. The resultant growth adjusted to reflect peak hour traffic. Traffic forecast was applied to the critical peak hour traffic volumes. While forecasts have been prepared at a turning movement level, the level of accuracy is only as good as the original data source which is calibrated at a screen line level. These alternative network improvements scenarios traffic forecasts have been developed for comparative purposes and have not been prepared to determine specific roadway requirements.

Scenario 1 - Do Nothing Scenario

The analysis is done for Do Nothing Scenario with 2029 projection and is shown in **Table 5**.

Table 3: 2029 Peak hr LOS (Do Nothing Scenario)

2029 PEAK HOUR LEVEL OF SERVICE											
DO NOTHING SCENARIO											
Intersection	**Approach/Movement**		**AM Peak Hour**			**Mid-Day Hour**			**PM Peak Hour**		
			LOS	**v/c**	**Delay sec**	**LOS**	**v/c**	**Delay sec**	**LOS**	**v/c**	**Delay sec**
Kula Dher	East	Left/Thru/Right	F	4.81	277.2	F	3.10	117.8	F	1.12	101.4
	WB	Left/Thru/Right	F	2.57	341.9	F	2.84	850.0	F	1.13	107.6
	NB	Left/Thru/Right	E	1.62	312.7	B	0.42	17.5	F	2.49	158.5
	SB	Left/Thru/Right	F	5.26	128.8	F	1.51	268.4	F	2.40	653.6
	Overall Intersection		F	1.69	278.0	F	2.84	503.2	F	2.40	323.9

In the Do-nothing scenario for 2029 horizon year as shown in **Table 5** above, in the a.m. mid-day, and p.m. peak hour at the intersection of Kula Dher, in all bounds shared left/through/right turning movements operate at poor levels of service and well above capacity. All the four legs movements' queues are blocked. The analysis for 2039-year projection for peak hour Do Nothing scenario are shown in **Table 6**.

Table 4: 2039 Peak Hr LOS (Do Nothing Scenario)

2039 PEAK HOUR LEVEL OF SERVICE											
DO NOTHING SCENARIO											
Intersection	**Approach/Movement**		**AM Peak Hour**			**Mid-Day Hour**			**PM Peak Hour**		
			LOS	**v/c**	**Delay sec**	**LOS**	**v/c**	**Delay sec**	**LOS**	**v/c**	**Delay sec**
Kula Dher	East	Left/Thru/Right	F	11.12	822.2	F	5.46	583.2	F	5.96	577.7
	WB	Left/Thru/Right	F	4.31	755.1	F	7.17	1738	F	2.48	476.1
	NB	Left/Thru/Right	E	3.11	732.4	F	1.97	466.1	F	2.00	398.8
	SB	Left/Thru/Right	F	11.77	483.6	F	15.7	1133	F	13.1	1634
	Overall Intersection		F	2.78	717.4	F	4.83	1195	F	4.60	923.9

In the Do-nothing scenario for 2039 horizon year as shown in table 5 above, in the a.m., mid-day, and p.m. peak hour at the intersection of Kula Dher, in all bounds shared left/through/right turning movements operate at poor levels of service and well above capacity. All the four bound movements' queues are blocked.

Scenario 2- Roundabout Scenarios

The intersection is considering roundabout with four-leg intersection with all-way yield, control. To run through the alternative basic parameters regarding number and width of the lanes were assumed. Percentage of the left turn movements is also anticipated. As the study intersection has two lane approaches; a central island of 30.0m in diameter was considered, providing greater area of maneuvering for heavy vehicles. For Round about analysis SIDRA software was used. The analysis is based on the 2039 horizon a.m., peak data and is shown in **Table 7**.

Table 5: 2039 Peak hr LOS (Roundabout Scenario)

2039 PEAK HOUR LEVEL OF SERVICE				
SCENARIO 2- ROUNDABOUT SCENARIO				
Performance Measure	**Approach**			
	South	**East**	**North**	**South**
Approach Flow (Veh/hr)	1993	2133	1356	1945

Circulation Flow (Pcu/hr)	1114	1239	897	1483
Degree of Saturation	2.06	1.54	1.12	1.69
LOS	**F**	**F**	**F**	**F**
Avg control delay (sec)	967.9	497.3	130.2	590.3
Avg queue length (m)	2858	2073	498	2297

In the roundabout scenario, all movements operate at poor levels of service and well above capacity. All the four legs movements' queues are blocked.

