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ScienceDirect

Procedia Computer Science 238 (2024) 610–617

Procedia Computer Science

www.elsevier.com/locate/procedia

The 15th International Conference on Ambient Systems, Networks and Technologies (ANT)
April 23-25, 2024, Hasselt, Belgium

# The Importance of Implementation of Traffic Light Optimization System: Greece Case Study

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**Abstract**

In recent years, vehicle traffic has become a major issue, with a significant increase in the number of vehicles leading to congestion on urban roads and motorways. This has resulted in an increase in accidents, causing more injuries and fatalities. In particular the cases with seriously injured road users who may not survive due to traffic congestion delaying emergency services. This paper tries to analyse the importance of the response time of the emergency services during road accidents, using real data from a hybrid environment (motorway and urban road). The presented model in this research aims to identifying the traffic problems, where the traffic lights are found to cause congestion issues and high travel times, even with low traffic volumes. The implementation of a traffic lights optimization system can be a crucial element in survival chances. The study also shows that an increase in traffic volume leads to drastic traffic congestion, highlighting further the importance of the traffic light optimization system.



*Keywords:* VISSIM analysis, vehicle travel times, queue lengths, emergency services, response time, injuries, fatalities

## 1. Introduction

Due to rapid growth of world population, the demand for vehicles has increased tremendously, consequently

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10.1016/j.procs.2024.06.068

problems of traffic congestion and road accidents have also increased. The general population's life is under high risk, given the accident occurs and there's a long reaction time which increments the number of deaths. Taken into consideration the significance, an automatic accident detection system must exist to help overcome this situation. Statistics show that leading cause of death by injury is road accidents [1]. There can be multiple causes of road accidents, be it driver negligence due to drowsiness, driving while intoxicated, over speeding, etc. Some studies show that weather conditions can also contribute towards the severity of an accident such as fog, rain, high winds. High winds can directly influence the vehicle which may deviate the vehicle from road, or indirectly due to obstruction dangers present on the roads such as trees, walls etc., [1]. Road crashes can be seen as a collision between any on-road vehicles, obstacles, or pedestrians. The survival rate of victim is highly reliant on how long an ambulance takes to reach the site of the accident and then carry the patient to the hospital. In cases of road accidents, when the injuries are not severe, and the life of the victim can be rescued, due to time constrains of the rescue teams, the injuries might lead to fatality. Thus, the goal is to identify where the accident occurred, send the information to the rescue teams in considerably less time, in order to allow the necessary actions, to save the life of a person [1]. Intelligent Transport Systems (ITS) based on Internet of Things (IoT) are getting popular and can be seen as a solution to improve the road safety [32]. One effective technique to reduce traffic hazards and save precious lives could be to reduce the response time after an accident has occurred. Significant research has been carried out to address this issue and to minimize the response time following an accident [31]. Research and technology advancement to identify and address the challenges and difficulties faced by EMS (Emergency Medical Services) personnel responding to vehicular crashes is limited. Emergency response to motor vehicle collisions (MVCs) is a complex chain of events that is dependent on the cooperation of multiple parties, a characteristic which in turn overs multiple opportunities for potential improvements. Three important areas where previous research has identified and suggested potential improvements in EMS performance are: (1) response time, (2) injury type and severity prediction, and (3) dispatching optimization. In this paper we will focus only on response time.

Response time is one of the primary ways in which emergency response effectiveness is evaluated. According to the observations of the research conducted by Mahama M. N. et. al. [24], a response time less than 17 minutes was associated with 95% survival. Observations of response time not only provide an overall measure for the different system components [2], but also represent an important factor in MVC investigation—longer EMS response times are associated with higher rates of MVC mortality [3,4]. Given that one of the primary delays present in the time between MVC occurrence and EMS response is in the notification of the MVC, many efforts to reduce EMS response times have focused on the development of automatic crash notification (ACN) and advanced ACN (AACN) systems [5]. Generally, the presence of an ACN/AACN system is expected to promptly alert EMS of the crash, eliminate the time lost by indirectly alerting EMS (e.g., a 911 call being directed to a dispatching center operator, who then contacts relevant/available EMS and reiterates the contents of the call), and electronically convey accurate and pertinent information about the crash [5]. Previous research has attempted to predict the impact that ACN/AACN systems will have on response times and MVC mortality, with consensus that such systems will have measurable benefits [6–7]. However, although these previous studies emphasize the importance of reducing response times to MVCs, the information that would be needed from ACN/AACN systems to improve care is generally not specified and the analyses exclusively focus on MVC mortality. Improved response times may not only reduce fatalities, but also decrease the severity or harmful effects of non-fatal injuries [8]. Intelligent Transportation Systems (ITS) address the complex issue of effective control and management of traffic at junctions. There should be a balance between safe and effective traffic control at the intersections to allow the maximum vehicles to move through while maintaining safety [12]. Nowadays, traffic-light signalling is used to regulate traffic at crucial junctions/crossings by distributing the same green light timings to all routes [13]. The complicated architecture of traffic systems does not coordinate/link the timings of traffic signals with the average daily road traffic, which leads to congestion at the intersections.

