Article

Intersection Performance Using Computer Simulation Sidra Program for Traffic Flow in Shaheed Intersection Kabul Afghanistan

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Abstract

Transportation is the movement of people and goods over time and space. This is an important matter in our lives, and people cannot live without it. Transport enables access for people from their homes to their work, education, health services, shops, and so forth. The transportation system has many problems in Kabul city, such as traffic congestion, lack of reliable and safe public transportation, road accidents, and difficulties for non-motorized transport. Therefore, it is vital to utilise advanced software tools to explore possible solutions to the traffic congestion problem. This study is aimed at evaluating and analysing Shaheed Intersection in Kabul, Afghanistan using the SIDRA INTERSECTION program. It evaluated traffic performance at one of Kabul's most important intersections using parameters such as level of service (LOS), delays, queue, fuel consumption, CO2, CO, (CH2O) n, and NOx emissions. The results revealed a significant time delay, a hazardous amount of emissions, and a low LOS (F).After a comprehensive investigation of the results, which is essential to build an underpass from east to west that will significantly reduce delays and emissions and increase the LOS until 2031.

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Introduction

Kabul's 2021 population is now estimated at 4,335,770. In 1950, the population of Kabul was 170,784. Kabul has grown by 114,238 since 2015, which represents a 2.71% annual change. These population estimates and projections come from the latest revision of the United Nations (UN) World urbanization prospects [1]. Kabul is a city located in Afghanistan. It is the capital city, as well as the largest city by population. Not only is it the largest city in the country, but it is also one of the largest in the world, ranking 64th. Rapid urbanization has also led to the city being the fifth fastest-growing in the world. The city is spread across a total of 1,023 square kilometers (395 square miles) and has a population density of 4,500 residents per square kilometer (12,000 per square mile) and 22 districts [1].

In over three decades of war (1989- 2001) Kabul has been ripped off of all its infrastructure including the transportation system. However, from the establishment of a new administration in 2001 supported by the United States (US) of America and the international community, Afghanistan has started a swift journey towards rehabilitation [2]. This rapid social and economic growth, urbanization, and population growth, however, has created some social issues as its by-products [2].

Kabul Traffic congestion is a serious problem that has adverse and huge effects on the quality of life (environment and human health) and the economy. It is also the main reason for wasting time stuck in traffic [3]. This wasted time could be used usefully in other actions [3]. The congestion results in losing large amounts of fuel and increasing the number of harmful emissions affecting air quality [3]. As the population of Kabul City (KC) continues to increase, the problem of traffic congestion is increasing and the need to confront this problem is becoming more imperious [4].

Furthermore, thousands of new vehicles enter Kabul city annually, which propagates the already existing traffic congestion problem. Another major contributor is the low road capacity in Kabul city [5]. It causes traffic jams, delays, noise pollution, and other environmental hazards. According to Kabul Municipality, Kabul city's streets were designed to cope with only 4000 vehicles, but there are currently at least 500 000 vehicles [6]. And also, the problem of traffic congestion is low-capacity roads. These numbers grow higher every year, adding up to the traffic congestion problem. As a result, to find potential solutions, this study will use the SIDRA INTERSECTION 5 program, which is "a micro-analytical traffic evaluation tool that employs lane-by-lane and vehicle drive cycle models."[7].

This paper is evaluated and analyzed Shaheed Intersection one of the most important and crowded junctions in Kabul city's traffic system to investigate various factors that cause traffic congestion and its effects on traffic flow. And also this paper attempts to propose potential solutions to the existing problems in Shaheed Intersection.

1.1 Problem Statement

Many problems such as delays, fuel consumption, fuel cost, and hazardous emission, can be created by a high volume of traffic and congestions. With a population of over 4 million people, most of which rely on private transportation and a total of 1,224,000 registered cars estimated for 2010 by United Nations Regional Information Network (IRIN), congestion has created leading problems in Kabul, Afghanistan [1, 3] & [8-10]. Congestions mostly occur due to the high number of vehicles on road, low road capacity, lack of geometric and traffic management, lack of response strategy to overcrowding in peak hours, and improper functioning signals. To prevent road congestion and overcrowding a proper strategy should be developed. By using micro-analytical traffic evaluation tools such as SIDRA traffic performance of roads, intersections and roundabouts can be evaluated, and then potential solutions to the present problems can recommend.

1.2 Study Purpose

This study concentrates on the minimization of traffic congestion in the Shaheed Intersection. The entire data will be obtained from the study area in peak hours (8:00 - 9:00 am) (9:00 – 10:00 am) and evening (4:00 – 5:00 pm) (5:00 – 6:00 pm). Using the volumetric traffic count method, which is a manual method. The data will be obtained by individuals on site. The suggestion of alternatives for traffic congestion includes signals control and underground of the junction due to traffic delay, reduction of the amount of fuel, CO_2, and so forth. In general, these tasks will be performed during this research:

- To increase the level of service.
- To decrease congestion by lowering vehicle delay
- To decrease fuel consumption.
- to decrease CO_2 and NO_x production.
- Easy and feasible commuting during peak hours.
- Noise pollution reduction and control, and
- Queue Analysis

2. The Fundamental Concept of Intersection

An intersection is an area, shared by two or more roads, whose main function is to provide for the change of route directions [11]. Intersection varies in complexity;

- A simple intersection is two roads crossing at right angles.
- A more Complex Intersection is three or more roads cross.

