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Optimizing Intersection Performance using Sidra Program on Sara-e-Shamali Intersection Kabul Afghanistan

Rustam Hafizyar[1], Khan Mohammad Shinwaray[1,2], Khawaja Abdul Rahman Sediqi[3] and Ahmad Walid Yusufi[4]
[1]Asst. Prof at Kardan University, Dept. of Civil Engineering. Kabul, Afghanistan.
[2]Head of Kabul Traffic Police, Kabul, Afghanistan
Email address: rustamr323@gmail.com, eng.khanm.sh@gmail.com
[3-4]Graduated Student, Kardan University, Dept. of Civil Engineering. Kabul, Afghanistan
Email: rahman.siddiqi773@gmail.com, ahmadwalidyu@gmail.com

***Abstract*— Traffic aggregation in urban and rural road networks is a ubiquitous problem that happened due to many causes. The rapid population growth urbanization, low capacity of roads, and lack of a comprehensive strategy to manage traffic systems and tackle traffic congestions are the leading contributors to the traffic congestion problem. Therefore, it is vital to utilize advanced software tools to explore possible solutions to the traffic congestion problem. This study was aimed to evaluate and analyses Sara-e-Shamali Intersection in Kabul city Afghanistan using SIDRA INTERSECTION software. It evaluated traffic performance in one of the most important junctions in Kabul based on parameters such as Level of service, delays, Queue, Fuel consumption, and production of CO2, CO, (CH2O)n, NOx. The results showed that there was a notable time delay, a dangerous amount of emissions, and a low level of service (LOS F). After a comprehensive investigation of the results, it was concluded that building an underpass from north to south direction will significantly reduce delays and emissions and increase the level of service until 2030.**

***Index Terms*— signalized intersection, roundabout metering, environment pollution, sustainable transportation, GHG emissions.**

I. Introduction

Every day and night, millions of people throughout the world use transport systems to move themselves and gods. For everyone to be able to get to their desired location, when traffic volume is steadily increasing, the need for an effective and adaptable system rises. To increase the effectiveness of a transport system and use it to its full potential, the traffic planner must have an effective traffic analysis tool [1]. The major use of traffic analysis tools is the possibility to evaluate strategies for current and future transport systems. With traffic analysis tools, the traffic planer can get a better basis for the decision-making process based on the evaluation and comparison of possible alternatives [2].

Kabul is the capital city of Afghanistan. It has about 4400 km2 area and 21 districts. Kabul, with a population of 4222000 and an average population growth rate of 2.5 percent [1]. In the last ten years, it is the world's fifth fastest-growing city [3]. In over three decades of war (1989-2001) Kabul has been ripped off of all its

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infrastructure including the transportation system. However, from the establishment of a new administration in 2001 supported by the United States of America and the international community, Afghanistan has started a swift journey towards rehabilitation. This rapid social and economic growth, urbanization, and population growth, however, has created some social issues as its byproducts. One of the important problems created is traffic congestion. Traffic congestion is one of the most predominant problems in developing countries around the world [4] [5]. There are some major causes of this problem. The sudden growth in private vehicle ownership can be considered as one of the leading contributors to the congestion problem. Since the only public transportation mode available in Kabul is the national bus services (Millie Bus), it cannot satisfy the needs of commuters [6]. This adds to the custom of using private vehicles used for the daily commute. 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. 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 40000 vehicles but currently at least 500000 vehicles [7]. This huge number of vehicles needs a comprehensive strategy to be managed through these low capacity roads. These numbers grow higher every year adding up to the traffic congestion problem. Therefore, to find potential solutions this study will employ SIDRA INTERSECTION 5 Software ''A micro-analytical traffic evaluation tool that employs lane by lane and vehicle drive cycle models'' [8]. This study will evaluate and analyses Sara-e-Shamali Intersection (one of the most important and crowded junctions in Kabul city's traffic system) to investigate various factors that cause traffic congestion and their effects on traffic flow. This study attempts to propose potential solutions to the existing problems in Sara-e-Shamali Intersection.

II. Highlighting The Problem

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 [9] [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 a micro-analytical traffic evaluation tools such as SIDRA traffic performance of roads, intersections and roundabouts can be evaluated, and then potential solutions to the existing problems can be proposed

III. Purpose of The Study

This study concentrates on the minimization of traffic congestion in Sara-e-Shamali Intersection. The entire data will be obtained from the study area in peak hours (8 AM-9 AM & 5 PM-6 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, CO2, and so forth. In general, these tasks will be performed during this study:

- To an increasing level of service.
- To decreasing congestion by lowering vehicle delay
- Fuel consumption reduction.
- CO2 and NOx production reduction.
- Easy and feasible commuting during peak hours.
- Noise pollution reduction and control, and
- To analyzing of Queue

IV. Literature Review

Transportation deals with the movement of humans and materials. A human movement called passenger and movement of materials and products is called goods transport [12]. Transportation and population are closely interdependent, as the population grows up in urban areas and expected to rise to 66% by 2050 [13]. It means more transportation demand will be needed such as more trips and movements and more demand will cause more congestion, thus there should be a proper plan and management for transportation to reduce the congestion.

