IMPROVEMENT OF INTERSECTIONS ON ARTERIALS IN URBAN AREAS OF GUJRANWALA

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ABSTRACT: Traffic congestion is a major problemof fastgrowing metropolises due to the constant mobility of people and goods.The main objective of this study was to identify existing and potential future traffic operations at Pindi Bypass and Chan Da Qillaintersections of Gujranwala along Grand Trunk (G.T) road and to evaluate potential future intersection improvements. Each intersection was analysed using the software SIDRA (Signalised&unsignalised Intersection Design and Research Aid). The traffic counts were conducted in which directional movements of selected intersections were recorded. The volumes were later converted into Passenger Car Unit (PCU) using equivalency factors mentioned in Punjab Geometric Design Manual (PGDM). Delay and Volume/Capacity (V/C) Ratio model was employed for Level of Service (Los)calculation. It was observed that the demand was more in comparison to the capacity of selected intersections. In order to alleviate the problems and accommodate the rising traffic of selected intersections several improvements were recommended and mentioned in detail with in depth traffic analysis.

Key words: Passenger Car Unit (PCU), Heavy Vehicles (HV), Level of Service (LOS), Degree of Saturation, Volume / Capacity (V/C) ratio.

(Received 27-11-2015 Accepted 18-08-2016)

INTRODUCTION

The achievement of sustainability through dependable, effectual and assimilatedtransportion system is one of the greatest challenges faced by urban centers (United Nations, 2010). In reality, this challenge has major insinuations for all especially transportation professionals. Traffic management mainly deals with the utilization and management of available limited resources in such a way that that the present needs are met without compromising upon future needs. A prime dare in this regard is to strike a balance between efficient traffic/ transport links and maintainineconomic strength, social cohesion and equity for all. Furthermore, the time space organization of households and facilities underline the need for transport system to provide a link between itself. (Klettner, 2009)

Gujranwala being the seventh largest urban center of Punjabis well linked with cities of the province through main roads like Grand Trunk (G.T) Road, Sheikhupura Road, Sialkot Road, Hafizabad Road and Pasrur Road. Over the years, rapid urbanization resulted in the development of industrial and commercial areas on the suburbs of thecity (Directorate of Industries, 2012).

The traffic on main roads is composed of87% motorized and 13% non-motorized vehicles. The huge volume of vehicular traffic especially during peak hours tendsto bring city at cessation. The situation is further exacerbated by the slow moving non-motorized vehiclessince it operates within the main traffic. This mixed traffic operation compromises upon safety of both vehicles as well as pedestrians commuting along the road and causes flow disruption, inconvenience and delays. Thisdisorganized and poor traffic operation of the city ultimately causes congestion, environmental pollution and other transport related problems within the city. (Transport Planning Unit, 2013)

An intersection is the area, in which two or more roads or streets join or cross, as the main goal of intersection design is to facilitate the innocuous and well-organized drive of vehicles and road-users through the intersections, in highly motorised countries.Intersection design is often driven primarily by capacity and performance considerations that prioritise vehicular traffic. (Corben*et.al*., 2010).

The need of this study is stressed out as a result of the previous studies in which it was highlighted that public transport utilization in Gujranwala is remarkably less in comparison to other modes operating in the city. The reason for this trend is based on the fact that the prevailing road network in the city follows a unique alignment and almost all public transport routes in the city pass through a single corridor i.e. G.T. Road, which results in heavy flow of the mix traffic on the road causing congestion(Urban Unit, 2013). The landuse along the study corridor is composed of educational institutes, commercial plazas and residential colonies which act as major generator of traffic. Surprisingly, the city has

observed spatial growth towards/ around the Gujranwala Bypass Road, which now acts as peripheral boundary between urban and rural areas of the city (The Urban Unit, 2008). Recent developments have extended the boundary of the urban areas further ahead of the By-pass roads. People living in these residential areas have to commute to G.T road first then make a transit journey to their desired locations; resulting in traffic related issues on the road (Punjab Development Statistics, 2014).The traffic congestion aggravates day by day is causing an immense delay and increased travel times (Tianziet.al,2013).

In order to improve the situation several steps have been taken to improve the traffic flow of city such as; reduction of intersections on G.T road along the city from ten (10) to four (4), along with the construction of flyover along G.T road in year 2013.It is most unfortunate that even after all these improvements, G.T road remains overloaded by the vehicles which raises serious concerns.(Tribune, 2014)

As per the data collected from the traffic counts it is observed that Pindi Bypass and Chan Da Qilla intersections (Figure 1)are the most heavily loaded intersections with increased delays and poor LOS. These two intersections also act as chocking points on G.T road causing traffic congestion whose flux can be experienced all along G.T road passing through the city. (Hussain et.al., 2016).

The first intersection of analysis is Pindi Bypass. It is a four legged signalized intersection connecting G-T Road with Sialkot Bypass and Alipur Chowk. The other intersection is Chanda qilla, which is a three legged rotary intersection on G-T Road. It connects Gujranwala city with MorAima Abad. The traffic counts conducted were further projected during 2020 to 2025 for each leg of the intersections (Figure 2 and 3), for traffic analysis.