The overall traffic flow on any highway "depends to a great extent on the performance of the intersections, since intersections usually operate at a lower capacity than through sections of the road" [11]. Intersections are classified into three general categories:

- Grade-separated without ramps.
- Grade-separated with ramps (Interchanges).
- At-grade intersections.

Grade-separated intersections usually consist of structures that provide for traffic to cross at different levels (vertical distances) without interruption [12]. The potential for crashes at grade-separated intersections is "reduced because many potential conflicts between intersecting streams of traffic are eliminated" [12]. At-grade intersections do not provide for the "flow of traffic at different levels, and therefore there are conflicts between intersecting streams of traffic" [12]. Figure 1 shows the different classes of intersection.

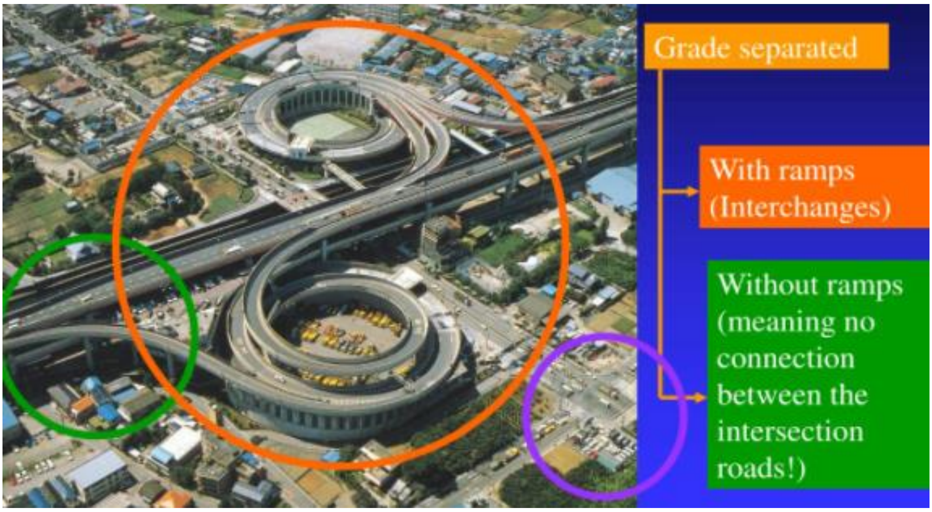


Figure 1: Different Types of Intersections [12].

The fundamental objective in the design of intersections is to minimize the severity of potential conflicts among different streams of traffic and between pedestrians and turning vehicles. At the same time, it is necessary to provide for the smooth flow of traffic across the intersection [13]. Intersection design involves;

- Design of alignment.
- Design of a suitable channeling system.
- Determination of minimum required widths of turning roadways at speeds higher than 15 m/h.
- Assurance of adequate sight distance for the type of control used at intersections.

2.1 Signalized Intersection

Signalized intersection approaches are usually channelized to serve directional flow and facilitate signal control [14]. In some cases, more than one approach lane is used to serve one single directional flow due to large traffic demands, and the exact number of such lanes is easy to calculate according to the volume. Moreover, studying the adjustment factors of the saturation flow rates at signalized intersections can also help determine the layout of the intersection, including the exact number of lanes in each direction [15]. Figure 2 shows the sample of signalized intersections.

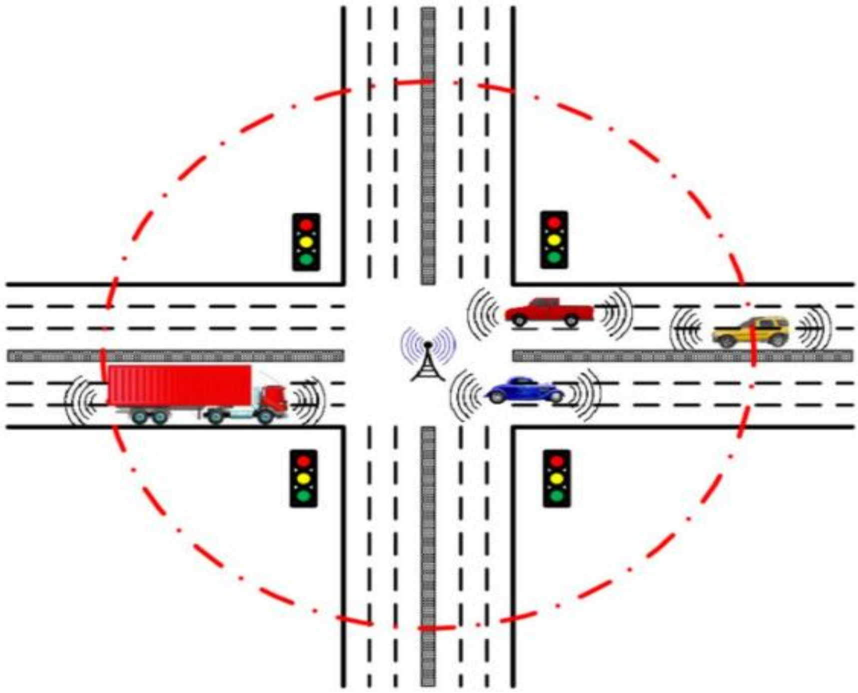


Figure 2: An example is signalized intersection with connected vehicle technology [15].

2.2 Unsignalized Intersection

An "unsignalized" intersection is not controlled by a traffic signal [16]. The term covers a wide variety of situations, including uncontrolled intersections. two-way STOP-controlled intersections (TWSCI), two-way YIELD-controlled intersections, all-way STOP-controlled intersections (AWSCI), and roundabouts. [16]. The traffic movements at a TWSCI unsignalized intersection are depicted in Figure 3.

