Towards development of a predictive model for structure fire – a review of the literature

Emergent Research Forum (ERF) Paper

Andrew Edwards  
Macquarie University, Australia  
andrew.edwards2@hdr.mq.edu.au

Stephen Smith  
Macquarie University, Australia  
Stephen.smith@mq.edu.au

Vincent Pang  
UNSW Business School, Australia  
Vincent.Pang@unsw.edu.au

Abstract

The principles of firefight have remained relatively unchanged throughout time, that is firefighters are on standby ready to respond as quickly as possible (Smith et al. 2016). But what if Information Systems tools and technology could make a change to the way that risk is identified and resources allocated and deployed. A review of Fire Fighting literature and examination of four exemplar case studies demonstrates that analytics could provide emergency managers with a toolset that could be used to make informed decisions on future fire emergency scenarios. We propose using the SCOR supply chain management concepts and applying these to the firefighting industry combined with predictive analytics to identify at risk properties. Firefighting appliances could be pre-deployed to locations that were at higher risk of structure fire thus reducing response times, which could save life, reduce damaging and environmental impact.

Keywords

Fire, Structure Fire, Emergency Management, Prediction

Introduction

A fundamental principle of firefighting has remained constant throughout the centuries, which is why Public Safety Agencies throughout the world are on standby ready and waiting to respond to when a structure fire starts. With improvement in technologies, Predictive Analytics is a business information systems tool used in many industries such as the military, police and retailers to forecast likely scenarios.

The objective of this paper is to review the current firefighting literature to demonstrate that analytical techniques could be developed to identify communities at risk of structure fires. By using Information Systems (ISs) to identifying the locations of where there is a higher probability of a structural fire occurring, decision makers could engage and educate those communities on fire safety thus reducing the likelihood of a fire occurring or pre-deploy resources to a location that is closer to the higher risk areas thus enabling a faster response (Smith et al., 2016). We use literature to demonstrate predictive analytics could be extended to identify communities and areas at risk of structure fire.

Methodology

A literature review is a research methodology that undertakes a secondary study of primary studies. It is used to summarize, analyze and synthesize ideas and concepts within a domain. Using the Thompson Routers Incites Journals Report, a search was undertaken to identify the top-ranked fire-related journals using the search term ‘fire’. Of each of the journals returned, a further search was undertaken using the terms ‘fire’ and ‘prediction’, and was then examined for relevance.
Literature Review

The results demonstrate that there is a body of knowledge that focuses mainly on the engineering aspects of fire prevention. There are few peer reviewed academic research papers in the field of fire prediction or the use of analytics within the structural firefighting domain. Of all the journal articles reviewed, only two identified in the need for theory development concerning resource allocation between preparing for and responding to structural fires (Jennings 1999, 2013), and alignment between three different fire propagation models (Rein 2006) and the use of Activity Theory by Chen (2013) to develop data models.

Jennings’ (1999) paper, which is identified as seminal work in this domain, provides a significant lead into other research in the domain. A common theme through primarily a literature review paper, Jennings (1999) has shown there is a relationship between the incidences of fire and socio economics fires. A summary of the factors provided insight into the types of data that will be required for the development of an IS that can be used to predict structure fire is shown in Table 1 (Jennings 1999). In 2013, Jennings (2013) focuses his literature review on public policy and prevention activities, and, again, notes the work being done in isolation and that structure fires continue to remain a problem.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Explanation</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overcrowding</td>
<td>Identifies overcrowding in substandard buildings (population density) as a contributing factor to fires.</td>
<td>Wallace &amp; Wallace (1984)</td>
</tr>
<tr>
<td>Socio economics</td>
<td>A study conducted in greater London found correlations between the instances of fire and socio-demographics</td>
<td>Chandler (1979)</td>
</tr>
<tr>
<td>Smoking</td>
<td>Developed over 1,000 different scenarios in which structure fire could occur.</td>
<td>Clarke &amp; Ottoson (1976)</td>
</tr>
<tr>
<td>Alcohol</td>
<td>An epidemiological study in Memphis in 1973 found that most people who lost their life to fire had consumed alcohol.</td>
<td>Unknown (1973)</td>
</tr>
<tr>
<td>Temperature</td>
<td>Found a relationship between the instances of fire and the use of heaters.</td>
<td>Gunther (1982)</td>
</tr>
<tr>
<td>Socio economics</td>
<td>Found relationships between children living with parents (aged under 18), income and education level with the instances of fire.</td>
<td>Schaanman et.al (1977)</td>
</tr>
<tr>
<td>Socio economics</td>
<td>Continued the work of Schaanman. Introduced the measure 'fires per 1,000 population'.</td>
<td>Karter &amp; Donner (1977)</td>
</tr>
<tr>
<td>Socio economics</td>
<td>Constructed a structure fire model using income, children, owner occupation, crowding, structural condition, temperature and social tension with findings that temperature, income and owner occupation were the most significant factors.</td>
<td>Muson et.al (1983)</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>Examined operating costs of fire departments but was unable to explain any association between costs and loss of buildings.</td>
<td>Goodhart (1982)</td>
</tr>
<tr>
<td>Socio economics</td>
<td>Examined population, socio economics, firefighter’s wages and fire damage to model supply and demand for fire services.</td>
<td>Southwick &amp; Butler (1985) &amp;</td>
</tr>
</tbody>
</table>