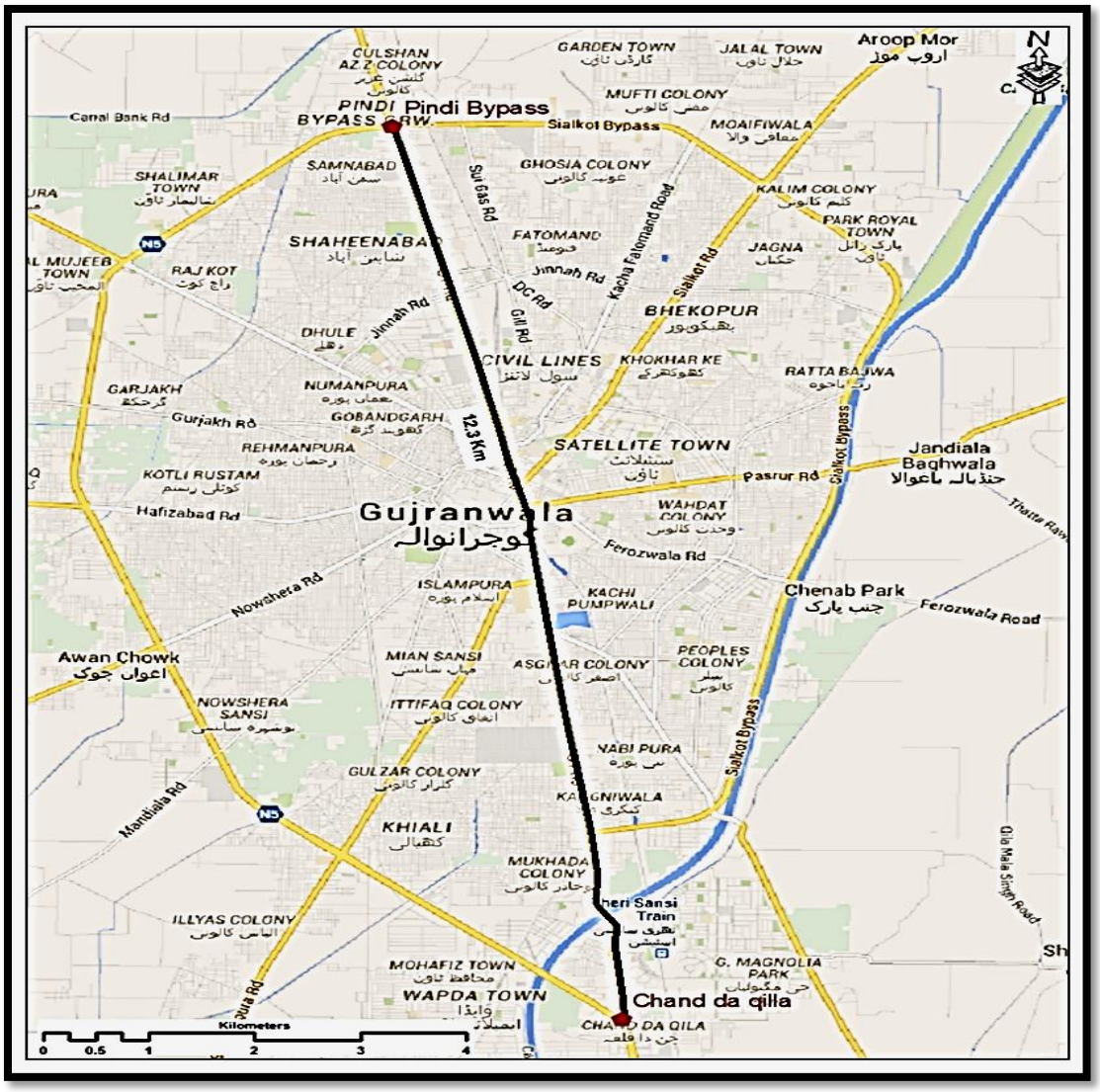


Figure 1: Study Area



Figure 2: Satellite Image of Pindi Bypass



Figure 3: Satellite Image of Chanda Qilla

SIDRA is an effective tool for analyzing the present and future intersection scenerios in Asian countries where right hand drive system prevails. SIDRA is employed effectively in congested areas of Banglore for intersection imporvements due to its flexibility as an operating system and microscopic nature. (Kumar, 2013).

In this regard, traffic analysis is conducted using SIDRA software for current and future traffic projections and improvements are checked in case of proposed changes in geometry. The delays and volume to capacity ratios were used as a benchmark for determing the LOS in case of existing and future scenarios using peak hour traffic.

MATERIALS AND METHODS

For the completion of this study a rigourous qualitative and quantitative analysis was carried out. The combined approach comprised of primary data collection through field visits that was traffic count etc.and secondary data wasobtained from the data archives, reports and publications. A list of tasks wasprepared for the primary data collection. These included review of existing transportation facilities and collection of available information if any, about the existing road networks by focusing on group discussions involving stakeholders and field surveys. Traffic Count Survey was performed on the selected intersections to assess traffic patterns and demand in the study area.Manual counting technique was used by the trained surveyors who recorded the traffic coming from each leg of intersection along with the vehicle volumes, their types and data regarding intersections inventory. The traffic counts were converted into Passenger Car Unit (PCU) using Passenger EquilencyTable-1 as per (Punjab Geometric Design Manual, 2011).

Table: 1 Passenger Equilency Unit.

Vehicle Type	Equilency Factor
Private Car including Taxis or Pick-Up	1
Motorcycle	0.5
Bicycle	0.2
Bus, Tractor, Truck	3.5
Horse Drawn Vehicle	4

The maximum peak hour volume for Pindi Bypass intersection Table-2 was 10139 PCUs and it occurred at 15:45-16:45 of time interval. Moreover, the percentage of heavy vehicle was found 15.

Table 2: Traffic Volume / Hour at Pindi Bypass Intersection.

Time period	AM Peak	Noon Peak	Evening Peak
	08:30-09:30	12:30-13:00	15:45-16:45
Traffic Vol./ hr.	9925	9489	10139

Likewise, the maximum peak hour volume for Chan Da Qilla intersection Table-3 was 5423 PCUs and it occurred at 13:45-14:45 of time interval. Moreover, the percentage of heavy vehicles was found 12.

Table 3: Traffic Volume / Hour at Chan Da Qilla Intersection.

Time period	AM Peak	Noon Peak	Evening Peak
	08:30-09:30	13:45-14:45	19:00-20:00
Traffic Vol./ hr.	5526	5423	5074

The peak hour traffic Table 2 and3 was used as an input value for performing traffic analysis in SIDRA. The analysis was done for existing traffic along with future projections with improved intersection geometry. All junction analysis parameters were defined according to local conditions of traffic, travel behavior and existing operational measures.

This initial analysis helped in finding the major operational capacity issues by lane, and by each leg. Further, design period analysis was also performed to assess either on current situation, as to how long this junction could sustain the future traffic growth and what will be the expected outcome in future travel demand. Moreover, each junction was further checked for operation under local conditions which led to the development of traffic control system which deemed important for resolving the ongoing issues.

