Improving Traffic Incident Management Using Intelligent Transportation Systems, A Case of Amman City

Wala'a Al-Khrisat[1], Nabil Hazim[2], Mohammad R. Hassan[3]

[1]Faculty of Engineering, Al-Ahliyya Amman University, Amman, Jordan
[2]Faculty of Engineering, Al-Ahliyya Amman University, Amman, Jordan
[3]Faculty of Engineering, Al-Ahliyya Amman University, Amman, Jordan
*Corresponding Author: mhassan@ammanu.edu.jo

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Abstract: The constant growth of urbanization, and the rising number of vehicle ownership, are affecting urban traffic and making accidents take place recurrently, resulting in traffic jamming, decreasing the efficiency of road network functions, and losses to the community economy. It is necessary to develop and utilize the tools of ITS like adding smart Roads-side unite (RSUs), smart sensors and Variable message signs (V.M.S) and their application to improved incidents management. In order to address this issue, a specific corridor was chosen as a study area, and all related necessary data was collected from governmental authorities, including traffic volumes and accident coordinates. A detailed analysis, and evaluation of the current situation was implemented, and case modeling were made using micro-simulation software VISSIM.10. This study presents eight multiple scenarios for traffic accidents, and improved strategies for managing traffic accidents using smart transportation tools. The results proved the effectiveness of these strategies in improving and raising the level of service on the selected corridor.

Keywords: intelligent transportation systems (ITS), Traffic Incident management, simulation, Variable message signs (V.M.S).

1.Introduction

In most countries of the world, including the Hashemite Kingdom of Jordan, the population is concentrated in urban areas and major cities, such as the capital Amman, due to the availability of services and the presence of governmental and private institutions. Amman has witnessed an increase in population growth, traffic congestion in network roads and a significant increase in the number of vehicles and an increased in the number of traffic incidents in the last few years, AS transport issues are among the most prominent challenges facing governments, Citizens and decision- makers [1]. According to the latest statistics of the Central Traffic Department (CTD) and as shown in table 1 for the year 2019 Jordan has witnessed a remarkable increase in the number of residents and vehicles, as vehicle ownership increased compared to the number of residents for one vehicle for every (58) person in 1971 and one vehicle every 6 person in 2019 [2].

Table 1: population and vehicles in Jordan

Year	Number of registered vehicles	Number inhabitants	Number of vehicles per 100,000 inhabitants	Vehicle ownership
1971	26000	1.5 million	1733.33	vehicle per 58 person
1986	232361	2.796 million	8310.48	vehicle per 12 person
2019	1677061	10.554 million	15890.29	vehicle per 6 person

Transportation Incidents or accidents sit a continuous challenge to incident management companies; traffic congestion is considered the main problem of traffic incidents. According to the annual traffic accident statistics in Jordan, the components of an accident are classified into three main elements: first, the behavior of drivers and people, secondly, vehicle breakdowns, and finally,

road faults [2]. Where the behavior of drivers and people accounted for the largest percentage by about 98.2%.

Through the increase in the population and vehicles over the past decade, the Incident management system used in Amman has become ineffective and useless; traffic congestion resulting from traffic incidents in Amman is mostly controlled manually by diverting the traffic flow with the help of traffic police. Unfortunately, this strategy is unscientific, ineffective and requires a large number of employees. besides, this strategy doesn't solve traffic congestion but rather transports it from one place to another. It is necessary to develop and utilize the tools of ITS like adding smart Roads side unite (RSUs), smart sensors and Variable message signs (V.M.S) and their application to improved incidents management, effective and speedily incident response by fast, smart detecting and restoring normal traffic operations as quickly as possible to maintain traffic flows and level of service, especially in peak periods that extend in Amman for long hours during the day. The world is turning to the implementation of intelligent transportation systems (ITS), as these systems have made a major shift in transportation, communications and management strategies[3], ITS helps to collect, organize, analyze, fusion, and share data about transportation and traffic systems for efficient and effective construction and operation of the transportation systems. These systems operate in an integrated manner to increase the efficiency and safety of road transportation systems, controlling traffic congestion, regulating traffic stations and reducing traffic incident response time are vital tools of intelligent traffic management systems, ITS are the best modern solutions to mitigate traffic congestion caused by several factors, the most important of which are traffic incidents[4]. The main objective for this study is to analyze and simulate traffic incidents in hot spots in the study area, and find effective incidents management strategies such as finding the best alternative methods and rapid and effective response to return road services to normal operation as soon as possible, thus maintaining quality levels of Service and relieving drivers' stress to avoid secondary accidents. Road users will also be provided with the state of the lane during their journey and the alternative routes available to them through variable message signs (V.M.S) .

