Integrated tripartite modules for intelligent traffic light system

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ABSTRACT

The traffic in urban areas is primarily controlled by traffic lights, contributing to the excessive, if not properly installed, long waiting times for vehicles. The condition is compounded by the increasing number of road accidents involving pedestrians in cities across the world. Thus, this work presents an integrated tripartite module for an intelligent traffic light system. This system has enough ingredients for success that can solve the above challenges. The proposed system has three modules: the intelligent visual monitoring module, intelligent traffic light control module, and the intelligent recommendation module for emergency vehicles. The monitor module is a visual module capable of identifying the conditions of traffic in the streets. The intelligent traffic light control module configures many intersections in a city to improve the flow of vehicles. Finally, the intelligent recommendation module for emergency vehicles offers an optimal path for emergency vehicles. The evaluation of the proposed system has been carried out in Al-Sader city/Bagdad/Iraq. The intelligent recommendation module for the emergency vehicles module shows that the optimization rate average for the optimal path was in range 67.13% to 92%, where the intelligent traffic light control module shows that the optimization ratio was in range 86% to 91.8%.

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1. INTRODUCTION

In the years when intelligent systems were the only topic everyone was talking about, a group of few people came up with the idea of improving lifestyles and taking modern technologies into account [1]. Although traffic jams are not exceptional, both economically and socially huge losses remain [2]. The terminology of “traffic” was looked as if it would facilitate the movement of vehicles also save human life. everywhere the world, people pay just about eight. One million hours that corresponding to 40% of operating hours attributable to traffic congestion that became a significant drawback specifically in space with high population density [3], [4]

Strategies to prepare the traffic either the exploitation of traffic light that sporadically sets a set times for every street, however, it cannot be thought-about as a good solution due to increasing the congestion at a particular road that contains a high range of vehicles. Or exploitation the second methodology that depends on a human intervention that's referred to as a police officer that is additionally not a good solution. Therefore, the researchers began to realize good solutions through exploitation the trendy technologies similar to the using of cameras and putting a somebody to monitor the traffic and perhaps set an amount of time depends on his considerations, also this methodology is not a good solution because it results in human energy consumption and lack of idealization of technology [5]. These issues encourage the researchers to extend the competition to search out the best solution.

On the other hand, Traffic congestion is an over-growing problem across the world as the increasing rate of population, cars usage that is proportional thereto will increase with none road infrastructure development. Thus, there'll be an opportunity for the high accumulation of vehicles at each traffic junction and through rush-hours, it ends up in high congestion compared to traditional times. Therefore, these situations create complexities for the flow of emergency vehicles in busy hours and it raises to putting one who is needing an emergency vehicle into a critical stage. Subsequently, to erase this issue researches on totally different technologies are done and explored to monitor emergency vehicle and manage traffic flow [6], [7]

To solve this problem, two optimization-based methods particular swarm optimization (PSO) and simulated annealing (SA) are used to propose an intelligent traffic light system via optimize global vehicle travel time, throughput, and/or the number of stops at multiple intersections. As well as improve and smoothen the movement of emergency vehicles. Emergency service vehicles (like ambulance and fire truck) are one of the major services which get affected by traffic congestion. In the same category, there is more than one emergency vehicle, the far vehicle can be reached quicker than the closest. This situation can often arise if the shortest route is congested. For these purposes, the shortest route will not always lead to optimum road, emergency vehicles need well-planned advisory systems to pick the emergency vehicle to drive correctly and a convenient route beforehand. The automation, intelligent, and integrated tripartite modules traffic light system has been proposed in this work to enhance the traffic light configuration of the current transportation system. The proposed system consists of three modules as shown in Figure 1: i) intelligent visual monitoring module, ii) intelligent controlling module, and iii) intelligent recommendation module for emergency vehicles.

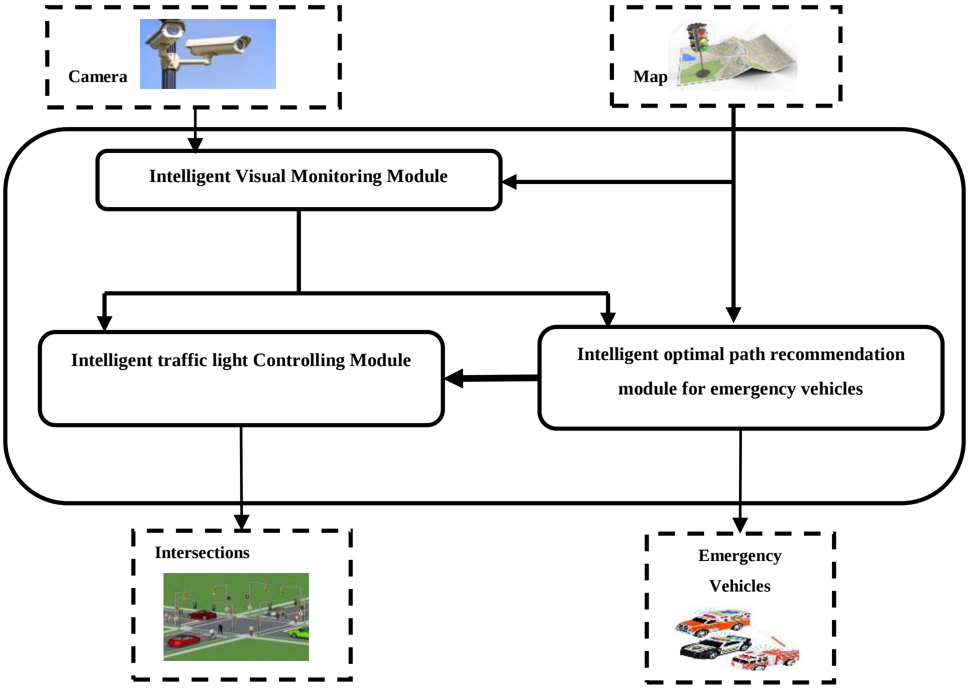

Figure 1. General framework for the proposed integrated tripartite modules traffic light system

2. RELATED WORKS

According to the techniques which are used during the last three years, many works of research have been used reinforcement learning techniques. In [8] a transfer learning-based technique for traffic signal management has been proposed. A multi-agent system has conjointly been used for modeling the traffic network. Guo *et al*. [9] shows how management agents can achieve signal coordination at the region-level. It also conducts intensive experiments on multiple scenarios. Shoeleh *et al*. [10] addresses the curse of spatiality by leverage transfer learning techniques that discover connected skills between the source and also the target tasks. It uses them to spice up learning performance within the target task. The results from experiments demonstrate that the projected technique will notice the relation between tasks and consequently transfer the obtained abstract skills effectively.