For the calculation of growth rate, the number of registered vehicles in the city were converted into Equivalent Passenger Car Unit (PCU) and growth factor was calculated by comparing the previous three years' data. (Punjab Development Statistics, 2013) Growth Factor computed was 5.68 and existing volume was projected to evaluate the future demand.

Likewise, the data obtained from secondary sources was analyzed to extract information relevant to the study. The archives, reports, government and private organizations publications, policy documents and plans, travel data and census data were the key sources of information for the secondary data.

After the collection of data (Primary and Secondary) the results of traffic count survey and road inventory survey were compiled to examine the present situation of traffic in the city. The existing traffic volumes were projected which considering the city socioeconomic statistical data related registered vehicles in Punjab Development Statics to evaluate the future traffic demands.

Essential model parameters used for the modeling were theaverage growth for the traffic at each junction was assumed to be 3.0% per year in correspondence with Lahore Urban Transport Master Plan (LUTMP) study findings, the average car occupancy was taken as 1.2, queue space length for Light Vehicles (LV) was taken as 5.5m and for Heavy Vehicles (HV) as 11.5m, whereas LV and HV lengths were taken as 4.5m and 10m respectively, critical gap for opposed vehicle entry was taken as 2.0sec, whereas follow up headway was taken as 2.0sec with respect to local travel condition and drivers behavior.

The selected intersections were analysed using SIDRA Software, whichis a micro-analytical traffic evaluation tool that employs lane-by-lane and vehicle drive cycle models.All the intersections were evaluated using this software (SIDRA, 2012) for current and future traffic projections. This section initially provided the results of traffic analysis conducted on the collected traffic volumewhereas, later several geometric improvements would be discussed. The traffic analysis results included the volume to capacity ratio valueswould lead to the level of service of the intersectionas has been reported by (Akcelik*et.al.*, 1991). Table-4 shows the LoS results in comparison to the volume to capacity ratios (Highway Capacity Manual, 2011).

Table 4: Volume /Capaity (V/C) vs Level of Service (LOS) Table.

Volume-Capacity Ratio	Delay (s/veh)	LOS
0.3	0-10	A-Free Flow
0.5	>10-15	B- Reasonably Free Flow
0.8	>15-25	C-Stable Flow
0.9	>25-35	D-Approaching Unstable flow.
1	>35-50	E-Unstable Flow
>1	>50	F- Forced or Breakdown flow

In this research Highway Capacity Software (HCS) and Signalized Intersection Design and Research Aid (SIDRA) standards and analysis results were used for the improvements and recommendations. These techniques also have been employed by the Jordanian Traffic Departments without any field validation or any other reference as has been reported by (Al-Omari andTa'amneh, 2007).

RESULTS AND DISCUSSIONS

The Pindi Bypass intersection was analysed using SIDRA software for the current and future yearsTable 5. During the analysis, the degree of saturation i.e V/C Ratio in 2015 was 2.333 and continuously increased to 2.885 till 2025, which showed a big demand of traffic in the near future than capacity of the junction. Due to the increased degree of Saturation, intersection delay was prominenetly high which resulted

in long queues, traffic congession, increase in travel time and fuel cost. This showed that Pindi Bypass needed a change in the geometric design either through addition in lanes or grade separated uninterrupted lanes for traffic movements as has been reported by (Nespak, 2014).

The selection of any geometric improvement for any intersection depended upon the volume to capacity ratios and delay values (Ranjitha*et.al*, 2015). A similar study in this regard was conducted in the Indian city of Banglore for the Vijaya Bank Intersection whose geometry was similar to Pindi Bypass. Table-6 showed the combined results of volume to capacity ratios and delays for Pindi Bypass, Gujranwala and Vijaya Bank Intersection, Banglore.

Table 5: Pindi Bypass Traffic Analysis Results.

Traffic Analysis Attribute	Degree of Saturation (V/C Ratio)		
	2015	2020	2025
V/C	2.333	2.593	2.885
Delay	110	155	203
LOS	F	F	F

Table 6: Result Comparison of Pindi Bypass vs Vijaya Bank BangloreIntersection.

Traffic Analysis Attribute	Vijaya Bank Intersection, Total PCU=9870			Pindi Bypass Intersection, Total PCU=10139		
	2015	**2020**	**2025**	**2015**	**2020**	**2025**
Volume to Capacity Ratio (v/c)	2.103	2.485	2.787	2.333	2.593	2.885
Delay	98	135	169	110	155	203
LOS	F	F	F	F	F	F

It can be observed that the results of Pindi Bypass and Vijaya Bank Intersection were in close conjunction and the both the intersections showed LOS of F. As mentioned earlier that Pindi Bypass had Level of Service (LOS) F from the base year i.e. 2015 with increased delays as mentioned in Table 6. It was clear that the demand was much higher as compared to capacity showing similar results atVijaya Bank Intersection, Banglore. Therefore, Pindi Bypass required immediate geometric improvement. Many possible traffic management solutions for the improvement of traffic at this intersection were taken into consideration and were checked for changes or improvements in LOS. The best possible solution for such high volume of traffic was grade separation. The underpass was prefered for this intersection as the expected benefits produced by utilizing an underpass at congested roadways included reduction of travel time, fuel usage and network wide stoppages. The intersection improved by the construction of two lane underpass for the traffic between Gujranwala City and Rawalpindi. The provision Figure-4 would provide smooth traffic flow operations for at least five years after which grade separation would be required for the other intersection leg i.e for the traffic coming from Rawalpindi and Gujranwala city.

The results of analysis in SIDRA after the provision of underpass are presented at Figures 5, 6 and 7.

The LOS of each leg shown in Figure-5 of Pindi Bypass intersection had considerably improved which will ultimately result in reduction in travel time and delays.

The degree of saturation (V/C) of Pindi Bypass intersection would considerabely improved by providing improvements shown in Figure-6 ultimately resulting improved service delivery.