2.Background

Traffic congestion is the situation, in which the number of vehicles trying to use a highway at any time exceeds the highway load-carrying capacity. Amman city like other countries in the world suffers from traffic congestion [5], traffic congestion has become one of the most prominent problems facing users daily in Jordan, specifically Amman [6], Traffic congestion leads to increased waiting time, reduced Level of service (L.O.S) increased air pollution and fuel consumption.

The causes of traffic congestion can be classified into two main categories, namely: Micro-level factors, macro-level factors and other random variables the first factor relates to traffic on the roads. For example, land-use patterns, income levels, car ownership and infrastructure may lead to a high level of congestion. While the other factor relates to the overall demand for road use, for example, large numbers of vehicles and people moving at the same time in limited way space, poorly timed traffic lights, bad weather, gatherings andspecial events [7].

The Incident: any event that significantly affects roadway operations infrequent event that reduces street capacity or an unusual increase in demand. Such issues involve traffic collisions, spilled cargo, disabled cars, road maintenance, and special non-emergency events. Although the difficulties commonly usually connected with road incidents consequence is passenger delay, a dangerous problem is the risk of the Possibility of secondary Collisions [8].

According to the statistics issued by the World Health Organization (WHO) and which referred to the results of accidents globally for the year 2016, that traffic accidents claim the lives of more than 35.1 million people annually, In addition to more than (50) million injured suffering from injuries that changed their lives or had long-term effects on them. Traffic accidents, increasing the level of traffic safety, and increasing the level of service are among the most important challenges facing all countries of the world, including The Hashemite Kingdom of Jordan, constitute a great burden that results in human and material depletion, Resources and great pressure on old road networks. The large and continuous increase in the number of vehicles leads to transportation problems, especially in large cities, which forces us to improve and develop the road network to reach the optimal transportation needed in any city.

The optimization and modeling of the highway network are very important; modeling of traffic is a generally used technique for transportation studies, planning, modeling, and optimization of transportation roads and systems, Simulation describes creating a business portrait that shows the relationship and similarity of characteristics of the actual problem under study [9].

The transportation simulation applications provide a beneficial way to experiment the suggested improvements in transportation management and control, also simulation enables decision-makers to avoid losing money in the infrastructure improvement before being experimented and validated, traffic simulations may be of microscopic or macroscopic nature. While the macroscopic models are illustrated passage method with aggregate quantities, such as flux and density, the microscopic models the behavior of individual drivers when interacting with their perceived environments [10].

Intelligent Transportation Systems (ITS) is an application and use of computer, electronics, and communication technologies and management strategies in an integrated manner to give travelers the knowledge and information to increase the level of safety and efficiency of the transportation systems. These systems include vehicles, drivers, passengers, road operators, and managers all interacting with each other, and with the diverse infrastructure systems to enhance the safety and capacity of road systems"[11]. ITS combine both the traditional, old systems of transport infrastructure with huge technology in information and communication systems, control devices, sensors, and high-level Algorithms with the evolution and deployment of Intelligent Transportation Systems (ITS) to enhance and improve transportation mobility and safety, decrease environmental impact, to reach an optimal transportation system Most of the modern study in Intelligent Transportation Systems .ITS has been introduced and developed to cope with the saturation situation in infrastructure and highways [12]. ITS sheds light on Automatic Incident Detection (AID) technologies, by using advancements in sensing technologies and wireless networks, new and more intelligent vehicles provide significantly to improving roadway safety and security because they can interact and communicate with Infrastructure Units (RSUs) as well as their ability to communicate with each other, vehicle-to-vehicle (V2V) communication, new developments in transportation and traffic systems contributed to the development of the traffic management system and its integration with data obtained from vehicles on the road to detect congestion accidents and transportation incidents. Recently, several technologies developed to warn drivers before transportation accidents happen and enable them to avoid traffic jams.