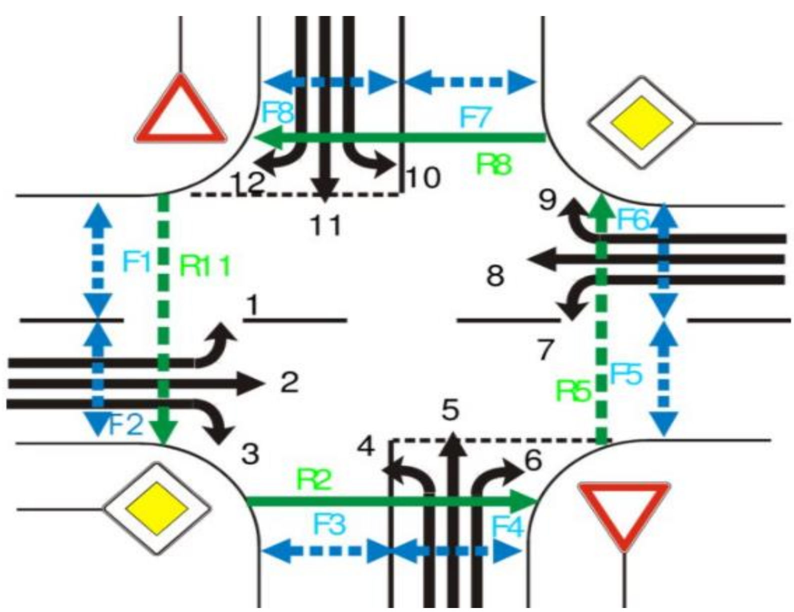


Figure 3: Traffic movements at a TWSCI unsignalized intersection.

2.3 Performance Evaluation

Akcelik (2005) defines capacity as the main factor that affects the performance of a roundabout and intersection [17]. For example, FHWA (2000) defines three key performance measures [18] for evaluating the performance of a roundabout:

- The degree of saturation
- Delay
- queue length

In Akcelik (2005), level of service is also mentioned as an additional performance measure [17].

2.3.1 Capacity

Capacity is defined by the HCM as "the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given period under the prevailing roadway, traffic, and control conditions". Prevailing conditions mean the current conditions in the intersection [18].

2.3.2 Delay

The performance measure is a delay, which represents how much a vehicle is delayed when passing an intersection. Different researchers define the delay in slightly different ways. The modeler must be clear about what kind of delay is estimated by the model. In HCM, the delay is divided into control delay and geometric delay [18]. Akcelik (2005) refers to delays as geometric delays and stop-line delays. The sum of geometric delay and stop-line delay is called "control delay" [17]. A traffic model usually gives the average delay of all vehicles, no matter if they are stopped or not. In a roundabout, all vehicles not queued will still experience the geometric delay compared to a signalized intersection where unqueued vehicles just pass through.

2.3.3 Length of the queue

The roundabout conditions are indicated by the queue length [17]. There are several different ways to measure queue length. The longest observed queue length is called the "back of the queue," and the average queue during a period is referred to as the "cycle average queue." In the average queue cycle, all queue lengths during the time are included, even when no queue existed. It is also possible to get percentile values for queue length. The 95 percent percentile indicates that queues are shorter than that value 95% of the time during a given period and thus longer than that value only 5% of the time.

2.3.4 Degree of Saturation

The degree of saturation, also called the utilization degree, is a ratio between the demand and the capacity of the entry lanes [18]. If the value is lower than 1, the capacity is greater than the demand, and the roundabout can handle the flow. If, on the other hand, the degree of saturation is greater than 1, demand will be greater than capacity, and queues will start forming and delays will increase. A degree of saturation at 0.85 is used as a guideline in several countries, including Australia. When the flow exceeds 85% of its maximum capacity, queue lengths and delay times become unstable and vary significantly around the mean values [19].

2.3.5 Level of Service

The FHWA (2000) presents the following definition of the level of service from the HCM: "characterizes operational conditions within a traffic stream and their perception by motorists and passengers" [17]. Compared to the other performance measures, the level of service (LOS) is a qualitative measure instead of a quantitative one. "Level of service" is used to describe operational conditions in traffic streams. Most often, it is presented as a combination of speed, travel time, interruptions, comfort, or convenience. For quantification, HCM has defined a measure of effectiveness (MOE) [20]. According to the Swedish guide for the design of roads, VGU (2004), the level of service can be classified according to the degree of saturation [21]. As shown in Table 1, the LOS

Table 1: Level of service according to VGU [21].

No	Level of service of saturation	Degree
1	High standard	< 0.6
2	Moderate standard	0.6-0.8
3	Low standard	> 0.8

Source: (VGU 2004).

3. Research Methodology

The location of this study is the 10th district Shaheed intersection in Kabul, Afghanistan. It is one of the most crowded places in Kabul, with frequent congestion during peak hours. At present, a huge volume of traffic commutes through this intersection, which has caused more congestion and a declining level of service. Solving these problems will significantly increase the level of service and will ease the pressure from the adjacent intersections.

3.1 Field of Study

This study will be conducted in Kabul city and data will be gathered from Shaheed Intersection, which has three ARAM or T intersection forms. In the east direction, it is connected with MAIDAN square; in the west direction, it is connected with LABE-JAR square; and in the south direction, it is connected with SALIM KARAVAN square. As shown in Figure 4, careful consideration will be given to this junction, as it is quite accessible and serves as a vital junction in the transportation network of Kabul city since most governmental offices are located on the south and east sides of it, and residential areas are located on the south and west sides of it.