Other techniques that have been used, which are image processing and computer vision, video camera has recently been widely employed in traffic monitoring applications, providing essential traffic flow information efficiently. Furthermore, the use of video cameras is supplemented by modern technologies including computer graphics, state-of-the-art cameras, high-end computer functions, and automated video analysis for traffic monitoring [11]. Simulation program is formed in [12] for a smart traffic light system using the laboratory virtual instrument engineering workbench (LabVIEW) It intends to measure the traffic density by investigating the number of vehicles in every lane. Dubey *et al*. [13] uses algorithms reminiscent of background subtraction and Haar cascade. Data on period time traffic image, traffic density, and alternative statistics sent to the server, at any time the info may be broadcasted from the server through digital solutions. Osman *et al.* [14] presents system police work the number of cars by mistreatment cameras and image process and depend upon that the system changes the timer with time to reduce the crowded of cars on the street. Field-programmable gate array (FPGA) and intelligent systems are utilized in several applications with nice efficiency. Saleh *et al*. [15] presents an intelligent traffic light system. Image process algorithms with the assistance of infrared sensors and cameras signals used to notice traffic density. An image with an empty road and compares it with a newly captured image to find the density of cars. Nodado *et al*. [16] developed a system that employs CCTV cameras stationed at every lane of the intersection for the capturing of traffic pictures. The pictures can then be sent to the Raspberry Pi 3 micro-controller for traffic density calculation. An intelligent controller system was proposed and designed by Aljuboori *et al*. [17] to reduce the congestion on the streets. The system consists of two intelligent controllers that are designed to be the same as the human brain in resolving issues. Two main strategies are utilized in the training of the controllers: the first is that the supervised feed-forward neural networks and also the second is PSO. Iyer *et al*. [18] presents an adaptive traffic light systems can be used to alleviate traffic congestion. They detect, classify and count vehicles passing through any traffic junction using a single camera. The count of each class (2-wheelers, cars, trucks, and buses) is used to predict the signal green-time for the next cycle. The model self-adjusts every cycle by utilizing weighted moving averages.

Finally, other works used other techniques, In, a work unit stochastic priority system was proposed in Asaduzzaman *et al*. [19] by extending the green period or cutting the red period to facilitate the emergency vehicles passing through the intersection. It assigns different weights to different forms of the work unit, admires the ambulance, fire engine, and police vehicles. Abdelghaffar *et al*. [20] presents a de-centralized flexible phasing theme, cycle-free, adaptive traffic signal controller employs a Nash bargaining game-theoretic framework. The Nash bargaining algorithm optimizes the traffic signal timings at every signalized intersection. Sathiyaraj *et al*. [21] The proposed Intelligent traffic light management and deviation (EITLCD) system is predicated on a multi-agent system. The planned system consists of two systems: traffic light controller (TLC) system and traffic light deviated (TLD) system. For route pattern identification, any traditional city map will be converted to a plate-like graph used Euler's path approach. Fayaz *et al*. [22] is meant to develop a density-based mostly dynamic traffic light management. The system contains IR (infrared) sensors (transmitter and receiver) which can be mounted on either aspect of the road on poles. It gets activated and receives the signal because the vehicles pass reachable it.

For more research in this issue, Kumar *et al*. [23] solves the traffic problem on crossroads by detecting the movement of the car with the assistance of piezoelectric sensors. This smart traffic signal project needed a sensor that may sense the vehicle movement and also the range or density of the car on a particular lane of a crossing. Zigbee communication is employed to communicate between the traffic signal and the sensor. Varma *et al*. [24] presents a traffic light and also the emergency vehicles are connected wirelessly by radio frequency identification (RFID) technology that has a vary of ten meters. The fundamental plan behind the projected system is, if any emergency vehicles halt on the means because of serious traffic congestion, RFID detects the RFID labeled vehicle and sends the information to the Arduino Uno microcontroller (ATmega 328P). Lee *et al*. [25] proposed smart traffic signal control (STSC) system is designed by a unified system architecture with an road side unit (RSU) middleware that is organized by standard useful design. It is backward compatible with traditional traffic signal controller so that applications may be quick and cost-efficiently deployed while not replacing inheritance infrastructure.

Ultimately, Mahali *et al*. [26] aims to build a smart traffic light as a solution with the goal of making the prioritized vehicle journey smooth when crossing the road with smart traffic light. A few meters before crossing, smart traffic application will send the location to mobile backend as a service (mBaaS) and continue to be read by smart traffic controller using internet. The smart traffic light has three important parts, including: i) smart traffic application, ii) smart traffic controller, and iii) mBaaS. Prioritized vehicle drivers cross the road using the smart traffic application when they are in an emergency situation. If it meets the criteria of high priority vehicle, then traffic light will be changed to green in the same path. Al-abassi *et al*. [27] is to create an intelligent traffic system using radio frequency identification (RFID) technology. It was devised and deployed to ensure that fines are registered autonomously. A mobile app has also been developed to help traffic managers manage their fieldwork. Low-cost equipment such as RFID, passive tags, personal computer, and a communication system have been employed. Low-cost equipment is used for this. Finally, police officers can utilize the mobile app for various activities, such as monitoring the specific auto, the recording of a new car identity and others according to processed data.

3. INTEGRATED TRIPARTITE MODULES FOR INTELLIGENT TRAFFIC LIGHT SYSTEM

Three modules will be presented in this section in keeping with the suggested general framework of the comprehensive traffic light system as shown in Figure 1. These modules are an intelligent visual monitoring module, an intelligent traffic light control module, and an intelligent recommendation module of emergency vehicles.

3.1. Intelligent visual monitoring module

The first module for the proposed traffic light system is the monitoring module. Our previous works [28]–[30] presented an intelligent traffic light monitor modules will be used. This monitor module supplies visual data about the condition of each street in the intersection.

In these works, the monitor will be able to determine three street cases (normal street case, empty street case, and crowded street case) in addition to determining any pedestrians waiting to cross the street by using small associative memory. The monitoring module is working in two phases: training phase and recognition phase, it could work with different weather conditions depending on the stream of images, which are extracted from the street video cameras, this monitor module shows high flexibility to learn all the street cases using a little training image, thus the adaptation to any intersection can be done quickly.

