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IMPACT OF TRANSFERRING LIGHT BUSSES TO BRT ROUTE ON TRAFFIC CONGESTION, MOBILITY, AND SAFETY AT SWEILEH INTERSECTION IN AMMAN

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This research aims to assess the impact of light buses on mobility and time delays. Extended wait times and unfavourable environmental factors lead to traffic jams and negative economic impacts. One suggestion is to relocate these minibuses to the bus rapid transit (BRT) lane. Three crossroads that are connected by a corridor were included in the analysis. The crossroads under consideration are the University of Jordan intersection, the Sweileh intersection, and the intersection of external patrols. Vissim simulation software is used for the evaluation and analysis, using data from detectors data at crossings. As a result of shorter wait times and shorter lines, both the simulation and the collected findings demonstrated an overall improvement in mobility. The environment would benefit from such an upgrade. The inclusion of light buses does, nonetheless, cause a little delay on the BRT lane; however, this is offset by an overall improvement in the mobility of all traffic at each crossing. Improved quantitative assessment of the dynamic traffic at each crossing was made possible based on simulation. The results generated by this study demonstrated intricate traffic interaction models (involving Sweileh, outside patrols, and the University of Jordan), which might be applied during the design phase of upcoming construction projects near these crossings.

Keywords: intersection, bus rapid transit, light busses, mathematical modelling, simulation, vissim

1 INTRODUCTION

Traffic congestion and the transportation system have an impact on our day-to-day life. There are numerous reasons for the sharp rise in traffic in many locations. One could argue that the primary cause is the population growth that has increased the number of cars on the road. Inadequate infrastructure, ineffective capacity management (such as bad traffic scheduling), work zones, special events, emergencies, unrestricted needs, auto accidents, driver behavior are additional causes of traffic congestion among others [1-4].

Nearly every city in the globe experiences a territorial expansion in accordance with the recorded population growth in urban centers. Bus rapid transit (BRT) systems have been implemented in major cities, such as Beijing in China, Jakarta in Indonesia Seoul in South Korea, Taipei in Taiwan, Toulouse in France, Amsterdam in Holland, Bradford in United Kingdom, São Paulo in Brazil, Santiago in Chile, Bogotá in Colombia, Ottawa in Canada, Boston in United States, among many other non-industrial countries in the world, specially throughout many industrialized countries in an effort to reduce traffic and air pollution, as it is an important issue for better socio-economical living. In Asia over 1600 km of BRT lanes length is used, with over 800km in Europe, and over 1700 in km in Latin America, with over 500,000 passengers per day in Africa, 8 million passengers per day in Asia, over 3 million passengers per day in Europe, and over 18 million passengers in Latin America per day, as examples of BRT utilization. In recent years, BRT systems have gained popularity in urban transit, especially in emerging capitals. With over 166 cities across nearly six continents using this system, the majority are still in the building stages [5-8].

Numerous studies have discovered that aspects of the built environment, like the availability of substitute modes of transportation, significantly influence the ownership of cars in developing nations and may even mitigate the effects of economic development. People are more likely to rely on private transportation when there are no other options for public transit [9-14].

By switching from private to public transportation, walking, and cycling, one can improve the sustainability of transportation, the environment, public health, and the economic standing of the local population. However, this transition can only occur provided public transportation is widely accessible and available to the general public [15-16].

A detailed analysis of the initiatives aimed at increasing the proportion of travel by public transportation is required. The efforts to increase public transportation are referred to as working practices. The concept of working practices is commonly used to combine various procedures and the situations in which they occur in order to boost the use of public transportation. As part of the analysis, the effectiveness of the current working practices that serve as a basis for the knowledge and experience transfer is also assessed [17-18].

Bus rapid transit (BRT) is a bus-based public transportation system that is intended to have significantly higher capacity, reliability, than a traditional bus system. It is often referred to as a bus way or transit way. BRT is part of an integrated system of facilities, services, and amenities that collectively improve the speed, reliability, and identity of bus transit. This integrated system is built for increased speed, dependability, and safety and has high-quality buses, unique infrastructure, and a restricted mix of traffic. In contrast to local buses, BRTS has a dedicated bus lane and fewer stops with wide spacing. Because of its fast speed, greater capacity, enhanced dependability, ability to successfully attract users, and advantages for the environment, society, and economy. Bus-only lanes, bus priority at junctions where they may interact with other traffic, and design features to reduce delays caused by people getting off or on the bus are all common features of BRT systems. Figure 1 shows a BRT bus in Amman coming from Sweileh area.

