# Development of Rewarding System for Solving Traffic Congestion in Saudi Arabia

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***Abstract*** **– Traffic congestion impacts economics, health, and productivity. Traffic congestion is increasing in the urban areas and negatively impacts people in these areas due to air pollution, accidents, delays in travel time, and more. In Saudi Arabia, more than 500,000 people have died or been injured because of traffic. To improve this problem, we developed a rewarding system that encourages people to drive during off-peak hours. In addition, the system provides recommendations for a preferred departure time in order to avoid traffic congestion. Recommended departure time is based on historical data. This system will be used to create dataset of drivers and traffic information in order to build an intelligent recommendation system**

***Keywords*** **– Rewarding system; traffic; tracking system; traffic data.**

## 1. Introduction

Congestion is defined as an excessive mass or quantity [1]. It describes the movement of a large number of vehicles at the same time in the same location and it causes a traffic jam [2], thereby, slowing the motion and increasing travel time. Congestion is growing concern in urban areas, where population density is very high. The worst example of car congestion happened in China in August 2010, when cars were stuck in a traffic jam for three days, the congestion was caused by too many trucks clogging the road [3].

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In another traffic jam that happened in India in 2018, cars were stuck in traffic for 12 hours due to heavy rain. Traffic congestion causes accidents, air pollution, increases in travel time, and more.

The number of deaths worldwide that are caused by traffic in the world is increasing. The World Health Organization (WHO) reported that 1.35 million people died because of road traffic 2018; 90% of whom are from low-to middle-income countries. Almost 3,700 people die each day due to traffic. Road traffic is categorized as the eighth leading cause of death, and these rates are to continue to increase in 2020 [9].

In Saudi Arabia, 564,762 people died or were injured in road traffic accidents between 1971 and 1997, which is equivalent to 3.5% of the total population in Saudi Arabia. WHO estimated road traffic deaths in 2013 to be 7,898; actual reported numbers were 7,661 people [9]. Based on the Ministry of Health, 81% of hospital admissions are due to road traffic accidents. In addition, 79.2% of patients were admitted to Riyadh Armed Forces Hospital with spinal injuries caused by vehicle accidents, which highlights the urgent need for traffic congestion solutions [10].

Traffic management is a research field concerned with traffic operation improvements to increase transportation safety and efficiency; an example of technology related to this field of study is the traffic controlling system, which controls traffic lights in fixed-time intervals. Such a system does not consider emergencies or utilizing empty roads. However, intelligent traffic management systems use different technologies, hardware, and algorithms to efficiently control traffic lights [7]. For example, if the sensor detects no car at a specific intersection, traffic light on busier streets are prioritized and allowed to stay green longer, thereby avoid traffic congestion on busy streets.

Research has been conducted to improve traffic. Real-time applications, such as Waze, Google Maps, Go-traffic provide real-time feedback on traffic. Wireless Sensor networks (WSNs) based systems is a trendy field that has been adapted to avoid traffic, control traffic lights to prioritize emergency cars, and reduce the waiting time for cars at intersections [7]. Internet of Things (IoT) is an application of WSN systems. Javaid et al. proposed a hybrid smart traffic management system, which inputs traffic density and analyzes the information to manage traffic signals. This system also uses algorithms to predict traffic, and it uses different sensors in the event of emergencies such as a fire [11].

A separate approach to improving traffic is the use of incentive systems, which relay on rewards and penalties. Padhariya et al. developed the E-VeT system, which rewards vehicles that follow system-assigned longer paths and penalize those that follow the shorter path [12]. Another approach uses positive incentives (i.e., rewards drivers when they avoid peak hours) to change driver behavior [13].

Even though conducted work has been done in this area, to the best of our knowledge, none has been conducted for Saudi Arabia specifically. There is no historical data that can be used to improve road traffic, and there is no rewards-based application with local third-party business affiliates available for Saudis. Therefore, our developed application will be the first step toward an intelligent reward system that will improve traffic congestion in Saudi Arabia.

We propose an incentive system that rewards users for following the provided recommendations based of historical data. It encourages driver to drive off-peak hours using rewards approach, and it allows users to schedule their trips, and get traffic information ahead of time. Traffic information derived from Google Maps and users who share traffic data when using the application; data will be analyzed and recommended departure times will be automatically sent to users. Thus, drivers will be able to register all their trips and plan their day based on the given recommendations.