Likewise, reduced/ minimum delays would also be observed as shown at Figure-7 after the provision of under pass at Pindi Bypass intersection.

Similarly, Chan Da Qilla intersection was also analysed using SIDRA software for the current and future years as shown in Table 7. The degree of saturation of Chand Da Qilla was 1.018 in 2015 which continuously increased to 1.802 till 2025. It means that initially demand and capacity were equal and further traffic was able to progress through the Chand Da Qilla but aftwards suffered from traffic congestion with the queues of vehicles. The high delay values showed traffic congestion which led to the LOS F. Chan Da Qilla was in good condition as compared to Pindi Bypass but the LOS in this case was also F, therefore, geometric improvement should be made in order to cater for future traffic demand.

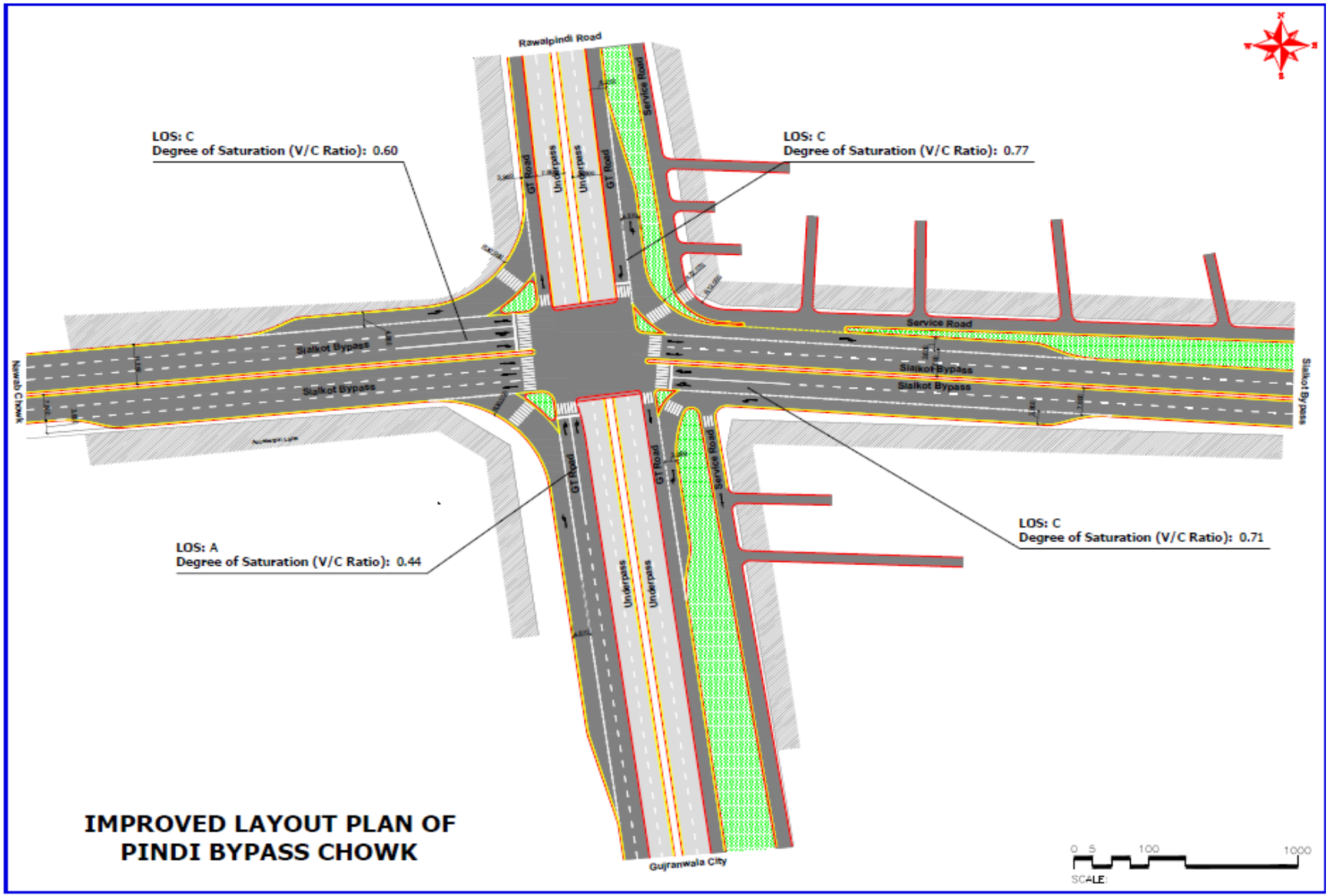


Figure 4: Improved Layout Plan of Pindi Bypass Chowk for Base Year

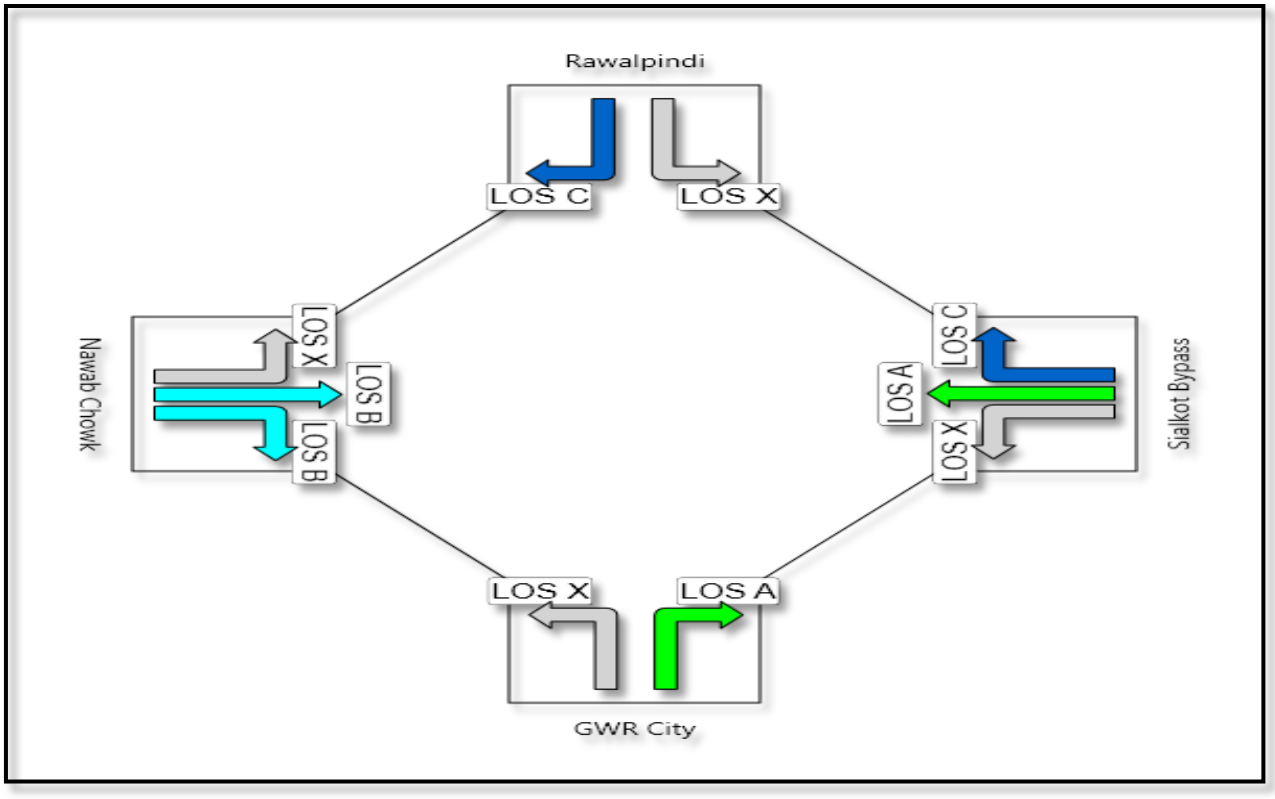


Figure 5: SIDRA LOS Results after provision of Underpass

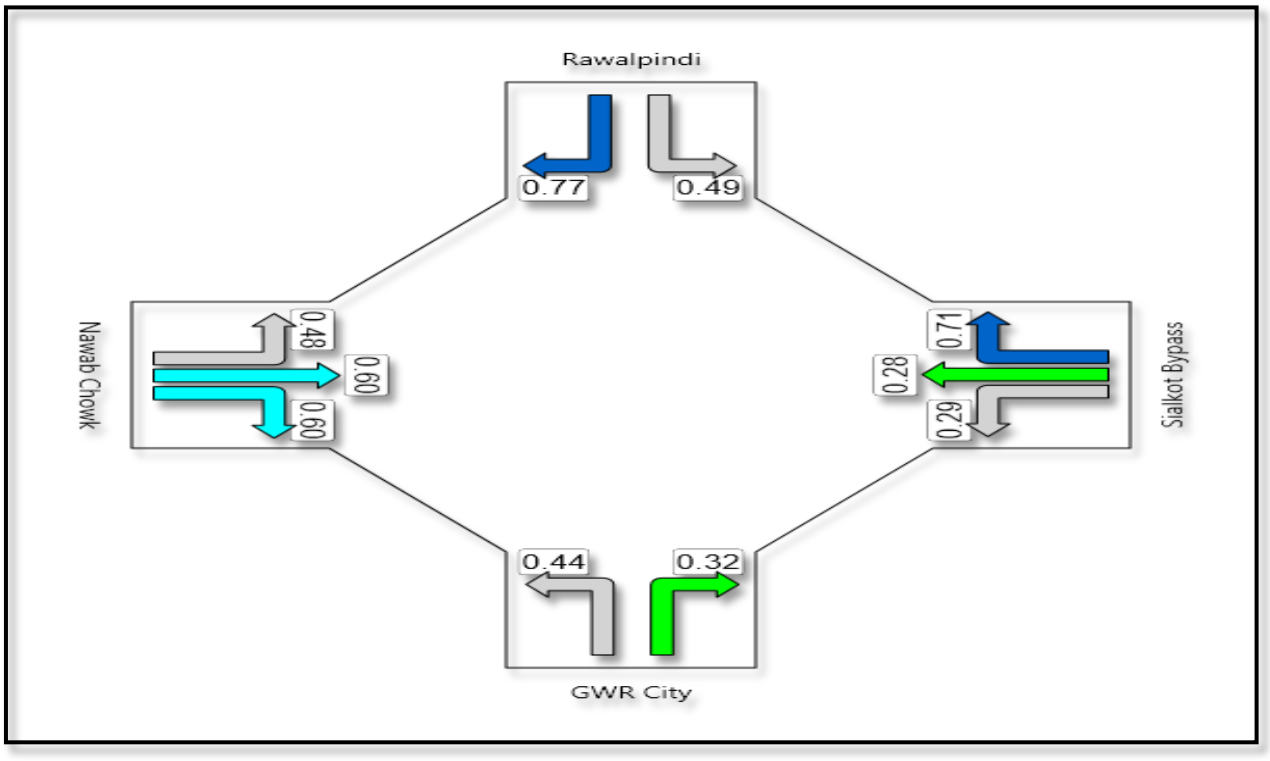


