Real-Time Traffic Patrol Allocation for Abu Dhabi Emirate (UAE)

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***Abstract*—The main objective of this research project is to develop, implement and test an efficient real-time system for the allocation of patrol cars to various locations within the boundaries of the Abu Dhabi Emirate. Patrol cars are allocated initially to provide adequate coverage over a wide area that is divided into geographic zones. However, during daily operations the patrol cars move to deal with traffic accidents or calls for assistance originating from various locations in each zone. The proposed patrol allocation system is essentially an automated decision support system that relies on Geographic Information System (GIS) and other data related to current and real-time traffic flow to assist the dispatch operators in making effective patrol allocation decisions. The system also computes the number of patrol vehicles required in order to make sure that the response time falls below a given threshold or upper limit. The basic system concept and structure are presented.**

***Index Terms*—Patrol car allocation, Patrol car dispatching, Geographic Information Systems, real-time Traffic, decision support systems**

I. Introduction

Emergency services such as police vehicles must provide reasonable service levels in order to ensure public safety. These services are typically provided by vehicles based at fixed locations. The number and placement of vehicles generally influences the quality of services offered. Increasing the number of vehicles is often limited by cost constraints; therefore the efficient deployment of such services vehicles is a crucial issue [1]. The emergency service vehicle location problem determines the best base locations for vehicles such that specific service level objectives are optimized. Covering of the network or area is one of the most important objectives, reflecting the quality of emergency services. Therefore, emergency service vehicles must be located in such a way that they may reach any demand point within a maximal response time [1].

In this research study, an efficient and real-time traffic police patrol vehicle location-allocation system is proposed. In the past, different solution approaches, such as integer linear programming and tabular search using GIS software, have been proposed. Those approaches have shown several limitations since they have been used offline and not in real-time and have relied only on linear programming and mathematical formulation. In our research, we propose a new approach based on advanced technologies such as artificial intelligence (AI) combined with GIS in order to propose a *real-time*, *optimal* and *intelligent* patrol car allocation system. As a case study, we will use the area of Abu Dhabi Emirate in the UAE.

This paper is organized as follows. Section 2 presents the current practice of Abu Dhabi Police department concerning the patrol car allocation problem as well as a brief literature review of the existing systems and model related to the patrol car allocation and the emergency service vehicle location problem. In Section 3, we present the main objectives of our research as well as the architecture of the proposed system and the development methodology. Section 4 presents the originality of our work as well as the conclusion and future work.

II. Survey of Patrol Car Allocation Systems

A. *Current Practices in Abu Dhabi Police*

The traffic police in Abu Dhabi perform two major functions: enforcing traffic laws and assisting road users. The main methods used to attain these functions include:

- Maintaining presence and conspicuousness;
- Issuing reports of traffic violations;
- Handling vehicle and pedestrian accidents and other traffic events;
- Directing traffic;

Manuscript received October 14, 2012; revised January 10, 2013.

doi: 10.12720/jtle.1.1.64-68

- Escorting special convoys and official motorcades.

Within the Abu Dhabi Police department, the Directorate of Traffic and Patrols, which is in charge of all traffic aspects, allocates the traffic patrol vehicles to routine work and to special operations. The special operation vehicles are involved in escorting convoys and motorcades and in enforcing traffic laws and regulations through the deployment of patrol officers in specific areas at certain times, or in dealing with incidents and special events. The routine patrols perform all remaining tasks. At present, the patrol car allocation process is largely manual and relies heavily on the knowledge, experience and expertise of the dispatch operators. The operators divide the Emirate into geographic zones and allocate patrols based on their knowledge about the areas' needs and other criteria such as traffic flow patterns, population density, etc. In the event of an accident or call for assistance, the dispatcher calls on one of the patrol vehicles nearby and assigns it the task of dealing with the event.

The current allocation method, while providing acceptable level of service, falls short of providing efficient state-of-the-art utilization of resources and guaranteeing fast response time in critical situations. Given the advances in AI and GIS technologies, our ability to monitor traffic flow and the availability of real-time information on traffic conditions, the time is ripe for providing a patrol allocation process based on sound methodology and state-of-the-art technology.

B. Survey of Patrol Cars Allocation Practices in Other Jurisdictions

Location-allocation analysis refers to a class of problems in Operation Research (OR) that deals generally with situating facilities in some given space. Generally, there are four components that characterize such a class of problems [1]:

(1) Customers to be allocated to facilities, who are presumed to be located at points on route or in a specific area,

(2) Facilities to be located within the area or on routes,

(3) Space (geographical area) in which customers and facilities exist, and

(4) A variable (metric) that indicates distance or travel time between customer and facility,

The desired objective in solving such problems is to arrive at an optimum location-allocation solution that will improve efficiency and level of service [2].