Fig. 1. BRT Bus in Amman

Para transit is defined as a flexible, non-scheduled public transportation system that uses small to medium-sized vehicles. Because of this, taking a journey using this type of bus service may seem less tempting compared to using private transportation or a rented car rather than transit; as travelers want to save time and avoid the uncomfortable congestion during peak travel times [22].

A light bus (Figure 2) is a vehicle which should carry passengers to their destinations in a secure and comfortable manner. Buses that can accommodate more than nine passengers but are still considered light vehicles—that is, they weigh less than 3500 kg when fully loaded—are known as light buses. A light bus is a motor vehicle that has been built or modified specifically to carry a driver, up to 19 passengers, and their personal belongings. Some light buses are designed as motor vehicles used for transporting passengers that can anywhere from 12 to 30 people. However, over time, and due to lack of comprehensive and dedicated bus line services in areas in Jordan, light buses resumed significant role in the expansion of paratransit services. Notwithstanding the benefits of their services, their competitiveness on the road, driven by their reliance on number of trips and passengers to make profit, together with lack of regulation, has resulted in traffic incidents, fatal accidents, and occasional road rage. In addition, and to keep vehicles on the move, maintenance issues are ignored by some operators. Many tactics have been applied with the deployment of BRT in Jordan. Light buses operators are encouraged, but not forced to join the BRT system. Similar situation occurred in other countries [23-24].

Fig. 2. BRT Bus in Amman

Four strategies for managing and reforming light buses were identified [25].

1. Incorporation into operating firms.
2. A step-by-step process of improving Para transit's operational efficiency and corporatization to become a future operator of conventional buses or BRTs.
3. Consolidation of operators and regulation of competition via concession or franchising
4. Gradual improvements to currently offered paratransit services that do not inevitably result in organized bus service or corporatization.

Even while their services are beneficial, their reliance on fees and lax regulations have made them competitive on the road, which has resulted to mishaps, angry drivers, and occasionally deadly altercations between operators. Due to unsafe driving practices and the usage of outdated, badly maintained, overloaded, and non-standard vehicles, paratransit in developing cities is more susceptible to traffic accidents [26-28]. Paratransit operators disregard regular maintenance and reinvest in larger new vehicles because of the nature of their operations. The quality of Para transport services has been negatively impacted by this behavior, and some commuters have mostly considered it to be subpar transit [29-30].

The creation of an efficient public transportation system is hampered by a number of concerns that require both a management strategy and a structural examination of the main problems. Based on current understanding, significant initiatives and policy packages are needed to increase the percentage of travel by public transit. Recent years have seen an exceptional expansion of bus rapid transit (BRT) systems, with new implementations occurring in developing country cities. Compared to railway systems, BRT systems are more flexible and reasonably priced, and they hold the potential to stimulate economic revitalization [31-32].

An integrated system of facilities, services, and amenities that collectively improve the speed, reliability, and identity of bus transit" is how the bus rapid transit system (BRTS) is defined by [33]. It is an integrated system built for increased speed, dependability, and safety that features high-quality buses, a unique infrastructure, and a restricted mix of traffic. BRTS has a separate bus lane and limited large spacing stops compared with local buses. BRTS is provided as it has a high speed, more capacity, an increased reliability, a successful attraction of ridership, and environmental, social, and economic benefits [34].

The importance of exclusive lane for BRT vehicles. A number of lane types can be assigned for BRT vehicles, such as painted lane, bridges/tunnels, exclusive lane guarded by personnel and lane separated by separators. For the purpose of giving BRT cars priority at crossings, devices and/or traffic signs may need to be added to BRT lanes [35].

It is expected that using BRT will result in accident reduction as an overall result, some exceptions could be at intersections, and a major safety increase for the pedestrians. The safety benefits of BRT are thought to outweigh the slight reduction in bus speeds caused by safety measures [37-38]. When BRT systems replace older, poorly maintained, high-emission light buses and microbuses, air quality has improved in areas where BRT formalizes transit services, such as Latin America. In addition to competing with other modes of transportation and operators, disputes must be settled in a complex organizational setting involving multiple participants [39].

The purpose of this work is to determine how the quality of street transportation services from the Sweileh neighborhood to the Sports city roundabout in Amman, Jordan, is now impacted by small public transportation buses, or coaster buses. The purpose of the simulation is to investigate the impact of switching the route of the small public transportation buses to the BRT route. Furthermore, an analysis will be conducted to determine the effects of redirecting pedestrian traffic from the main roadway to BRT stations [40-42]. It is important to use latest techniques in modeling and construction such as Building Information Systems (BIM), together with construction resolution approach to resolve application and development of new projects in developing countries, such as Jordan [43-44].

The rest of this paper is divided as follows: Methodology, Results and Discussion, Conclusions, References.