Scenario 3 – New Bridge Crossing/Flyover

Table 6: 2039 Peak hr LOS (New Bridge Crossing)

2039 PEAK HOUR LEVEL OF SERVICE							
SCENARIO 3- NEW BRIDGE CROSSING							
Kula Dher	**Approach/Movement**		**AM Peak Hour**		**PM Peak Hour**		
			LOS	**v/c**	**LOS**	**v/c**	**Delay sec**
	NB	Left	Not Analyzed		A	0.68	2.1
		Thru/Right			A	0.06	0.1
	SB	Left			A	0.69	5
		Thru/Right			C	0.95	21.1
	Overall Intersection				B	0.95	10.4

In this scenario, the westbound and eastbound has a dedicate flyover. The northbound and southbound left turning will be provided a dedicated lane, while right turns will go straight and take a U-turn about 200 to 300 meters behind the intersection. In this scenario the intersection operates at good levels of service and within capacity.

Traffic Intensity: Classified Traffic Volume Counts

Different cars have different impacts on traffic variables that headway, speed, and density. Therefore, to measure the effect of the different classes of transportation mode with respect to single standard passenger car; Transportation Engineer has introduced Passenger Car Unit (PCU) to evaluate the traffic flow rate.

For this purpose, the filed data was collected for 3 days continuously. The vehicle classification used in the survey along with their PCU factors, are presented in **Table 9**.

Table 7: Vehicle Classification & PCU Factors

VEHICLE CLASSIFICATION & PCU FACTORS	
Vehicle Type	**PCU Factor**
Rickshaw, Car, Jeep, Van	1.0
Minibus, Coaster, Tractors	1.5
Truck 2-axle	3.0
Truck 3-axle	3.0
4 to 6-axle truck	4.5
More than 6-axle	4.5

The analyses of the classified traffic volume at selected locations were carried out to deduct at the following:

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• Average Daily Traffic (ADT) and Annual Average Daily Traffic (AADT)

• Daily variation of traffic volume.

• Average Composition of traffic

Average daily traffic (ADT)

The average values of the traffic volume data were taken to get Average Daily Traffic (ADT). **Table 10** shows the ADT based on vehicle type.

Table 8: Average Daily Traffic

AVERAGE DAILY TRAFFIC			
Mode of Vehicle	**Traffic Volume**	**PCU**	**Total PCU**
Rickshaw, Car, Jeep, Van	17919	1	17919
Minibus, Coaster, Tractors	570	1.5	855
Truck (2-3) Axle	405	3	1215
Truck (4 to 6) Axle	228	4.5	1026
Grand Total (Nos.)	19122		21015

Annual Average Daily Traffic (AADT)

Seasonal factor was applied for converting ADT to AADT. **Table 11** shows the AADT for different mode of vehicles. To project the traffic volume up to horizon year; base year **(2008-09)** was taken.

Table 9: Annual Average Daily Traffic (PCU)

ANNUAL AVERAGE DAILY TRAFFIC (PCU)			
Mode of Vehicle	**ADT**	**SAF**	**AADT**
Rickshaw, Car, Jeep, Van	17919	1.97	35300
Minibus, Coaster, Tractors	855	1.8	1539
Truck (2-3) Axle	1215	1.84	2236
Truck (4 to 6) Axle	1026	1.79	1837
Grand Total (Nos.)	**21015**		**40912**

Conclusions:

The study was commenced at Kula Dher intersection to come up with optimal solution through traffic assessment study. Field data was collected, and analysis were done through simulation software and based on the preceding information and analysis, the following conclusions are reached:

a) Based on an analysis of the most recent traffic volume data, intersections within the Study Area operate with long delays and are approaching or exceedingly well above capacity. This is consistent with field observations and the observations of local residents.

b) Based on an analysis of a.m. and p.m., peak hour major operational issues exist on all right turning movements of the subjected intersection, observed significantly larger queuing length on all bounds.

c) Based on the greatest reductions in delay and greatest safety improvements, Scenario 3– new bridge crossing.

Although traffic assessment study is an important criterion while choosing the best possible solution of the highway facility, we cannot disregard the significance of geotechnical, geological, environmental, Land Acquisition and resettlement plan and social studies of the project facility. A thorough studies needs to be done while selecting best alternative solutions for the road facility.

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