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A Case Study on Roundabout under Congestion: Proposal to Improve Current Traffic Operation

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Abstract

Roundabouts are progressively being utilized on occupied arterial streets for traffic quieting purposes. Be that as it may, on the off chance that one indirect leg is close to a conveyance center point, for instance, stopping territories of strip malls, the passage traffic volumes will be especially high in pinnacle hours. On the basis of the Al-Turkman Roundabout, which is one of the most important roundabouts in Baghdad city, linking the areas of east of Baghdad to the city center in the area of Bab Al-Moatham. This area is characterized by its high traffic volumes (congestion), especially at peak periods causing a low level of service (LOS) with increased travel time delay, costs, and CO_2 emissions. The research relied on the use of the SIDRA software to assess these variables by collecting traffic volumes in this area. The research proposed a series of planning procedures which are divided according to serial time scales. These planning procedures are to address the problem of congestion and traffic jams in the area, improve the level of service, and reduce travel time, cost and CO_2 emissions. The research concluded that the application of the planning proposals in the study area has improved the level of service from E and F to C, reduced travel time by 16%, reduced costs by 25% and reduced CO_2 emissions by 29%.

Keywords: Planning Proposals; Travel Time Delay; Cost; CO_2 Emissions; Level of Service; SIDRA Software.

1. Introduction

Traffic congestion could be a major challenge in cities of all sizes. The traffic conditions on any intersection area are characterized by slower speeds, longer trip times, and expanded queuing [1]. Level of service (LOS) and delay are the main variables to assess intersection efficiency. Level of service could be an assessment by which transportation planners verify the standard of service on a selected transportation facility or infrastructure. LOS vary from A to F; A being the higher when drivers don't seem to be influenced by other vehicles in the traffic stream, and F being the lowest. LOS for signalized intersections could be measured by average stopping delay time per vehicle [2]. Numerous planning and marketing measures tend to under-price vehicle travel and urban extension of the city, counting road and vehicle parking facilities that are not supported through user fees, uncompensated traffic congestion, accident, and pollution harms, as well as different costs of an urban extension [3, 4].

With a more efficient valuation, the car movement would cost less than it does currently, leading to less driving and sprawling, and less total costs. Public transit subsidies are usually validated, in part, as the best solution to vehicle

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underpricing (for example, to reduce traffic and parking congestion). Even if, mostly, more economical pricing of vehicle travel and urban sprawl are most effective [3].

- The main urban strategies aimed at improving the transport industry are: Intensive city and mobility: by promoting sustainable progress and urban forms through improved integration of the different parameters in policy establishment and urban design. It also can be achieved through the extension of a network of heavy public transport as the backbone of urban progress [5].
- Sharing the street, alternative modes: by combining a set of actions that should encourage a more sufficient use of private vehicles. This could be achieved by generating more sustainable modes of road space distribution. This could be translated into a well-structured road network and optimizing current roads. Walking could be encouraged as a manner through a cohesive pedestrian network and facilities [5].

Push and Pull approach: by emphasizing that urban transport actions should encourage road users to use public and non-motorized modes of transport while trying to offer solutions to push them out of vehicles and such transport modes. To accomplish the "pull" element, one should provide high-quality service for public transport, build suitable infrastructure for public and non-motorized transport and, at large, come up with policies that could enhance conditions of these modes use [6].

- Avoid, Shift, Improve approach [6], The three strategies of this approach can be defined as follows:

➢ Avoid: This tactic aims to prevent unnecessary travel and lessen trip distances. It implements solutions in order to achieve more integrity between land use and transport planning and mixed-use development is encouraged. There is a larger function for information and communications technologies (ICT) to decrease the number of trips that could be done by an individual.

➢ Shift: It aims to encourage passengers towards more sustainable transport modes. The citizens who are using vehicles or motorcycles can be encouraged to start using more public and non-motorized transport modes.

➢ Improve the third measure concentrations on policies that aim to enhance transport actions and technologies. It is a more proper approach to improve urban transport difficulties. Its solutions contain refining fuel quality and competency standards, rising vehicle emission standards, applying vehicle inspection and maintenance (I&M) policies, and transitioning to "intelligent transportation systems" that take advantage of technologies like information and communication to advance transport management. It also highlights the necessity to enhance cargo transport technologies and logistics.

Roundabouts have generally been advanced essentially as a security countermeasure and the operational execution advantages of expanded throughput contrasted and conventional crossing points [7]. Even though there have been numerous studies from local and international transportation experts to understand and evaluate the traffic performance at the roundabouts. This performance analysis usually relies on two aspects:1) entrance capacity, 2) operational performance measures [8].