Figure 6: SIDRA V/C Ratio Results after provision of Underpass

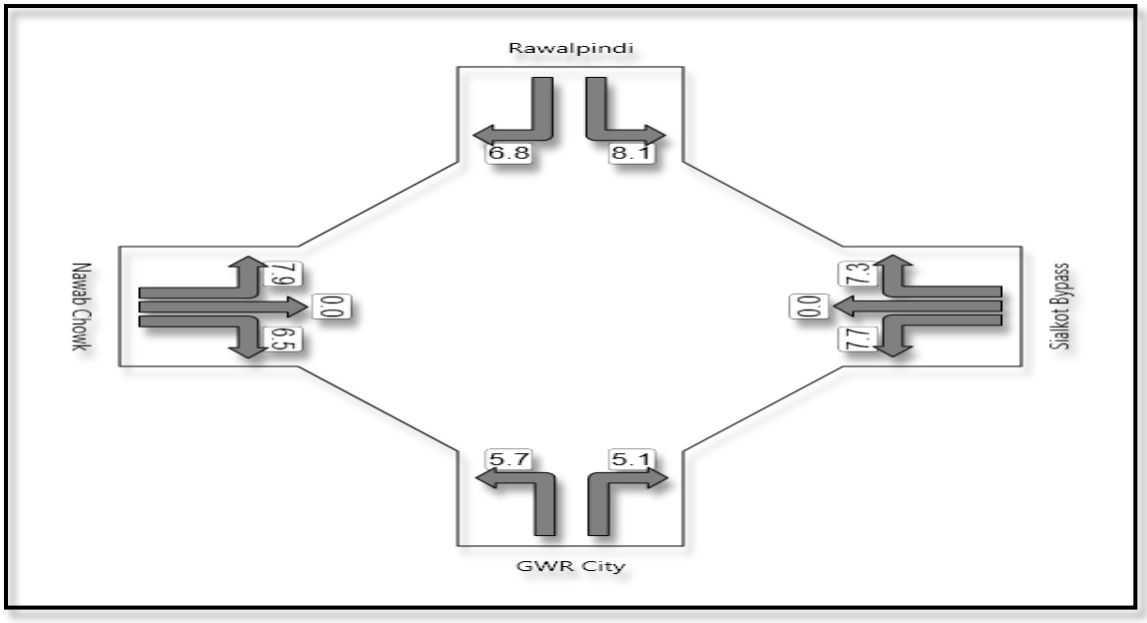


Figure 7: SIDRA Delay per Vehicle Results after provision of Underpass

Table 7: Chan Da Qilla Traffic Analysis Results

Traffic Analaysis Attribute	Degree of Saturation (V/C Ratio)		
	2015	**2020**	**2025**
V/C	1.018	1.322	1.802
Delay	85	120	170
LOS	F	F	F

This degree of saturation, delays and LoS obtained from SIDRA required to be improved for the current and future years as has been reported by (Galelli*et.al*., 2008 and Ranjitha*et.al*, 2015) also reportedBilikahalliintersection which lied next to the Vijaya Bank Intersection. Bilikahalli Intersection was similar to the geometry of Chan Da Qilla, having close traffic PCU values. Table-8 showed the comparison of traffic analysis attributed results of Bilikahalli Intersection and Chan Da Qilla Intersection. It was observed that the LOS of both the intersections were F with increased delays and out of limits volume to capacity ratios. Due to the lesser traffic volume as compared to Vijaya Bank Intersection, no grade separation was proposed and the intersection was improved using traffic management techniques.

Similarly, in case of Chan Da Qillaintersection, geometry was improved by the provision of a dedicated left turn which provided free flow to the traffic intending to commute towards Khiyaali Bypass. Exclusive left turning lane for vehicles ensuredobstruction free operation and resulted in improvement of LOS. Left-turn lanes at intersections substantially reduced rear-end crashes and also substantially increased the capacity of many roadways. This solutionwouldwork well for at least ten years as checked by SIDRA software as presented in Figure-8 by providing exclusive free flow to traffic. The detailed results of analysis using SIDRA are shown in Figures 9, 10 and 11.

Table 8: Result Comparison of Chan Da Qilla vs Bilikahalli Intersection.

Traffic Analysis Attribute	Bilikahalli Intersection, Total PCU=6497			Chan Da Qilla Intersection, Total PCU=5423		
	2015	**2020**	**2025**	**2015**	**2020**	**2025**
Volume to Capacity Ratio (v/c)	2.103	2.485	2.787	1.018	1.322	1.802
Delay	91	141	165	85	120	170
LOS	F	F	F	F	F	F

