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Traffic Management For Emergency Vehicles

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Abstract: Traffic congestions are one of the traffic management critical point in modern cities. An inefficient traffic light system and lack of traffic control led to adverse traffic conditions. Different research studies the solutions to traffic density using the new technologies to make smart traffic light information systems. Making way for any emergency vehicle can help maximize the rescue and survival rates during the emergency operation. Therefore, the traffic light system should be designed to facilitate the emergency vehicles route and should be able to accommodate and prioritize them in the traffic. This project looks at imitating the traffic light system to accommodate emergency vehicles in one junction by using the Internet of Things (IoT) technolody. The traffic light management system will behave in a normal condition, however, would change its condition when emergency vehicles are detected and adjust the timing to allow the vehicles pass the traffic light as quickly as possible. However, different timing for the traffic light and how it will affect the whole performance was tested using Microsoft Excel. The system will provide the green signal for the ambulance by switching the signals based on the performance on the road. The results showed that the system could help increase efficiency and reduce the delay of emergency vehicles during emergency operations.

Keywords: *Arduino, emergency vehicle, Traffic congestions, IoT, radio frequency, traffic light*

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1. Introduction

In the 1990s, the concept of a smart city was coined to show how urban development turned towards technology and globalization. The intelligent traffic light system is included as one of the significant applications for implementing smart cities.

Traffic congestions are a significant issue in modern cities. An inefficient traffic light system and lack of traffic control led to unfavourable traffic conditions. Most of today's traffic is programmed by detecting the number presents of a car in a junction. Some traffic lights have a fixed length of colours in each side of the junction. This condition is not suitable for emergency vehicles that require quick and clear road to pass the traffic lights. As a result, emergency vehicles such as police cars, ambulances, and fire engines; just to mention a few, are caught in a long queue of vehicles stop at a junction waiting for green traffic light. Consequently, it delay the vehicles which does not facilitate the department to response to the emergency situation. As a result, most emergency vehicles spent much of their time in endless traffic congestion and delayed getting to their destination can result in property loss and valuable lives.

It is possible to achieve intelligent recognition, management, and perception of things and systems using

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Internet of Things (IoT) devices. It enables the development of a network that connects any everyday physical items that may be addressed individually. This research is studying the benefits of using an intelligent traffic control system and what could be the right timing to change the red light to green at the junction. Smart traffic control systems can retrieve data and adjust the desired traffic light to allow emergency vehicles to pass the green light. An intelligent traffic signal provided might guarantee the safe movement of cars to help them avoid collisions with cars and pedestrians. Furthermore, smart traffic signals can reduce inefficiency. Traffic light controllers decrease the time drivers of emergency vehicles spend waiting in endless traffic congestion.

2. Project Background

The invention of first traffic lights was gas-lit and installed in London were placed at the crossroad in 1868. The inventor, J.P. Knight, was a railway signalling engineer who got the ideas from his railway signal system. The system was 22 feet high and crowned with a gaslight for night use. Later, Americans invent the modern traffic lights [1]. In Cleveland, the red-green systems were installed in 1914. However, the three-colour signals were introduced a few years after that, in 1918. At that time, police officers operated the three-colour signals manually, using switches.