A. 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 means the current conditions in the intersection [14].

B. Delay

The performance measure delay 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 on what kind of delay is estimated by the model. In HCM, the delay is divided into control delay and geometric delay [14]. Akcelik (2005) refers to delay as geometric delay and stop-line delay. The sum of geometric delay and stop-line delay is called control delay [15]. A traffic model usually gives the average delay of all vehicles, no matter if they 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.

C. Queue length

The queue length measure indicates the conditions in the roundabout [15]. 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 cycle average queue. In the cycle average queue, 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 % percentile means that the queues are shorter than that value 95 % of the time during a given time and therefore also longer than that value during 5 % of the time.

D. Degree of Saturation

The degree of saturation, also called utilization degree, is a ratio between the demand and the capacity of the entry lanes [14]. 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 higher than 1 demand is greater than capacity and queues will start forming and delay increases. A degree of saturation at 0.85 is used as a guideline in several countries, including Australia. When the flow increase over 85 % of capacity queue lengths and delay times become unstable and varies significantly around the mean values.

E. 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" [14]. Compared to the other performance measures level of service (LOS) is a qualitative measure instead of quantitative. The 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).

V. METHODOLOGY

The study is located in Districts 4, 11 & 17of Kabul, city. This is the most crowded place in Kabul with frequent traffic jams during peak hours. Currently, a large number of vehicles pass at this intersection, resulting in high congestion and a low level of service. Solving these problems will significantly increase the level of service and reduce loads from neighboring intersections.

A. Study Area

The study will be done in Kabul city and all the information will be collected from the Sara-e-Shamali Intersection. In the south direction it is connected with PARWAN III, in the southeast with SHAHEED SQUARE, in the northeast with HESE AWAL, in the north with KOTAL KHAIR KHANA, and in the southwest it is connected with KARTE PARWAN. As shown in Figure 1, at the below. Careful consideration will be selected to this intersection, as it is quite accessible and serves as an important junction in Kabul's transportation network because most commercial areas are located near the intersection.

B. Analysis of Procedure

As a result, the study will be conducted at an intersection, the SIDRA Intersection program is proposed for data analysis. Therefore, all collected data should be under the requirements of the SIDRA Intersection software.