2 METHODOLOGY

The impact of light buses on traffic, mishaps, and incidents is the source of recurring problem in Jordan, particularly in Amman. This is more closely tied to the actions of the light bus drivers than it is to the width of the road. The high emissions rate these buses emit, frequent stop-and-go situations, abrupt lane changes, a lack of stopping stations, irregular maintenance, and noncompliance with laws and regulations are some of the characteristics of light bus drivers.

Aside from the effects of their driving on other motorists, such as when they follow other vehicles in the street (bumper to bumper), which puts pressure on other drivers and could impair their performance or cause them to make poor decisions when driving, which could also result in traffic accidents, Given the aforementioned factors as well as the fact that a semi-dedicated BRT road is already in place, it may be possible to lessen the impact of light buses, lower the number of incidents and accidents, and aid in further traffic regulation.

Every previously listed item transgresses the triangle formed by the three fundamental of Intelligent Transportation Systems (ITS) principles: environment, mobility, and safety. It also goes against the productivity, throughput, and economics tenets of the second triangle in the ITS. The aim is to address such issues by moving those light buses to the BRT, which is a semi-dedicated bus route.

Thus, the goal of this work is to raise the quality of service in the area under consideration, by making the most of the current infrastructure and managing it wisely. By moving light public transportation buses to the BRT lane, thus utilizing an intelligent transportation systems approach that involves preliminary simulation and potential prediction through results projection, it is possible to reduce traffic congestion in this area and significantly improve road safety. Better mobility can also be attained, resulting in less fuel consumption and a more favorable environmental impact. This will result in improved driving conditions, improved environmental situations, improved driving environments, and improved economies. This could incentivize more people to take public transportation, which could lower the number of private vehicles on the road and improve service.

2.1 Site selection

This busy part of Amman, which has a BRT lane and numerous light bus lines (Coasters), was the study's route along Queen Rania Street, which began at the Sweileh intersection, went through the intersection of external patrol signals, and ended at the intersection of University of Jordan signals, as shown in Figure 3.

The three intersections selected for this work are identified as follows:

1. Sweileh intersection area: this area connects the capital Amman to the northern governorates (Irbid, Jerash, and Ajloun) and the Balqa Governorate. From there, it branches into the city center of Amman and the airport road, which leads to the southern governorates. A significant portion of the population uses public transportation, particularly public transport buses (light buses), to travel to the Sweileh area from all of these areas. As a result, this neighborhood is thought to be among the busiest in Amman. Thus, the presence of light busses parking at the intersection, and their intensive movement from and to this intersection, causes delays and traffic congestion, and disruption to the other intersections feeding from and supplying traffic to Sweileh intersection. In particular the two intersections closest to Sweileh, as shown in Figure 1, where Sweileh intersection (number 1), followed by the external patrol intersection (number 2), and then the University of Jordan intersection (number 3). Detailed Sweileh intersection is shown in Figure 4.

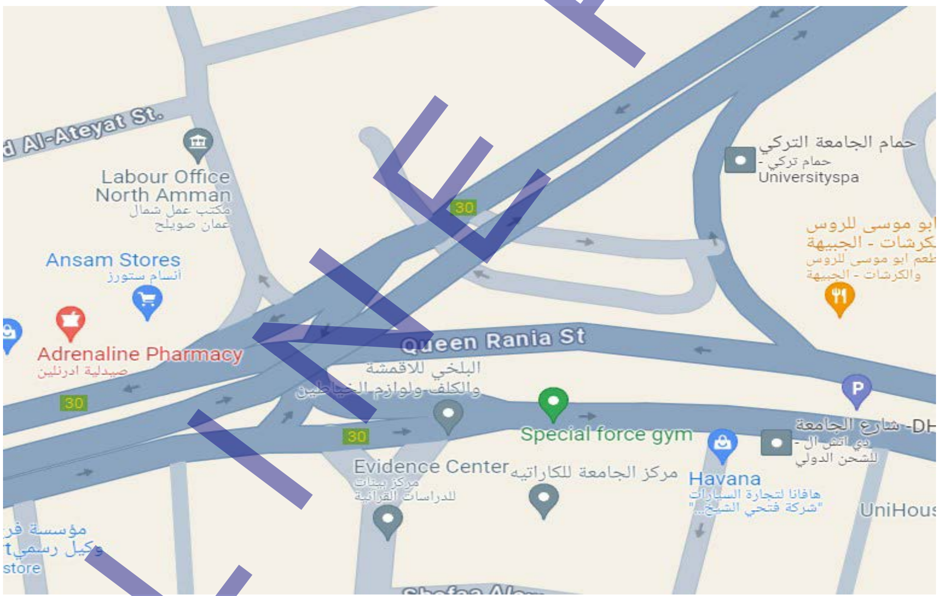

Fig. 3. The Three intersections included in the analysis

Fig. 4. Sweileh intersection adopted from Google maps

2. The exterior patrol signal intersection, which branches off to the northern Amman districts and Yajouz Road, which connects to the governorates of eastern Jordan and Zarqa, as shown in Figures 5 and 6.