After extensive study, the outputs of the above-mentioned monitoring modules can be converted into a unified truth table which in turn can be used by the other modules that are supposed to be integrated with this monitoring module. As mentioned before, these modules are intelligent traffic light controlling module and intelligent recommendation module for emergency vehicles (depends on the general framework for the proposed tripartite modules for intelligent traffic light system, as shown in Figure 1). Table 1 includes all the possible conditions of each street in the intersection includes every case (whether or not it happens logically) in addition to another one information which is “Are there any pedestrians?”. After excluding all logically impossible cases (shaded rows in the table) there will be only six cases as shown in Table 2.

Table 1. Truth table of the monitoring modules outcome

Case Code	Is this street crowded?	Is this street Normal?	Is this street Empty?	Are there any pedestrians?
0000	No	No	No	No
0001	No	No	No	Yes
0010	No	No	Yes	No
0011	No	No	Yes	Yes
0100	No	Yes	No	No
0101	No	Yes	No	Yes
0110	No	Yes	Yes	No
0111	No	Yes	Yes	Yes
1000	Yes	No	No	No
1001	Yes	No	No	Yes
1010	Yes	No	Yes	No
1011	Yes	No	Yes	Yes
1100	Yes	Yes	No	No
1101	Yes	Yes	No	Yes
1110	Yes	Yes	Yes	No
1111	Yes	Yes	Yes	Yes

Table 2. Truth table of all logically possible cases which were extracted from Table 1

Case Code	Is this street crowded?	Is this street Normal?	Is this street Empty?	Are there any pedestrians?
0010	No	No	Yes	No
0011	No	No	Yes	Yes
0100	No	Yes	No	No
0101	No	Yes	No	Yes
1000	Yes	No	No	No
1001	Yes	No	No	Yes

3.2. Intelligent optimal path recommendation module for emergency vehicles

This recommendation module uses to find the optimal path from the sources (i.e., emergency vehicles) to the destination. Figure 2 illustrated a block diagram from many sources to a single destination for the proposed recommendation module. This research proposed to use a simulated annealing SA optimization algorithm to determine the optimal path for each vehicle and choose the vehicle with its corresponding optimal path to be transferred to the destination node avoiding crowded streets (As much as possible). The closest vehicle may not reach the destination node in an optimal path.

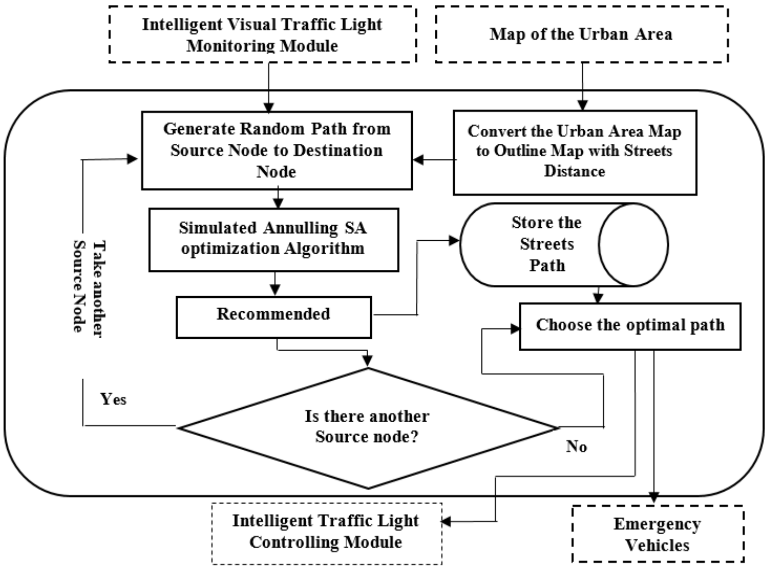

Figure 2. Recommendation module block diagram

As shown in Figure 2, the first step is to convert the urban area map to an outline map with street distance. Streets distance can be calculated from the map developers which has a simple tool (i.e. map distance calculator) that is used to draw lines on a map and measure it distances for each street between a pair of traffic intersections. The proposed module will get a random path from a source node to the destination node. SA optimization algorithm starts with a high temperature and minimizing it slowly with iteration in each temperature to get the optimal path. This process will be repeated for each source. Each path with its corresponding source gained from the SA process will be stored temporarily to be used later to choose the most optimal path with its corresponding source (emergency vehicle). The chosen path will be pass to the chosen emergency vehicle and the next module (i.e., intelligent control module) to know which streets will be used by emergency vehicles to take that into account. The details of the above process have been shown in algorithm 1.

Algorithm 1 shows that the distance value of each street for each random path has been calculated using equation 1. According to this equation, a penalty value will be added for each street distance. This penalty equal to *P* value if the street is crowded otherwise it will be equal to zero. This penalty value will decry the proposed path chosen chance which includes crowded streets. In other words, a more crowded street means more penalty value will be added causing less chosen chance to be the most optimal path. Finally, a comparison process among all the stored path gained by the SA optimization algorithm will be done to choose the most optimal path, see algorithm 1.

Algorithm 1

```
Input: SN: source node (i.e. emergency vehicles).
       DN: destination node (i.e. target place).
       m: number of source node.
       n: number of destination node.
Output: OP: is the Optimal Path from one of the source node to destination node.
       OPD: Optimal Path Distance from one of the source node to destination node.
```

Step 1: Repeat step 2 to step 4 for *m* source node, where *m* is the number of emergency vehicles.

Step 2: Get a random path RP_j (i.e. set of streets) from a source node SN_j to destination node *DN* for the jth vehicle V_j.

$$RP_j = \{St_1, St_2, \dots, St_n\}$$

Where n is the number of streets in the path.

Step 3: Calculate the summation street distance SSD_j for all street distance SD in the random path RP_j and adding the penalty value P to the crowded street.

$$SSD_j = \sum_{i=1}^{n}(SD_i + penalty) \quad (1)$$

where:

$$penalty = \begin{Bmatrix} p & if\ street\ is\ crowded \\ 0 & if\ street\ is\ not\ crowded \end{Bmatrix}$$

Step 4: SA optimization algorithm will be use RP_j and SSD_j as input to optimize the random set of street RP_j to get optimal path OP_j and optimal path distance OPD_j to be saved as optimal path and optimal path distance for emergency vehicle number j.