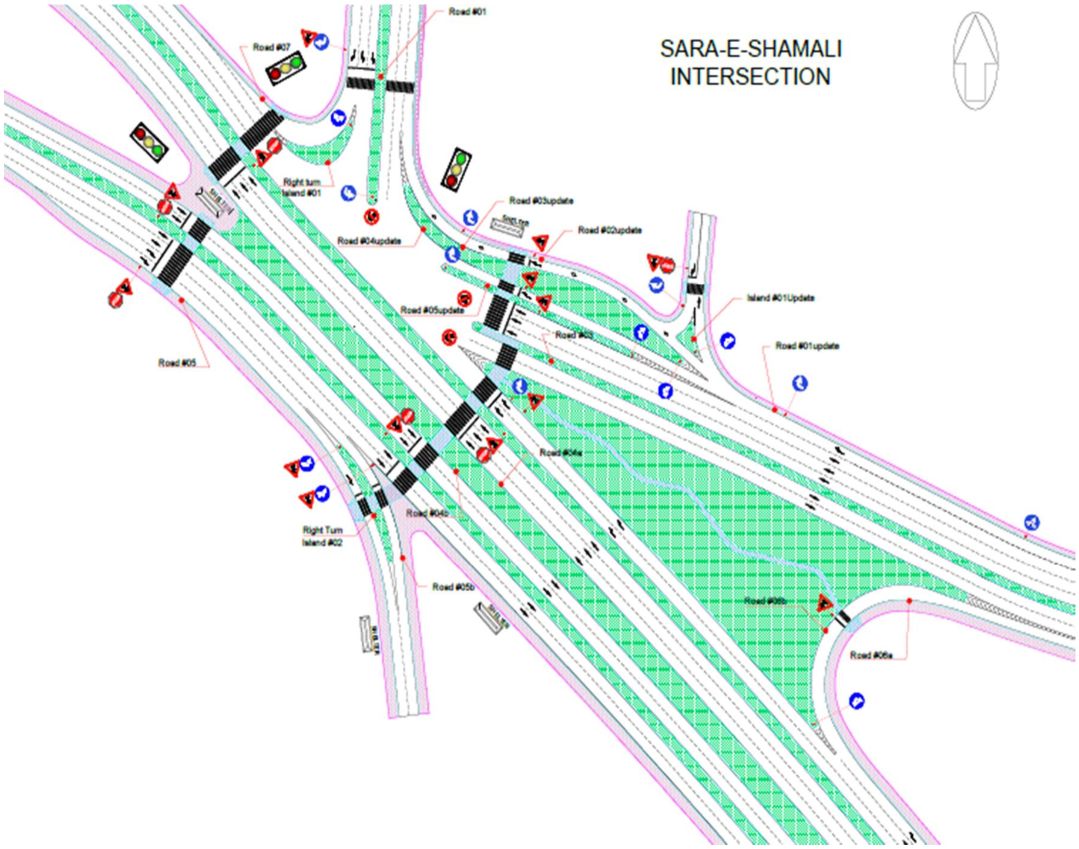

Figure 1. Shows the study location

They should be tablets and sorted according to the needs of the SIDRA. This data includes street geometry, traffic patterns, and tools such as stopwatches, pens, papers, hand counters, and special sheets.

C. SIDRA Intersection Software

SIDRA Signalized & un-signalized Intersection Design and Research Aid, SIDRA is engineering software for evaluating and analyzing intersections, service levels, operational processes, and plans. It also estimates environmental impacts, greenhouse gas emissions, fuel consumption, and traffic congestion costs. The following figure shows the SIDRA intersection section software procedures used to analyze the intersection. By this method, by inputting the obtained data and adjusting the geometric parameters of the compound, the following outcomes as shown in the below chart will be obtained. As shown in Chart 1, the methodology of SIDRA Intersection Software.

VI. RESULTS AND DISCUSSION

This section will be covered by the presentation of obtained data, the depiction of results in charts and tables after analyzing them through the Sidra Intersection Software. Available and suitable options will be considered and investigated in this part, in preparation for solving the mentioned problems for the Intersection users.

A. Data Collection

Data are collected using the manual volumetric traffic count method during peak hours in the morning (08:00 - 09:00) and evening (05:00 – 06:00). All data are recorded for every 15 minutes into special sheets and labeled based on the needed parameters. Category of vehicles, the direction of vehicles, and lanes of intersection have been considered during the data collection. The below tables are depict the collected data. As shown at bellow tables.