Developed a simple macroscopic model based on the Highway Capacity Manual, and give proof that establishment of a metering signal on roundabouts with some interest mixes can possibly decrease deferral contrasted and that on an unmetered roundabout [9]. On the other hand, Liu et al. (2013) analysed the operation performance of Mengxi roundabout in Zhenjiang, China, and included vehicle velocity distribution, gap distribution, and lane changing distribution in the analysis. The result indicates that this work will be a base for improving the capacity of the roundabout in this area [10]. Chen and Lee (2016) conducted a study by using the East Dowling Road Roundabouts in Anchorage, Alaska. The authors estimated several performance measurements like capacity, queue length, and delay by using RODEL, SIDRA, and VISSIM. The results indicated that SIDRA and VISSIM will, in general, think little of deferrals and line lengths for the multi-path roundabouts under the blockage, while RODEL results in higher postponement and line length estimations all things considered of the passage approaches [11]. Giuffrè et al. (2016) displays an interesting writing audit about the key methodological issues in the operational investigation of the modern roundabouts. The concentrate is made on the angles related with the whole acknowledgment conduct, the inference of the investigative based models, and the computation of parameters included into the limit conditions, just as unfaltering state and non-consistent state conditions and vulnerability in section limit estimation [12]. Finally, bits of knowledge on future advancements of the exploration in this field of the examination will be additionally sketched out. More details on different roundabout geometric design can be found [13, 14]. As a nutshell, the urban development strategies (planning proposals) are trying to increase the benefits and decrease the costs so as to give a sustainable inheritance for upcoming generations. Planning proposals can be optimized for multiple economic, social and environmental objectives.

In addition, might contain numerous planning aspects including client demands, effective public services, safety, and public health, effective transport, affordability, cost-effective productivity and opportunity, energy preservation, emission decreases, and urban liveability (local environmental quality) [15]. Starting from these issues the research aims to:

- Estimating and assessing the Level of Service for the current status at Al-Turkman roundabout.
- Assessing the average delay, average cost and CO_2 emissions for the existing status at Al-Turkman roundabout.
- Present proposals for planning to improve the traffic operations at Al-Turkman roundabout to resolve the existing problem of congestion.
- Comparing the status of traffic before and after the application of planning proposals at Al-Turkman roundabout to assess the extent of improvement in LOS, average delay, cost and CO_2 emissions.

2. Experimental Work and Methods

2.1. Study Area

Palestine Street is one of Baghdad's largest and longest roads, located on the Tigris River's Rusafa side. It is a long street from Maysaloun Roundabout at the entrance to Mustansiriyah University of New Baghdad District This road has six routes and the surrounding residential areas are one of Baghdad's most lovely regions, such as the 14th of July, Zayouna, Engineers, Idrissi, Al-Mustansiriyah, Al-Nile, and other districts. Public agencies on this road, such as the Iraqi Olympic Committee, the Irrigation Ministry, the Police College, the Air Force Club, as well as some minor exceptional organizations, such as the University of Mustansiriyah, which have revived many organizations, such as the AlRafiden University College, the Institute of Teacher Training and the Ministry of Youth and Sports and many other. Al-Turkman Roundabout was chosen to collect and analyze information using SIDRA software to assess the emissions of LOS, delay, cost, and CO_2. The land use research region is as shown in Figure 1.

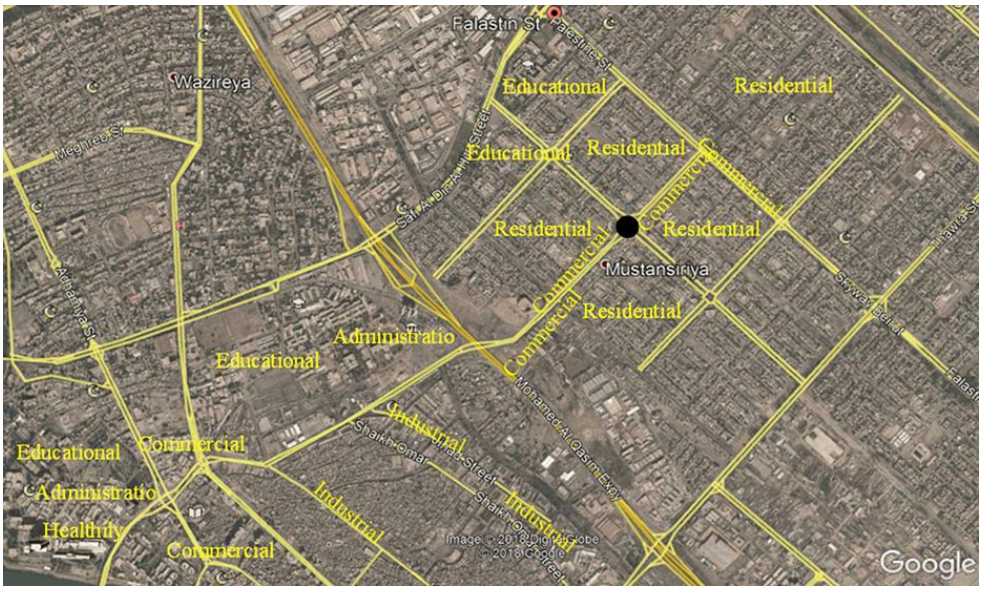

Figure 1. The study area land use

2.2. Data Collection

Collecting data is a critical step in the method of evaluation. Before beginning the collection, knowing what to gather, when to collect, how long to collect and how to handle the information must be addressed. In this study, two methods were applied to collect the required data:

- The manual counting technique used to collect traffic volumes from 2:00 pm to 3:00 pm for one week and one hour to determine the level of service (LOS), the travel time delay and the CO_2 emissions by applying SIDRA Software. After the roundabout recognition and identification of the maximum traffic volume, this hour was selected. The traffic volume was recorded for every 15 minutes to compute the peak hour factor (PHF) for all directions (north, east, west, and south) for Sunday, Monday, Tuesday, Thursday and Saturday.
- Questionnaire: The questionnaire was designed to include questions about the road data for 20% of users traveling from Al-Turkman Roundabout. The questionnaire includes the determination of the origin and destination of the journey in terms of land use. The purpose of the questionnaire is to determine the percentage of attraction for land use in the study area that affects and is affected by the daily trips of users, and increase the congestion and traffic jams in the Al-Turkman roundabout, and thus, the possibility of knowing the use of land that affect the congestion to develop solutions and planning proposals that reduce the congestion in that roundabout.

2.3. SIDRA Program

The SIDRA software has been established by the Australian Road Research Board (ARRB), Transport Research Ltd., as mean to design and assess the performance of intersections such as signalized intersections, roundabouts, two-way stop control, and yield-sign control intersections [16]. There are some advantages that the SIDRA has over any other software model in estimating and comparing the efficiency of the signalled junction. Akcelick et al. (1997) indicated that the SIDRA method emphasizes the consistency of capacity and performance analysis methods for roundabouts, sign-controlled, and signalized intersection through the use of an integrated modelling framework [16]. SIDRA program is software needs input data to analyse the traffic in the roundabout as follows:

- The traffic volume for each direction (north, south, east, and west) and for all movements (through, right, left), all the traffic volume in passenger car unit (PCU), so buses were converted to PCU by using a factor (1 bus = 1.25 pcu).
- Percentage of heavy vehicles for each direction and movement.
- Peak hour factor (PHF).
- The number of lanes.
- The radius of Island.
- The width of Lane.
- Lane path.

The flowchart below illustrates the whole research methodology for this work:

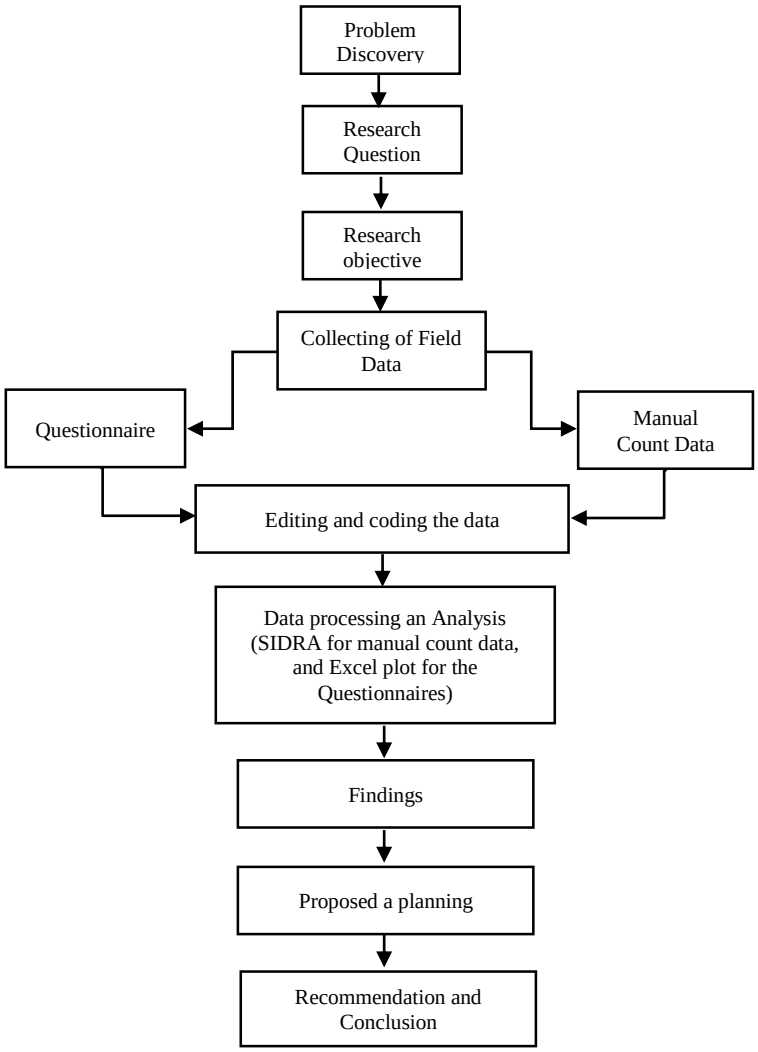

Figure 2. Flow chart for the research methodology

3. Results and Discussions

3.1. SIDRA Software Analysis

At Al-Turkman Roundabout, volumes of traffic were collected for 6 days a week and analysed using SIDRA Software. The research area's traffic volumes indicate the following:

- During the study period, the highest volume of traffic affecting the study area comes from Bab Al-Moatham by 35%, followed by traffic volumes from Palestine Street to the study area by 30%, then traffic volumes from Al-Rafidain College and Mustansiriyah University to the roundabout by 19% As shown in Figures 3 and 4, traffic from the Nahdha region to the roundabout improved by 16 %.
- Tuesday was the worst day in terms of its level of service (F) in all directions due to the high delay in travel time and high-cost losses.
- Al-Turkman roundabout service level was between F and E. Therefore, it requires to be improved.
- The roundabout's delay was 270 seconds/hour over the six days of traffic, with Tuesday's highest delay rate (430 sec / h) and Saturday's lowest delay rate (131 sec / h).
- During the six days study, the average cost was 9088 cents, the highest on Tuesday (15880 cents) and the lowest on Saturday (3615 cents).
- During the six days traffic study, average CO_2 emissions were 3536 Kg/hour. Tuesday has the highest emission with (5685 Kg per hour) and Saturday has the lowest emission with (2042 Kg/hour).

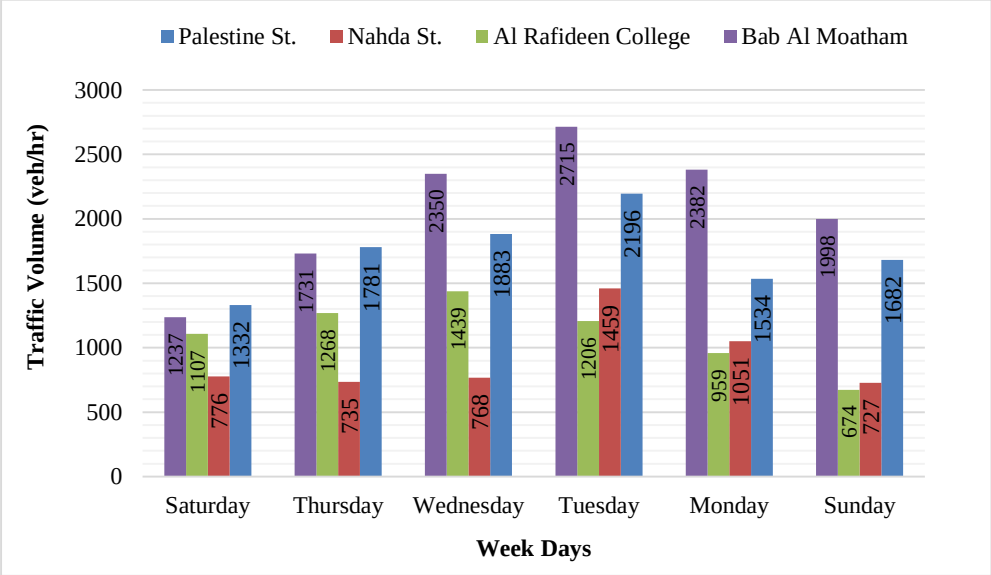

Figure 3. Traffic volume in Al-Turkman roundabout

Figure 4. Traffic volume percentiles in Al-Turkman roundabout

3.2. Questionnaire Analysis

- The analysis of the questionnaire forms showed the following: A total of 1041 questionnaires forms were distributed over six days among the Palestine street users towards Al-Turkman Roundabout. Figure 5 demonstrates the distribution of travel from Palestine Street by source and distribution by location by land use.
- The largest land use for the origin of travel was residential use by 40%, followed by schooling by 17%, busiss and administrative use by 11% and health by 8%. While the rate of accommodation destinations was 37%, followed by education at 22% and business trips (commercial, industrial and administrative) by 20%.