The effects of using a smart traffic station in controlling the Jordanian transportation system were studied using a simulated Cup-Carbon. Cup Carbon Simulator is used to model different scenarios explaining actual roads and vehicles, and scenarios were tested to choose the best route from the accident site and the closest available hospitals, in order to enhance the time rescue operations [6].

3. METHODOLOGY

The Ahmad Suleiman AL-Nejdawi Street corridor has been chosen and defined as the study area. It is considered one of the most famous and critical arterial roads in the Capital, Amman because it carries transportation volumes among the most attractive areas in Amman; Mecca Street, Al- Madina Al-Monawara Street, khalda Street and other minor streets. Moreover, it does not contain enough alternate secondary roads. This arterial road has three intersections, these intersections are the communications intersection, AL-Nejdawi intersection and The Al-Dur Al-Manthour intersection. All these intersections are controlled and managed by a completely actuated computer system by using also Sydney Coordinated Adaptive Traffic System (SCATS) and Closed-Circuit Television (CCTV) and the previously mentioned intersections are signalized intersections.

The necessary data was collected from the Greater Amman Municipality (GAM) and the Public Security Directorate (PSD). And traffic data was collected for one month period at the three intersections starting from18 July 2020, While the data collected form the Central Traffic Department (C.T.D) started from 2019 to 2020, the records and history of traffic incidents or accidents in Ahmad Suleiman AL-Nejdawi corridor and their coordinates (x, y) were taken from the unit of the Public Security Directorate ,the Jordan Traffic Institute (JTI) for the years 2015 to 2019 Where (1034) incidents or accidents were observed over the five years, distributed as shown in the figure 1.

Traffic analysis and modeling of the current situation in the morning and evening peak periods of the study area and the finding of the current service level were carried out using the VISSIM traffic analysis software. The average traffic volumes were taken for the following days: Monday, Tuesday

and Wednesday of the same week, and remaining days were excluded because they may give an inaccurate indicator of traffic volumes at the beginning and end of the week. Morning and evening peak hour were calculated depending on the automatic count of Ahmed Suleiman Al-Najdawi corridor, and by calculating the count rate for a working day for eachdirection of the road.

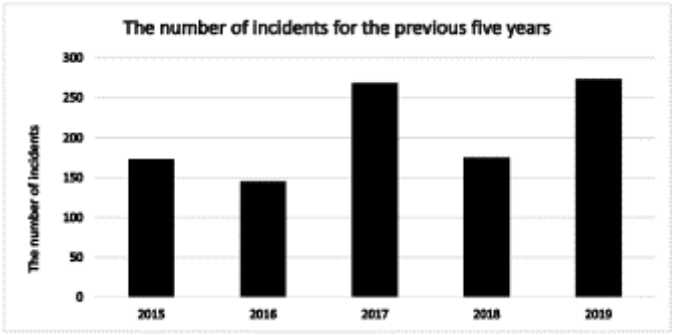

Figure 1 The number of incidents for the years 2015 to 2019

Determining the highest volume of the morning peak period (6:00 - 10:00), where the peak hour volume (9:00-10:00) with 6912(vehicles per hour) for the three intersections. And to determine the highest volume of the evening peak period (14:00 - 19:00), where the peak hour volume (16:45 – 17:45) with 7942 vehicles per hour) for the three intersections. Using a growth factor of (3%) according to what is applied in the projects of the Greater Amman Municipality to calculate future traffic in 20 years, upto 2040, then analysis of future traffic volume using the traffic program VISSIM.