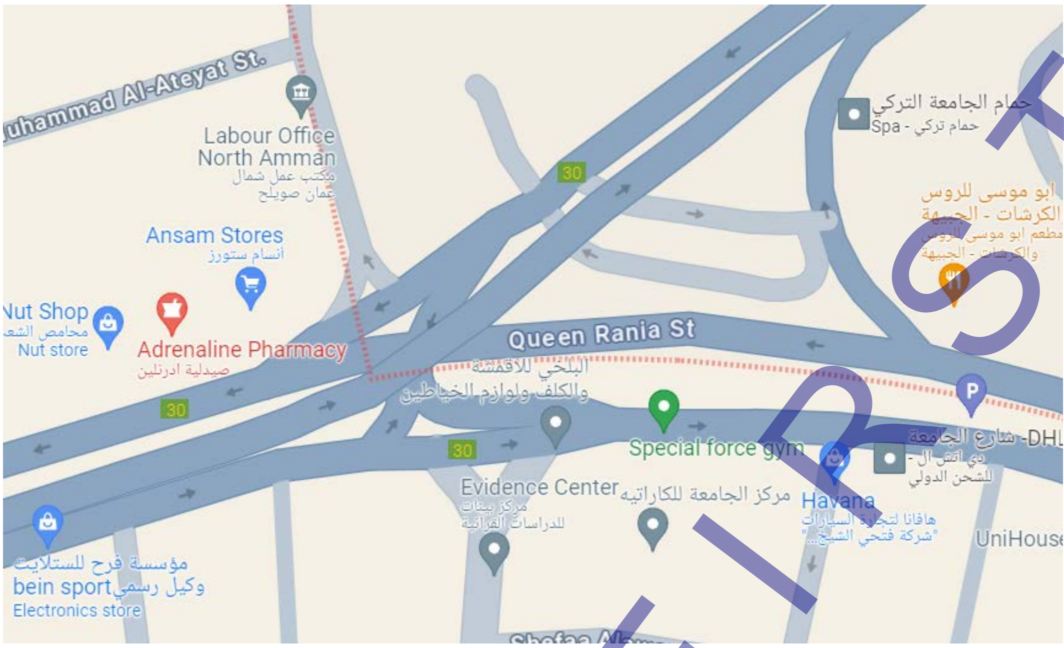

Fig. 5. External patrols intersection adopted from Google maps

Fig. 6 External patrols intersection adopted from (Sydney Coordinated Adaptive Traffic System (SCATS) from Greater Amman Municipality (GAM))

3. The intersection of the University of Jordan signals, is the third study area. It is home to the University of Jordan, which is regarded as Jordan's largest and oldest university and draws students from all over the Kingdom, this neighborhood is one of the most important ones in the city. Along the route are a number of hospitals as well as public and private institutions; an overview of the intersection is shown in Figures 7 and 8.

Fig. 7. University of Jordan intersection adopted from Google maps

Fig. 8. University of Jordan intersection adopted from (Sydney Coordinated Adaptive Traffic System (SCATS) from Greater Amman Municipality (GAM))

2.2 Data collection

One method used to gather this type of data:

1. Historical data, which came from the Greater Amman Municipality (GAM).
2. Current and real-time, practical traffic monitoring.

The collected data comprised the following variables:

1 Lane width for Main Street
2 Main street width
3 Light buses count
4 Hourly volume
5 BRT frequency
6 BRT Lane width
7 BRT lane width
8 Traffic volume
9 Signal timing
10 Detectors distribution

Figures 9, 10 show detectors distribution, which provide useful quantitative data. This data, along with the other obtained data, plays a crucial role in subsequent analysis and provides valuable insights into traffic patterns.