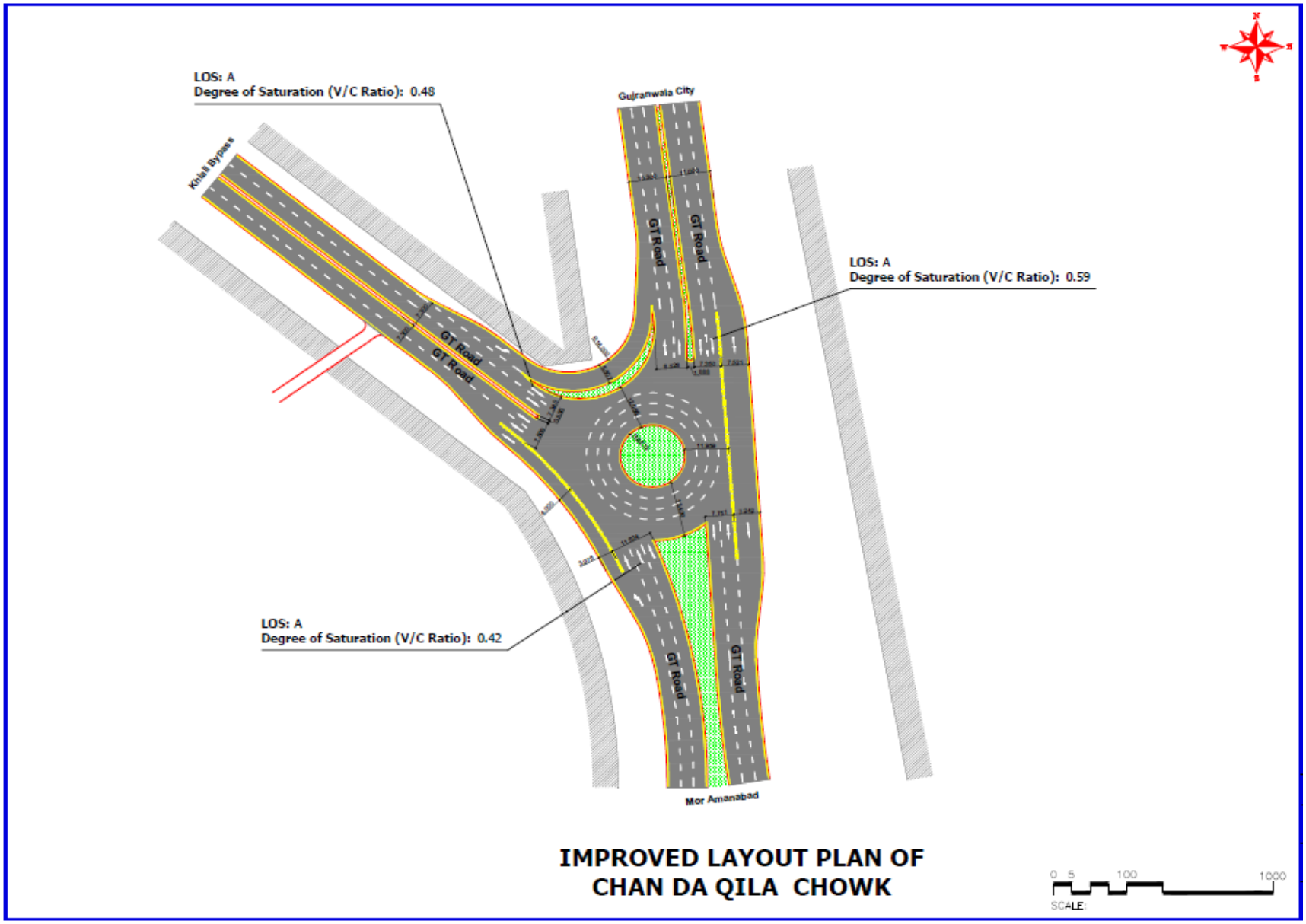


Figure 8: Improved Layout Plan of Chan Da Qila Chowk for Base Year

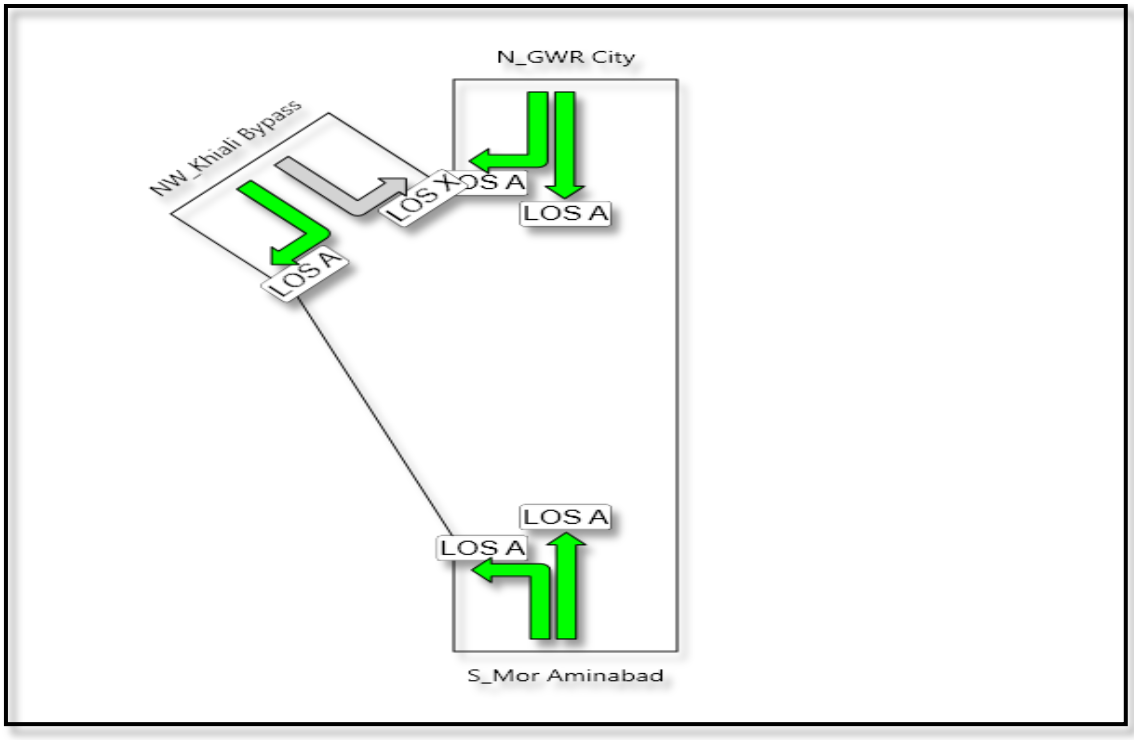


Figure 9: SIDRA LOS Results with the provision of Exclusive Left Turn

The LOS of each leg Figure-9 of Chan Da Qilla intersection has considerably improved which will ultimately reduction in travel time and delays.