This paper will present the importance the traffic light optimization system is in reducing intervention time of emergency services, resulting in the reduction of the deaths of the seriously injured in traffic accidents.

## 2. Traffic Light Optimization System

Various research has been carried out regarding the light optimization system issue. The work here is divided in two subcategories, in traffic data collection technologies and traffic control algorithm [29]. Traffic collection data refers to the count of vehicles, detect vehicles, detect the speed of vehicles and the ability to distinguish different vehicle types. Another challenge is how the technology could be used in a multi-lane scenario, and the bandwidth required to communicate the information to a central control. The presented technologies are not suitable to detect special vehicles such as emergency and police cars [29]. Cars in urban traffic can experience long travel times due to inefficient traffic light control. Optimal control of traffic lights using sophisticated sensors and intelligent optimization algorithm might therefore be very beneficial [30]. Optimization of traffic light switching increases road capacity and traffic flow and can prevent traffic congestion [30].

## 3. Motivation About the Study

Each year about 1.2 million people die due to road traffic crashes in the world [15]. Many of these deaths could have been prevented had there been adequate pre-hospital medical care at the right time, in the right place [15]. This fact continues to raise the importance issue of reducing the emergency response times to handle road traffic crashes. Indeed, several research works of Cabral E. L. Dos Santos et. al. [25] and RapidSos [26] have outlined the benefits of shortening response times in reducing casualties. These benefits have been commonly demonstrated with safety analysis techniques, using simulations [27, 28]. However, the wide adoption of emerging technologies (e.g., internet of things) is making unclear how emergency response times have changed over the last few decades [14]. More precisely, innovative automated, autonomous, and intelligent approaches are being deployed to optimize emergency response times. In this context, automatic accident detection and notification systems as well as intelligent traffic lights are being adopted to reduce and mitigate fatalities and severe injuries.

## 4. Study Area – Aegean Motorway Greece

Aegean Motorway has its registered seat in Larissa (Moschochori, Post Code 41500); where the main administration offices and the Motorway Management Centre are also located. There are two Operation and Maintenance Centers along the Motorway, (in Moschochori and Leptokarya) as well as two Technical Bases, (in Korinos and Drymonas). The main Network of Toll Stations along the length of the main axle includes five (5) Frontal Toll Stations at Pelasgia, Moschochori, Makrychori, Leptokarya and Kleidi. Aegean Motorway expands over 230 km of motorway (each direction), 34 km of old national road and 11.8 km of twin tunnels (the T2 tunnel is the longest tunnel in the Balkans) [16]. It operates throughout the year, on a 24/7 basis, providing drivers with a high level of service during their journeys. In 2021, a total of 22.440.000 transactions were processed, whilst the total annual average daily traffic was 9.665 [16].

We report in Table 1, a summary of accident data regarding the Aegean Motorway for the period from 01/01/2022 to 31/09/2022. During this period 490 traffic accidents have happened. These accidents have resulted into 40 slightly injured people, 2 seriously injured people and 3 fatalities in total of 30 accidents, while the remaining 460 accidents were only material damages [16].

Table 1. Aegean Motorway Accident Data.

| Aegean Motorway | | | |
|---|---|---|---|
| Total Accidents | Slight Injuries | Severe Injuries | Fatalities |
| 490 | 40 | 2 | 3 |

To investigate more in-depth incident statistics, it is important to have a picture of the response times of each emergency service. Along the Athens direction (Table 2) the statistics show that the fire department and the Traffic Police arrives at the incident locations after 17.3 minutes and 22.3 minutes in average respectively. The ambulance services take an average time of 26.3 minutes to arrive at the accident locations. The main reason of this difference lies on the fact that traffic police and fire brigades have facilities inside the motorway whereas the ambulance services are departing either from the city of Larisa, from Katerini or from the local health centres. Furthermore, patrollers need and average time of 28.2 minutes to reach the incident locations while the towing services need from 25.1 minutes (for light vehicle assistance) to 32.7 minutes (for heavy vehicle assistance). Table 2 is also showing that the average duration of an incident is estimated to 55.5 minutes, whereas the motorway closure is estimated to 82.1 minutes [16].