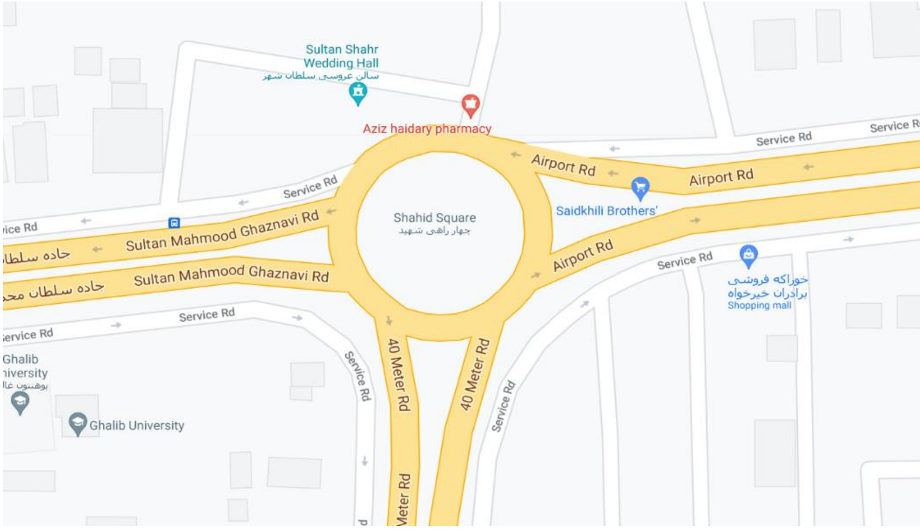


Figure 4: Shows the study location

3.2 Analytic Strategy

Hence, the study will be conducted at an intersection. SIDRA INTERSECTION software is proposed for the analysis of the data. All the data gathered, therefore, must fit the requirements of SIDRA INTERSECTION software; they should be tabulated and arranged to fit SIDRA input requirements. This data includes street geometry, movement patterns, and tools such as stopwatches, pens, papers, manual counters, and special sheets.

3.3 SIDRA Intersection Program

Signalized and un-signalized Intersection Design and Research Aid (SIDRA) is engineering software used to evaluate and analyze intersections, levels of service, operations, and planning. It also estimates environmental impacts, greenhouse gas emissions, fuel consumption, and the cost of traffic congestion. The below Chart 1 illustrates the tips and procedures of the Sidra Intersection software which are used to analyze a junction. Through this methodology, inputting the obtained data and setting the geometric parameters of the junction.

3.4. Analysis and Design Outcome

This part covers the data presentation, results for each category, proper presentations using tables, results obtained during the peak hours, as well as the category of the vehicle, which will be entered into the software accordingly as stated in the methodology. Forecasts and predictions are made based on this input, present options for today and the future are obtained, and finally, solutions are presented.