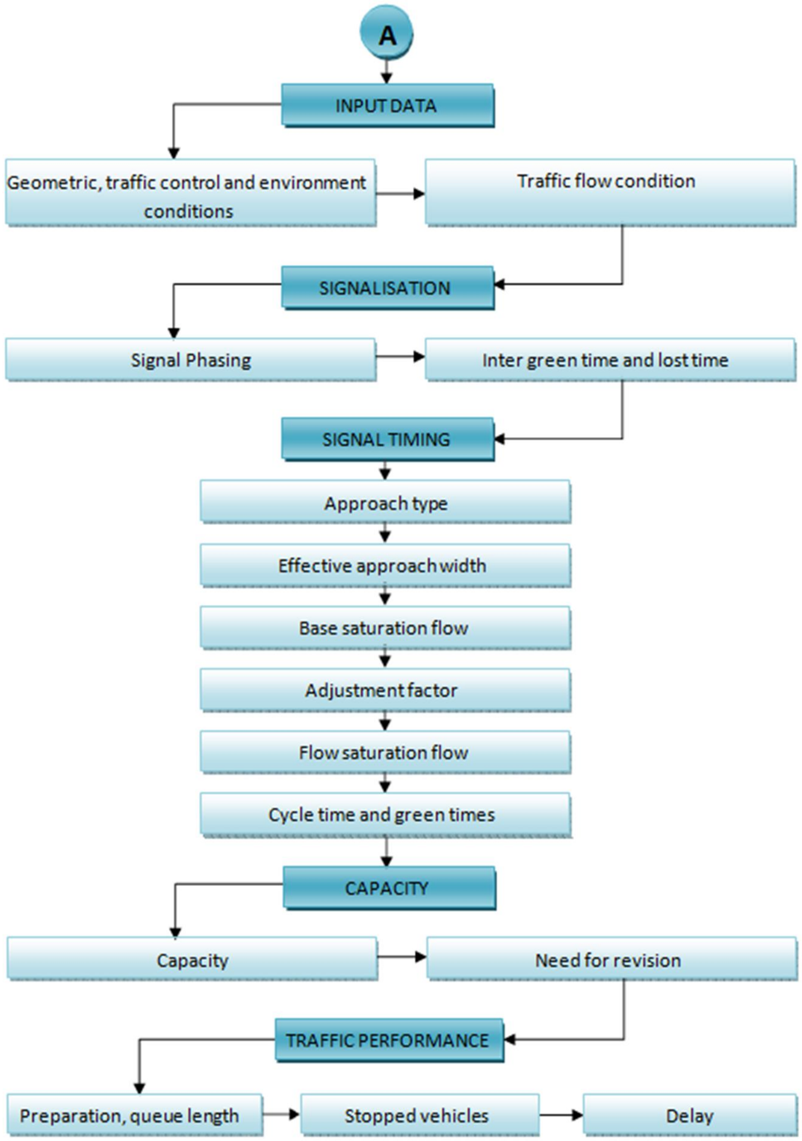

Chart 1. SIDRA Intersection Methodology

TABLE I: TOTAL INFLOWS OF VEHICLES TO THE SARA-E- SHAMALI INTERSECTION FROM HESSE-AWAL, ARM A

Time	Sara-e- Shamali - Hesse Awal arm A (in)						
	Car	Taxi	LGV	HGV	Bus	Mini Bus	Total
8:00-8:15	187	85	8	7	18	18	323
8:15-8:30	531	120	11	13	20	15	710
8:30-8:45	360	82	21	4	27	23	517
8:45-9:00	538	108	12	15	25	21	719
Total	1616	395	52	39	90	77	2269
5:00-5:15	250	13	15	30	24	37	369
5:15-5:30	286	14	28	20	47	45	440
5:30-5:45	183	20	29	14	46	49	341
5:45-6:00	311	24	25	14	48	40	462
Total	1030	71	97	78	165	171	1612

TABLE II. TOTAL OUTFLOWS OF VEHICLES FROM SARA-E- SHAMALI INTERSECTION TO HESSE AWAL, ARM B.

Time	Sara-e- Shamali - Hesse Awal arm A (out)						
	Car	Taxi	LGV	HGV	Bus	Mini Bus	Total
8:00-8:15	481	301	9	15	20	51	877
8:15-8:30	463	292	7	11	23	47	843
8:30-8:45	452	313	2	6	31	41	845
8:45-9:00	275	276	2	15	25	50	643
Total	1671	1182	20	47	99	189	3208
5:00-5:15	527	259	27	13	29	32	887
5:15-5:30	481	289	31	15	29	35	880
5:30-5:45	475	267	30	29	24	30	855
5:45-6:00	547	292	51	18	21	15	944
Total	2030	1107	139	75	103	112	3566

TABLE III. TOTAL INFLOWS OF VEHICLES TO THE SARA-E- SHAMALI INTERSECTION FROM KOTAL KHAIR KHANA, ARM B.

Time	Sara-e- Shamali - Kotal Khair Khana arm B (in)						
	Car	Taxi	LGV	HGV	Bus	Mini Bus	Total
8:00-8:15	480	280	13	14	10	70	867
8:15-8:30	468	268	15	29	8	72	860
8:30-8:45	497	307	14	30	10	56	914
8:45-9:00	437	318	6	14	12	60	847
Total	1882	1173	48	87	40	258	3488
5:00-5:15	604	370	12	11	21	78	1096
5:15-5:30	573	346	5	14	15	76	1029
5:30-5:45	589	335	8	6	2	31	971
5:45-6:00	581	333	5	10	1	64	994
Total	2347	1384	30	41	39	249	4090

TABLE IV. TOTAL OUTFLOWS OF VEHICLES FROM SARA-E SHAMALI INTERSECTION TO KOTAL KHAIR KHANA, ARM B

Time	Sara-e- Shamali - Kotal Khair Khana arm B (out)						
	Car	Taxi	LGV	HGV	Bus	Mini Bus	Total
8:00-8:15	401	158	15	13	31	81	699
8:15-8:30	395	181	21	15	38	86	736
8:30-8:45	368	167	15	23	45	91	709
8:45-9:00	463	170	23	25	40	85	806
Total	1627	676	74	76	154	343	2950
5:00-5:15	145	87	3	4	5	2	246
5:15-5:30	146	98	14	6	2	5	271
5:30-5:45	142	81	3	4	2	8	240
5:45-6:00	178	89	5	6	1	7	286
Total	611	355	25	20	10	22	1043