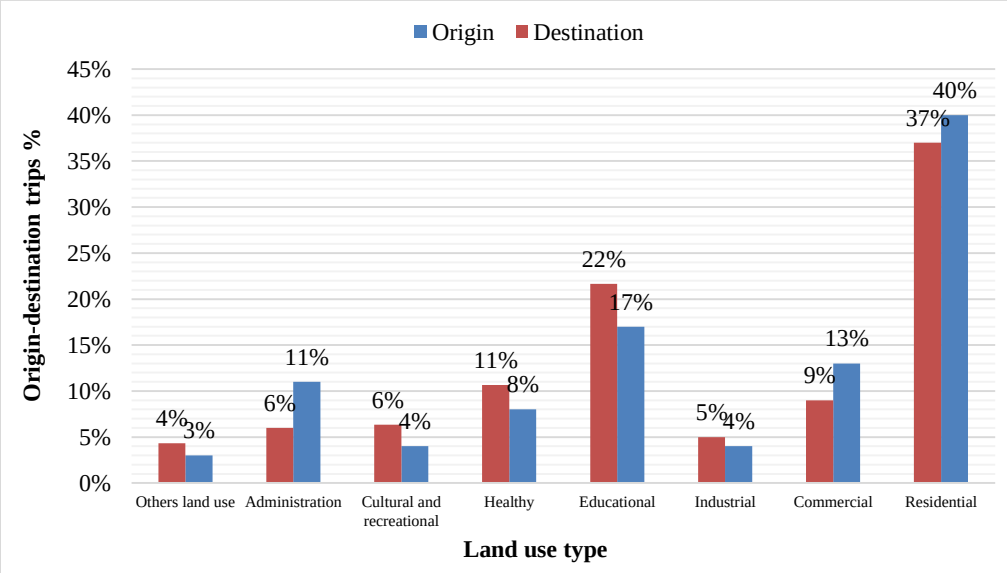

Figure 5. Origin-Destination trips from Palestine St. to Al-Turkman roundabout

- Approximately 552 questionnaires were distributed and collected over a period of 6 days from Al-Rafidain College and Al- Mustansiriyah University to Al-Turkman Roundabout as shown in Figure 6. The largest land use for the origin of the journey was academic use by 43 %, followed by residential use by 2% and administrative use by 12 % and commercial use by 11 %, while destination travel rates were 38 % for residential travel, then 27 % for business travel (commercial, industrial and administrative), 16 % for education and 11 % for health.

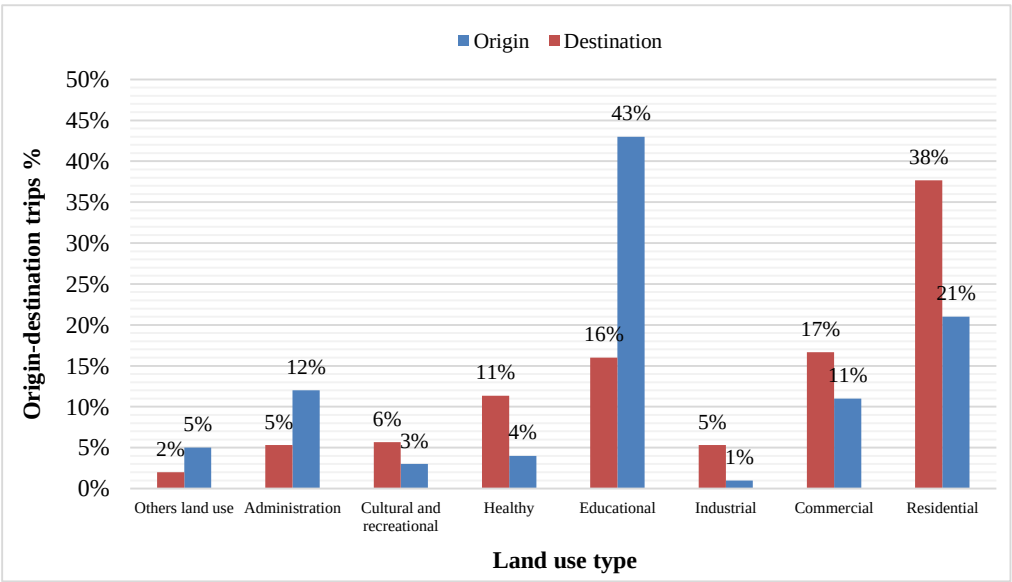

Figure 6. Origin-Destination trips from Al-Rafidain college to Al-Turkman roundabout

- Approximately 655 questionnaires have been spread from Nahdha to Al-Turkman Roundabout over 6 days. Figure 7 demonstrates the allocation of trips from the Nahdha region by their original land use allocation. The largest land use for the origin of the journey was residential by 48%, followed by 18% of administrative use, 12% of educational

and 6% of health. While the rate of travel destinations for accommodation was 32%, followed by education by 29%, business (commercial, industrial and administrative) by 21% and health by 10%.