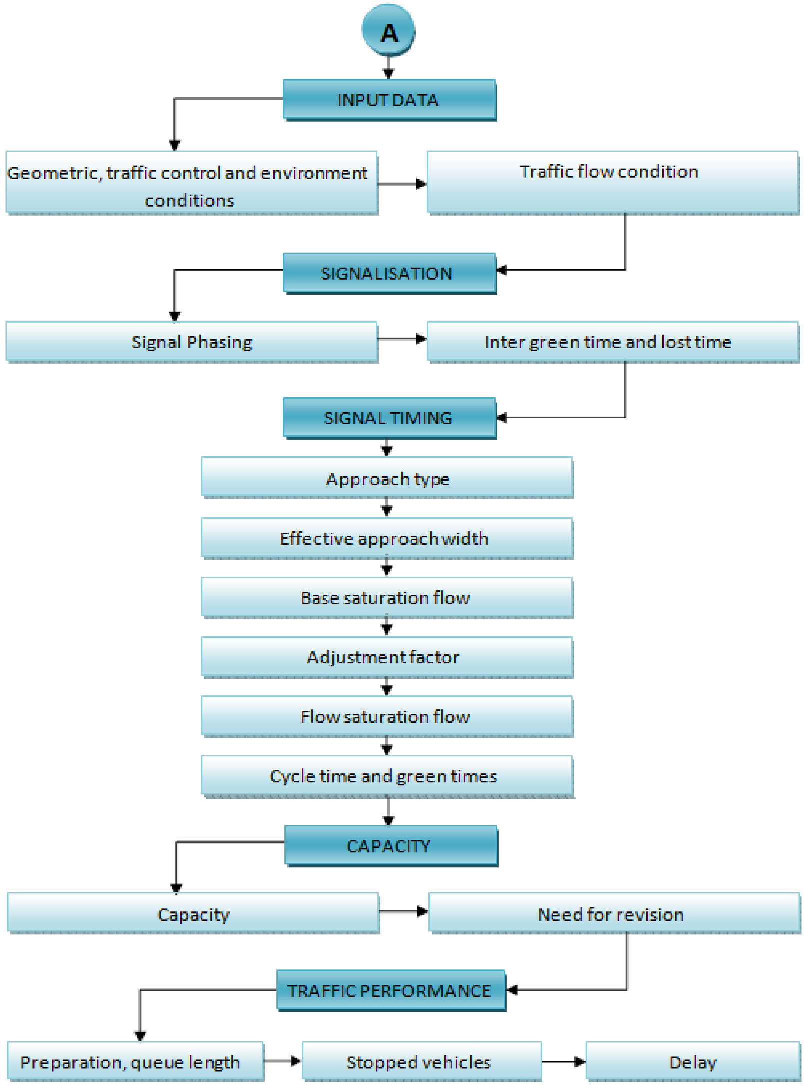


Chart 1: SIDRA Intersection Program Methodology

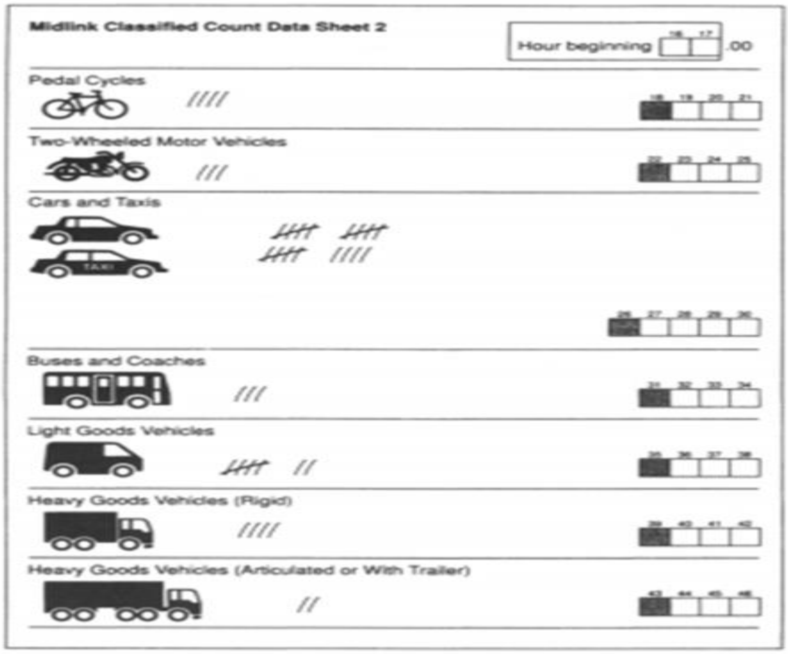


Figure 5: A typical (four-bar gate) turning movement traffic survey form (reduced from an A4 original)

3.4.1 Data Visualization

Data was collected from Shaheed Intersection in July 2021 during peak hours in the morning and evening, as shown in the tables below. The researcher considered the types of vehicles, the morning peak hour and the evening peak hour, respectively, for each direction of the intersection. The LGV represents light-duty vehicles, and the HGV represents heavy-duty vehicles. Other types of vehicles, such as buses, minibusses, cars, and taxis, are elucidated as the vehicle composition as shown in Figure 5. The Shaheed Intersection has three arms that connect three major areas in Kabul and are labeled with A, B, and C. Shaheed-Saleem Karvan arm A, Shaheed-Maidan arm B, Shaheed-LAB-E-JAR arm C. As shown by the data from all arms in Table 2-4 below.

Table 2: Total inflows of the vehicles to the shaheed intersection from Salim Karvan, ARM A

Traffic flows from Salim Karvan to Shaheed intersection, ARM A									
Road Direction	S- Am		S- Am		S- Pm		S- Pm		Total
TIME	8:00- 9:00		9:00- 10:00		4:00 - 5:00		5:00 - 6:00		
TOW WAY	IN	OUT	IN	OUT	IN	OUT	IN	OUT	
Car	570	580	625	512	655	570	675	537	4678
Taxi	244	218	252	153	259	137	225	114	1602
Light G- Veh/Van	31	41	59	32	34	60	42	60	359
Havey G- Veh/Van	11	17	36	9	9	23	17	13	135
Bus	39	10	18	15	13	10	15	20	140
Min bus	112	110	117	72	120	75	97	85	788
Total	1007	976	1107	739	1090	875	1071	829	
Net Total	IN		OUT		IN		OUT		7702
	2114		1769		2161		1704		

Table 3: Total inflows of the vehicles to the shaheed intersection from Maidan to Shaheed, ARM B

Traffic flows from Maidan to Shaheed to Shaheed intersection, ARM B									
Road Direction	E- Am		E- Am		E- Pm		E- Pm		Total
TIME	8:00- 9:00		9:00- 10:00		4:00 - 5:00		5:00 - 6:00		
TOW WAY	IN	OUT	IN	OUT	IN	OUT	IN	OUT	
Car	570	470	655	481	589	564	717	656	4702
Taxi	245	220	235	187	240	167	202	184	1680
Light G- Veh/Van	37	34	59	42	69	40	38	42	362
Havey G- Veh/Van	19	22	43	29	42	12	17	36	220
Bus	33	38	13	27	30	26	25	26	219
Min bus	135	112	190	173	221	187	196	145	1359
Total	1039	896	1193	939	1191	996	1195	089	
Net Total	IN		OUT		IN		OUT		8542
	2234		1835		2388		2083		

Table 4- Total inflows of the vehicles to the shaheed intersection from Labi- jar, ARM C

Traffic flows from Labi- jar to Shaheed intersection, ARM C									
Road Direction	W- Am		W- Am		W- Pm		W- Pm		Total
TIME	8:00- 9:00		9:00- 10:00		4:00 - 5:00		5:00 - 6:00		
TOW WAY	IN	OUT	IN	OUT	IN	OUT	IN	OUT	
Car	552	678	682	461	678	698	697	622	5068
Taxi	215	170	233	185	219	228	215	122	1583
Light G- Veh/Van	73	31	75	59	37	27	43	42	387
Havey G- Veh/Van	33	14	24	33	27	18	24	16	189
Bus	45	32	22	10	8	11	9	12	179
Min bus	162	142	185	171	252	126	165	124	1327
Total	1080	1067	1221	947	1221	1108	1153	938	
Net Total	IN		OUT		IN		OUT		8735
	2234		1835		2388		2083		

The given standard for converting vehicle occupancy is 1.2 per person to car ratio. The growth rate per year is given as 2 percent equivalent per year as well as the heavy good vehicle percentages and buses.