TABLE V. TOTAL INFLOWS OF VEHICLES TO THE SARAY SHAMALI INTERSECTION FROM BADAM BAGH, ARM C

Time	Sara-e- Shamali - Karte Parwan arm C (in)						
	Car	Taxi	LGV	HGV	Bus	Mini Bus	Total
8:00-8:15	243	106	15	147	15	17	543
8:15-8:30	214	113	15	18	12	15	387
8:30-8:45	215	86	11	15	21	10	358
8:45-9:00	202	92	10	8	20	13	345
Total	874	397	51	188	68	55	1633
5:00-5:15	359	190	9	10	12	14	594
5:15-5:30	379	152	6	8	14	10	569
5:30-5:45	548	197	6	7	14	6	778
5:45-6:00	537	180	4	5	10	12	748
Total	1823	719	25	30	50	42	2689

TABLE VI. TOTAL OUTFLOWS OF VEHICLES FROM SARA-E SHAMALI INTERSECTION TO BADAM BAGH, ARM C

Time	Saray-e-Shamali - Karte Parwan arm C (out)						
	Car	Taxi	LGV	HGV	Bus	Mini Bus	Total
8:00-8:15	480	212	6	23	17	30	768
8:15-8:30	393	210	8	19	20	15	665
8:30-8:45	455	230	15	14	15	33	762
8:45-9:00	406	206	20	12	13	32	689
Total	1734	858	49	68	65	110	2884
5:00-5:15	475	325	16	5	13	27	861
5:15-5:30	407	353	15	9	17	20	821
5:30-5:45	477	354	12	10	16	18	887
5:45-6:00	406	514	9	12	31	25	997
Total	1765	1546	52	36	77	90	3566

TABLE VII. TOTAL INFLOWS OF VEHICLES TO THE SARA-E- SHAMALI INTERSECTION FROM SHAHEED SQUARE, ARM D

Time	Sara-e- Shamali - Shaheed Square arm D (in)						
	Car	Taxi	LGV	HGV	Bus	Mini Bus	Total
8:00-8:15	441	221	15	18	11	60	766
8:15-8:30	300	262	18	15	15	45	655
8:30-8:45	255	255	20	26	22	37	615
8:45-9:00	345	245	27	28	16	30	691
Total	1341	983	80	87	64	172	2727
5:00-5:15	436	274	10	9	5	35	769
5:15-5:30	463	265	8	12	8	27	783
5:30-5:45	390	278	6	15	8	35	732
5:45-6:00	465	295	10	9	2	35	816
Total	1754	1112	34	45	23	132	3100

TABLE VIII. TOTAL OUTFLOWS OF VEHICLES FROM SARA-E SHAMALI INTERSECTION TO SAHEED SQUARE, ARM D

Time	Sara-e- Shamali - Shaheed Square arm D (out)						
	Car	Taxi	LGV	HGV	Bus	Mini Bus	Total
8:00-8:15	262	125	22	15	5	40	469
8:15-8:30	275	151	15	18	3	37	499
8:30-8:45	267	112	18	11	8	30	446
8:45-9:00	251	111	10	10	9	28	419
Total	1055	499	65	54	25	135	1833
5:00-5:15	504	253	8	3	9	31	808
5:15-5:30	398	246	10	6	8	35	703
5:30-5:45	396	257	9	6	1	45	714
5:45-6:00	446	361	9	6	5	56	883
Total	1744	1117	36	21	23	167	3108

TABLE IX. TOTAL INFLOWS OF VEHICLES TO THE SARA-E- SHAMALI INTERSECTION FROM PARWAN II, ARM E.

Time	Sara-e- Shamli - Parwan III arm E (in)						
	Car	Taxi	LGV	HGV	Bus	Mini Bus	Total
8:00-8:15	189	100	26	2	1	9	327
8:15-8:30	171	166	12	8	9	36	402
8:30-8:45	110	91	14	10	2	3	230
8:45-9:00	290	110	12	3	6	28	449
Total	760	467	64	23	18	61	1393
5:00-5:15	345	220	2	1	9	30	607
5:15-5:30	299	215	11	6	8	31	570
5:30-5:45	364	214	3	8	6	41	636
5:45-6:00	345	311	2	8	6	51	723
Total	1353	960	18	23	29	153	2536

B. Result of Data 2020

After entering data into the SIDRA intersection software, the results obtained in the form of charts and tables represent delays and emissions of hazardous gases, and the table shows the level of service (LOS) for intersection 2020.

TABLE X. PRESENTS THE LOS FOR EVERY SINGLE APPROACH FOR SIGNALIZED INTERSECTION 2020

Signalized Intersection 2020					
Direction	South	Southeast	Northeast	North	Southwest
LOS	F	F	F	F	F
Result of LOS	F				

Table X above shows the level of service for signalized intersection in 2020. As shown in the table the LOS is F for each approach. Also, the Signalized intersection for 2020 causes an average delay of 558.625 seconds in the morning and an average delay of 705.45 seconds in the evening as shown in the below chart. 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. As shown in Chart II.