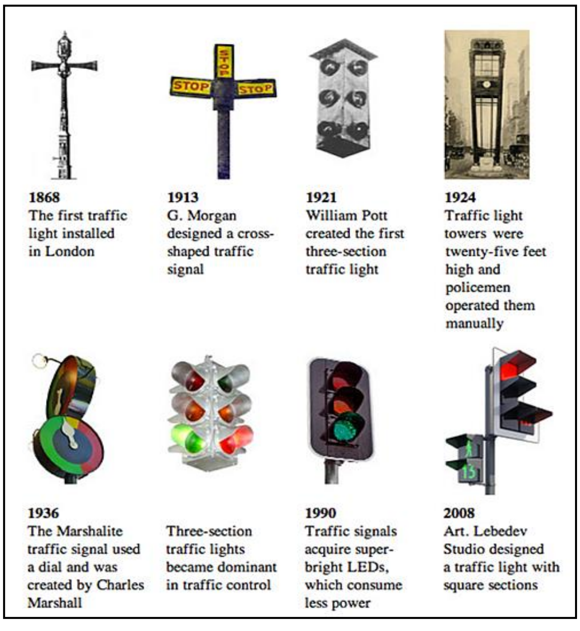


Figure 1. History of Traffic Lights Traffic Signals

In Malaysia, traffic light commonly has three leading light, red, yellow, and green. The red-light signal is used to prevent any automobiles from crossing, the yellow light denotes drivers to prepare to stop at a junction, and the green light allows vehicles to pass the junction.

Traffic lights are also called road traffic lamps, stoplights, and traffic signals, which are signalling devices placed at road junctions to control the traffic flow. Due to the rapid increase of automobiles, congestion often happens. However, congestion at traffic lights prevents emergency vehicles such as ambulances and fire trucks from passing the traffic light immediately, causing a delay that could be avoided if the traffic light had an intelligent control system.

Several types of research work on traffic management systems, especially in optimization traffic light systems. Table 1 compares methods and techniques for optimizing traffic light signals. Each research in the table applies one of the methods of Artificial Intelligence to optimize light traffic systems as indicated above. Besides, some models are based on a mathematical model, as shown above.

Table 1. Comparison of previous works on techniques for Optimizing Traffic Management for Emergency Vehicles

Paper	Technology used	Principle / Parameter	Simulator	Disadvantages / Limitations
Chao et al. [10]	Neural Network	The technique can provide an adaptive response to traffic demand and conditions like reducing delay and queue	Extension Neural Network	The whole system was difficult to be explained qualitatively
Turky et al. [15]	Generic Algorithm	The technique is able to provide timing for vehicles and pedestrians	Cellular Automata	The study proposed a dynamic optimization model that outperformed the static model.
Anokye et al. [3]	Queuing Theory	The technique minimized the delay of vehicles on the road	Mathematical Modeling	The study unable to address the unexpected drivers' disruption
Teixeira et al. [14]	Fuzzy Theory	The technique organize the flow and time for vehicles and pedistraians	Mamdani Model	Traffic lights control the crossing point for pedestrians
Babicheva et al. [4]	Query Theory	• The technique look at the flow of the traffic and alert on the maximum capacity • Minimize the delays at the signal-controlled road intersection	Mathematical Modeling	Complex mathematical apparatus is required
Mannion et al. [11]	Reinforcement Learning	• Reduce delay times and queue lengths	Adaptive Traffic Signal Control (ATSC)	Stimulated real-world traffic networks with multiple signalized

		• The new method of Reinforcement Learning for Traffic Signal Control application (RL-TSC)		junctions

3. Methodology

This study was conducted using adapting System Prototyping [2]. Four basic processes are planning, analysis, design, and implementation. The flow of the phases is illustrated in Figure 2.

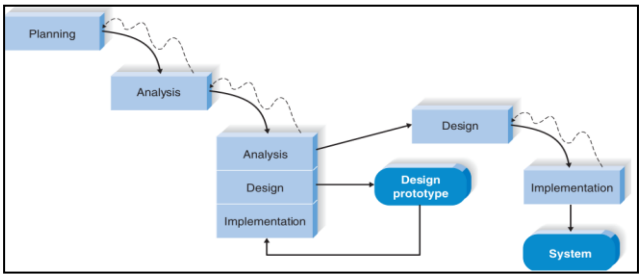


Figure 2. System Prototyping

The requirements planning phase involves acquiring the traffic management requirements for emergency vehicles. A problem was identified in the current road conditions where the emergency vehicles cannot pass the trafic light in short periods, especially during traffic congestion. The requirements of the traffic light information system will be analyzed by conducting a requirements analysis process. The activities involved in this phase are identifying the functional and non-functional requirements for the traffic light information system. Finally, an evaluation is conducted during the implementation phase to test the traffic light system and measure its usability.