4. Result of Data 2021

After entering data into the SIDRA intersection program, the results obtained in the form of charts and tables represent delays and emissions of hazardous gases, and Table 5, shows the level of service (LOS) for intersection 2021.

Table 5: Present the LOS for every single ARM for the signalized intersection in 2021

Signalized Intersection 2021			
Direction	South	East	West
LOS	F	F	F
Result of LOS		**F**	

Table 5, above, shows the LOS is (F) for each signalized intersection in 2021. And also the signalized intersection for 2021 has caused an average delay of

482.315 seconds in the morning and an average delay of 552.35 seconds in the evening As shown in chart 2. This is a great delay time that can cause many serious problems for the mobility of people and goods. Also, it causes dangerous levels of greenhouse gases that are dangerous to natural habitats and humans.

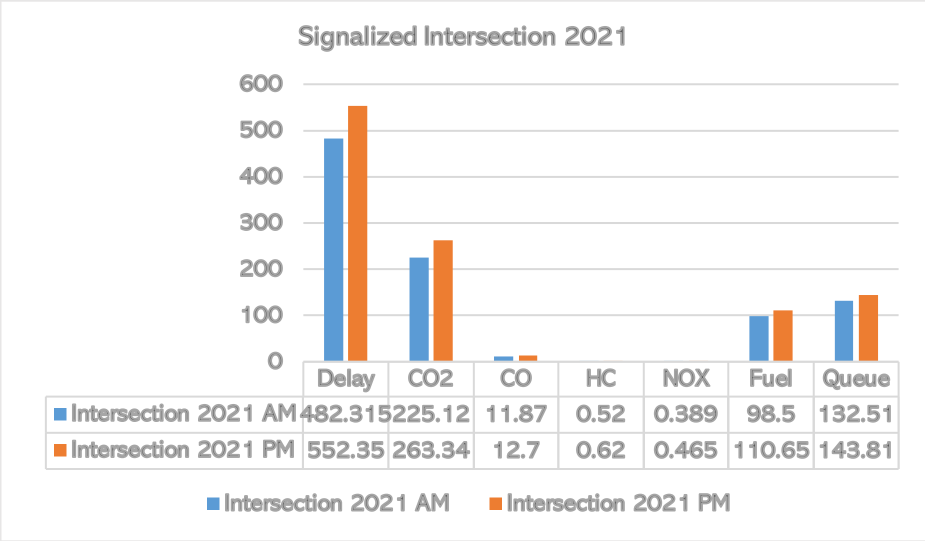


Chart 2: Represents the delay and the emissions of hazardous gases of both peak hours of the intersection in 2021.

Possible solutions to these problems could be changing the intersection to a roundabout metering, which can decrease the emission of hazardous gases and time delay while constructing an underpass from east to west will control these parameters remarkably.

4.1 Option I: Analysis of Roundabout Metering for 2020

Changing the intersection shape to roundabout metering could decrease the time delay and production of hazardous gases. As shown in Table 6 and Chart 3, furthermore, the LOS will be increased from F to A for this intersection.

Table 6: Present the LOS for every single ARM for the roundabout metering in 2021

Roundabout Metering 2021 PM			
Direction	South	East	West
LOS	A	A	A
Result of LOS		**A**	

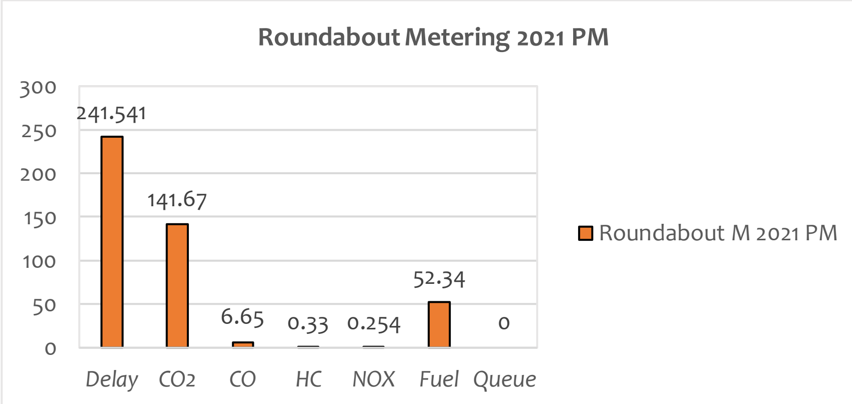


Chart 3: Represents the delay and the emissions of hazardous gases of roundabout metering in 2021

4.2 Option II: Analysis of underpass for 2021

Constructing an underpass from the east to the west direction will have a remarkable impression on the intersection users. As shown in Table 7 and Chart 4, it can obtain the LOS of A by constructing an underpass from East to West and a high decrease of hazardous gases will be seen. Approximately 95.92% of the time delay will decrease, 96.95% of CO2, 98.93% of CO, 98.96% of HC, and 99.93% of NOX will decrease. These amounts show a huge improvement compared to the intersection.

