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A fleet management model for the Santiago Fire Department

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ABSTRACT

The Santiago Fire Department (from here referred to as SFD) lacks a fleet management strategy since their vehicles remain allocated in fixed fire stations, while the presence of seasonal patterns suggests that the frequency of events changes according to their geographical distribution. This fact has led to inequitable service in terms of response times among the nine zones of the SFD. In this empirical study we propose a fleet assignment model for the Santiago Fire Department to maximize the number of incidents successfully attended (standard responses). Results suggest that the implementation of the fleet management proposal will lead to an increase in the number of standard responses of between 6% and 20% with respect to the current situation. This increase in performance is especially important since it does not require new vehicles; it just optimizes the existing siting via dynamic reallocation.

1. Introduction

In general the resource management process in the public sector, in particular the fleet management in Fire Departments, differs from the traditional private resource management. The difference mainly is in the nature of the objectives that decision makers are considering: while the private sector focuses on profit maximization or cost minimization criteria, social cost minimization, efficiency and equity are some of the main concerns in the public sector. The task of modeling this problem in the praxis is very complex because of these factors: there are multiple competing objectives, there is the strong influence of political decision makers, and there is a lack of data and constrained planning resources [28].

Although the fleet management for emergencies has been studied as reported in the literature during the last decades, there are no fleet management techniques applied in the SFD. Some political constraints coming from the current organization in the SFD makes hard to dynamically allocate vehicles among different fire stations, but by adequately applying fleet management models it is possible to propose alternatives to improve in practice the current performance of the SFD.

The purpose of this paper is to propose a dynamic fleet reallocation for the Santiago Fire Department. To accomplish this objective we developed a model for monthly fleet allocation, and we applied it to a real world case with real data gathered from the SFD. In this context, this work can be considered to be an application paper, because its main contribution rests on the proper application of a mathematical model to a real world problem.

This paper is organized as follows. Section 2 characterizes the Santiago Fire Department. Subsequently, we present a brief review of the relevant literature regarding the fleet management in Section 3. A statistical analysis of the events for the different zones is presented in Section 4. The proposed model is detailed in Section 5. Section 6 contains the results we obtained applying the proposed methodology to the SFD. Finally, conclusions are drawn from our work in Section 7.

2. The Santiago Fire Department

Founded in the year 1863, the SFD (*Cuerpo de Bomberos de Santiago*) is a not-for-profit public organization, whose objective is to protect the lives and property of the citizens in case of fire or other events. The range of action of the SFD involves nine zones of the Chilean Capital: Santiago (downtown), Recoleta, Independencia, Estación Central, Providencia, Las Condes, Vitacura, Lo Barnechea and Renca.

The functioning of the SFD is mainly supported via donations and by the Chilean government. The services provided by the volunteers of the SFD are free of charge, and include both in field operations and administrative aspects. Although the call processing and vehicle dispatch to events is centralized in the SFD, the distribution and maintenance of vehicles is the individual responsibility of each fire station. Moreover, the operative decisions

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Table 1
Fleet distribution by zone with respect to the distribution of incidents.

Zone	% Incidents	% Fleet
Estación Central	8.9	6.8
Independencia	2.6	4.5
Las Condes	14.5	13.6
Lo Barnechea	5.6	4.5
Providencia	12.8	9.1
Recoleta	7.3	9.1
Renca	9.8	4.5
Santiago Downtown	32.8	43.2
Vitacura	5.7	4.5
Total	**100**	**100**

for event response are centralized only in the nine zones that constitute the SFD, but do not involve the other zones of the city of Santiago (even adjacent zones) and the rest of the country. This lack of centralized administration and coordination leads to less efficient fleet assignation and overall performance in terms of the number of events attended with standard response.

While most of the SFD's 22 fire stations, distributed in nine zones of the city, were established about 100 years ago, the limits that originally defined Santiago and its density have changed dramatically during this period. Additionally, vehicles assigned to these fire stations remain allocated every time to the same station. The migration of people from rural zones to the capital has caused a significant increase in terms of populated surface. This has resulted in an uneven (and fixed) fleet distribution, in which Santiago Downtown has 43.2% of the fleet but just the 32.8% of the incidents (see Table 1). This fact implies uneven response times to the events in the other zones, as is shown in Fig. 1. Given that funds to install or even relocate stations are very scarce, a much more affordable alternative is a fleet redistribution that could lead to a significant improvement in the mean response times for each zone, resulting in more equitable and efficient service.