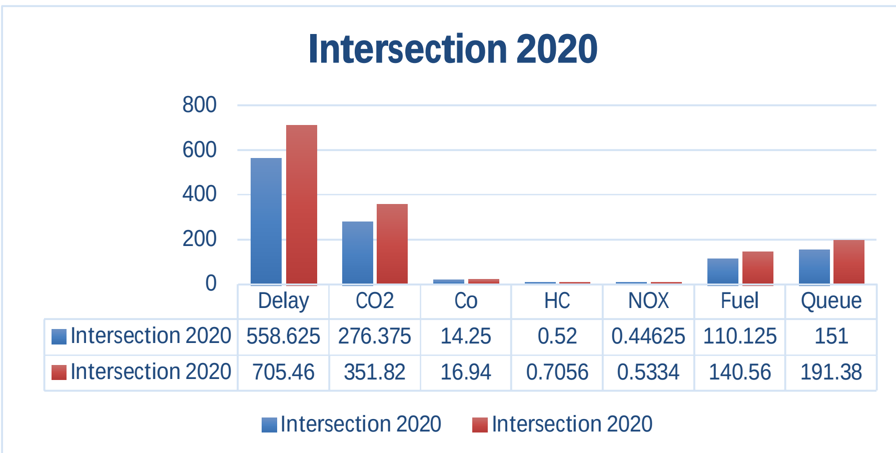

Chart. II. Represents the delay and the emissions of hazardous gases of both peak hours of the intersection

Possible options to these problems could be changing intersection to a roundabout metering which can decrease the emission of hazardous gasses and time delay while constructing an underpass from north to south direction will control these parameters remarkably.

C. Option I: Analysis of Roundabout Metering for 2020

Changing intersection shape to a roundabout metering could decrease the time delay and production of hazardous gasses. The below chart and table depict that in construction of a roundabout level of service will be B for this intersection and about 50%-time delay and 50%-production of hazardous gasses will decrease.

Chart II. Represents the delay and the emissions of hazardous gases of roundabout metering in 2020

TABLE XI. PRESENTS THE LOS FOR EVERY SINGLE APPROACH FOR ROUNDABOUT METERING 2020

Roundabout Metering 2020					
Direction	South	Southeast	Northeast	North	Southwest
LOS	B	B	A	B	B
Result of LOS	B				

D. Option II: Analysis of underpass for 2020

Constructing an underpass from north to south direction will have a remarkable impression on the intersection users. As shown in the below chart and table we can obtain the level of service of A by constructing an underpass from north to south and a highly decreasing of hazardous gases will be seen. About 99.98%-time delay will decrease, 99.95% Co2, 99.93% Co, 99.96% HC and 99.93% NOX will decrease. These amounts show a huge improvement compared to the intersection.

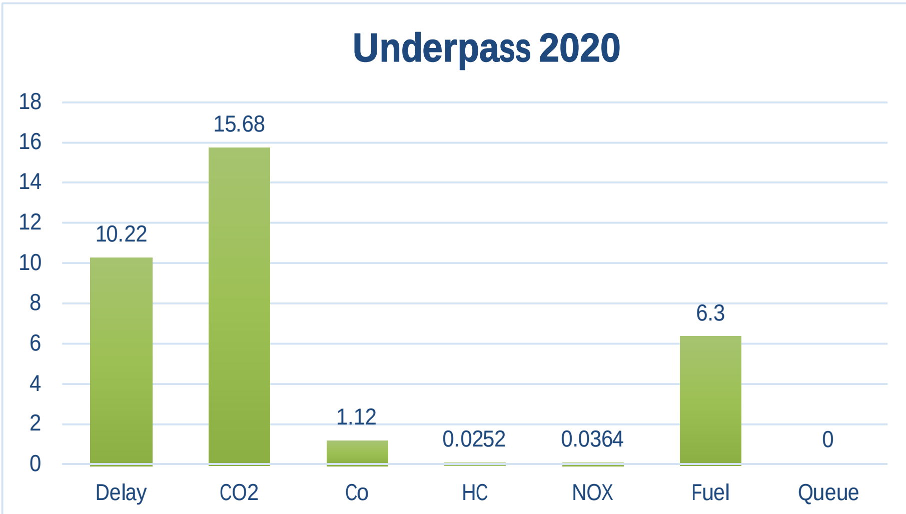

Chart IV. Represents the delay and the emissions of hazardous gases of underpass in 2020

TABLE XII. PRESENTS THE LOS FOR EVERY SINGLE APPROACH FOR UNDERPASS 2020

Underpass 2020					
Direction	South	Southeast	Northeast	North	Southwest
LOS	A	A	A	A	A
Result of LOS	A				

E. Forecasting of an option I and II for 2030

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

F. Analysis of option I and II for 2030

To determine that the conditions will not deteriorate in the future, roundabout metering and underpass has been analyzed for the year 2030. 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 2030. 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.