Table 1: Summary of factors contributing to structure fire as cited in Jennings (1999)

Jennings summaries his work from the 1999 paper and notes the relationships between the many factors identified by the disparate, uncoordinated and unpublished research that relate to structure fire and the limitations in the early work due to funding, computing power, software, the types of studies undertaken, bias and belief. Moreover, Geographical Information Systems (GIS) has been identified as an analytical tool enable to show clear patterns of structure fires in space and time (Jennings, 1999; Asgary 2010). Injuries can be predicted using age of housing, income and English as a second language (Shai 2006).

Corcoran has undertaken many studies (2007, 2009, 2010 and 2011), particularly in relation to the use of GIS to identify spatial and temporal trends, and with Chhertri (2010) used Australian Bureau of Statistics data to align socio economic indicators, weather, time of year and location with the instances of structure fire.
Jennings (2013) points out that in the move towards the development of a theory of structure fire, risk can be examined at the individual, building or neighbor level and also in terms of life, injuries and property. He cites his own model using vacant housing, population aged under 16 and over 65, income level and single parent households as providing some success in a number of cities in the United States.

Of specific interest in all this research was that regression modelling was the toolset that was used and alternates did not appear to be considered. Jennings work has highlighted the different studies and models that have been developed. His work is a cornerstone in the structure fire domain in that it has brought together the disparate work that has been undertaken in this domain.

The Current State of the Art – Four Case Studies

To highlight the disparate research into fire prediction, we have selected, reviewed and summarized for relevant case studies from the academic literature. These case studies (Table 2) were selected as the best examples of real world outcomes using Information Systems to predict structure fire emergencies.

<table>
<thead>
<tr>
<th>Case Study</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Novato Fire District, California</td>
<td>Uses cases for predictive analytics are identified with cultural issues noted as being an inhibitor to change.</td>
</tr>
<tr>
<td>The London Fire Brigades, England, United Kingdom</td>
<td>The 2008 Global Financial Crises enabled the London Fire Brigades to redeploy human resources to undertake inspection work of properties that high risk through the use of analytics.</td>
</tr>
<tr>
<td>South East Queensland, Australia</td>
<td>Analytics are used to determine optimal response times to best service at risk properties.</td>
</tr>
<tr>
<td>Surrey Fire Service, British Columbia, Canada</td>
<td>Data analytics identified 18,473 at risk properties that were visited over a 1-week period by fire fighters that effectively reducing structure fires by 63.9% over a 12-month period.</td>
</tr>
</tbody>
</table>

Table 2: Summary of Case Studies.

In the case of the Novato Fire District, California, the Nickel (2014) identified a 50% success versus a 50% failure/mixed result rate in the use of predictive analytics across the military, police, emergency services and the retail sectors. There are two important insights noted by Nickel. The first revealed in the Walmart example, where an analysis of sales data identifies that weather (a hurricane forecast) drives human behavior to purchase specific types of goods - an increased demand for certain goods (eg canned food, water and beer). The second being that firefighters are unlikely to accept the use of predictive analytics as a tool to inform a risk based approach to structure firefighting due to long held beliefs and an aversion to change.