Step 5: Comparing among all the optimal path OP and optimal path distance OPD for all m source to choose the best optimal path OP with its corresponding optimal path distance OPD as output for this algorithm.

Step 6: End.

3.3. Intelligent traffic light controlling module

The proposed control module has been developed based on a PSO technique as shown in Figure 3. It will optimize traffic light configure for a set of urban area's intersections. The proposed control module aims to devote the green period time to the street that has the highest priority in each intersection. Street priority will be calculated based on a unified truth table. This truth table has been constructed by unifying the outcome of the monitor module and the intelligent recommendation module with the other one attribute as shown in Table 3. This table contains all the expected street traffic cases (only sixteen cases) with its aggregate priority value of street. These attributes include: i) pedestrians existence (PE), ii) crowded street (CS), iii) emergency vehicle existence (EVE), iv) street green period time (GPT) role, and v) aggregate street priority value AP. In this Table 3 aggregate street priority value AP has been calculated using (2).

$$Ap = (CS + EVE + GPT) - PE \quad (2)$$

Initially, PSO will randomly choose a set of streets (one street from each intersection). Then using the total streets' priorities, PSO will optimize this set of streets until obtaining the optimal set of streets with optimal total streets' priority. This optimal set of streets will involve the green period time until the next traffic cycle. The above process should be repeated for each traffic light cycle based on streets cases.

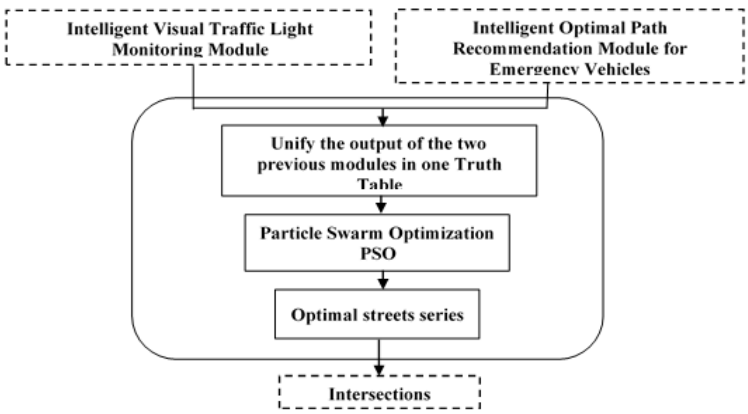

Figure 3. Intelligent traffic light control module flowchart for one traffic light cycle

The priority value for each attribute in Table 3 has been assigned experimentally. The highest priority value has been assigned to the street that has an emergency vehicle to accelerate the passage of emergency vehicles. Where the next highest priority attribute has been given to the crowded street to increase the flow of vehicles across the street. For pedestrian availability and the street role for the green period time got the lowest priority values. Each street will take its turn in the green period time only once without submitting to a specific sequence. Rather than, the role sequence will be according to the state of the streets, based on Table 3.

Table 3. The unify truth table

Case No.	Pedestrians Existence PE		Crowded Street CS		Emergency Vehicle Existence EVE		Street Green Period Time role GPT		Aggregate Street's Priority Value AP
0000	0	(No)	0	(No)	0	(No)	0	(No)	0
0001	0	(No)	0	(No)	0	(No)	3	(Yes)	3
0010	0	(No)	0	(No)	6	(Yes)	0	(No)	6
0011	0	(No)	0	(No)	6	(Yes)	3	(Yes)	9
0100	0	(No)	5	(Yes)	0	(No)	0	(No)	5
0101	0	(No)	5	(Yes)	0	(No)	3	(Yes)	8
0110	0	(No)	5	(Yes)	6	(Yes)	0	(No)	11
0111	0	(No)	5	(Yes)	6	(Yes)	3	(Yes)	14
1000	1	(Yes)	0	(No)	0	(No)	0	(No)	1
1001	1	(Yes)	0	(No)	0	(No)	3	(Yes)	2
1010	1	(Yes)	0	(No)	6	(Yes)	0	(No)	5
1011	1	(Yes)	0	(No)	6	(Yes)	3	(Yes)	8
1100	1	(Yes)	5	(Yes)	0	(No)	0	(No)	4
1101	1	(Yes)	5	(Yes)	0	(No)	3	(Yes)	7
1110	1	(Yes)	5	(Yes)	6	(Yes)	0	(No)	10
1111	1	(Yes)	5	(Yes)	6	(Yes)	3	(Yes)	13

As shown in Figure 4, the impact of 'emergency vehicles availability' and 'crowded street' was greater than other attributes. This gives more opportunity to solve the two most important challenges in this scope. On the other hand, you will not neglect the influence of other factors, which will have a chance (although they were less than the others) on the choice of the street to own the green period time, see Figure 4.

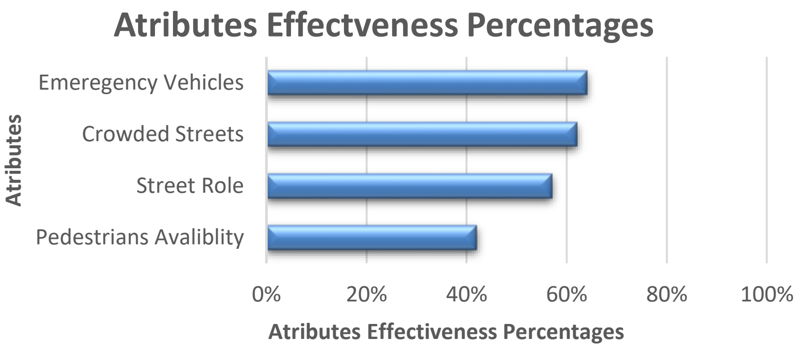

Figure 4. Attributes effectiveness percentages

In this research, the issue of the configuration of the traffic light system was overcome by a framework for a traffic light control module that could control the intersections of an urban area. The proposed module should be able to assign the green period times to a specified collection of streets, which will prioritize the streets by Table 3. In this approach, congestion and traffic flow were controlled by calculating the score of the highest priority across streets for traffic light control configuration. The proposed control module used PSO algorithm to configure many intersections in a city that will be integrated with the other two modules.