G. Analysis of option I for 2030

As the result showed the level of service of roundabout metering is C for the next 10 years. The amount of time delay will also increase again and cause the previous problem for road users. By constructing a roundabout metering for 2030 all the mentioned parameters will decrease compared to the current intersection, for instance, about 25% delay, 33% emission of carbon dioxide, 26% emission of CO, 25% emission of HC, 20% NOx, 25%

consumption of fuel and 25% of the queue will decrease which is not the desired solution for the current intersection then it is necessary to find a better option.

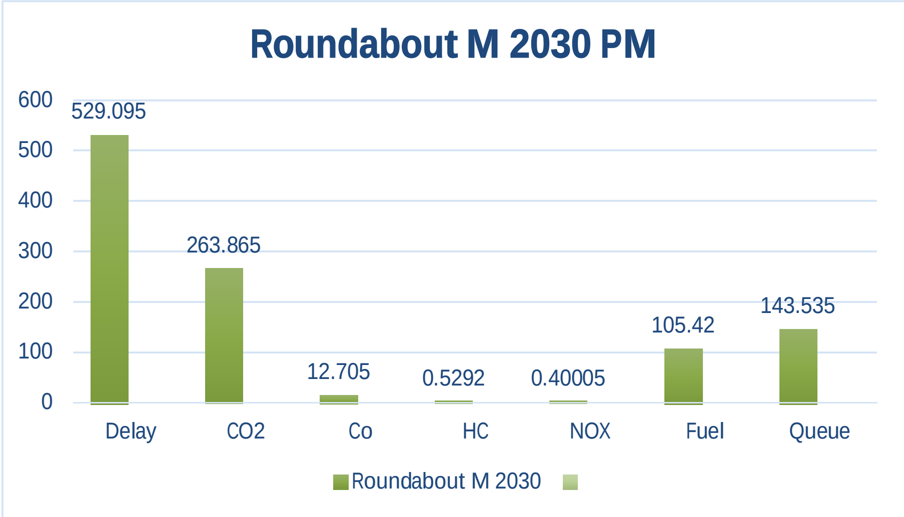

Chart V. Represents the delay and the emissions of hazardous gases of roundabout metering in 2030

TABLE XIII. PRESENTS THE LOS FOR EVERY SINGLE APPROACH FOR ROUNDABOUT METERING 2030

Roundabout Metering 2030					
Direction	South	Southeast	Northeast	North	Southwest
LOS	B	C	B	C	B
Result of LOS			C		

H. Analysis of option II for 2030

As results show the LOS for underpass 2030 is A in all directions and it is in A for the next 10 years.

All in all, the level of service is F for signalized intersection and roundabout metering in 2020, and in 2030 only roundabout metering is in F (LOS), and the gasses emission is at an alarming rate. This article proposes to create an underpass from north to south. The design of the underpass will improve the level of service to A and significantly reduce gas emissions and fuel consumption. The 2030 underpass data have also been analyzed so that the situation does not worsen in the future. The results show a slight increase in the perceived parameters.

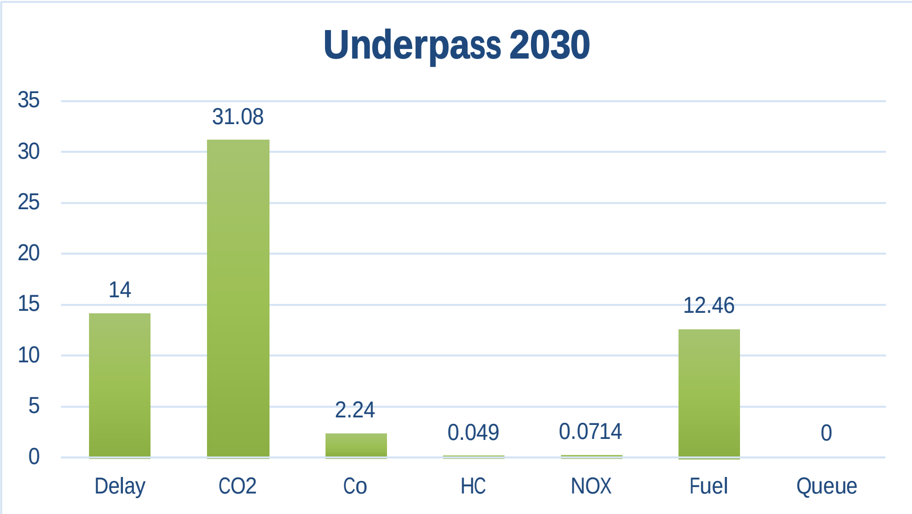

Chart VI. Represents the delay and the emissions of hazardous gases of underpass in 2030

