FACULTY
OF MATHEMATICS
AND PHYSICS
Charles University

BACHELOR THESIS

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Emergency services shift plan optimization

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Study programme: Programming and Software Development

Study branch: Computer science

Prague 2023

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Abstract:

Keywords: one two

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Introduction

1. Introduction

1.1 Problem definition

One of the primary challenges faced by emergency medical service providers (EMS) revolves around determining the optimal availability schedule for their ambulances at specific depots. The primary objective is to maximize the number of successfully handled incidents while minimizing the operational costs associated with the ambulances. This allocation of ambulances and their availability is commonly referred to as a shift plan.

A shift plan entails assigning shifts and ambulances for a given time interval, typically a single day. It serves as a representation of when ambulances are available throughout the day.

Each shift represents a time interval during which an ambulance crew operates the vehicle, rendering it available for emergency response. Ambulance crews may possess specialized skills or equipment, such as the inclusion of a doctor or experienced personnel. Similarly, different ambulances can vary in size or possess advanced medical tools. To capture these distinctions, each ambulance is assigned a specific type.

Ambulance types provide an abstraction of these varying scenarios and specify the incidents they are equipped to handle. For instance, certain incidents may require specific tools or a larger ambulance. Consequently, only select ambulances may be suitable for handling such incidents.

Ultimately, our primary concern is determining whether a given ambulance can effectively respond to a particular incident, based on the mapping between ambulance types and incident requirements, hence such abstraction is sufficient for our purposes. Throughout the day, only one shift can be assigned to each ambulance, and there may be instances where no shift is assigned, rendering the ambulance unavailable for the day and unable to participate in incident response.

A shift plan incurs a cost, which we aim to minimize. This cost is determined by the duration of the shift and the associated cost of the ambulance type.

In evaluating the performance of a shift plan, we measure its effectiveness in handling a set of incidents. This set represents the spatial and temporal distribution of incidents that occur within a day. We can obtain such incident sets through two main approaches.

The first approach involves leveraging historical data, which document the occurrence of incidents in a given area over months or years. By uniformly sampling a representative subset of this data, we can test the generated shift plan's performance. This approach assumes that past incident patterns will persist in the future. Historical data provide the most reliable means of simulating incident occurrences accurately.

The second approach involves defining a distribution that generates incidents based on prior knowledge. For instance, we may observe that incidents primarily occur during early mornings, around lunchtime, or at transportation hubs due to commuting patterns. Conversely, we may notice a lower incidence rate during nighttime compared to the daytime.

While the first approach more accurately depicts the occurrence of incidents in the area of interest, obtaining such historical data can be challenging and time-consuming. Moreover, these data often remain confidential, making it difficult to access them, especially from other EMS organizations.

Therefore, for the purposes of this thesis, we will adopt the second approach, generating representative incident sets using a predefined distribution. This approach offers greater flexibility, allowing us to experiment with different distributions and simulate various scenarios, including unexpected or extreme situations.

Finally, with all this information at our disposal, we can now shift our focus towards evaluating the performance of the shift plan against a set of incident sets. In order to measure performance, we will assess the ratio of successfully handled incidents to the total number of incidents in the set. A higher number of handled incidents and lower costs indicate a better shift plan. While this approach is reasonable, we will take a slightly different route in this thesis. Since this thesis is associated with the Computer-Aided Dispatch System Organization Logis Solutions s. r. o. (Logis), which employs advanced solutions for existing EMS, Logis has the advantage of having historical incident data sets available. This leads us to examine the success rates achieved by each incident set on a given day. As the proposed solutions in this thesis may be utilized in the production software developed by Logis for their EMS clients, it would be ideal to generate a shift plan that maintains or surpasses the success rates indicated by the historical data, while concurrently reducing costs. Therefore, the success rate will be provided for each incident set, and our optimization will solely focus on minimizing the cost.

Introducing the concept of success rate provides a useful framework for considering a shift plan as either valid or invalid. A shift plan is deemed valid if it can meet the given success rate, indicating its ability to satisfy the incident requirements. Conversely, a shift plan is considered invalid if it fails to meet the specified success rate. It is worth noting that there may be scenarios where no shift plan can handle the incidents to meet the desired success rate, resulting in all shift plans being invalid. However, this particular case is not our primary concern, as the success rates derived from historical data are based on shift plans employed on previous days, which were not necessarily designed using highly sophisticated methods. Therefore, the probability of encountering such a situation in high-quality historical data is very low. Nonetheless, even in such scenario the proposed solutions will prioritize maximizing the success rate to the greatest extent possible.

1.2 Evaluating success rate of a shift plan

Our primary objective is to ensure that the evaluation of the shift plan closely reflects real-world conditions. It is essential that the success rate of a shift plan, as determined by a given incident set and specific ambulances, closely aligns with its real-world performance. To achieve this, we will employ evaluation strategies that mirror those used in actual ambulance dispatching.

The most direct and flexible approach is to develop a simulation that emulates the real-world dispatching of ambulances to incidents based on the shift plan. This simulation will also incorporate the handling of incidents at the occurrence location, as well as the travel to the hospital and return to the depot. In reality, ambulance dispatching decisions are guided by a set of rules. While these rules can become quite complex, often requiring approval from a dispatcher, we can devise our own rules that closely approximate real-world dispatching practices. By doing so, we can ensure that the probabilities of dispatching in the simulation closely mirror those in the real world and are easier to work with and simulate. Leveraging Logis's extensive expertise as one of the top CAD dispatchers in the market, Logis has derived the following abstracted rules. If multiple ambulances satisfy a given rule, the selection process will follow the subsequent rules in the specified order.

(1) Rule of Availability: Give priority to ambulances that are free, either stationed at the depot or returning from a hospital after completing an incident.

(2) Rule of Promptness: Prioritize the ambulance with the earliest estimated arrival time to the incident scene.

(3) Rule of Workload Distribution: Favor ambulances with the least overall active time, ensuring a fair distribution of workload among all available ambulances.

(4) Rule of Cost: If multiple ambulances can handle an incident equally well, choose the one with the lowest operating cost.

By adhering to these rules in the simulation, we aim to closely emulate real-world dispatching practices, ensuring that the decisions made in the simulation closely resemble those employed in actual emergency medical service operations.

2. Title of the second chapter

2.1 Title of the first subchapter of the second chapter

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A. Attachments

A.1 First Attachment