If each driver follows the recommendations, points will be added to their account, and these points can then be redeemed with the business partners (supermarkets, gas stations, airlines, etc.). To build a system that will provide accurate times and routes to avoid traffic congestion, data will need to be collected and analyzed, so we designed our system to collect driver and traffic data in one centralized database. The main contributions of this work will be:

- Develop a phone application that notifies users on real-time traffic conditions for registered trips.
- Develop a rewarding system to encourage drivers to re-schedule their trips in order to avoid traffic congestion.
- Collect traffic data to develop an intelligence recommendation system.

## 2. Related Work

A traffic management system (TMS) is concerned with the operation of traffic to minimize congestion and maximize safety and efficiency. A TMS collects traffic data from different sources, such as roadside cameras, vehicles, and sensors. Data is then analyzed and a solution for more efficient traffic is provided. A TMS consists of a set of applications and tools to integrate different traffic-related technologies. De Souza et al. conducted a comprehensive study to classify and review TMS applications [8]. They classified these applications based on the communication architecture, which is either infrastructure-free or infrastructure-based. The first includes cooperative congestion detection [14], [15], [16], congestion avoidance [17], and accident detection and warning [18] and the latter includes traffic-light management [20], [21], route suggestion [22] congestion detection [23], [28], and re-routing and speed adjustments [20], [21].

An intelligent traffic management system is a subset of TMSs that depends on technologies, hardware, and algorithms to optimize traffic control systems. Shinde and Jagtap conducted a comprehensive study on intelligent traffic management systems [4]. One method depended on VENET (Vehicular Ad Hoc Network) to design intelligent systems [24], and others made use of infrared signals to track vehicles and detect violations [25]. Fuzzy logic is used to manage time spend at intersections [26]. Sensors are installed on roadsides to monitor vehicles and collect traffic data that is sent to the data center [27]. Image processing is also used to build an intelligent traffic system [6].

All of the work presented above led to a proposed traffic management system. Dubey and Borkar conducted a review study on techniques for reducing and avoiding congestion [5]. For jam detection, an image-processing technique is used to calculate vehicles density by processing pictures coming from cameras or videos. Sensing is another technique that uses sensors, which are commonly used in highways. Sensors can be intrusive (i.e., embedded under the surface), and nonintrusive (i.e., installed on the surface). There are also techniques that depend on GPS and smartphones, which are used to collect traffic data and detect traffic jams.

Other techniques that are used for congestions avoidance include: vehicle re-routing, which applies a prediction algorithm that uses previous collected data and real-time traffic data [29], [24]; a VANET-based technique that allows vehicle communication to share traffic information, thus allowing drivers to select a different route to avoid traffic [25] ,[30]; and traffic-light timing optimization, which presented different algorithms to improve traffic flow in case of an emergency [31], [32], [33].

Traffic Demand Management (TDM) is a different approach that creates a balance between travel demand and the road facilities called Traffic Demand Management (TDM), penalties that include vanpooling, congestion pricing, and parking pricing. Active Traffic and Demand Management (ATDM) aims to create better balance by providing more travel options, including departure time, route, and mode of travel. ATDM uses real-time traffic information, which depends on communication technologies to share information between populations. Thus, more data will be collected and shared with public who can use this information to plan their trips. Rewards (free tickets or free coupons) are another form of incentive used in an ATDM.

Many rewards-based systems have been developed for traffic reduction. Padhariya et al. developed the E-VeT system, which rewards vehicles that follow system-assigned longer paths and penalizes those who follow the shorter paths. It also applied an allocation algorithm to assign a shorter path to vehicles that earned higher rewards for following the system's suggestions [12]. They found that proposed method is able to manage traffic effectively. Another approach by de Souza used positive incentives (i.e., rewarded drivers when they avoided peak hours) to change driver behavior [16]. Rewards include money in the current currency or points to purchase smartphone.  The study showed that using rewards encouraged drivers to reschedule their trips to a different time, before or after peak time, which in turn decreased traffic during peak times by 60%.

## 3. Proposed Approach

Our proposed approach is a reward-based system that encourages drivers to start trips off-peak hours. It will help drivers to plan their trips, especially their daily trips, based on the recommendations for departing certain location at a certain time.

Drivers register by entering trip details such as departure time, departure location, and final destination. Traffic map and alternative roads will be reviewed, and our system will also suggest departure time to avoid traffic. Thus, if the driver has flexibility and choose to follow the suggestions to avoid traffic, points will be rewarded.

Points will be collected and can be redeemed with participating businesses; some examples of rewards include cancel violation ticket, free fuel from gas stations, and discount coupons to purchase from supermarkets. Figure 1 illustrates the overall structure of our system.