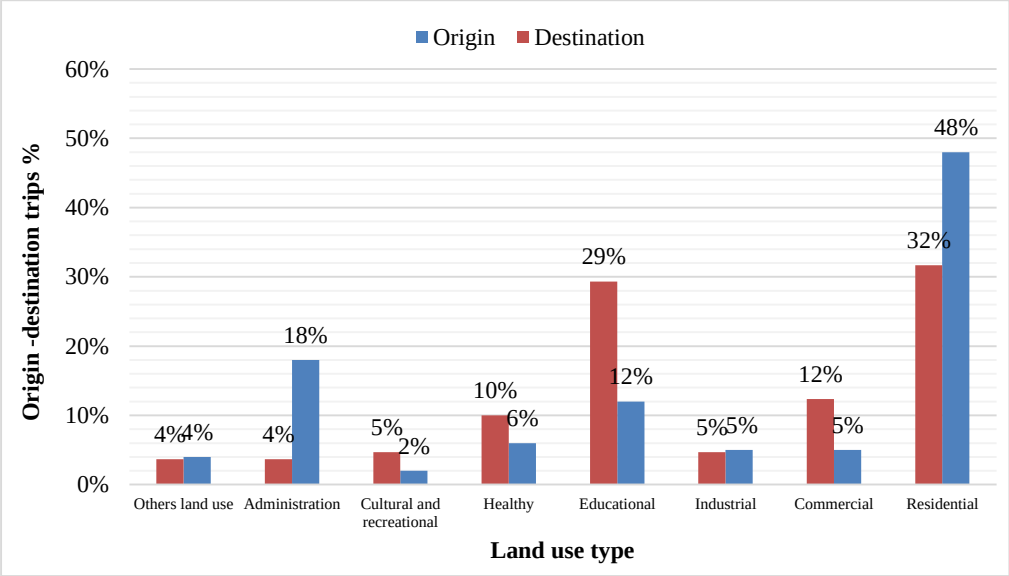

Figure 7. Origin-Destination trips from Nahdha St. to Al-Turkman roundabout

- A total of 1241 questionnaires from Bab Al-Moatham to Al-Turkman Roundabout were distributed over 6 days. Figure 8 shows the distribution of trips coming from Bab Al-Moatham area according to their origin-distributing regarding land use. The largest land use for the origin of the journey was business use by 25%, followed by industrial use by 20%, academic use by 18%, health and administrative use by 12% and residential use by 10%. The rate of destinations for accommodation was 43%, followed by business (commercial, industrial and administrative) by 23% and education by 14%.

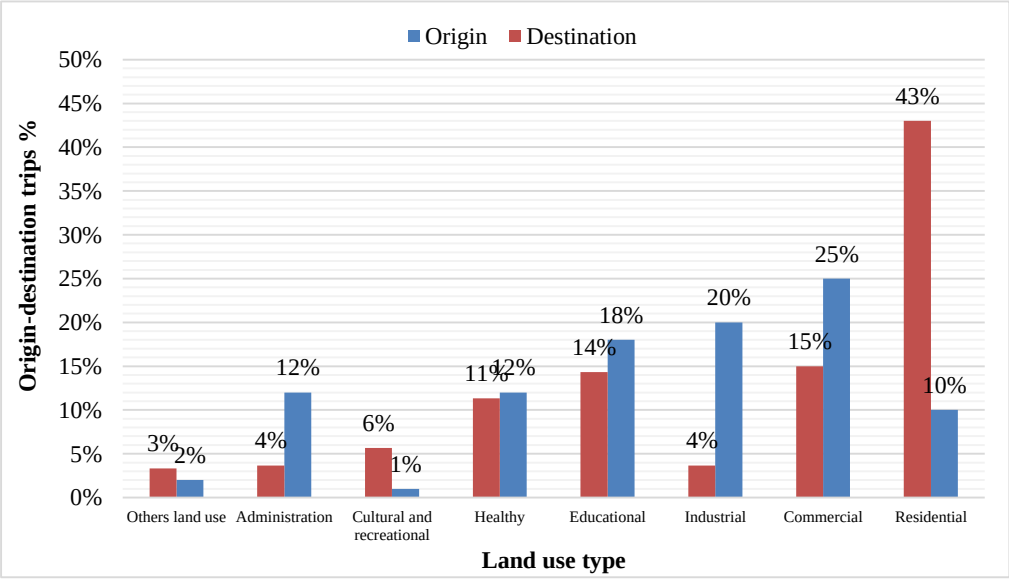

Figure 8. Origin-Destination trips from Bab Al-Muadham to Al-Turkman

The questionnaire assessment showed that Al-Turkman roundabout with neighbouring fields and Palestine Street are appealing places for predominantly residential use, followed by academic use, and the region is a route to attractive uses the Bab Al-Moatham region. The area of commercial, industrial, educational, administrative and health use owing to the concentration of these operations in the region leading to increased traffic volumes in this roundabout, thereby increasing traffic congestion and traffic jams in the field, which calls for the development of alternatives to tackle these issues by understanding their causes and developing suitable alternatives. The primary reasons for Al-Turkman roundabout's bad service level, enhanced congestion and traffic jams may be as follows:

The existence of appealing traffic utilizes through the field to the Bab Al-Moatham region, characterized by high-density travel. The key uses as shown in Figure 9 are:

- **Educational use:** The area of Bab Al-Moatham is characterized by a group of different colleges, which includes a large group of students.
- **Health use:** The area includes various health institutions with affiliated colleges and some services attached there.
- **Commercial Use:** The region has highly concentrated commercial activities in Baghdad city and represents one of the most important trade centres in Baghdad and Iraq.
- **Administrative use:** The presence of a group of organizations of government and administration such as the Ministry of Finance, Health, and others. The change of Al-Turkman roundabout area's planned uses according to the master plan of Baghdad city, namely:
  - Changing land use in the surrounding area from residential use to commercial and industrial use (auto repair areas), as well as the Sheikh Omar area and other areas.
  - The existence of Bab Al-Moatham garage for public transport, which can attract a lot of trips.
  - The presence of Mustansiriyah University and many private colleges near the roundabout, which may attract more trips.