4. Design and Development of Traffic Management for Emergency Vehicles

A few factors may affect the requirements specified in the Traffic Management for Emergency Vehicles. The following is a list of assumptions (1) the roads are ideal with no environmental variations like potholes, rash drivers, elevation changes, or changing weather conditions and (2) All traffic signals are visible and not malfunctioning. In addition, the following is a list of dependencies (1) the user has Google Maps installed on their mobile phone (2) the system is dependent on an Internet connection to operate. In the priority column, the following short hands are used (M) – mandatory requirements, (D) – desirable requirements, and (O) – optional requirements. Table 2 lists the functional and non-functional requirements.

Table 2. The list of requirements

No.	Requirement ID	Requirement Description	Priority
	TLS_01	**Register**	
1.	TLS_01_01	System will allow new users to register before login.	M
2.	TLS_01_02	The system must display a page that allows the user to key in their details: Username Password Confirm password Email address	M
3.	TLS_01_03	System must save all the information and send the username and password number via email.	M
	TLS_02	**Login**	
4.	TLS_02_01	System will allow users to login by key in their username and password.	M
5.	TLS_02_02	System must verify the username and password of the user.	M
6.	TLS_02_03	If the user forgot their username or password, the user must key in their email to recover the system.	D
7.	TLS_02_04	System must display a page that allow user to key in new username, password and confirm password when the user request for username and password.	D
	TLS_03	**View Traffic Light Status**	
8.	TLS_03_01	The system must retrieve current traffic light status from the database and display the current traffic light status to the user.	M
9.	TLS_03_02	**Red Light**	D
10.	TLS_03_02_01	The system displays the red-light signal to the user.	M
11.	TLS_03_03	**Yellow Light**	D
12.	TLS_03_03_01	The system displays the yellow-light signal to the user.	M
13.	TLS_03_04	**Green Light**	D
14.	TLS_03_04_01	The system displays the green-light signal to the user.	M
	TLS_04	**View Countdown Timer**	
15.	TLS_04_01	The system must retrieve current traffic light status from the database and display the countdown timer to the user.	M
16.	TLS_04_02	**Display Remaining Waiting Time**	D
17.	TLS_04_02_01	The system must retrieve current traffic light status from the database and display the remaining waiting time to the user.	M
	TLS_05	**View Speed Limit**	
18.	TLS_05_01	The system must retrieve current traffic light status from the database and display the speed limit to the user.	M
19	TLS_05_02	**Display Speed Limit**	D
20.	TLS_05_02_01	The system must retrieve current traffic light status from the database and display the desired speed limit to the user.	M
	TLS_07	Security	
21.	TLS_07_01	All the user must have own account to use this system.	M
22.	TLS_07_02	The system must ensure every user has a unique username.	M
23.	TLS_07_03	The system only allows the user to login once the username and the password are match.	M
	TLS_08	**Performance**	
24.	TLS_08_01	The system shall not take longer than 5 seconds to respond to a traffic light request for turn on or response to controller or sensors.	M
	TLS_09	**Supportability**	
25.	TLS_09_01	The system should be supportable in current equipment such as mobile phones.	M
	TLS_10	**Reliability Issues**	
26.	TLS_10_01	The system will be unavailable once the user no active for 30 minutes.	M
27.	TLS_10_02	If the system unavailable for 30 minutes, the user must key in their username and password to restore.	M
	TLS_11	**Usability**	
28.	TLS_11_01	System should be user-friendly and should provide an informative error message to inform the user when something goes wrong.	M

Figure 3. A flow chart of traffic control signals

The prototype is shown in Figures 4 and 5. The assembled traffic light and vehicle include Arduino Uno modules with LEDs to represent the traffic lights [3]. Each button can be used to control the traffic light LEDs from different directions. Figure 6 shows the interfaces of the traffic light timing system.