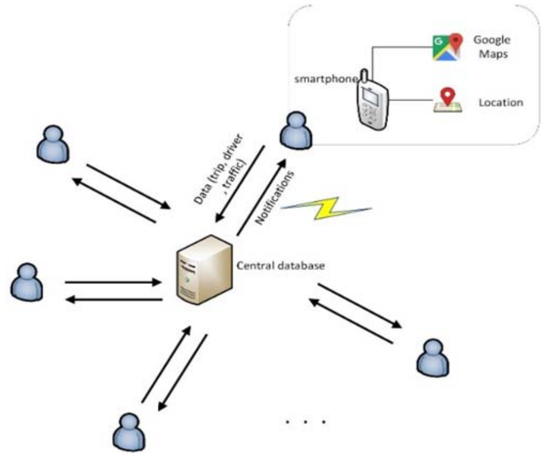


*Figure 1. The overall structure of the proposed system*

Our system consists of a central database and smartphone users, each of whom participated as individual agents. Each agent is used to populate the system with data; this data is then transmitted to serve of the other users. Smartphones are used to access traffic data from Google Map API, detect car location and movement, and send data to the server. The collected data will be analyzed and processed to send notifications to users regarding traffic and relevant recommendations.

In order to reward points to the driver, car movements will be tracked if the driver follows the recommended departure time, they will get points. In addition, to create traffic data for Saudi Arabia, we will save driver information and trip details. Users can provide more information about road conditions such as accidents, construction, potholes, etc. This data  will be used then to build a system that predicts traffic and suggests departure times. The first version of the system will depend on Google Maps. The system will notify the driver if the selected departure time is at peak-time and provide an alternate suggestion. Then, it is driver's decision whether they leave the location at that time or not.

The second version of our proposed system depends on the historical data that was previously collected from users. Data will be analyzed to predict traffic in advance in order to calculate estimated traffic, and provide recommendations for the best departure time for certain locations. Thus, for all scheduled trips, the system will send recommendations before the start-time for each based on a time frame defined by the user. For example, the user can choose to get recommendations three hours before their trip departure time. As the data-set is populated with more data, the system will calculate more accurate estimations of traffic and provide better recommendations.

## 4. Examples

Scenario 1: Alice leaves home every day at 9 a.m. to travel from Location A to Location B. Alice used the application for the first time; Google Maps shows traffic at the midway to her destination. The application suggested a new time 10 minutes later to leave Location A. Alice agreed and left after 10 minutes, and her car movements were tracked. Alice left at the suggested time; so points were added to Alice's account

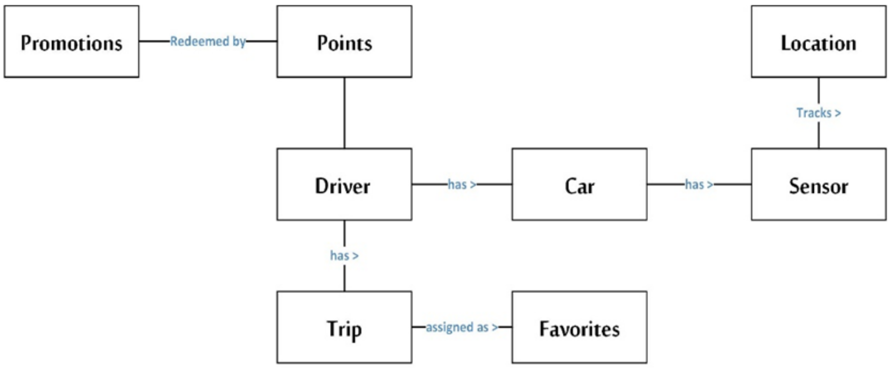


*Figure 2. The class diagram of the proposed system*

Scenario 2: Alice leaves home every day at 9 a.m. to travel from Location A to Location B. She has previously used the application for this trip. The application sent a notification to Alice the day before that is based on data collected from other users for this same trip, along with recommended time to leave home in order to avoid traffic. Alice followed the recommendation time and rescheduled her trips, and her car movements were tracked. Since she left at suggested time, points are added to her account for this trip.

Scenario 3: Alice scheduled many trips for a specific day. The application analyzed the traffic data and sent notifications with recommended times prior to the trip based on Alice's selections. Alice followed the recommended times for all of her trips, points were added to Alice's account for each trip.