Where this score is calculated for each street according to Table 3, which has provided 4-bit values (Case Street). The smart decisions are taken when the proposed control module determines the street traffic case at the intersection based on Table 3. This table contains all the expected street traffic cases (just sixteen cases) with their priority score. Thus, the fitness function for the PSO can be calculated using (3).

$$Fitness\ Function = AP_i = (CS_i + EVE_i + GPT_i) - PE_i \quad (3)$$

When the implementation of the PSO algorithm depends on (4) and (5). Thus, the particle velocity has been calculated according to (4). Where the particle position has been calculated according to (5).

$$V_i[t+1] = V_i[t] + C_1 \times r_1 \times (pbest_i[t] - X_i[t]) + C_2 \times r_2 \times (gbest_i[t] - X_i[t]) \quad (4)$$

$$X_i[t+1] = X_i[t] + V_i[t+1] \quad (5)$$

PSO is initialized with a group of random particles (solutions) and then searches for optima by updating generations. In every iteration, each particle is updated by following two "best" values. The first one is the best solution (fitness) it has achieved so far. (The fitness value is also stored. This value is called *pbest*. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the population. This best value is a global best and is called *gbest*. When a particle takes part of the population as its topological neighbors, the best value is a local best. After finding the two best values, the particle updates its velocity and positions with (3) and (4) respectively. For each cycle, the algorithm should be stopped when a series of streets achieve the best priority score without repetition (i.e. the module can avoid choosing the same street twice).

Algorithm 2

```
Input: One-dimensional array contains the case of each the streets in the intersections
                Street numbers at intersections 1... N,    where      N<=100.
Output: The particle with Best fitness value (PBest)
Step 1: For each particle
      Initialize particle randomly.{Which it a set of streets}
          K=1, {where: K is the iteration, K <= 90}
Step 2: For each particle do
          Step 2.1: Calculate fitness value using (3)
          Step 2.2: If the fitness value is better than the best fitness value (pBest) in
              history set current value as the new pBest.
Step 3: Choose the particle with the best fitness value of all the particles as the gBest
End for
Step 4: All streets in gBest will be eliminated for the next cycle.
Step 5: For each particle do
          Step 4.1: Calculate particle velocity according (4).
          Step 4.2: Update particle position according (5).
End for
       K=K+1
Step 6: End.
```

4. RESULTS AND DISCUSSION

This section has been managed in two trends. The first trend is to evaluate the intelligent optimal path recommendation module for ambulance emergency vehicles in a large city in Baghdad-Iraq. While the second trend is to evaluate the intelligent traffic light controlling module. The results have been analyzed to have a full conceive of the efficacy of the proposed intelligent traffic light system.

4.1. Intelligent optimal path recommendation module for ambulance emergency vehicles

A large city, which was considered as a real case study by Al-Sader city in Bagdad-Iraq. The maps of Sadr City that it has been given from the Google map are shown in Figure 5. This is made up of 89 intersections and 312 streets. There are two hospitals (Jwader and Martyr Sadr) in the city. Only these hospitals have emergency vehicles. A two-source module was used to get the optimal vehicle and path from the hospital to the location of the emergency patient.

To refine this evaluation, this module has to be tested by varying rates of traffic congestion to see how effective it is to adapt to multiple traffic congestion situations to identify and pick the optimal path for the hospital ambulances over it. Thus, Sadr City was simulated with crowded streets starting from the crowded ratio starting from 10% to 90% as shown in Figure 6.

Figure 6 shows that the crowded streets ratio was assumed from 10% to 90%. The 0% and 100% ratios have been excluded because the proposed module will work on the assumption that the shortest path is optimal. This phenomenon is because within the absence of uncrowded streets or all streets are crowded, the shortest path is the optimal path. These figures also show, 10 tests will be carried out on each of the aforementioned percentages. The crowded streets are identified randomly. The emergency patients were often believed to take place randomly on the map to increase the precision of this evaluation. The proposed module will choose the best path that passes with the fewest crowded streets, taking into account the length of the traveling distance as shown in Table 4. This table has been summarized all the details of these evaluations in order of the number of crowded streets as well as the experiment number that selected Al-Jawadir Hospital ambulance or Martyr Sadr Hospital ambulance.

Figure 5. Sadr city from Google Map

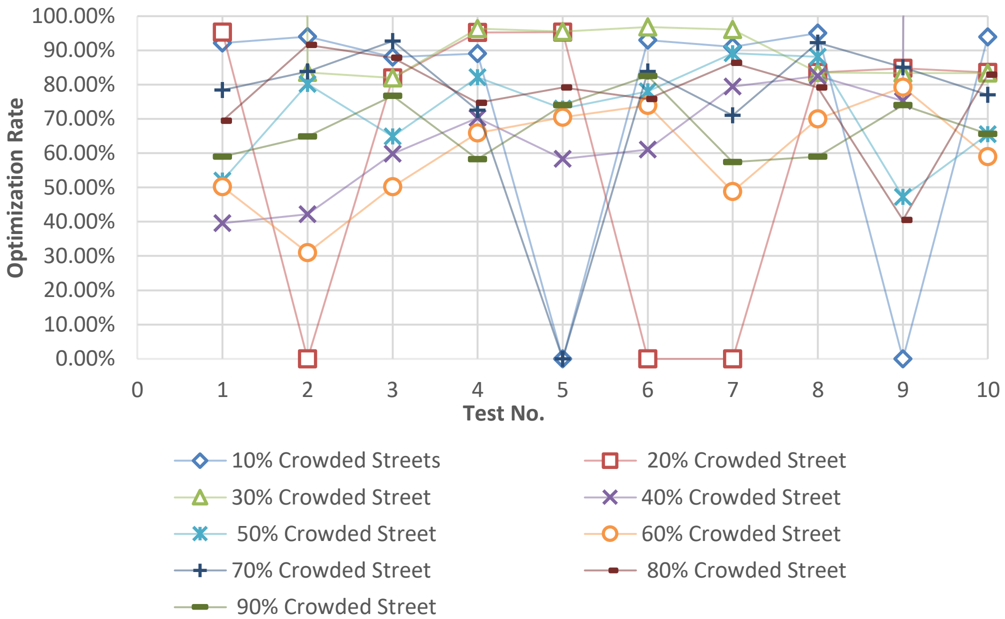

Figure 6. 10 Tests carried out on each of the aforementioned percentages

Table 4. Summary of evaluation

Crawdad streets percentages	No. of Crowded streets	Experiments No. that selected Al-Jawadir Hospital ambulance	Experiments No. that selected Martyr Sadr Hospital ambulance
10%	31	2,4,8,10	1,3,5,6,7,9
20%	62	1,2,4,5,8,10	3,6,7,9
30%	93	2,5,6	1,3,4,7,8,9,10
40%	124	3,6,8,9,10	1,2,4,5,7
50%	155	1,2,3,4,5,6,7,9	8
60%	186	1,2,3,7,9	4,5,6,8,10
70%	217	1,8,9,10	2,3,4,5,6,7
80%	249	1,2,3,8	4,5,6,7,9,10
90%	280	1,8,9	2,3,4,5,6,7,10