These reasons require alternatives and processes to be developed that enhance the service and decrease congestion and traffic jams in the arena.

Figure 9. Land uses in the study area

4. Planning Proposals

The most significant scheduling suggestions in the Al-Turkman arena to decrease traffic quantities are:

- Regulatory actions:

A number of regulatory measures could be made in the route extending from the intersection of Al-Sakhrah through Al-Turkman Roundabout to Bab Al-Moatham area. These procedures are:

- Use of gas-powered cars reducing CO_2 emissions.
- Using contemporary model private cars (2016-2019).
- Use of various kinds of cars for public transport.

The change in public departments, institutions and universities ' formal operating hours. Through the adoption of traffic laws and regulations, these legislative processes should be enacted within one year.

- Determination of an exclusive route for public transport and car-sharing:

The route extends from Al-Sakhrah intersection in Palestine Street passing through Al-Turkman Roundabout to Bab Al-Moatham (Public Transport Garage) as a route for public transport vehicles and car-share. This might be done by legislating strict traffic laws preventing private vehicles from passing this route, besides reorienting sub-roads extended to it in an orderly manner (Figure 10).

The planning proposal could be implemented by defining special paths for public transport during a period of 2-5 years through the establishment of private parking areas and the application of (Park and Ride) approach at the beginning of Al-Turkman Street with the allocation of a suitable route for public transport and car-share.

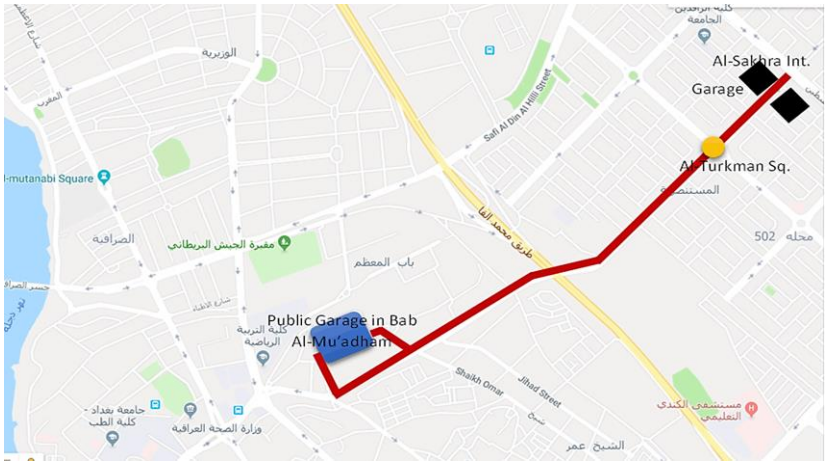

Figure 10. Proposal for an allocated lane for public transportation and car-share

- Re-planning land use:

Improving the level of service for the roundabout requires re-planning of land use, especially that causing congestion and increasing daily trips through the following actions (Figure 11):

- Removing the industrial use of cars along the highway from the Al-Turkman Roundabout to the Bab Al-Moatham region, as well as the industrial area of the Sheik Omar region, and transferring them to the fields identified in the new Master Plan for the town of Baghdad, mostly in the periphery of the town of Baghdad such as Owaireej and Boob Alsham, and replacing them with recreational, green and open spacesto increase the use and achieve environmental and construction balance of Baghdad city, in general, and for the area of Palestine Street and the surrounding areas.
- Transfer of the business region from Bab Al-Moatham to Al-Shorja and Bab Al-Sharqi, with a heritage and cultural character of the town of Baghdad, to the housing sector facilities scheduled as a single trade, and transfer of shops to locations outside the town of Baghdad in its periphery, close to the primary transport hubs connecting Baghdad with other governorates. The commercial area in Bab Al-Moatham could be created and transformed into a region of cultural heritage.
- Within the plan of the Ministry of Higher Education and Scientific Research, transferring universities and colleges outside the boundaries of the master plan for Baghdad city in the districts of Rashidiyah and Taji. It is proposed to transfer the faculties from Bab Al-Moatham complex to the designated areas, and allocate this area for health use, medical colleges and health-related use.

The proposed re-organization and planning of land use can be activated and achieved during a period of 5-10 years through the enactment of laws that prevent the change of land use in the study area, and transfer uses that do not conform to the design of the master plan to their specified locations, inside or outside Baghdad city.

Figure 11. Proposals for upgrading land use in the study area.

The implementation of these planning proposals according to their time limits ensures the reduction of the traffic volume in the arena about 35% of the current traffic volumes, improve the level of service and reduces the travel delay, cost and CO_2 emissions, as shown in Table 1.