The coordinates (X, Y) of traffic incidents or accidents taken from the Traffic Institute are converted global coordinates to local coordinates and projected on Google Earth. It was noticed that the study area is considered a hot area in terms of traffic incidents, especially the intersections of communications and Al-Dur Al-Manthour, inevitably form an effect on the intersection that mediates them, which is the Najdawi intersection as shown in figure 2.

Figure 2 Frequency of traffic incidents on Al-Dur Al-Manthour intersection

Based on the information of the traffic incidents history and coordination of incidents along the previous five years and projected on Google Earth, the most frequent places of incidents were observed, in light of this, two expected scenarios (strategies) were imposed for traffic incidents in critical and hot locations, where incidents are repeated and they were at the communications intersection and Al-Dur Al-Manthour intersection. As for the middle Najdawi intersection, it will be affected by both scenarios due to its location, which mediates the traffic between the other two intersections, afterward analyzing the level of service after imposing the scenarios.

VISSIM simulation was used to model both the current situation and the future traffic volumes expected for each year until 2040, to be able to calculate the average delay time for vehicles and the level of service at each intersection. An intelligent management scenario and strategy is proposed to solve the incidents problem on each traffic incident scenario, the level of service is analyzed after imposing the scenarios using the VISSIM simulation program. The results of the scenario analysis and the level of service before and after the implementation of the ITS tools in incidents management scenarios will be compared to validate the proposed solution.

4. TRAFFIC SIMULATIONS MODELS AND RESULTS

This section presents the traffic simulation results for the basic model at each intersection for the AM and PM peak hours, in current and the future situation. Also, it presents traffic incidents prediction scenarios on each of the two communications intersections and the AL-Dur AL Manthour intersection, in addition, we propose an alternative models for traffic solutions after including traffic scenarios. The level of service was chosen in terms of control delay, volume-to-capacity ratio, and queue length for each scenario.

There are two ways to validate the form; Statistical and visual verification. Statistical validation shows metrics such as value relevancy, statistical tests, and confidence intervals as validation keys. Validation, actual results and simulation work in parallel in reading true value and realized value[12], Statistical verification was used in this research; the simulation time was 60 minutes. Figure 3 shows the study area on the traffic simulation program VISSIM and the nodes 1, 2 and 3 represent the communications intersection, AL-Nejdawi intersection and Al-Dur Al-Manthour intersection respectively on the Ahmed Suleiman Al-Najdawi Corridor.

Figure 3 Ahmed Suleiman Al-Najdawi Corridor on VISSIM simulation program

In table 2 we present the traffic delay values for the intersection, in order to get the level of service for the intersections (LOS).[13], note that all the intersections within the study area are signalized intersections.

Table 2 Delay Values to Get the LOS (HCM), 2010

LOS	Delay time for the signalizedintersections (Seconds)
A	0 to 10
B	10 to 20
C	20 to 35
D	35 to 55
E	55 to 80
F	Or higher 80

The following scenarios presents all possible situations

A. **First and Second scenarios**: Traffic analysis in 2020 at AM & PM Peak. The performance and effectiveness of intersections depend on their level of service. Using the previous traffic analysis methodology, a traffic analysis was performed at the intersection under study for the existing situation in the AM Peak time (9:00-10:00) and the evening peak time (16:45 to 17:45).

B. Third and Forth scenarios Traffic analysis in 2040 at AM &PM Peak. Traffic analysis was carried out in the future situation under study for the current situation at the morning peak time (9: 00-10: 00) and evening peak time (16:45-17:45) using a growth factor of 3%.By comparing the results of

the first four scenarios we found the following results shown in table 3.

The results of traffic analysis and simulations for the first fourth scenarios that have been developed for the study area showed out that the corridor of Ahmed Suleiman Al-Najdawi is peaked in the evening hours more than in the morning hours, and it was noted from the previous summary that all factors in the evening peak are the worst at all intersections on the corridor under study.