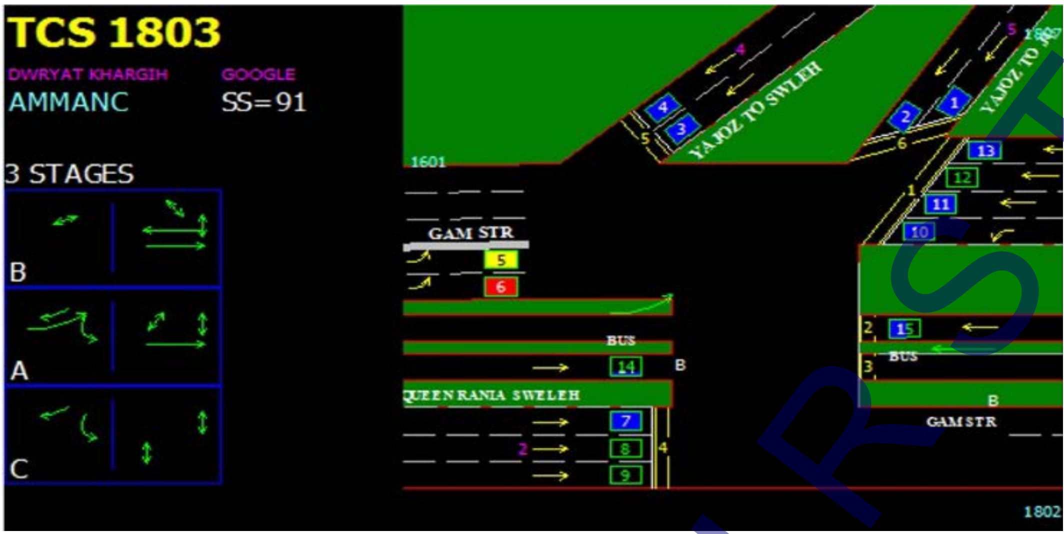

Fig. 9. Detectors distribution and lane movements at external patrols intersection

Fig. 10. Detectors distribution and lane movements at University of Jordan Intersection

3 RESULTS AND DISCUSSION

Peak hours are obtained by analyzing the traffic flow trend based on the data that collected from detectors on the signals linked to Amman municipality's control center via the SCATS program on Queen Rania Street at the intersection of external patrol signals and the intersection of the University of Jordan signals. Such peak hours are selected using the following guiding points:

1. Selecting days of the week with the highest traffic volume: this is carried out by adding all detectors volumes for each day and finding the highest two days by volume from historical data.
2. The total daily movement for each detector is calculated separately.
3. Finding the sum of traffic volume for all detectors on a typical week day.
4. Finding the hourly volume for a typical day by adding the traffic volume of all detectors during each hour.
5. Determining the peak hour (maximum hourly volume).
6. Finding the peak hour volume for each detector.

As for the Sweileh roundabout area and because of the lack of information which is due to the absence of the detectors at the intersection, data is obtained on site through localized counting of vehicles.

The impact of public transit buses on intersection delays and queue length is examined using the Vissim software. The simulation process is as follows:

1. The intersections in PTV Vissim are drawn.
2. The parameters are added.
3. The simulation covered two scenarios:

I. The current main street condition with public transport buses;
II. The proposed scenario for the main street after moving the public transport buses to the rapid frequency bus lane.

The two simulated models will be correlated.

Figure 11 shows a closer look at Sweileh intersection, where the light buses park close to the intersection, and the intention is to simulate effect of moving them to the BRT lane.

Fig. 11. Sweileh intersection adopted from Google maps.

Table 1. Vehicles volumes at each lane as shown in Figure 10.

Monday	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7
11:00-11:15	101	96	99	91	89	92	90
11:15-11:30	100	91	94	95	92	95	86
11:30-11:45	96	89	101	89	85	97	91
11:45-12:00	105	109	100	86	89	83	93
Total	402	385	394	361	355	367	360

Table 2. Light buses and the transportation line at Sweileh corridor during peak hour.

Direction of movement	Corridor							
	Zarqa'a-Sweileh		Salt-Sweileh-Amman		Baqa'a-Sweileh-Amman		Sweileh-Amman	
	To	From	To	From	To	From	To	From
11:00-11:15	8	7	6	7	8	12	8	12
11:15-11:30	6	9	8	8	6	13	9	14
11:30-11:45	5	10	7	8	9	10	7	16
11:45-12:00	8	6	5	5	9	8	10	9
total	27	32	26	28	32	43	34	51

Table 3. Total number of light buses inbound and outbound of Sweileh intersection.

Statistics	
Total light buses incoming to Sweileh intersection at peak hour	119
Total light buses outgoing from Sweileh intersection at peak hour	154

Tables 1 to 3 show:

1. There are two primary types of traffic: vehicles and light buses.
2. Many light buses use the same route as the BRT but lack a dedicated lane, which disrupts traffic and increases the risk of incidents and accidents, as they can stop wherever they choose to drop off and pick up people.
3. The information in the Tables shows that light buses are creating traffic jams at the Sweileh intersection.

Figure 12 displays the layout design of the simulation software, which uses the obtained data as inputs. Two simulation models are used:

1. Pre-transfer of light public transportation buses, the first for the main street and BRT lane.
2. Post relocation of light public transportation buses to the BRT lane.

Fig. 12. The simulation layout design using PTV Vissim.