## 5. Design

We used object-oriented criterion to design our proposed system. The class diagram consists of eight classes. The Driver class consists of driver information, and each driver object has a relation to three classes: car, trips, and favorite destinations. Each car object then has access to an object of the Sensor class, which will then track car through objects of the Location class. The class diagram is shown in Figure 2.

Figure 3 (due to its size, it is placed at the last page) is the activity diagram, which shows the activity flow between the different agents in the system.

## 6. Implementation

We developed a phone application that uses Google Maps API. Each user has to create an account. For each trip, the user will enter departure and destination location, and desired departure time. Google Maps is used to view maps, calculate the distance between locations, and find alternative routes. Notifications regarding traffic and a recommended departure time are then sent to the user.

In order to track the car movements, the application depends on the "share location" feature on smartphones which requires drivers to activate the feature when using the application. Points will be added to each user's account when the application detects that the car departed time at the recommended time. Collected points can be redeemed using third-parties promotions.

### *6.1. Data-Gathering*

The application will collect driver data users register for the application. Driver data will include name, age, nationality, educational level, years of having a driver's license, and number of accidents.

Additionally, the application will collect traffic data for trip, such as trip departure location and time, and destination. Data will be extracted from Google Maps API and from the data entered by the driver. For example, the driver will be asked for the traffic conditions (i.e., very bad, bad, okay, not at all) and the reason for traffic conditions (i.e., construction, accident, etc.). All data are saved in one database that will be used to send notifications to all users.

Points will be then added to each user's account. Car location will be detected using smartphones. If car movement is detected to be off-peak hours, points will be added to the user's account.

### *6.2. Feedback Notifications*

First, the application will send notifications at the time of the trip, and these notifications will be based on data provided by Google Maps API. However, as soon as users start to use the application, their trip information will be used to provide better recommendations to drivers as to the best departure time for specific location.

## 7. Evaluation

We evaluated our application on 100 users with different age, backgrounds, and educational levels. We initially performed unit testing to individually validate the interface. We then tested the integration of different units through system testing. Finally, we evaluated system usability by applying the System Usability Scale (SUS).

### *7.1. Unit Testing*

*Table 1. Test Cases for "Schedule Trip Lists"*

| Function | Input | Expected output | Result |
|---|---|---|---|
| Modify list | Change departure time | Departure time changed | Pass |
| | Change destination | Destination changed | Pass |
| | View trips | Show all saved trips | Pass |
| | Delete trip | Remove trip from the list | Pass |
| | Change departure time | Departure time changed | |

Unit testing was used to validate individual units. In our application, units are represented by interfaces, and we tested each interface separately, including all of its functions. For example, the schedule list interface includes a list of scheduled trips, details of each trip, edit trips list. We first tested whether the list showed all scheduled trips for different users. We checked the details of each trip and validated the details. We then edited the list by deleting a trip and checked if the list was updated. Table 1 shows the test cases for testing the "trip list" unit.

### *7.2. System Testing*

System testing relates to regarding the integration of system units and functionalities. We evaluated integration by creating test scenarios to validate the system outputs after performing different tasks, as shown in Table 2.

*Table 2. Test Scenarios for System Testing*

| Test Scenarios | Result |
|---|---|
| Sign up - sign in - profile - determine destination on the map - schedule trip - view trips list | Pass |
| Sign in - view trip list - delete trip - view trip list - promotions - redeem points | Pass |
| Test3 Sign in - view point history - view trips list - modify trip details - view trip list | Pass |
| Sign in - view point history - view trips list - modify trip details - view trip list - sign out - sign in - view trips details | Pass |

### *7.3. Usability Testing*

The SUS is the most appropriate measurement for small samples. It consists of a10-item questionnaire with five responses [19]. We computed the SUS value for each user, and then the overall average, which represents the application usability, is computed. The overall system average was acceptable (85); however, the system still needs some improvements. We explain some limitations in the following section, which can be addressed for improvements to our proposed system.

## 8. Limitations and Threats to Validity

Our system depends on the functionalities provided by Google Map API. Thus, there is a limit to the functionalities we adapted due to the data-sharing policy for Google Maps API. For example, Google Maps API does not provide the raw data or the estimated time for a specified trip. Therefore, we will need to collect this data to provide better recommendations. This means that the system will encourage people to use it, which can be done through the business partners that provide promotions. Recommendations will depend on data collected from users; the accuracy of the recommendations will depend on the accuracy of the collected data, which represents a threat to the validity.

To mitigate this threat, we can manually compare our recommendations with the results of the estimated data from Google, at the first stage until our results reach an acceptable level of accuracy, at which time our application can be independently used to provide recommendation.