Table 2. Average Response Times – Athens Direction

| Athens Direction | | | | | | | |
|---|---|---|---|---|---|---|---|
| Average Response time (minutes) | | | | | | Average Duration | |
| Patroller | HV Road Assistance | LV Road Assistance | Police | Fire Brigade | Ambulance Services | Incident | Motorway Closure |
| 28.2 | 32.7 | 25.1 | 22.3 | 17.3 | 26.3 | 55.5 | 82.1 |

Table 3. Average Response Times – Thessaloniki Direction

| Thessaloniki Direction | | | | | | | |
|---|---|---|---|---|---|---|---|
| Average Response time (minutes) | | | | | | Average Duration | |
| Patroller | HV Road Assistance | LV Road Assistance | Police | Fire Brigade | Ambulance Services | Incident | Motorway Closure |
| 27.8 | 28.5 | 24.7 | 24.8 | 16.1 | 21.1 | 54.6 | 281.9 |

Furthermore, the emergency response times along the direction to Thessaloniki is reported slightly better (Table 3). More precisely, the fire department, the Traffic Police, the ambulance services, and the patrollers are arriving at the incident locations on average after 16.1 minutes, 24.8 minutes, 21.1 minutes, and 27.8 minutes respectively. In addition, the average time being taken by towing services to reach incident locations is ranging between 24.7 minutes (for light vehicle assistance) to 28.5 minutes (for heavy vehicle assistance). Table 3 shows that the average duration of an incident is estimated to 54.6 minutes on average, whereas the motorway closure is estimated 281.9 minutes [16] (much higher than the average closure time in the direction to Athens).

## 5. Experimental Design

In this research we will focus on the hybrid road interchange of Agia. The interchange is simultaneously combining an urban environment and a motorway environment. Indeed, it connects to the big city of Larisa via a motorway and connects to the city of Volos via an old national road. The users of Agia I/C can, therefore, follow all directions moving to Athens and Thessaloniki. The interchange includes traffic lights to manage the complex traffic flows. This hybrid configuration will particularly allow us to compare the performance of our solution in two complex environments at the same time. The availability of the data is an additional motivation for the selection of this interchange.

Agia includes several challenges particularly at the microscopic modelling level, like interchange spacing roundabouts, merging, and diverging areas [16]. To carry out the expected microsimulation and evaluate our scenarios we obtained the necessary data about the motorway geometries, traffic volumes and traffic compositions from Aegean Motorway database [16]. Using the above-mentioned data, we will try to understand how the traffic is distributed at the interchange, to be able we to justify the implementation of the traffic light optimization system at the I/C. Our Preliminary analysis of this data showed that the nine-month traffic volume from 01/01/2022 to 31/09/2022 reached 2,895,261 transactions from Agia I/C (Table 4). Our data showed that 93.5% (2.707.198) of these transactions were from private vehicles (cat 2), 4.8% (137.607) were from heavy good vehicles and buses (cat 3 & 4) and 1.7% (50.515) were from motorcycles (cat 1) [16].

Table 4. Agia I/C Monthly Transactions

| Monthly Transactions | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
| Transactions | 276.682 | 319.731 | 260.517 | 317.466 | 325.081 | 338.117 | 377.088 | 356.885 | 323.694 |
| Total | 2.895.261 | | | | | | | | |

To give an idea about traffic volumes, we report in Table 5 and 6, some statistics for the 6th of March and the 29th of July 2022. From the data we can deduct that there is a difference of more than 400% in traffic volume. The table is showing that traffic volume was 3.497 and 15.296 vehicles per day for the 6th of March and 29th of July respectively. It is also showing the distribution of these volumes per vehicle type. More specifically, the 6th of March transactions included 97.2 % (3.399) of private vehicles (cat 2), 1.9% (67) of heavy good vehicles and buses (cat 3 & 4) and 0.9 % (31) motorcycles (cat 1). Moreover, during the 29th of July, the transactions included 93.1% (14.245) of private vehicles (cat 2), 4.6% (692) of heavy good vehicles and buses (cat 3 & 4), and 2.3% (359) of motorcycles (cat 1) [16].