Table 4. Simulation of the current situation before moving light buses to BRT lane..

Location		Delay	Que	LOS
Sweileh Intersection	Main Street	63.4	178.5	E
	BRT	2.36	0	A
External patrols traffic lights intersection	Main Street	169.25	512.13	F
	BRT	93.5	0	F
University of Jordan traffic lights intersection	Main Street	77.9	512.1	E
	BRT	67.15	0	E

Table 4 and Figures 13 and 14 describe the current state (Before diverting light buses to BRT lane) of the three considered intersections.

From Table IV, the following is realized:

1. The highest delay is at the external patrols intersection.
2. The highest Queue length is at the external patrols intersection.
3. The worst LOS is at the external patrols intersection.

Thus, the light buses negatively affecting not only the Sweileh intersection, but also the other considered intersections. From the previous points and as the three intersections are part of the same traffic corridor, it's obvious that the external patrol traffic light intersection is one of the main sources of traffic congestion, and it is located in the middle between the other two intersections. Hence, the light buses paths through this middle point from and to Sweileh. Due to the topology of the external patrol traffic intersection and its location, it is most affected by the light buses traffic and other traffic compared to other intersections. In addition, it is clear that Queue length increases as delay increases.

Fig. 13. Vehicles speed in (km/h) for the whole network for the current situation adopted from PTV Vissim

Fig. 14. Density in (vehicle/km) of the whole network for the current situation adopted from PTV Vissim

Table 5. Simulation of the current situation after moving light buses to BRT lane

Location		Delay	Que	LOS
Sweileh Intersection	Main Street	63.4	178.5	E
	BRT	2.36	0	A
External patrols traffic lights intersection	Main Street	169.25	512.13	F
	BRT	93.5	0	F
University of Jordan traffic lights intersection	Main Street	77.9	512.1	E
	BRT	67.15	0	E

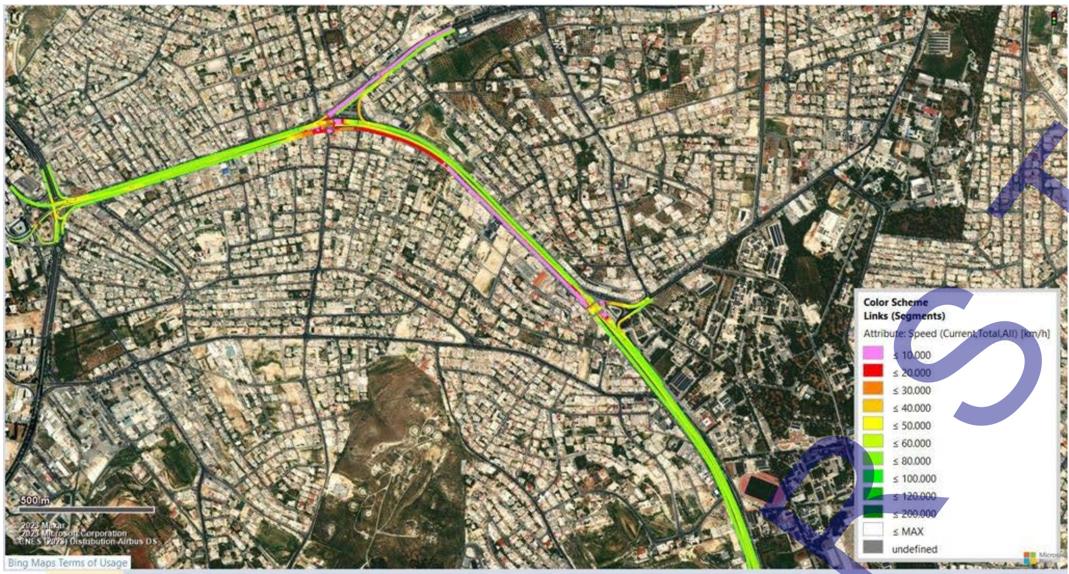

Fig. 15. Vehicles speed for the whole network in (km/h) for the proposed situation (scenario) adopted from PTV Vissim