In the location-allocation literature, there is a special focus on the rescue services including ambulances, fire stations and police stations [3] - [5], [11]. In each case, it is crucial that such vehicles and personnel arrive at the locations in which assistance is required in a timely manner.

In the following, we present a brief description of few examples of existing patrol cars allocation systems that are currently in use in cities across the USA and Canada. The examples were chosen as representative cases for many other similar systems deployed in other cities around the world.

Dubai, UAE: In the Emirate of Dubai, the allocation of patrol cars takes place manually and is based on one criterion, namely, the response time measured as the travel time of the patrol car from its current location to the location of the incident. The maximum response time in consideration is 7 minutes. In this allocation, Dubai police has considered that the maximum speed inside the city is 60 km/h and outside the city is 100km/h and the closest location of the patrol care to the location of the accident or incident is less than 7 Km inside the city and 12 Km outside the city.

The Police Department of the City of Dallas, Texas, USA: In order to solve the problem of patrol cars allocation, the Police Department of the City of Dallas has used an efficient spatial distribution model of police patrols in the metropolitan region. This model, which is called Police Patrol Area Covering (PPAC), employs inputs from GIS data layers, analyzes that data through an optimal covering model formulation, and provides alternatives optimal solutions for presentation to decision makers. The goal of this model is to increase the level of police service by finding more efficient spatial allocations of the available law enforcement resources. The variables used by the PPAC models include, the set of known incidents locations, the weights of incidents at the locations, the number of patrol cars, the number of police patrol areas to be located, the set of potential locations for police patrols, the acceptable service distance (surrogate for desired response time), and the shortest distance from incident location to police patrol location [6].

The Austin, Texas, Police Department: One of the major issues that is given high priority by the Austin Police Department (APD) is determining the best way to allocate officers across the city. The two major priorities for this issue are: (1) respond to calls for service and (2) solve problems within the community. In order to solve this issue, the APD has used existing software packages that help guide law enforcement in allocating officers and resources. For each of these packages, calls for service, number of officers, time from dispatch to disposition, and prioritization of calls are considered crucial data elements [7].

The San Jose Police Department (SJPD): The Police Department of San Jose has built and evaluated both geographical and temporal deployment plans that would best meet the operational goals of the SJPD. These goals are: (1) Not exceed a 10% threshold of the probability of all units being busy (call saturation) (2) arrive at priority or emergency calls, on average, within 6 minutes of receipt of that call by communications and (3) allow on-duty officers to have 40% of their time (24 minutes per hour) available for proactive patrol time. In order to achieve these goals simultaneously, the SJPD has adopted a spatial-deployment- based model in order to allocate the patrol cars in the regions by combining linear programming and GIS [8].

The City of Vancouver (B.C, Canada) Police Department (VPD): Initial analysis of VPD patrol data revealed that not enough patrol resources are available on the road to handle even the normal load. Subsequently, a recent review of the Vancouver Police Department's staffing requirements recommended that a study of patrol deployment be conducted in order to: (1) Determine the number of sworn officers and supervisors required now and in the immediate future, (2) prepare a plan for deploying the required number of patrol officers and supervisors that is cost-effective, and (3) develop schedules for assigning the required personnel most productively and equitably. In order to attain these goals, the VPD has used an approach called "Patrol Shifting Model" which is based on linear programming and GIS technologies in order to schedule the patrol allocations in an efficient and effective way [9].

The Idaho state Police department of planning (ISP): In March 2007, the Idaho State Police Department of Planning, Grants and Research was selected to conduct a study on the appropriate number of police officers needed to patrol the federal and state highway systems of Idaho 24 hours a day. The primary responsibility of Idaho State Police patrol is to promote safety on state interstates and highways through proactive patrol. To have adequate coverage for calls for service, as well as assisting other agencies, it was determined it would be best to have a trooper pass by all state highway mileposts at least once per day. The findings of this study have shown that the average response time (dispatch time to time on scene) is over 18 minutes, which is too much. In order to decrease the time, the ISP has developed and used a Police Allocation formula in conjunction with GIS in order to estimate the number of police patrol vehicles needed [10].

Previously developed systems have shown their operational efficiency and effectiveness by guaranteeing that the police coverage of roads in a specific area is maximized and that the average and maximum response time meet acceptable limits. Most of these systems use specific algorithms in order to determine the configuration of facilities (locations of patrol cars) and assignment of duties to the respective facilities is in accordance with chosen criteria. In most of the allocation applications, the criterion considered is the average response time, measured as the time interval between receipt of a call reporting accident or request for assistance and the arrival of at least one patrol car at the site. The input data available for processing the allocation algorithm include:

- The status of traffic in the roads of the regions, including traffic flow, traffic density, etc;
- The number of incidents (expected and unexpected) representing accidents, emergency calls and calls for assistance;
- The coverage area defined by GIS;
- Patrol vehicles required to serve special functions such as escorting convoys and official motorcades;
- The number of patrol vehicles available for patrol duty;
- The start time and duration of each patrol duty cycle;
- The distance between patrol cars;
- Typical allocation of patrol officer time (administrative work, reporting work and available time to respond to calls); and
- Other criteria, such as the population density and distribution across the geographic zone.