The London Fire Brigades used a mashup of marketing and response data to identify its top three at risk communities. Austerity measures implemented by the government enabled the resistance to change identified by Nickel to be overcome and have firefighters engage with the at risk communities.

In South East Queensland a mashup of data including fire incidents, weather and Australian Bureau of Statistics Socio-economic Indexes for Areas enables the insights into increased risk in winter because there are more cold days in winter than there is in summer, school holidays and public holidays, low socio economic indicators and weather. The Surrey Fire Services identified used 20 years of response data to identify at risk properties. Fire fighters then visited these 18,473 homes (13.8% of the city’s housing stock) over a 1-week period and delivered fire safety messages, equipment and inspected the households to provide advice. The activity effectively reduced the instances of structure fire over a 12-month period by 63.0%. (Clare et al. 2012).

In all these cases for structure fire risk the use of dynamic data such as weather information (used by Walmart), social media or resource location were considered. These data in addition to those being used could be used to pre-position appliances, warn communities or match resources to anticipated demand.

In other words, in certain types of weather conditions available resources could be prepositioned closer to communities that were at a higher risk. In doing so the time to respond to a structure fire would be reduced damage to property, injuries or loss of life.
The current structure fire model is the firefighters are waiting before response to an incident fire as shown in Figure 1. Firefighting activities only start the response process after a fire incident is reported. With the new approach of structure firefighting, which we proposed, we borrow supply chain concepts, such as used in the SCOR model (SCOR 2017), to assist us in changing the process. The three processes of Plan, Source and Make in the SCOR model could be used to improve the current structure fire model. Although the original concept is based on manufacturing, the SCOR has been modified to fit the service industry. In supply chain, data and information drive the forecast on what stock, and the amount to be produced. In our proposed model, as shown in Figure 1, like in supply chain, there should be a Plan process. Firefighting should be planned in advance based on available data and information (such as weather, demographics and location). Potential structure fire areas can be identified using Predictive Analytics. As in supply chain, resources have to be managed as in the Source process. Movement of firefighting resources to an area/region where a potential structure fire is likely to happen could be scheduled and controlled based on risk. The actual structure fire can be compared with the Make process, where the firefighters put out the fire as fast as they can, which this process technically does not change. However, the reduction in response time (time to travel to the fire) could lead to a reduction in structure (house) damages, human casualties and environmental impact (Smith et al 2016). Thus, using supply chain concept, we could improve with the structure firefighting model. To complement the proposed model, supply chain management systems (inter-organizational systems), and Enterprise Systems are expected to be adopted for these emergency agencies as the underlying system to communicate and share data and information (Pang et al., 2007).
Conclusion

This literature review has demonstrated that analytical techniques could be developed in an Information System that could be used to identify communities at risk of structure fires. By using Information Systems to identifying the locations of where there is a higher probability of a structural fire occurring, decision makers could engage and educate those communities on fire safety thus reducing the likelihood of a fire occurring or pre-deploy resources to a location that is closer to the higher risk areas thus enabling a faster response. Development of an information system would enable identification of and at risk communities in these areas, and could improve the management of resources, save lives and reduce costs before a fire even starts.

REFERENCES


Clare, J., Garis, L., Plecas, D., and Jennings, C. (2012) Reduced frequency and severity of residential fires following delivery of fire prevention education by on-duty fire fighters: Cluster randomized controlled study Journal of Safety Research 43, 123–128


InCites Journal Citation Reports, Thomson Reuters, Available at: https://jcr-incites-thomsonreuters-com.simsrad.net.ocs.mq.edu.au/JCRMasterSearchAction.action?pg=SEARCH&searchString=fire Date Accessed: 31 July 2016


Nickel, E. D. 2014. Forecasting calls for service in the Novato Fire District: Using predictive analytics to improve community safety Available at :
https://www.academia.edu/6360726/Forecasting_Emergency_Calls_for_Service_using_Predictive_Analytics Date Accessed: 1 February 2017