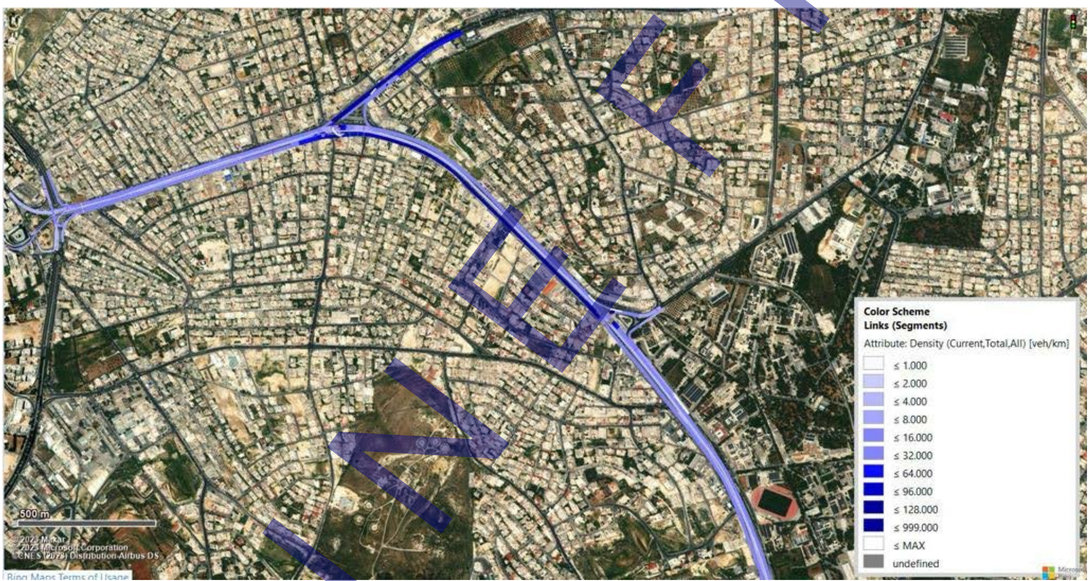

Fig. 16. The density in (vehicle/km) of the whole network for the proposed situation (scenario) adopted from PTV Vissim

Table 5, and Figures 15 and 16 describe the proposed new situation of the three considered intersections, after transferring light buses from Sweileh to the BRT lane. From Table V, the following is realized:

1. Improvement of the level of service (LOS) at the three intersections.
2. Reduction in delay at the three intersections at the main street.
3. Moderate increase in BRT delay at Sweileh area due to adding of the light buses to the BRT lane.
4. Increase in the Queue length at the BRT lane.

Table V results show that there has been an overall improvement in the LOS at the three intersections and a decrease in the main street's delay. However, there has also been a moderate increase in the BRT's lane delay and queue length, due to light buses transfer. This can be attributed to the main street's improved LOS, which occurred at the intersection of the University of Jordan and external patrols, where the BRT shares traffic lights with the main street.

Transferring light buses to the BRT lane resulted in an overall improvement in the LOS, supporting the validity of the proposed system. It also helped to enhance mobility on the route that connected the three crossings. These results also help to raise the standard of safety at every intersection. Additionally, after the suggested method is implemented, a favorable environmental impact ought to be observed. The external patrols traffic intersection, which is situated in the center of the other two intersections, has a primarily negative impact on traffic movement.

A comparative analysis of the data covering the current state and the proposed state is presented in Figures 17 and 18. The Figures show how transferring light buses will benefit both main traffic (cars) and public transportation. The reduction in delay following the transfer of light buses implicitly shortens waiting times and enhances network-wide line of sight (LOS).