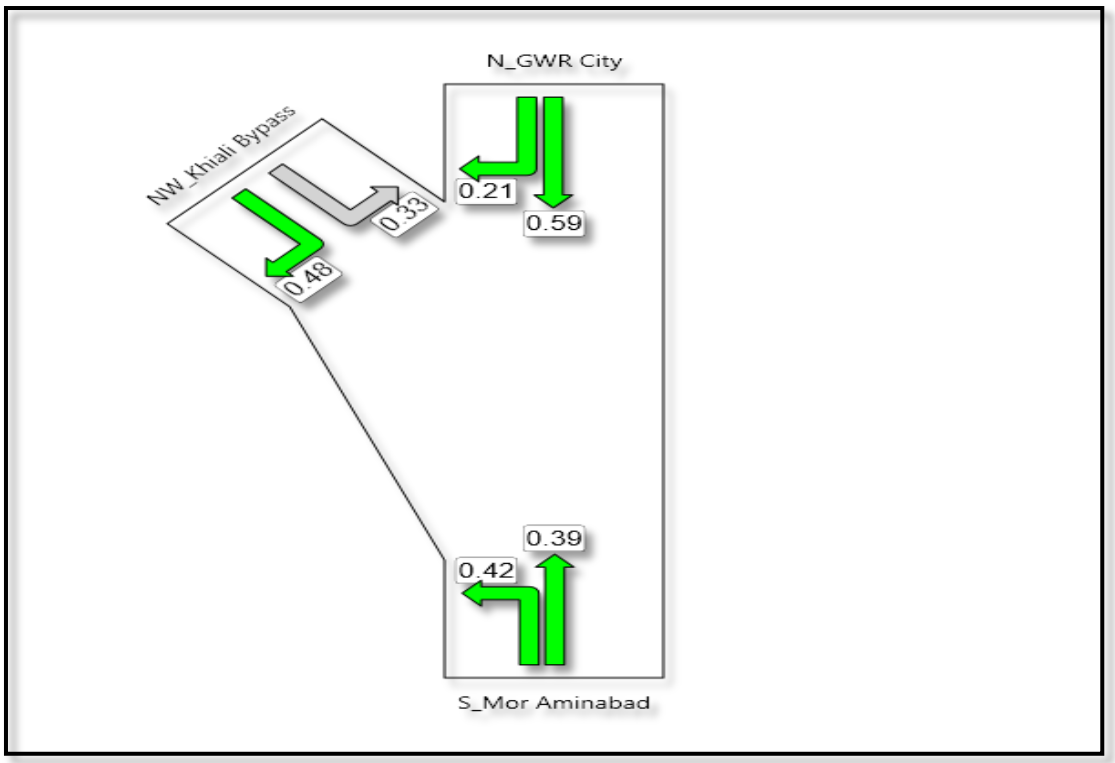


Figure 10: SIDRA V/C Ratio Results with the provision of Exclusive Left Turn

The degree of saturation (V/C) of Chan Da Qilla intersection has considerabely improved by providing the mentioned Figure-10 improvements resulting improved service delivery.

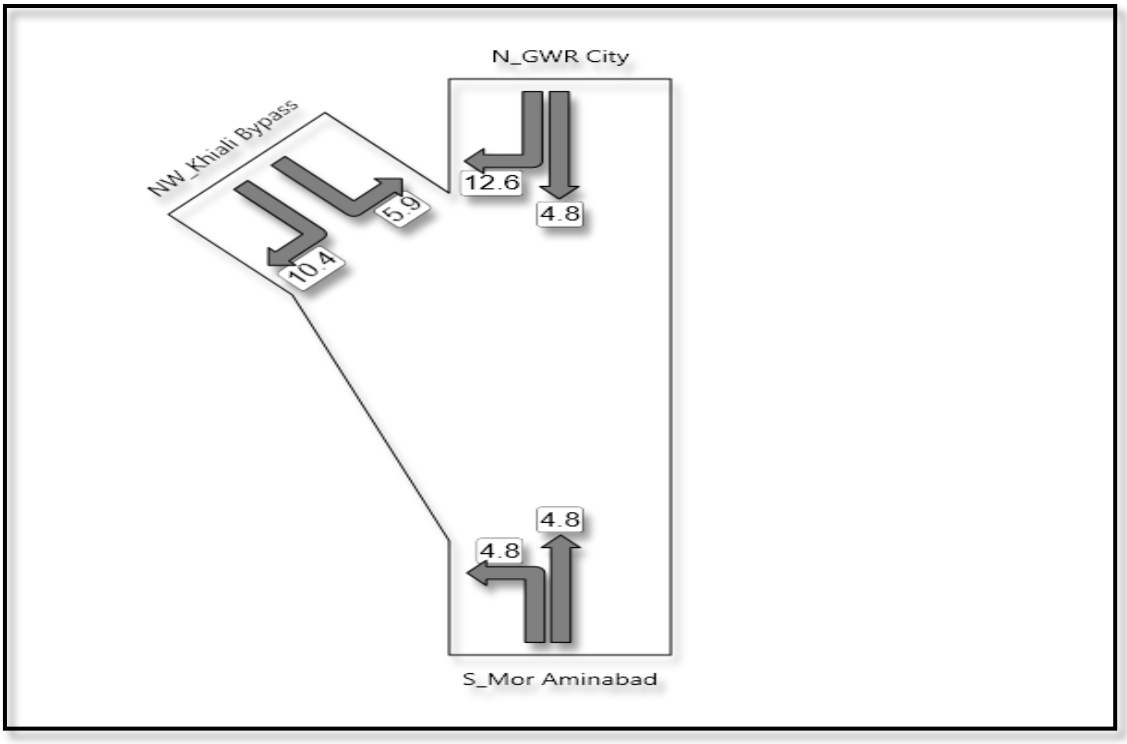


Figure 11: SIDRA Delay Results with the provision of Exclusive Left Turn

Likewise, reduced/ minimum delays were also observed as has been shown in Figure-11 after the provisionof exclusive left turn at Chan Da Qilla intersection.

Conclusions: The study concluded that the load on G.T road passing through Gujranwala city along with the Gujranwala Bypass can not be reduced until or unless the intersection of Pindi Bypass and Chan Da Qilla are improved solely upon the best traffic engineering principles. There is a need of limiting the urbanization along the Gujranwala Bypass road which is causing traffic congestion problems. In order to alleviate these problems different solutions are provided for both selected intersections and are mentioned as under:

In case of Pindi Bypass, grade separation is proposed based upon the traffic analysis results conducted in Sidra. For the base year (2016) at Pindi Bypass intersection, the infrastructural imprvements proposed include: provision of fixed time signals, construction of two lane flyover from Gujranwala to Rawalpindi city direction with the provision of dedicated left-turn at every approach. Proper signage should be installed along the dedicated left turns which includes installation of give way, pedestrian crossing, speed limit signs and other regulatory and warning signs. In case of Chan Da Qilla efficient utilization of space may solve the traffic flow problems as per analysis conducted in SIDRA. The recommended infrastructural changes for base year (2016) includes the construction of a dedicated left-turns from Gujranwala Bypass to Gujranwala City and from MorAiman Abad to Gujranwala Bypass. Along with theses dedicated left turns provision of 2 through lanes from Gujranwala City to MorAiman Abad are proper signage are extremely necessary for smoth traffic flow with minmal delays. If these changes are implemented as per the provided time frame as mentioned earleir, then the level of service of both selected intersections will improve from F to C which will lead to significant reduction in delays thus, making an overall intersection traffic flow improvement.

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