TABLE XIV. PRESENTS THE LOS FOR EVERY SINGLE APPROACH FOR UNDERPASS METERING 2030

Underpass 2030					
Direction	South	Southeast	Northeast	North	Southwest
LOS	A	A	A	A	A
Result of LOS	A				

VII. CONCLUSION

This research paper has been conducted at Sara-e- Shamali intersection in Kabul, Afghanistan. The obtained results represent that the level of service (LOS) in this intersection is on the category of F, which is the worse level of service in transportation engineering. An average of 558.625-sec delay in morning and 705.46-sec delay in evening peak hour time shows a crowded intersection with a worse performance in Kabul. Changing the intersection to roundabout metering will solve the problems compared to the current intersection. The level of service will be in the category of (B) in 2020. About 50%-time delay and 50%-production of hazardous gasses will decrease, But the situation in 2030 will be worse back which that situation considered fail. Building an underpass will decrease by about 99.98% of time delay 99.95% of carbon dioxide emission, 100% of the queue, 99.93% of carbon monoxide emission, 96.96% of hydrate of carbon, and 99.93% nitrogen oxide. The level of service (LOS) after building an underpass was measured to be in category A. Using the population growth factor, roundabout metering and underpass performance were evaluated for the year 2030. While the results of an underpass in 2030 presented a decline of about 98.01% in time delay, 100% of the queue, 91.16% in carbon dioxide emission, 86.76% in carbon monoxide emission, 93.04% in the production of hydrate of carbon, 86.60% in nitrogen oxide emission compared to the current values. The underpass will perform at the level of service LOS A. all the results are compared in the below chart.

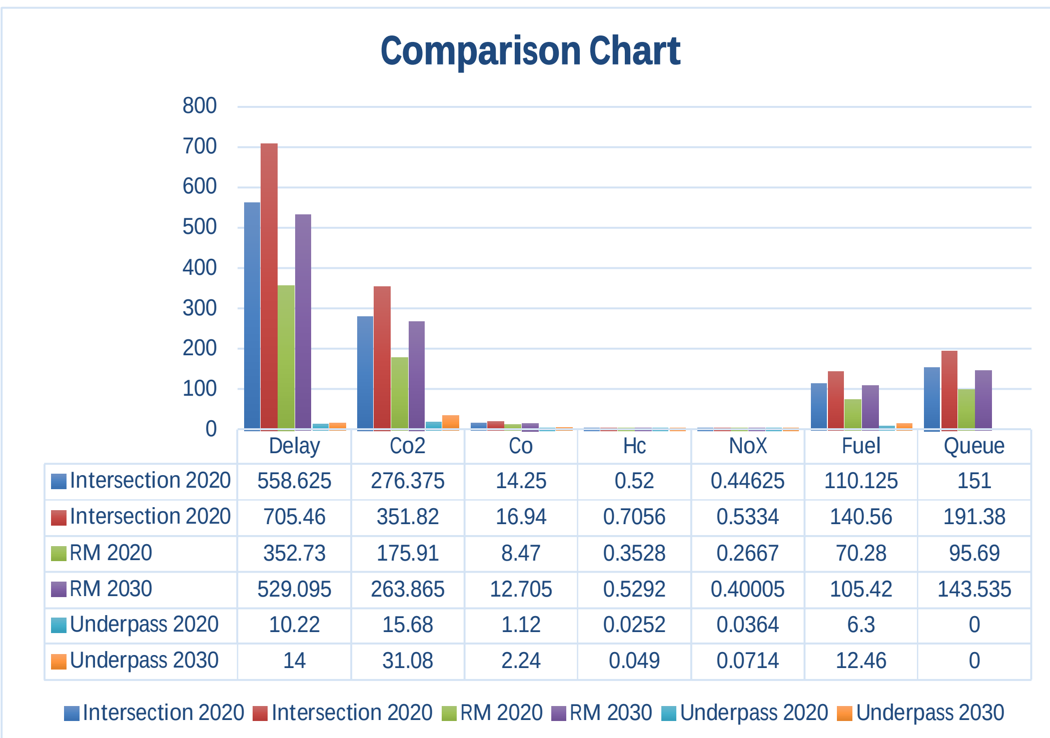

Chart VI. Comparison chart

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