III. Our Proposed Patrol Car Allocation System

Most of recent research studies and applications concerning patrol cars allocation have produced fully automated systems by using two techniques: (1) optimal location formulations from the operational research and linear programming fields and (2) GIS. Our research project aims to benefit from advances in specific technologies and real-time observation and measurements of traffic conditions in order to develop an efficient real-time patrol allocation system in the Emirate of Abu Dhabi. Such technologies include without limitation aspects such as GIS, linear programming, operational research optimization techniques, AI, and trainable expert systems.

The essential architecture of the proposed patrol cars allocation system is shown in Fig. 1.

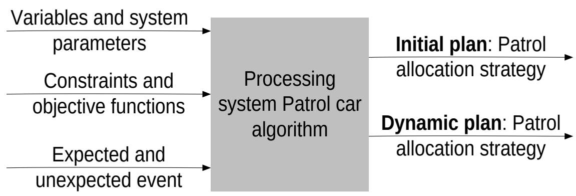

Figure 1. The architecture of the Real-Time Patrol Cars Allocation System.

This configuration of this system is explained in the following.

A. Inputs

The system receives several inputs (variables) such as:

1) Variables and System Parameters:

The number of patrol cars: The number of cars which are actively involved in the allocation;

Real time traffic conditions (density, flow): This variable will be collected from other systems which provide the real traffic conditions by using real-time counters, telecommunication providers services, etc.

Populations density and distribution: This variable exists in the GIS system;

Frequency and nature of incidents (accidents, calls for assistance, emergency calls): This variable exists in the GIS system;

The coverage area: This variable exists in the GIS system; and

Patrol duty parameters (start time, patrol duty cycle, allocation of officer time among various tasks)

2) Constraints and optimization criterion: one or more of the following

Response time (upper bound)

Number of patrol cars on duty (upper bound)

Coverage/visibility: minimum number of patrol vehicles in each geographic zone

3) Expected events related to the traffic

Planned events such as convoys, motorcades, etc.

4) Unexpected events affecting traffic flow

Traffic congestion;

Accidents/crashes;

Climate conditions: poor visibility due to fog, heavy rain, sand storm, etc.

B. Processing

A sophisticated algorithm that takes into account the input data in real time, the performance constraints and the optimization criteria in order to produce an optimal allocation strategy for the traffic patrol cars. Broadly speaking, the algorithm utilizes three approaches:

The algorithm maps the input data onto a GIS structure since most of the input variables are location-based,

The algorithm uses an decision support system module to capture the knowledge and develop formal rules for the allocation procedures based on knowledge, insight and experience gained from the current system operators. This prior knowledge is useful for fine-tuning the system parameters,

Using linear programming, artificial intelligence and multi-agent systems techniques, the algorithm will be able to compute in real-time and with a high degree of accuracy the travel time between each available patrol car and the site of accident or assistance (the target site). This module requires knowledge of the actual, real-time traffic conditions on most roads and highways. The travel time depends also on the initial direction of the patrol vehicle and the available routes,

The available patrol car with the *shortest travel time* to the target site is normally given the assignment and directed to proceed to the target site.

C. Output

The output of the processing system consists of: (1) *an initial patrol car allocation strategy* for the allocation of traffic patrol cars to geographic zones at the beginning of each patrol duty cycle. This initial allocation is optimized on the basis of the projected traffic pattern and the expected number of accidents and calls for assistance and (2) a *dynamic and real-time allocation strategy* for traffic patrol cars that assigns patrol cars to the site of accidents or calls for assistance. The output is determined by the processing algorithm in such a way that optimizes the objective function and meets the stated constraints.

IV. Originality, Conclusion and Future Work

The availability of an efficient patrol allocation system that is based on modern, computer based GIS as well as other advanced technologies, is essential for the smooth flow of the traffic across the roads and highways of the Emirate. In most of the previous research studies, the researchers used GIS data in order to provide static patrol car allocation solution based mathematical formulations using linear programming concepts and GIS. In our research project, the proposed system is able to deal dynamically with varying traffic situations (travel time) caused by accidents or other unexpected events over the space (GIS) and time; and at the same time provide an advanced AI-based decision support service to the officer in change of monitoring and regulating the flow of traffic under all conditions. By using AI, our system will be more accurate, realistic and comprehensive relative to other systems described in previous publications. In the future, our proposed system will be deployed with other real-time systems which collect real-time data about incidents, traffic, etc. This deployment will enrich our system with the real-time aspect.

Acknowledgment

This project was supported and sponsored by the Traffic and Patrol Directorate of the Abu Dhabi Police Department.

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