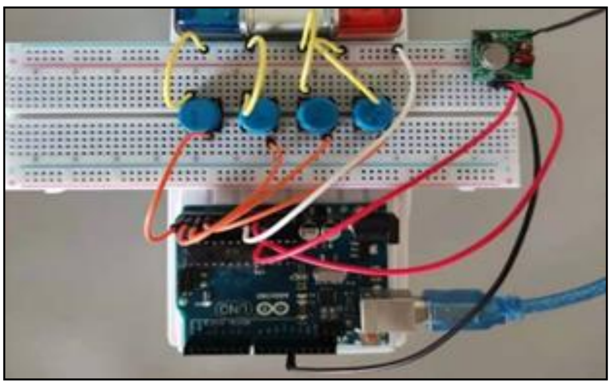


Figure 4. Assembled Emergency Vehicle

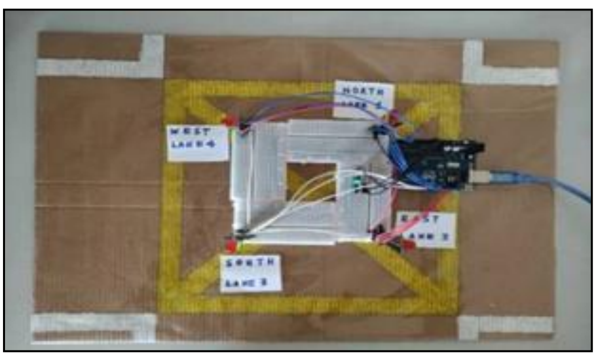
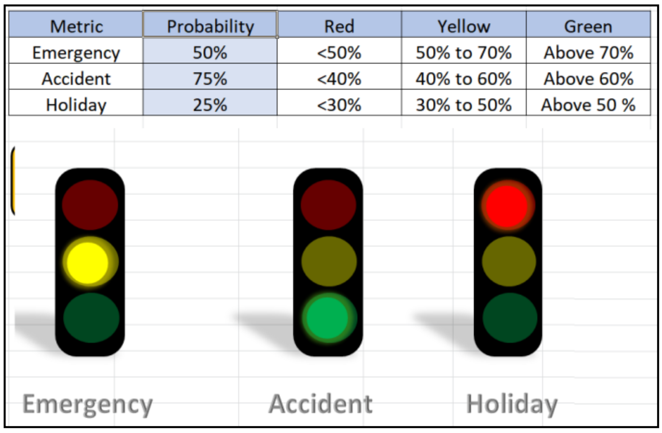


Figure 5. Assembled Traffic Light



Metric	Probability	Red	Yellow	Green
Emergency	50%	<50%	50% to 70%	Above 70%
Accident	75%	<40%	40% to 60%	Above 60%
Holiday	25%	<30%	30% to 50%	Above 50 %

Figure 6. IDE interface to check traffic light timing

Different traffic light systems' timing was calculated using Microsoft Excel to show the traffic performance. This traffic light is generated using shapes and text boxes and then linked with the data. Therefore, as soon as the value changes, Traffic Light will be on or off accordingly.

The prototype reflects the specifications set out in the preceding paragraph. Software prototyping is a common way of showing the program's specifications so that users can receive more feedback and recommendations based on their experience communicating with the prototype. Microsoft Excel was used as an integrated development environment (IDE) tool. The probability of particular light being on in different situations like normal times, emergencies, and accidents can be tested in the excel sheet.

5. Evaluation of Traffic Management

30 respondents participated in a usability evaluation for the study. The participants are given the link to the Google Form. The participants were required to read the Information Sheet and sign the Participant Consent Form before answering the questions. The instrument used for the evaluation was a post-task questionnaire. The post-task questionnaire consists of two sections to measure the usability of the system. Section I asked about the respondents' demographic and background information, while Section II asked about the respondents' opinion on the traffic light system on a five-point Likert scale where one indicates a strongly disagree, and five indicates strongly agree. The respondent carried out the following step-by-step procedure for the evaluation: (1) read and sign the consent form, (2) interacted with the traffic light system in Microsoft Excel, and (3) answered the post-task questionnaire.

A total of 73% of female and 27% of male respondents conducted the usability evaluation, and most of them were from the age group of 21 to 25 years old. Furthermore, an analysis was conducted on the respondents' responses about the traffic light system. 83% of them have heard about smart traffic light systems and think that smart traffic light systems are important nowadays.

