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Modelling residential fire incident response times: A spatial analytic approach

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A B S T R A C T

Rapid response to fire incidents is critical as delays in the departure and arrival at the scene can have significant consequences in terms of damage, injury and death. Research on the dynamics of residential fire incident response times has barely begun, a situation arguably underpinned by limited access to disaggregate command and control data. In this paper we draw on unit record data and employ quantile regression to examine the role that socio-demographic, infrastructure characteristics and temporal factors play on response times. Results reveal that response times are slower during the winter, in locales with larger populations of elderly people, and in areas that have more complex street layouts. We conclude through emphasising the importance of these findings in their capacity to contribute to a new evidence base to inform policy decisions from a resource allocation perspective through the spatial allocation of finite fire resources.

1. Introduction

The effect of being a victim of fire extends to physiological damage, economic costs, physical injuries, and death (Ceyhan, Ertuğay, & Düzgün, 2013; Corcoran, Higgs, Brunsdon, & Ware, 2007). For these reasons, substantial public resources are devoted to provide ongoing protection against the effects of fire (Murray, 2013). Despite the provision of these protective measures the annual costs that result from loses due to fire reaches into the tens of billions of dollars worldwide, which is estimated to be about one per cent of global GDP (The Geneva Association, 2012, p.9). Residential fires continue to pose the main threat to people significantly impacting both lives and properties (Ceyhan et al., 2013).

Each year fires in Australia cause 100 fatalities, 3000 injuries and billions of dollars of property loss (Productivity Commission 2007). Given these impacts, approximately 30 percent of the total cost of fire in Australia (~AUD$1.2 billion) is estimated to be spent in responding to calls for emergency service (Ashe, Mcaneney, & Pitman, 2009). Despite such investments, timely response to calls for emergency service remains a persistent issue in terms of achieving the stipulated target response standards, especially in urban areas where population growth places ever growing pressures on the capacity of fire agencies to respond in a timely manner given increasing demand, rising traffic congestion, and growth in the urban footprint (Productivity Commission 2015; Sufianto & Green, 2012). Given the problem of achieving target response standards, the purpose of this research is to examine the spatial patterns of residential fire response times and identify their key determinants. The outcomes of this work are important in their capacity to contribute to a new evidence base with the potential to inform future policy and planning related to the spatial targeting of response services (e.g., fire station location planning).

The importance of a timely response is highlighted by the work of Challands (2010) who shows that a quicker response to a call for service results in fewer casualties in most circumstances. Furthermore he finds a positive correlation between response to calls for emergency service and the amount of structural damage and estimated that the cost of damage to the structure increases at the rate of approximately AUD$3830 per fire per minute of response time.[1] Collectively these findings point strongly to the critical need for timely response to calls for emergency service for reasons of both personal safety and structural damage (Challands, 2010; Tamat et al., 2014). Underpinning a timely response to fires are Service

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[1] Approximate exchange rate is NZ$1.00 = AUD$0.96.

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Delivery Standards (SDS) that are targets imposed by fire agencies and authorities to establish benchmark times for response to a call for emergency service (Chevalier et al., 2012). For example, the National Fire Protection Association (NFPA) in the United States stipulate a guideline advising that fire services be spatially distributed in a manner such that 90 percent of calls in urban areas can be responded to in 9 min (NFPA, 2015). The Insurance Services Office (ISO) in the United States provides information on property and liability risk, which is used by insurers and government regulators for ensuring adequate fire protection and establishing response time standards (Murray, 2013). Many countries have an equivalent organisation and impose SDS, however determining these SDS is ultimately a compromise that on the one hand attempts to minimise the risk to people and property (Murray, 2013) whilst on the other hand minimises the public cost of fire cover (Aleisa & Savsar, 2013). In addition, given that settlement patterns and populations are in a continue state of flux and change ensuring the continued achievement of the established SDSs demands regular monitoring to ensure the risk to people and their property is minimised (Schilling, Revelle, Cohon, & Elzinga, 1980; Li, Zhao, Zhu and Wyatt, 2011).