Table 5. 6th of March Traffic Volume

| 6th of March | | | |
|---|---|---|---|
| Cat 1 Vehicles | Cat 2 Vehicles | Cat 3 & 4 Vehicles | Total Vehicles |
| 31 | 3.399 | 67 | 3.497 |
| 0.9% | 97.2% | 1.9% | 100% |

Table 6. 29th of July Traffic Volume

| 6th of March | | | |
|---|---|---|---|
| Cat 1 Vehicles | Cat 2 Vehicles | Cat 3 & 4 Vehicles | Total Vehicles |
| 359 | 14.245 | 692 | 15.296 |
| 2.3% | 93.1% | 4.6% | 100% |

From the data obtained from the Aegean Motorway database [16] we identified the average lane width as 3,75m. The entry and exit ramps extended between 220m and 290m. Traffic volume data were determined for both the mainline and the on-ramp and off-ramp at each link during the 7 peak hours, between 10:00 am and 16:00 pm. Fig. 1 and 2, show the traffic volumes for the mainline as well as for the exit and entry ramps along each direction. [16].

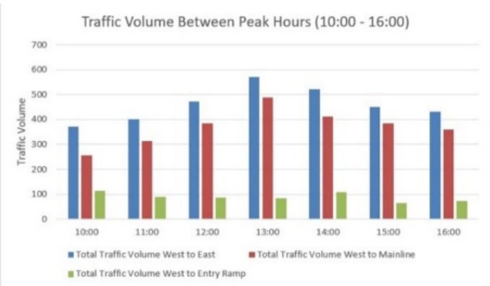


Fig. 1. Traffic Volume of Agia I/C Westbound

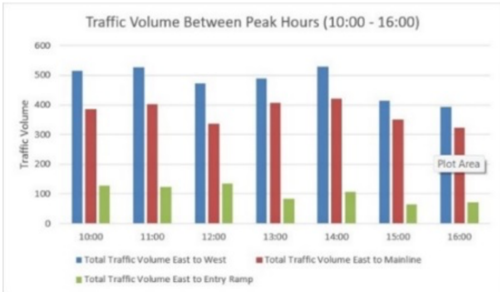


Fig. 2. Traffic Volume of Agia I/C Eastbound

On the main links, these volumes varied between 370 vehicles per hour and 572 vehicles per hour between 10:00 and 16:00. On the entry and exit ramps, the volumes varied between 65 and 128 vehicles per hour during the same period [16].

## 6. Result Analysis

The 7 simulation runs were executed with the parameters of VISSIM as well as with all the above-mentioned changes. We run the model on different times without changing the VISSIM parameters and we analysed the data base on queue lengths and vehicle travel times to identify if the desired system (traffic light optimization) can be implemented on the specific interchange and how the interchange can be affected by the implementation. Traffic light optimization system is a system that can optimize the operation of the traffic lights and decongest the traffic in the desired direction.

In order to facilitate the collection of the appropriate data, 6 different vehicle routes were created: (1) West to east (from the city of Larissa to the city of Volos direction), (2) East to west (from the city of Volos to the city of Larissa direction), (3) West to the entry ramp to Athens, (4) West to entry ramp to Thessaloniki, (5) East to entry ramp to Thessaloniki and finally (6) East to entry ramp to Athens. Although we have decent amount of data, we focus on minimum and maximum travel times inside the interchange network.


Fig. 3. Maximum and Minimum Travel Times for Different Routes

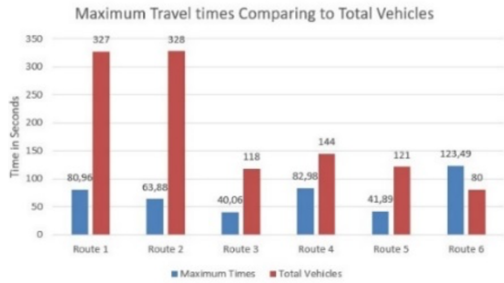


Fig. 4. Maximum Travel Times Comparing to Total Vehicles

In Fig. 3, it is presented the maximum and the minimum travel time of each route. These times vary for each route. For example, the route 3 (west to the entry ramp to Athens) is the shortest route and we see no delays comparing to route 6 (east to entry ramp to Athens) where a vehicle needs more than two minutes to go through the network. Comparing the two edge values, we see that there is a difference of almost two minutes into the same network.