Figure 6 shows that the optimization rate average was in range (67.13% to 92%) for all crowded street ratio. Some of these tests had a 0 percent optimization rate. This phenomenon occurred when the randomly selected initial set of streets by PSO was the set of streets that formed the optimal path. The proposed system was therefore not finding a more optimal path. There was therefore no optimization process. Optimization's rate has been found best in (6).

$$Optimization\ Ratio = \frac{Best\ Cost}{Intial\ Cost} \times 100 \quad (6)$$

As the crowded streets ratio rose, the optimization average decreased. This decline was increased due to the decrease in the number of normal streets. This eliminates the probability of having normal streets as an alternative to crowded streets within the set of streets that are being optimized. This phenomenon is hardly clear in Figure 7.

The time needed to find the optimal path between these two hospitals was determined to show the reliability of the proposed module. When it comes to the optimal path, the considerations affected are the number of crowded streets. Thus, in 10% to 30% the number of crowded streets were less than normal streets. This makes the average time of the process of finding alternative streets to crowded streets during the optimization process in range 62.26 to 77.38 seconds.

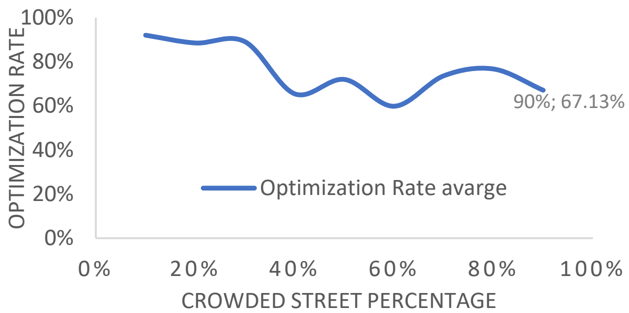

Figure 7. Optimization rate average for all crowded street ratio

In contrast, the crowded street rates from 50% to 90%, the availability of alternatives is few and, in some cases, non-existent, which reduces the time for obtaining the optimal solution based on the already available streets leading to the scene of the accident. The average time was in the range of 56.73 to 65.18 seconds. On the other hand, the small percentage of normal streets may not be available within the set of streets leading to the accident site.

In case that the percentage of crowded streets is close to the normal streets, there are many alternative normal streets available that can be a good alternative during the optimization process. This abundance requires the system to take a longer time to choose the optimal ones during the optimization process. This explains why the processing time for the proposed system increases as the number of crowded streets approaches the number of normal streets (i.e., 40% crowded streets ratio). The average process time was 267.71 seconds, as shown in Figure 8.

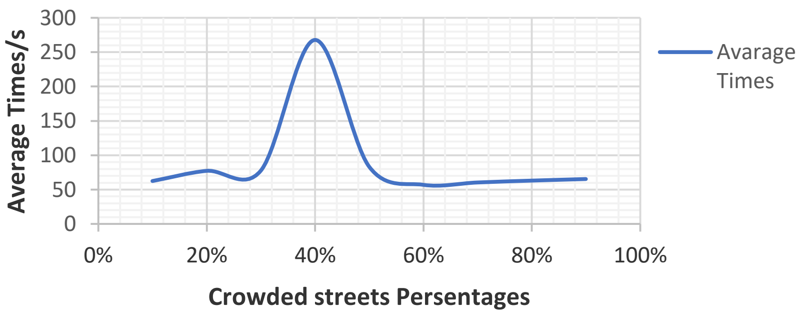

Figure 8. The average time needed to find the optimal path between two hospitals in Al-Sader city

4.2. Intelligent traffic light controlling module evaluation

The proposed control module has been evaluated using a different number of traffic lights and streets. In this evaluation, the optimization ratio has been calculated. Where, optimization ratio reflects the module's disposition to increase vehicles flow ratio by gives the green period time to the maximum number of crowded streets in a specific urban area. Optimization ratio with best aggregate street priority value has been found by calculating the percentage number for normal street according to the number of crowded streets from the chosen set of streets as shown in (7).

$$Optimization\ Ratio = \frac{No.of\ normal\ street}{No.of\ normal\ street + No.of\ crowded\ street} \quad (7)$$

In this evaluation, the proposed control module should configure the traffic light intersections all the time with more than one cycle. This means the proposed control module should reconfigure the traffic light intersections according to the shortest green period time in the traditional streets sequence. The selection of the best cycle time considers the volume, intersection configuration, approach speeds, and coordination with nearby intersections. Thus, typical cycle times 30 s to 120 s. On the other hand, the cycle time should be as short as possible in off-peak periods the 40s to 60s. While cycle times of 120 s to 150 s are often required in peak periods in urban areas (National Academies of Sciences, Engineering, and Medicine, 2015).

Thus, three types of the experiment have been presented according to the previous mentioned: the first experiment will be taking typical cycle times, the second will be for off-peak periods and the third experiment will be for peak periods using the same case study (which is Al-Sader city). As previously mentioned, Al-Sader city has 312 streets with 89 intersections. In this city, the traffic lights are configured based on the previously mentioned time period (i.e. typical cycle, off-peak, and peak). The proposed module evaluation target is the peak periods time which represents a big challenge that needs to be overcome via this proposed module.

As shown in Figure 9, the proposed module has been needed 102 seconds to proceed with the optimization process. The module reached the saturated state in the second 228 with a 95% optimization ratio. During the off-peak period time, the proposed module had no role in traffic lights configuration due to its short green period time.