Table 3 Summary of the first four scenarios

The scenario		AM peak		PM Peak	
		2020	2040	2020	2040
The communications intersection	Queue length(vehicle)	8.13	12.43	12.26	43.76
	Vehicle Delay time s))	27.07	31.23	35.75	77.04
	L.O.S	LOS_C	LOS_C	LOS_D	LOS_E
AL-Nejdawi intersection	Queue length	15.49	22.64	15.51	20.04
	Volume(vph)	20.06	22.92	19.87	21.51
	L.O.S	LOS_C	LOS_C	LOS_B	LOS_C
Al-Dur Al-Manthour intersection	Queue length (vehicle	4.54	9.29	5.83	9.97
	Vehicle Delay time (s)	14.66	22.98	17.19	22.47
	L.O.S	LOS_B	LOS_C	LOS_B	LOS_C
Vehicle network Performance	DELAY AVG	40.37	49.82	45.31	76.94

C. Fifth scenario: Traffic analysis with the first scenario of an expected Incident at the communication intersection.

Based on the traffic incidents records, and their coordinates, and the observation of the accident hot spots; a vehicle incident "breakdown" scenario was imposed at the communication intersection between the East and South bound as shown in figure 4.

Figure 4 location of an Incident at Communication intersection

D. Sixth scenario: Traffic analysis with proposed solution

The idea of the proposed traffic solution is by finding unconventional and smart alternatives in managing the traffic accidents process without changing or expanding the infrastructure or completely transferring congestion from one place to another and providing alternatives to the movements at the intersection in a way that ensures the smooth flow of traffic and the absence of interference with the movement of vehicles.

This is done from the moment when the incident is discovered through RSUs(sensors on the poles) located in the road which communicate and share the real-time data to the central traffic department and the traffic control room, in order to implement the alternative plan in managing the accident, in addition, to warn and inform drivers about the state of the road before they reach the accident area, and reduce their speed in order to avoid traffic congestion, and minor incident, as shown n figure 5.

Using intelligent transportation system tool (V.M.S) alternatives were provided to traffic movements on the southern approach, through the intersection preceded by the un-signalized intersection, and an alternative was provided to the movement of vehicles heading forward via the right- in/right-out intersection, and vehicles use an alternative residential road, thus connecting to the eastern approach and making a detour from it and completing its path towards the front through the right-hand movement approach. Approximately 60% of vehicle traffic has been diverted, with the aim of not transferring the total traffic from the mainroad to the residential road.

Figure 5 V.M.S Figure

An alternative to the left movement was provided through the road opposite to the right-hand movement, thus directing vehicles towards Right IN /Right OUT On the western approach, then making a detour at the intersection of the western approach and completing its way. As for the movement of vehicles on the eastern approach, only the movement of vehicles heading to the left was affected, and an alternative was provided through the rotation hatch located on the western approach. And as for the vehicles coming from the northern approach and heading towards the left, and the vehicles coming from the western approach heading towards the front, an alternative was provided for movement through the rotation hole on the southern approach

By comparing the results of the evening peak scenarios in current and future situation, showing the first incident scenario at the communications intersection and the alternative solution scenario, the result of comparison in terms of L.O.S is shown in table 4.

Table 4 Summary of the second, fourth, fifth and sixth scenarios.

The scenario		PM		PM incident in the communication intersection		PM incident solution in the communication intersection	
		2020	2040	2020	2040	2020	2040
The communications intersection	Queue length (m)	12.26	43.76	194.16	199.02	15.07	70.20
	Vehicle Delay time (s)	35.75	77.04	Vehicle Can't Move	Vehicle Can't Move	28.55	58.30
	L.O.S	LOS_D	LOS_E	LOS_F	LOS_F	LOS_C	LOS_E
AL-Nejdawi intersection	Queue length	15.51	20.04	223.28	282.59	14.04	22.15
	Vehicle Delay time (s)	19.87	21.51	27.77	30.34	18.28	22.19
	L.O.S	LOS_B	LOS_C	LOS_C	LOS_C	LOS_B	LOS_C
Al-Dur Al-Manthour intersection	Queue length	5.83	9.97	118.59	167.06	5.45	8.04
	Vehicle Delay time (s)	17.19	22.47	17.78	21.76	LOS_B	18.62
	L.O.S	LOS_B	LOS_C	LOS_B	LOS_C	15.50	LOS_B
Vehicle network Performance	DELAY AVG	45.31	76.94	1605.12	1642.41	109.13	170

E. The seventh scenario: Traffic analysis of expected Incident at Al-Dur Al-Manthour

intersection.