Table 7: Present the LOS for every single ARM for the underpass in 2021

Underpass 2021 PM			
Direction	South	East	West
LOS	A	A	A
Result of LOS		**A**	

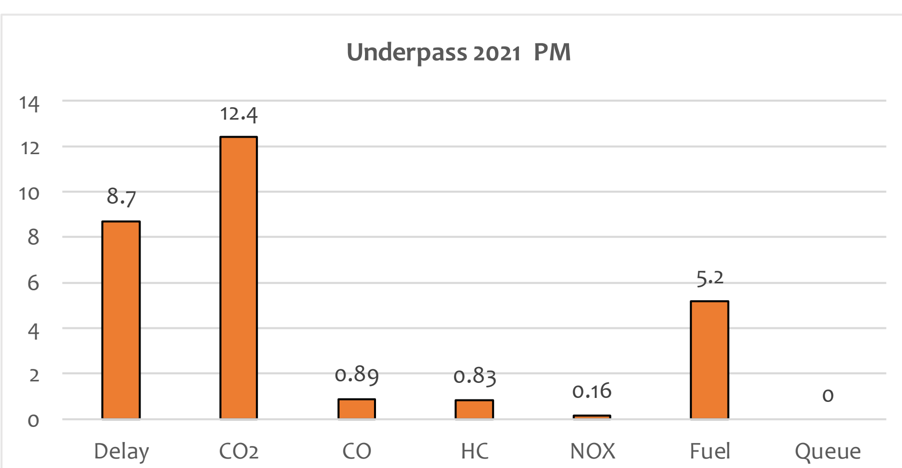


Chart 3: Represents the delay and the emissions of hazardous gases of an underpass in 2021

4.3 Underpass Forecasting for 2031

As per the official website of the Kabul Afghanistan Metro Area Population, the growth factor for the year 2030 is 3.35%. Current population (1+(growth factor/100)) = 2031 population

4.5 Analysis Options I and II for 2031

To determine that conditions will not deteriorate in the future, roundabout metering and underpasses have been analyzed for the year 2031. After finding the population of 2030 via the method of anticipated population, researchers obtained the number of vehicles passing through this roundabout metering and underpass in 2031. The obtained results show that by constructing roundabout metering, researchers will not get their desired result while constructing an underpass will decrease the time delay and emission of greenhouse gases remarkably.

4.5.1 Analysis of Option I for 2031.

As the result showed, the LOS of roundabout metering is A for the next 10 years. The amount of time-delayed will also increase again and cause the previous problem for road users. By constructing a roundabout metering for 2031, all the mentioned parameters will decrease compared to the current intersection. For instance, about 75% of the delay, 85% of carbon dioxide, 83% of CO, 85% of HC, 85% of NOx, 85% of fuel consumption, and 50% of the queue will decrease, which is not the desired solution for the current intersection. Then it is necessary to find a better option. As shown by the results in Table 8, and Chart 4.

Table 8: Present the LOS for every single ARM for the roundabout metering in 2031

Roundabout Metering 2031			
Direction	South	East	West
LOS	A	A	A
Result of LOS		**A**	

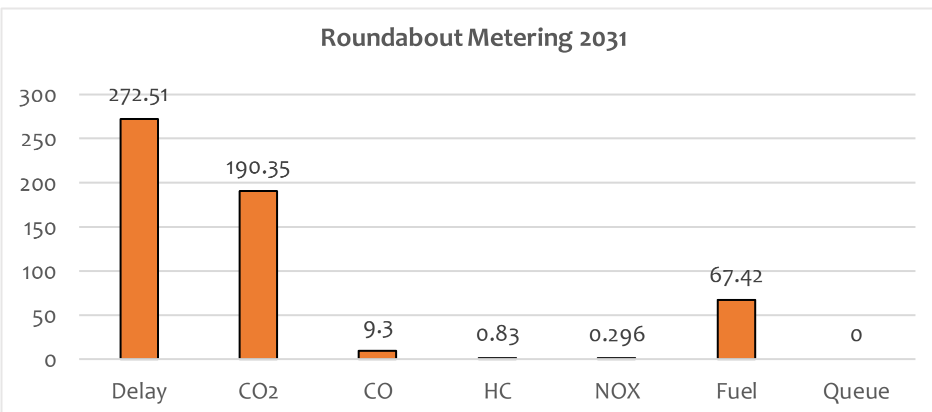


Chart 4: Represents the delay and the emissions of hazardous gases of roundabout metering in 2031

4.5.2 Analysis of option II for 2031

As results show, the LOS for Underpass 2031 is A in all directions, and it will be A for the next 10 years. All in all, the level of service is F for signalized intersection and roundabout metering in 2021, and in 2031, only roundabout metering is in A LOS, and the gas emissions are at an alarming rate. This article proposes creating an underpass from east to west. The design of the underpass will improve the LOS to A and significantly reduce gas emissions and fuel consumption. The 2031 underpass data have also been analyzed so that the situation does not worsen in the future. The results are shown in Table 9 and Chart 5, which show a slight increase in the perceived parameters.