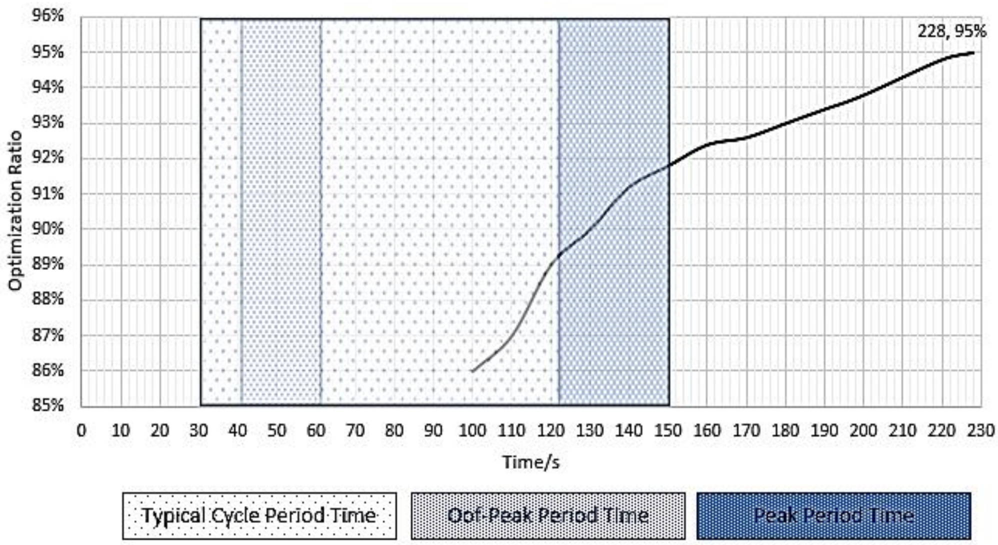

Figure 9. Proposed control module evaluation for Al-Sader city's

For the typical period times, the proposed module did not proceed with the optimization process until the second 102 with 86%, then the optimization ratio was gradually increased until the end of this period time (i.e. until second 120) with 88.8%. Fortunately, in keeping with the target for which the module was proposed, the module was able to increase the optimization ratio along the peak period. From the starter of the peak period time, the module was able to increase the optimization ratio (i.e. from second 120) with 88.8%, then the optimization ratio has gradually increased until the end of this period (i.e. until second 150) with 91.8%.

5. QUALITATIVE AND QUANTITATIVE COMPARISON

In the preceding section, it was proposed a detailed assessment of the proposed system. This evaluation included the work of each module separately and all the particulars of each module. In this section a qualitative and quantitative comparison of the proposed system work with all modules depending on the case study originally accredited in this research to determine the efficiency of the work modules of the proposed system.

5.1. Intelligent optimal path recommendation module for ambulance emergency vehicles

In this subsection, the comparison process will be depending on two factors: the first factor is the length of the optimal path in terms of the number and length of streets in this path. The proposed system leis out to obtain the optimal path by reducing the number of streets forming this path, as well as choosing the shortest one. The second factor is the cost factor of the optimal path. The cost includes the length of the optimal path. Moreover, the cost resulting from the number of crowded streets that will be included in the optimal path. Thus, the proposed system leis out to decrease the number of crowded streets as much as it can. On the other side, the proposed system concern choosing the shortest streets to construct the optimal path as well.

Based on the above, the case study that was adopted in the evaluation process will be used taking both hospitals into account. For Al-Jawadir Hospital, Figure 10(a) showed that the proposed system was able to reduce the number of streets forming the optimal path from this hospital. As for the cost, the system has been able to reduce the cost to reach the patient from this hospital, as shown in Figure 10(b). As Figure 10(c) shows, the system's ability to reduce the number of crowded streets in the optimal path from this hospital. In the same context, Figures 11(a), 11(b), and 11(c) showed the same results above for Martyr Al-Sadr Hospital respectively.

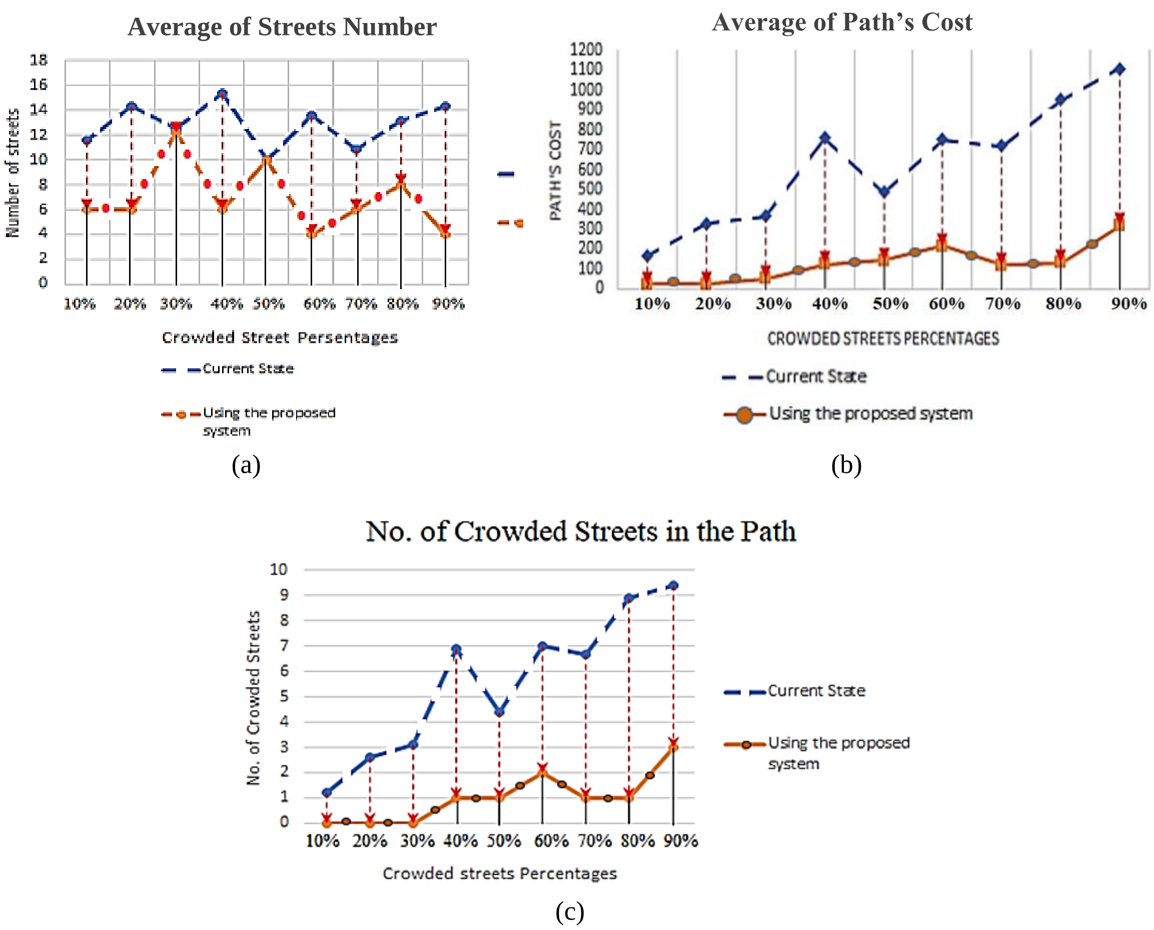

Figure 10. (Al-Jawadir Hospital) comparison between the path in current state and optimal path based on the proposed system in term of (a) average number of streets, (b) average of path's cost, and (c) a number of crowded streets