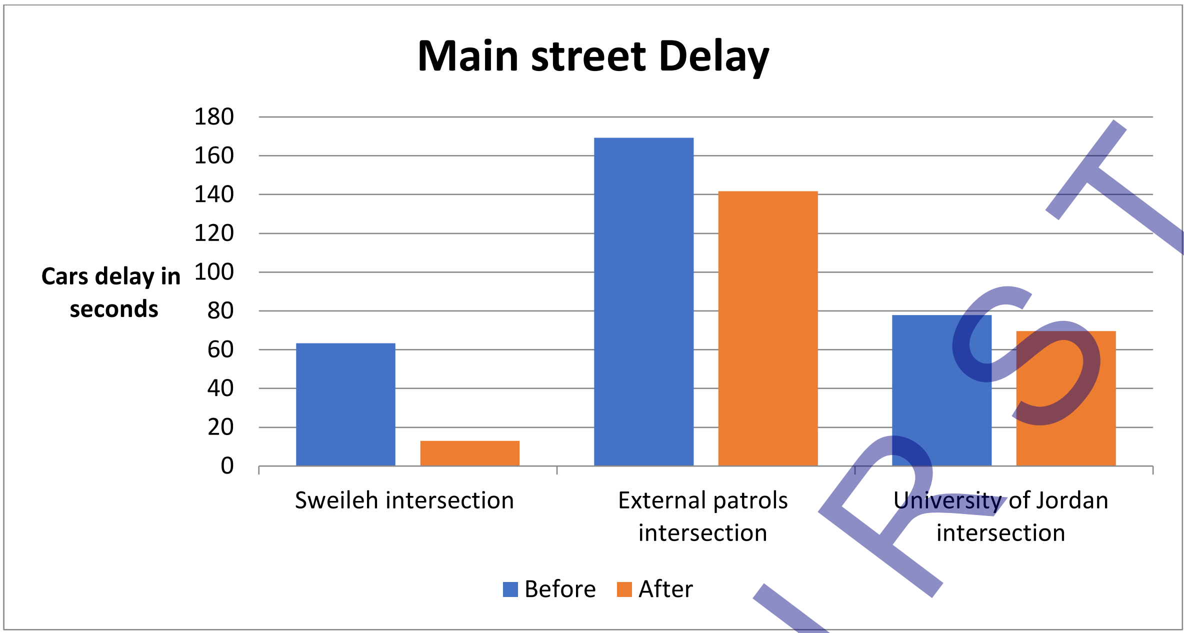

Fig. 17. Comparative analysis of cars delay for the whole network before and after applying the simulation model
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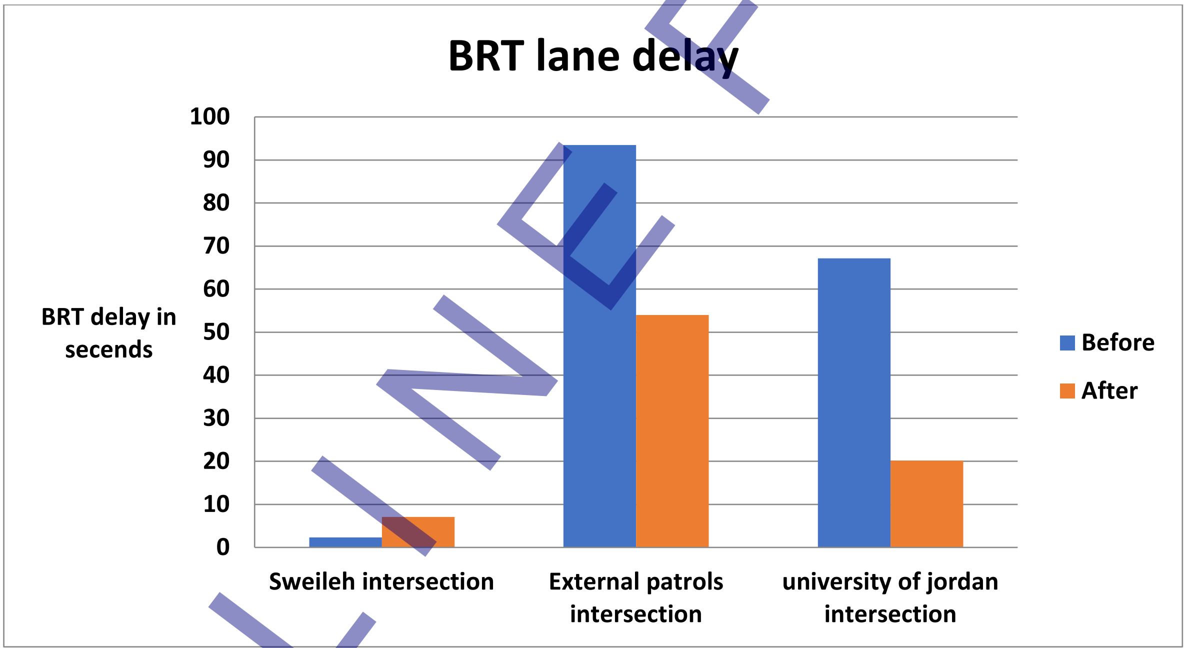

Fig. 18. Comparative analysis BRT delay for the whole network before and after applying the simulation model

4 CONCLUSIONS

The achieved purpose of this study is to evaluate how light buses affect travel times and congestion. Traffic congestion and adverse economic effects are caused by prolonged wait times and bad environmental conditions. Moving these minibuses to the bus rapid transit (BRT) lane is one option. The investigation comprised three junctions that are connected by a corridor. The University of Jordan intersection, the Sweileh intersection, and the intersection of external patrols are the intersections that are being examined. The evaluation and analysis are performed using Vissim simulation software and data collected from detectors at crossings. Both the simulation and the gathered data showed an overall improvement in mobility as a result of lower wait times and shorter lineups. An update of this kind would be beneficial to the environment. Table 6 shows measured CO2, NOx, and VOC covering the studied area of Sweileh before and after applying and simulating the proposed approach of BRT system. The values in the table show good reduction is emission after implementing a proposed BRT system.

Table 6. Comparison of emissions before and after using BRT system.

Chemical (gm)	Before	After
CO_2	9610.4	8390.8

Chemical (gm)	Before	After
NO_x	1869.8	1632.5
VOC	2227.3	1944.6

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