Table 9: Present the LOS for every single ARM for the underpass in 2031

Underpass 2031			
Direction	South	East	West
LOS	A	A	A
Result of LOS		**A**	

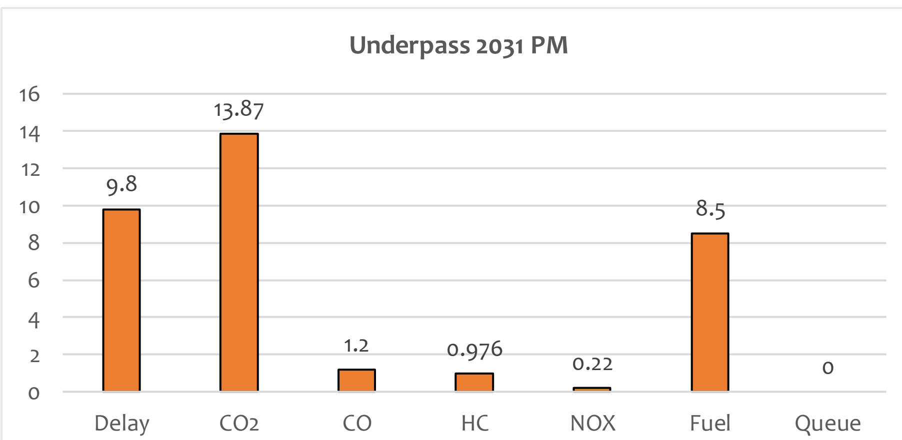


Chart 5: Represents the delay and the emissions of hazardous gases of an underpass in 2031

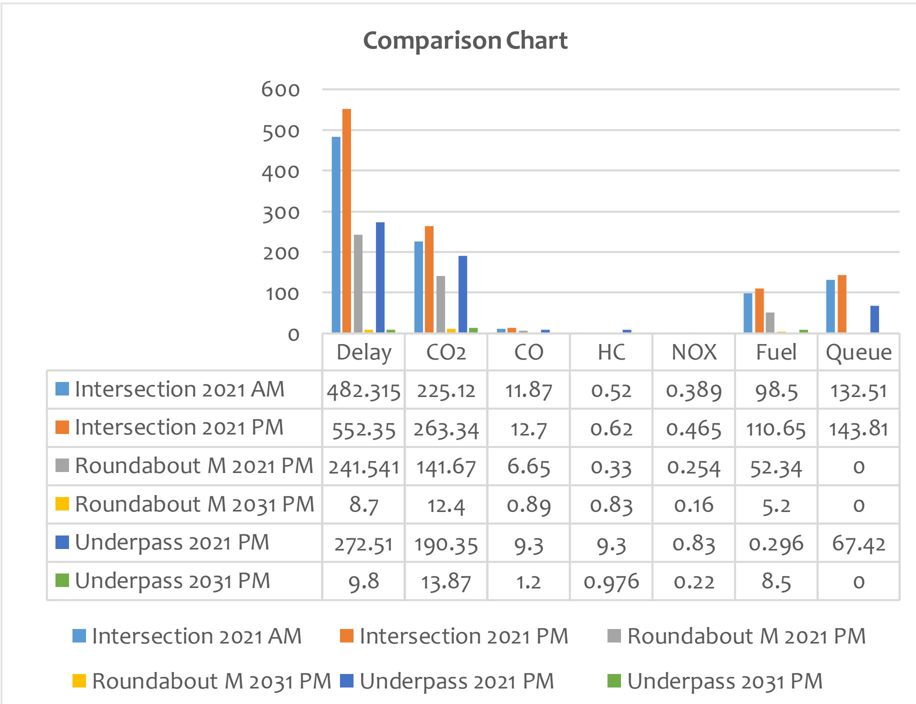
5. Conclusion

This research has been conducted at the Shaheed intersection in Kabul, Afghanistan. After a thorough evaluation using the Sidra Intersection Program, it was concluded that currently, the level of service LOS in this intersection is in category F, with an average of 552.35 seconds delay in evening peak hours and about 482.315 seconds in morning peak hours. This shows a crowded intersection with a low LOS and high hazardous emissions.

To solve the congestion problem, decrease delays, and decrease hazardous emissions, this study suggests building an underpass from the east to west direction. Building an underpass will decrease time delay by about 94.525%, 90.5% of carbon dioxide emissions, 87.5% of fuel consumption, 100% of the queue, 92.38% of carbon monoxide emissions, 95.42% of hydrate of carbon, and

93.17% of nitrogen oxide. The level of service (LOS) after the building underpass was measured to be in category A.

Using the population growth factor, underpass performance was evaluated for the year 2031. The results presented a decline of about 96.25% in time delay, 95.23% of fuel consumption, 100% of the queue, 97.16% in carbon dioxide emissions, 98.77% in carbon monoxide emissions, 95.05% in the production of hydrates of carbon, and 96.61% in nitrogen oxide emissions compared to the current values. The underpass will perform at the level of service (LOS A). And also shown in Chart 6, which represents the comparison of all the results.



	Delay	CO2	CO	HC	NOX	Fuel	Queue
Intersection 2021 AM	482.315	225.12	11.87	0.52	0.389	98.5	132.51
Intersection 2021 PM	552.35	263.34	12.7	0.62	0.465	110.65	143.81
Roundabout M 2021 PM	241.541	141.67	6.65	0.33	0.254	52.34	0
Roundabout M 2031 PM	8.7	12.4	0.89	0.83	0.16	5.2	0
Underpass 2021 PM	272.51	190.35	9.3	9.3	0.83	0.296	67.42
Underpass 2031 PM	9.8	13.87	1.2	0.976	0.22	8.5	0

Chart 6: Comparison chart

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