SDS and their associated target response times vary by country, from 5 min in Turkey, 9 min in the United States, and 14 min in Queensland, Australia (Aktaş, Özaydın, Bozkaya, Ülengin and Önsela, 2013; Aleisa & Savsar, 2013; Murray, 2013). In Australia, the target response times also vary by state and territory (e.g., 8 min for 90 percent of calls in Victoria, 12 min for 90 percent of calls in Western Australia) reflecting differences between the various fire agencies and the underlying settlement geography (Productivity Commission, 2015). Furthermore, the governance structures through which these SDS are set varying with the Turkish Standards Institute (TSE) establishing these in the context of Turkey (Santia Consulting Ltd, 2016), the NFPA in the United States, and Standards Australia in conjunction with the Australasian Fire and Emergency Service Authorities Council (AFAC) in Australia. Further, the national entities are governed by the regulatory authorities (Ministry of the Interior and Ministry of Public Works and Settlement in Turkey, Department of Homeland Security in the United States, and Department of Emergency Services in Australia) who impose and monitor the standards by examining the performance measurements (i.e., evaluation of achieved outcomes compared to desired outcomes) reported through annual reporting on government services. The principals on which the SDS is set are not publicly available, such that it is not possible to ascertain the key criteria that are used to establish the target response times. Nevertheless, fire agencies consider response times as key criteria to assess the distribution and staffing of current fire stations and to establish whether new fire stations are required in order to maintain adequate fire cover and continue to meet SDS (NFPA, 2015). Given access to finite resources (for example, personnel, fire stations and associated infrastructure) establishing whether the response to calls for emergency service by current fire stations is adequate and determining the factors influencing the speed of response is crucial in terms of locating new fire stations to ensure timely response to calls for emergency service (Murray, 2013).

To date, existing fire research has largely been focused on identifying the key determinants of risk (Warda, Tenenbein, & Moffatt, 1999; Corcoran, Higgs, & Higginson, 2011; Oliveria et al., 2014). This body of work has shown that fire disproportionately affects individuals from different socio-economic backgrounds (Jennings, 2013), who exhibit certain types of behaviour (e.g., smoking, drug taking, and excessive alcohol consumption) (Bruck, Ball, & Thomas, 2011; Diekman, Ballesteros, Berger, Caraballo, & Kegler, 2008; Duncanson, Woodward, & Reid, 2002, 2000; Holborn, Nolan, & Golt, 2003; Jennings, 1999; Miller, 2005; Warda & Ballesteros, 2007; Warda et al., 1999) and with particular demographic characteristics (Wallace & Wallace, 1984; Bell, Schuurman, & Hameed, 2009; Špatenková & Stein, 2010). Furthermore, structural factors (e.g. building age and type of dwelling) (Chandler, Chapman, & Hollington, 1984; Shai, 2006), weather conditions (e.g., low temperatures, rainfall, and humidity) (Chandler, 1982, 1984; Gunther, 1982; Drobyshev, Flannigan, Bergeron, Girardin, Suran, 2011; Corcoran et al., 2011) as well as specific days of the year (e.g. public holidays) (Long, 2006) have also been identified as escalators of fire risk.

While previous studies have highlighted the need for rapid response to calls for emergency service, few studies have drawn attention to the importance of determining the factors that influence response to calls for emergency service (Catay, 2011; Sufianto & Green, 2012; Tamat et al., 2014). Previous empirical studies have found that response to calls for emergency service is associated with certain population characteristics (for example, population density and age of resident), dwelling characteristics (such as, dwelling type and age of structure), physical infrastructure (presence of traffic lights, street connectivity, street network and road density), environmental conditions (weather), time and day of the incident, incident location, station location, and awareness of fire risk and preparedness by individuals (Catay, 2011; Murray, 2013; Productivity Commission, 2015; Sufianto & Green, 2012; Tamat et al., 2014). Tamat et al. (2014) in particular examined the temporal patterns of response times in the State of Penang, Malaysia and identified significant differences in the fire brigade's response times by month and year, and explained these differences as a function of inadequate fire-fighting resources (e.g., personnel and fire stations), traffic congestion and the location of the incident relative to the responding station (Productivity Commission 2015; Sufianto & Green, 2012). In a study that reported on siting new fire stations in Istanbul, Turkey, Catay (2011) emphasized that in fast growing cities the strategic placement of new fire stations is crucial in order to ensure an equitable and reliable emergency response system that satisfies changing demands that emerge as a consequence of urban growth and population densification. In a related study, Sufianto and Green (2012) echo this same point in an analysis of urban fire stations in Jakarta and Surabaya, Indonesia revealing that certain types of physical infrastructure such as narrow streets allied with traffic congestion significantly increases response times. Existing empirical studies have revealed that response times were associated with the connectivity and density of the street network (Handy, Paterson, & Butler, 2003; Productivity Commission 2015; Sufianto & Green, 2012). The findings from Handy, Paterson & Butler (2003) study in Charlotte, North Carolina showed that response to calls for emergency services were significantly slower in areas with decreased street connectivity (e.g. locales with more dead ends or cul-de-sacs) and denser street networks. In other words, areas with more complex street layouts were found to have significantly slower response times. A study by Park et al. (2016) in Saskatoon, Canada further highlighted the role played by physical infrastructure, in particular rail lines and grade-crossings that were shown to increase response times up to 20 min (Park et al., 2016). Response times were also shown to be slower in areas where there were larger numbers of blockages created as a result of long and/or slow moving or stationary freight trains (Park et al., 2016).

To conclude, while the majority of existing empirical studies on fire have been based on identifying the key determinants of fire