In Section B of the post-task questionnaire, an analysis was performed on the responses of the respondents. This section tests the understanding of the respondents about the effectiveness and ease of use of the Traffic Management for Emergency Vehicles. It also measured the respondents' satisfaction with Traffic Management for Emergency Vehicles. Tables 3, 4, and 5 show the number and percentage of the responses. Most respondents rated four or five of the post-task scales for the three aspects of usability. None of the respondents rated one or two. Only a few rated neutral.

Table 3. The Respondents' Responses On the Usefulness of Traffic Management for Emergency Vehicles

Post-task questionnaire	Strongly Agree	Agree	Neural	Disagree	Strongly Disagree
Traffic Management for Emergency Vehicles increases my productivity	8 (27%)	16 (53%)	5 (17%)	1 (3%)	0 (0%)
Traffic Management for Emergency Vehicles meets my needs	10 (33%)	13 (43%)	7 (23%)	0 (0%)	0 (0%)
Traffic Management for Emergency Vehicles does everything I would expect it to do	6 (20%)	20 (67%)	4 (13%)	0 (0%)	0 (0%)
Traffic Management for Emergency Vehicles is useful in overall	9 (30%)	18 (60%)	3 (10%)	0 (0%)	0 (0%)

Table 4. The Respondents' Responses On the Ease of Use of Traffic Management for Emergency Vehicles

Post-task questionnaire	Strongly Agree	Agree	Neural	Disagree	Strongly Disagree
Traffic Management for Emergency Vehicles is easy to use	6 (20%)	20 (67%)	4 (13%)	0 (0%)	0 (0%)
Traffic Management for Emergency Vehicles is user friendly	8 (27%)	19 (63%)	3 (10%)	0 (0%)	0 (0%)
Traffic Management for Emergency Vehicles is flexible	8 (27%)	19 (63%)	3 (10%)	0 (0%)	0 (0%)
Traffic Management for Emergency Vehicles is easy to learn how to use it	7 (23%)	20 (67%)	3 (10%)	0 (0%)	0 (0%)
I can easily remember how to use it	7 (23%)	17 (57%)	6 (20%)	0 (0%)	0 (0%)
I can use Traffic Management for Emergency Vehicles successfully every time	11 (37%)	10 (33%)	9 (30%)	0 (0%)	0 (0%)

Table 5. The Respondents' Responses On Their Satisfaction with Traffic Management for Emergency Vehicles

Post-task questionnaire	Strongly Agree	Agree	Neural	Disagree	Strongly Disagree
I am satisfied with Traffic Management for Emergency Vehicles	10 (33%)	15 (50%)	5 (17%)	0 (0%)	0 (0%)
Traffic Management for Emergency Vehicles works the way I want it to work	8 (27%)	14 (47%)	8 (27%)	0 (0%)	0 (0%)
Traffic Management for Emergency Vehicles is wonderful and pleasant to use	13 (43%)	17 (57%)	0 (0%)	0 (0%)	0 (0%)

The evaluation results suggested the usefulness and ease of use of the Traffic Management for Emergency Vehicles. The respondents further reported being satisfied with the traffic light system's features. The respondents indicated that the system was easy to use without any instructions regarding the user interface, and they could easily remember how the traffic light system was used. In addition, the respondents were pleased with the functionality of the traffic light system and that it was pleasant to use.

6. Conclusion and Future Works

This paper explored the feasibility of using advanced traffic information systems in developed world cities to control traffic congestion. This program has tremendous potential to help drivers cope with congestion issues in towns. The system relies on specific theories and rules for ordering the priority and the interval of green light, the timing controller used in this proposed method, and the input to the database system is based on the data obtained from the traffic light system. Based on the traffic light status, the emergency vehicles can decide to drive more smoothly to maintain a continuous journey by decreasing their waiting time. In future, this prototype system can be modified by analyzing its limits to respond to actual traffic circumstances. Furthermore, different modules or equipment can be used in a real-life scenario to improve the prototype. Also, a larger scale of traffic management can be tested, considering the synchronization of two or more different traffic lights located in different junctions.

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