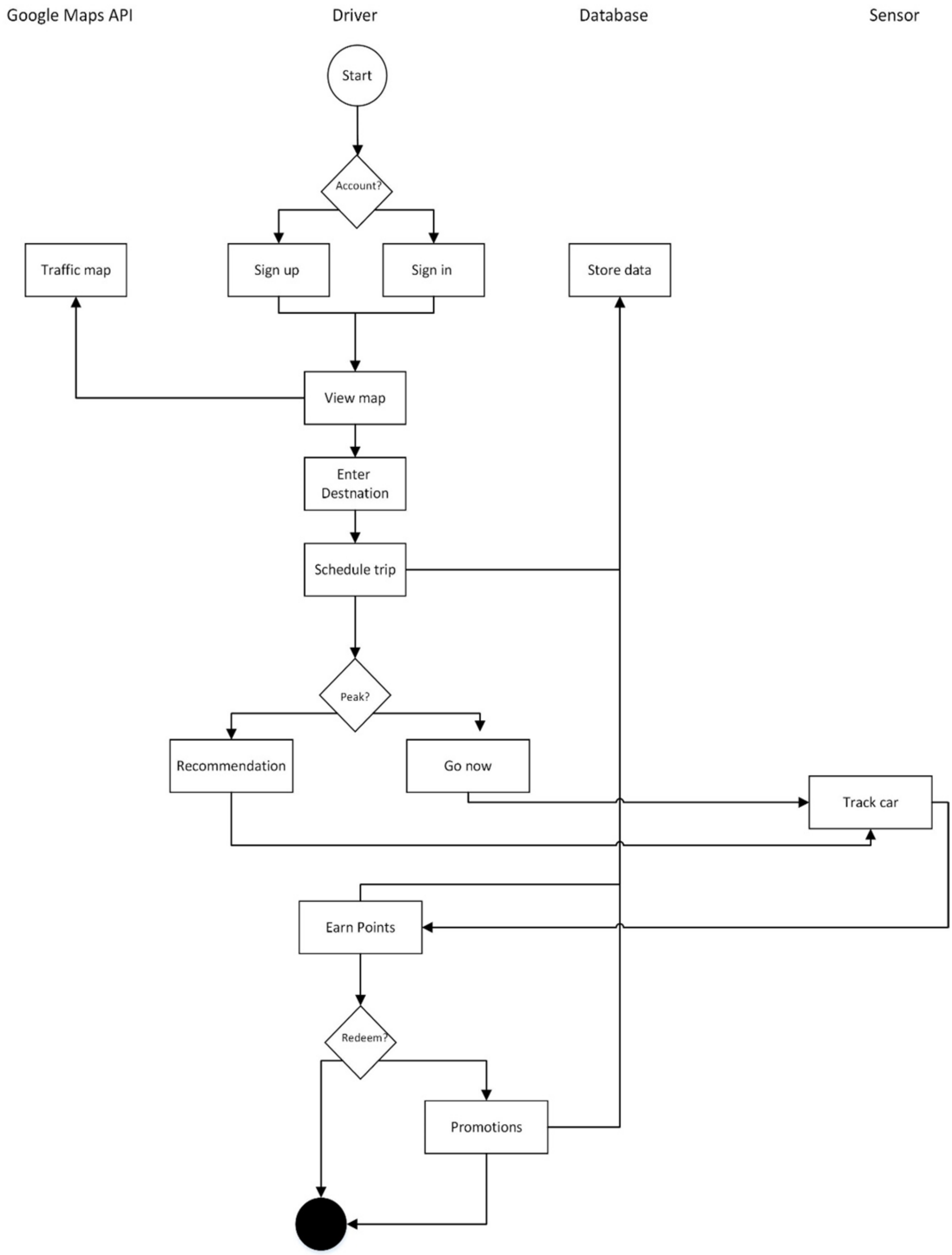


*Figure 3. Activity Diagram*

## 9. Conclusion

Traffic congestion is a big issue in urban areas. It is the cause of high number of deaths in the world, and in Saudi Arabia specifically. TMS proposes different solutions to improve road traffic. An incentive system is one proposed approach to change driver behavior in order to improve traffic congestion. Our proposed system is reward-based system and it will encourage drivers to re-schedule their trips and drive during off-peak hours, thus reducing traffic. It will also be used to collect data related to traffic in Saudi Arabia, and will thus enable us to build customized intelligent recommendation system, which will allow users to schedule their entire day ahead-of-time in order to avoid traffic and contribute to improving overall traffic.

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