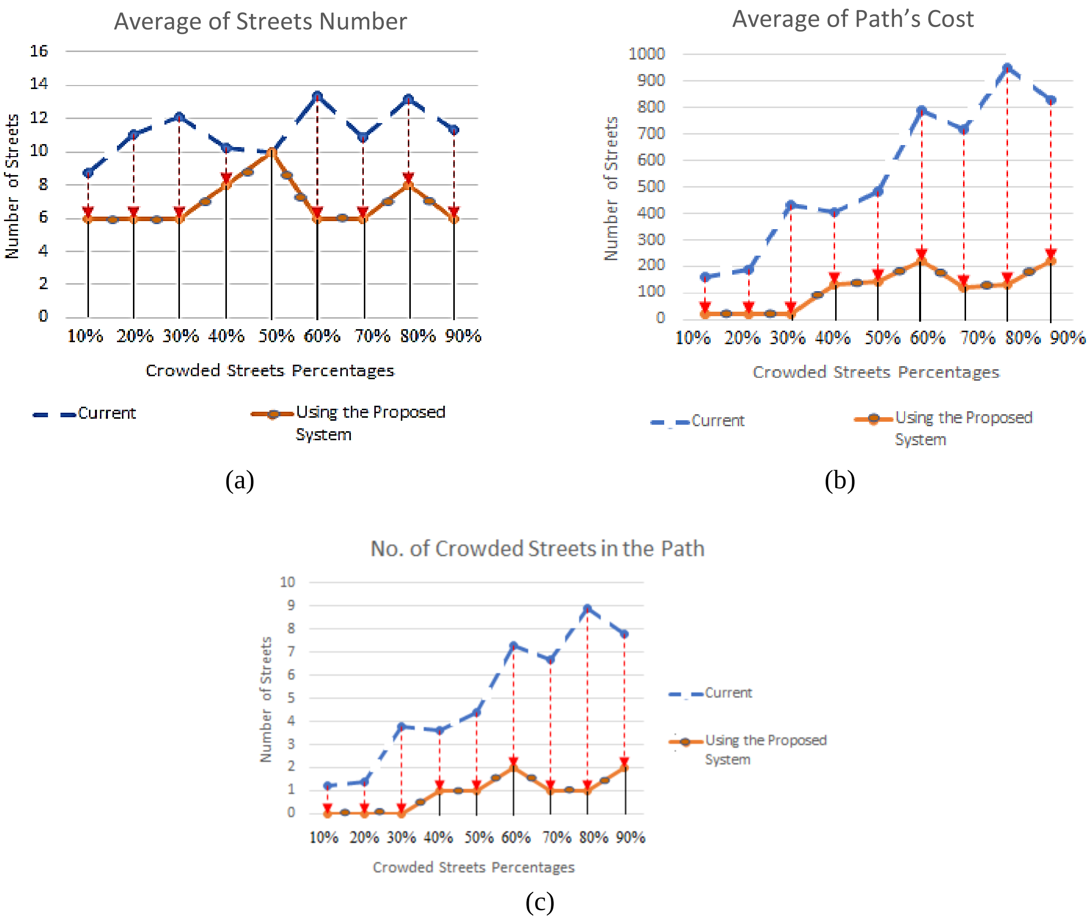

Figure 11. (Martyr Al-Sadr Hospital) comparison between the path in current state and optimal path based on the proposed system in term of (a) average number of streets, (b) average of path's cost, and (c) a number of crowded streets

5.2. Intelligent traffic light controlling module evaluation

In this regard, the system needs to increase the number of crowded streets that will be covered by the green light period during the traffic light cycle. The proposed system made sure to choose the greatest number of crowded streets to give them a green light period in each cycle of the traffic light (i.e. each street will be included in the green light period for only once in each traffic light cycle without repetition). This mechanism gives well-balanced to avoid giving the green period time many crowded streets without affecting the role of other streets in obtaining this period) avoiding the undesirable waiting period for vehicles on non-crowded streets as shown in Figure 12.

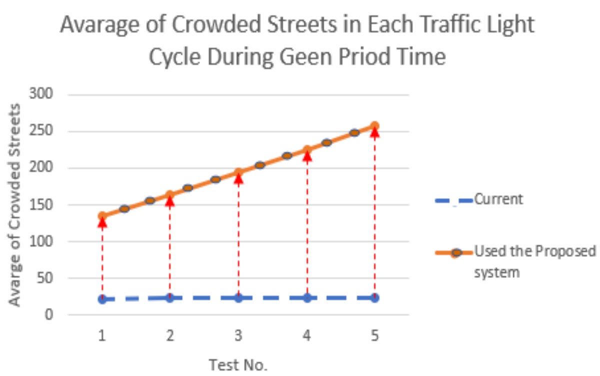

Figure 12. Average number of crowded streets in each traffic light cycle during green period time

6. CONCLUSION

The proposed system was able to make three modules integrate to avoid major challenges related to traffic flow in the streets of a particular city. The system succeeded in creating a successful mechanism for exchanging information between these modules. The efficiency of the system was demonstrated by applying it to one of the largest cities in Baghdad/Iraq. Although this city is densely populated, the system can improve the traffic flow. The system has also demonstrated the ability to regulate waiting time for pedestrians who want to cross intersection streets. On the other hand, the system was successful in raising the efficiency of transporting the emergency vehicle to the scene of the accident. This efficiency came from finding an optimal path to guide the emergency vehicles to their destination avoiding most of the crowded streets as much as it can, as well as using the shortest streets in this path. The proposed system shows a masterful balance to reconcile the length of the streets with their traffic conditions, in terms of whether it is crowded or not.

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