Based on the traffic incidents records and their coordinates and the observation of the incidents hot spots, a vehicle incident crash scenario was imposed for the vehicle at the Al- Dur Al-Manthour intersection as shown in figure 6.

Figure 6 location of expected Incident at Al-Dur Al-Manthour intersection

The incident traffic impact of the expected incident at Al-Dur Al-Manthour intersection on the corridor under study in the PM Peak is shown in figure 7

Figure 7 The incident traffic impact at Al-Dur AlManthour intersection.

F. The eighth scenario: Traffic analysis with proposed solution of expected Incident at Al- Dur Al-Manthour.

The idea of the proposed traffic solution is to provide alternatives to the movements at the intersection in a way that ensures the smooth flow of traffic and the absence of interference with the movement of vehicles. This was provided by using circumferential roads around the intersection The proposed traffic solution ensures that there are no traffic accidents and takes into account public safety, by using new light signals that help controlling the intersection, these signals remains green, they only operate in the event of an accident, and changed the status of the signal from Green to red.

The movement of vehicles coming from the northern side (all movements on the northern side except for the right-hand movement) will be diverted to Right in /Right out intersection. The same mechanism is used for the southern side. With regard to the movement of vehicles coming from the west, all movements on the approach were diverted to the right movement on the intersection , and then a backward turn and thenback to the southern approach.

Table 5 Summary of the second, fourth, seventh and Eighth scenarios.

The scenario		PM		PM incident in AL-Dur intersection		PM incident solution in the communication intersection	
		2020	2040	2020	2040	2020	2040
The communications intersection	Queue length(vehicle)	12.26	43.76	107.08	143.36	58.22	61.83
	Vehicle Delay time (s)	35.75	77.04	91.37	98.40	102.56	108.70
	L.O.S	LOS D	LOS E	LOS_F	LOS_F	LOS_F	LOS_F
AL-Nejdawi intersection	Queue length(vehicle)	15.51	20.04	160.36	193.45	18.28	23.84
	Vehicle Delay time (s)	19.87	21.51	14.14	19.36	21.84	23.85
	L.O.S	LOS B	LOS C	LOS_B	LOS_B	LOS_C	LOS_C
Al-Dur Al-Manthour intersection	Queue length(vehicle	5.83	9.97	193.88	200.96	8.81	47.58
	Vehicle Delay time (s)	17.19	22.47	Vehicle Can't Move	Vehicle Can't Move	13.41	48.51
	L.O.S	LOS B	LOS C	LOS_F	LOS_F	LOS_B	LOS_D
Vehicle network Performance	DELAY AVG	45.31	76.94	1272.13	1352	109.13	143.75

By comparing the results of the evening peak scenarios in current and future situation, showing the first incident scenario at Al-Dur Al-Manthour intersection and the alternative solution scenario, the result of comparison in terms of L.O.S is shown in table 5.

5. CONCLUSION

This study was conducted to improve the management of traffic accidents in the city of Amman, and for this purpose, eight multiple traffic scenarios were simulated and the application of Intelligent t transportation tools was carried out. Restoring the normal service process in a short time and reducing waiting times, which in turn improves the traffic process.

The results proved that the proposed alternative scenario to solve the traffic incident problem at Al-Dur Al-Manthour intersection and The communication intersection has proven its effectiveness and worked to raise the level of service and reduce the waiting time, by comparing these results with the current situation, it becomes clear that the proposed alternatives have reduced the delay time and raised the level of service for the road. This study recommends increasing the number of V.M.S in the main roads and working to increase communication between the concerned authorities and the sharing of real- time information to optimize traffic management.

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