Regarding the maximum travel times, it is imperative to mention that the time is high for all the seven hours where the research is conducted. In other words, there was no gradual increase, but the time was constantly high. In Fig. 4, we see something interesting. Indeed, although in some routes the number of vehicles is quite significant, the total travel time is low given only one traffic light on the specific route. For instance, on the one hand on route 1 we have a total of 327 vehicles, but the travel time is 81 seconds. On the other hand, on route 6 although we have 80 vehicles only, the total travel time is more than 2 minutes. We need to mention that on route 1 there is only one traffic light whereas for the route 6 there are two traffic lights that vehicles should pass through. There is a clear indication that the number of traffic lights play a crucial role to the total travel time of a vehicle. The more the traffic lights, the longer the vehicle travel times, even in cases of considering the same intersection. Certainly, traffic volume is important, but if there are no traffic lights, we have shorter delays [23].

Regarding the queue lengths data, five different queue counters were fitted to the network, where the traffic lights are located. For the sake of the study, we are also going to focus on minimum and maximum queue lengths inside the interchange network. These queue lengths are depicted on Fig. 5.

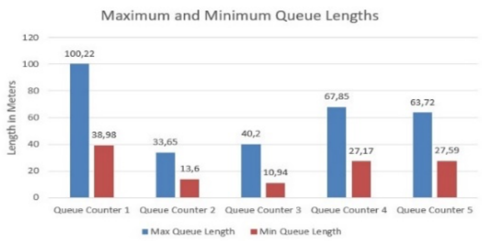


Fig. 5. Maximum and Minimum queue Lengths for Different Queue Counters

In this Figure the situation is different compared to Fig. 4, in which we saw the maximum and minimum travel time of the vehicles. We see indeed bigger variations in values in each queue counter. The shorted queue length is around 40m and the longest one (for the same counter) is 100m (which means 2,5 times longer). It is very important to note that on route 3, even though we have the longest queue and the most vehicles, we observed the shortest travel times. This shows again the importance of multiple traffic lights. According to the ADOT [23] (where the pros and the cons of traffic signals are analysed), traffic signals can reduce the number of angle collisions at an intersection. They can also cause an increase in other types of accidents, notably rear-end collisions [23]. In addition to an increase in accident frequency, traffic signals can also cause excessive delays [23].

## 7. Conclusions

In this research a microscopic simulation model was presented, to find the vehicle travel times and the maximum queue lengths at the Agia I/C. This intersection presented several challenging features including: two entry and two exit motorway ramps in each direction and different types of vehicle composition and speed limits. The goal was to explore the traffic situation at Agia I/C and explore if the traffic light optimization system can be implemented at this specific interchange and consequently avoid delays for the emergency service vehicles. We demonstrated the required procedures, which include gathering processing field data and microscopic simulation using the VISSIM software. The model was developed by building the base model and using the traffic volumes and speed values of each road segment. It was concluded that the VISSIM microsimulation model with default parameter values for some network settings can replicate the field conditions.

After multiple simulation runs with the same parameters, the results showed us the traffic condition at Agia I/C on that specific date. In conclusion, several important findings result from the simulation can be summarized as follows:

- Using our model, we have seen that although we have not such high traffic volumes at the interchange, traffic lights can create queue problems and high travel times inside the interchange. Indeed, two minutes delay may seem a short time, however when we are talking about emergency response times and human lives, every second counts. Reducing the response time of emergency services by two minutes and more using the traffic light optimization system, we can increase the chances of survival of the injured people.
- Furthermore, our experiments showed that an increase in the traffic volume will increase traffic congestions drastically. The implementation of the traffic light optimization system is therefore necessary to help emergency services to enter the motorway as fast as possible. To meet this goal our future works will focus on using our model for further investigations.

In this paper we were able to identify the size of the traffic problem at Agia interchange and future traffic problems that may occur. The implementation of the traffic light optimization system is a must and will help us to avoid vehicles delays and especially emergency services response times. Shorter response times automatically means better survival chances of injured people. The use of this system will certainly reduce the response times of all involved in the various accidents and make the motorway even safer.

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