2.1. The fleet

The fleet of the SFD includes the following types of vehicles:

- Fire engines: These vehicles are designed to assist by transporting fire fighters to the event and providing them with access to the fire, along with conveying water or other equipment. According to their function, two subtypes are distinguished: the conventional pumper engine, denoted with the initials *P*, and those vehicles with an additional ladder (pumper–ladder), used to gain access to fires occurring at great height, denoted by the initials *PL*.
- Hazardous materials apparatus: These engines are especially designed to deal with hazardous materials (HAZMAT), such as spilled oil or other chemicals, on streets and highways. We denote this type of vehicles with the initials *H*.
- Telescopic/hydraulic platform ladder trucks: These fire apparatuses are specialized for aerial work for fire fighting use, they do not have pumping capabilities. We denote them with the initials *L* and *T*. Vehicles of type *L* are exclusively ladder trucks, while type *T* trucks have ladder and telescopic platform capabilities.
- Rescue engines: These vehicles are designed for technical rescue situations such as extrications of passengers from vehicles following traffic collisions, confined space rescues, or collapses of building. We denote these vehicles with the initials *R*.

3. Previous work in fleet allocation and emergency response

Most of the research on fire management focus on facility location and planning of fire and rescue services. Early covering models for emergency services [32,33] considered a deterministic demand, accomplishing coverage whenever at least one server was located within a certain travel time or a standard distance from the demand area.

Another extension of the maximal covering models is the approach called FLEET (Facility Location and Equipment Emplacement Technique) [26]. Note that in this case there are also present decisions related to vehicles. In fact, the FLEET model considers the simultaneous allocation of different types of servers (engine brigades and truck brigades) and facilities. The authors propose a multi-objective problem where frequency, property value, and population at risk for coverage are maximized simultaneously, providing a more realistic representation of public sector decisions [20]. This approach was successfully applied to a fire-fighting services location problem in the city of Baltimore, Maryland, leading to the construction of six new fire stations in its five-year capital improvement programs [26]. A more recent application is presented in Aktas et al. [1], where two location model strategies (set-covering and maximal-covering) were implemented for 10 different scenarios for the city of Istanbul, Turkey, increasing the coverage from 58.6% to 85.9%.

In addition to the experiences in Baltimore and Istanbul, several other applications of fire station siting and fleet allocation have been presented in the literature. A study was conducted in

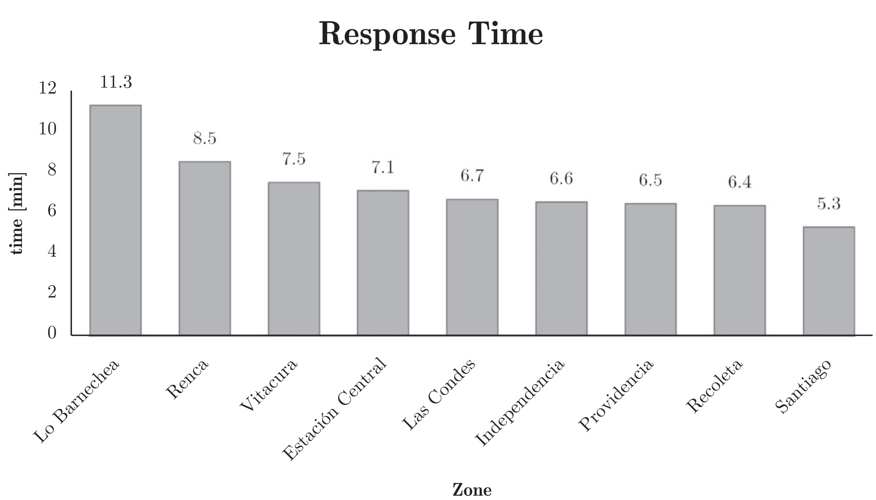

Fig. 1. Average time of arrival of the second vehicle to events for the nine zones of Santiago.