Table 1. LOS, Delay, Cost, and CO_2 Before and After Application of Planning Proposals in the Study Area

Day		Factor	South	East	North	West	Intersection
Sunday	Before	LOS	F	F	E	F	F
	After		C	C	B	E	D
	Before	Delay (Average)	61.3	168.2	37.5	335.6	201.4
	After		23.3	21.9	13.2	35.6	26.3
	Before	Cost (Total)	382.6	1610	288.8	3166.9	5448.3
	After		175.1	379	142.3	516.6	1212.9
	Before	Co_2 (Total)	210.2	735.7	177.3	1192.7	2315.5
	After		110	242.9	95.6	302.5	750.5
Monday	Before	LOS	E	F	F	F	F
	After		C	C	D	D	D
	Before	Delay (Average)	49	166.8	232.9	596.9	329.5
	After		18.2	18.9	26.7	113.1	46.2
	Before	Cost (Total)	508	1451.2	1149	6286.9	9395.2
	After		238.6	335.9	236.7	842.1	2030.2
	Before	Co_2 (Total)	298.3	651.8	476.5	2260.3	3687.1
	After		155.9	216.3	1482	667.2	702.6
Tuesday	Before	LOS	F	F	F	F	F
	After		D	E	E	E	E
	Before	Delay (Average)	184.1	358.1	409.9	731.9	466.8
	After		22.6	36.2	37.1	41.3	39.2
	Before	Cost (Total)	1501	3706	2271	8402.6	15880.6
	After		394.5	736.6	629	2771.7	4558.8
	Before	Co_2 (Total)	668.5	1401.1	841.3	2778.3	5686.2
	After		234.9	399.4	286.5	1033.1	1953
Wednesday	Before	LOS	C	F	F	F	F
	After		B	C	C	D	C
	Before	Delay (Average)	23.1	191.4	513.2	730.2	439.8
	After		13.7	20.5	54.4	306.2	159
	Before	Cost (Total)	304.2	1970.5	3257.5	7532	13064.1
	After		169.7	419.3	455.2	2745.8	3790
	Before	Co_2 (Total)	211.5	857.1	1135.5	2742.6	4943.5
	After		118	265.3	250.4	788	1297.6
Thursday	Before	LOS	C	F	F	F	F
	After		B	C	D	C	C
	Before	Delay (Average)	23.6	147.8	425.4	354.9	260.1
	After		15.5	18.6	34.9	35.6	27.3
	Before	Cost (Total)	286.3	1511.8	2445.4	2878.6	7122.2
	After		163,6	380.8	337.6	447.6	1329
	Before	Co_2 (Total)	221.6	768.3	694,8	850.3	2541.7
	After		110.4	238.4	201.4	265.1	815.3
Saturday	Before	LOS	D	E	F	F	F
	After		B	B	C	C	C
	Before	Delay (Average)	33.7	46.6	275.8	167.2	134.9
	After		13.6	11.8	21.9	25	18.3
	Before	Cost (Total)	347.1	590.1	1517.9	1160.8	3615.9
	After		174	261	260.4	287.8	983..2
	Before	Co_2 (Total)	221.6	546.9	760.1	831.7	2042.5
	After		123.1	169.1	167.6	181.5	641.2

5. Conclusion

For the repair of void under slab of cement concrete roads, both high polymer materials and cement concrete materials are of good effect, and can effectively reduce the stress value of the slab bottom.

This study analysed the current traffic operation at a roundabout under congestion in Iraq. Although roundabouts have favorable characteristics in soothing the traffic, and it considers a better replacement for the intersections and the stop control [17], this roundabout has a very heavy traffic density. Furthermore, there are no sufficient studies focused on the general effects of this roundabout in view of efficiency. By applying SIDRA software to the collected data, the results showed that in general, the roundabout has LOS between F and E. Tuesday has the worst level of service with (F) level for all the directions. The delay in the roundabout was 270 seconds/hour during the six traffic days, with the highest delay rate on Tuesday (430 sec/h) and the lowest delay rate of (131 sec/h) on Saturday. The average cost during the six days of traffic survey was 9088 cents, the highest cost was on Tuesday (15880 cents), and the lowest cost was on Saturday (3615 cents). In addition, the average CO_2 emissions during the six days of traffic survey were 3536 Kg/hour. The highest emission on Tuesday (5685 Kg/hour). The lowest emission on Saturday (2042 Kg/hour). So this study contributes to propose new planning that can improve the traffic condition at the roundabout. However, this study has some limitations, the implementation and application of the planning proposals according to the time limits specified could affect in:

- Improving the level of service in the area from E-F to C;
- Reducing the travel time delay by 16%;
- Reduction of costs by 25%, reaching 9088 cents (90.88 $/h);
- Reduction of CO_2 emissions by 29%, with an average CO_2 emission of 3536 Kg/hour.

Improving the level of service could enhance the well-being and the overall health of society, thus increasing human life and productivity and improving environmental, social and economic aspects as a whole. Hope this work will be a baseline to the transportation specialist in Iraq and take in consideration the establishment of a committee to prepare a code for sustainable transport in Iraq, which includes specialists from academics and engineers in the transport sector.

In addition, Preparation of legislation and regulatory laws in the field of public transport to start with the transition from traditional transport based on private cars and private-public transport to a mode of sustainable public transport in Iraq.

6. Acknowledgments

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7. Conflicts of Interest

The authors declare no conflict of interest.

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