AFAC STREAM PAPER

Understanding the Geographic Distribution of Risk

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Abstract

Profiling the geographic distribution of fire risk involves quantifying the level and nature of risk present in small areas (1 sq km grids or smaller) across a state or territory.

In emergency services management, having an accurate understanding about the nature and distribution of risk at a micro level benefits many areas of the organisation, from the targeting of treatments to the setting of appropriate performance standards.

Developing an accurate measure of small area risk is difficult as incident data is an unreliable indicator of risk at a micro level. In addition, most performance measures and outcome statistics fail to quantify the true costs to community resulting from fires in various environments.

In order to produce accurate risk profiles at a small area level we need to firstly understand the true cost to the community of fire at a macro (state) level as well as the drivers or characteristics that contribute to increased risk. Once this has been done, a variety of methods can be used to apportion this risk down to the small area level.

Introduction

Understanding the geographic distribution of fire risk is an important ingredient for delivering an effective fire service, allowing planners to work toward ensuring that areas of equivalent risk are receiving equitable and appropriate treatments.

A means for quantifying levels of risk down to the micro level is not immediately obvious. Incident frequency and outcome statistics are unreliable indicators of risk at the micro level due to the random nature of fire events, diversity of environments and variability of fire outcomes.

The following paper outlines a method for quantifying small area structure fire risk across a state or territory of interest.

Background

The following methodology was devised by Spectrum Analysis Australia in order to generate small area risk profiles for Victoria. This research has been conducted in collaboration with the Office of the Emergency Services Commissioner (OESC) in Victoria. The results are currently being evaluated by OESC as well as CFA and MFESB.

A Brief Overview of the Methodology

In essence, the methodology involves determining cost to community of structure fires at the macro (state) level across a number of different environment types. This realised risk is then distributed down to small area level using appropriate measures of structural population density coupled with analysis into the drivers of fire risk.

There are four key components of the methodology

1) Estimating the annual state-wide cost to the community of structure fires within a variety of risk environments.
2) Defining the *Small Areas*
3) Disaggregating *Cost to Community* from State to Small Area
4) Calculating total structure fire risk within each grid.

Step 1 Estimating the Annual State-Wide Cost to Community Of Structure Fires

The first port of call is to estimate the annual state-wide cost to the community resulting from structure fires. This is done by estimating the costs borne by the community as the result of structure fires across a variety of risk environments.

Categorising Risk Environments

Due to differences in structure types and fire outcomes it is necessary to consider the different types of environments that can be impacted by fire. Different environments possess different characteristics that will impact upon levels of risk and severity of outcomes. In addition, different environments require different suppressive and preventative treatments.

Decisions regarding the level of detail to which risk environments are segmented provides challenges and trade-offs. If there are too many categories the profiles quickly become overly complex and difficult to interpret. Conversely, overly generalised categories can fail to recognise specific risks unique to particular environments. The selected approach was to establish a common set of ten base-level classifications (see Table 1) that conform to existing data Standards.[1] Further sub categorisation can then take place if a more detailed analysis is required.

TABLE 1 Structure Fire Risk Segmentation

Risk Environment	Hazard Type		
	Structure Fire	Wild Fire	Non-Structure Fire
1 Agriculture	✓		
2 Commercial	✓		
3 Health/Special Accom	✓		
4 Industry	✓		
5 Infrastructure	✓		
6 Natural Environment			
7 Public Accom'	✓		
8 Public Assembly	✓		
9 Residential	✓		
10 Transport			

✓ A tick indicates that the Hazard type exists in this type of environment. Wildfire and Non-Structure Fire Hazards have not been considered in this paper.

[1] These classifications conform with the Australian Incident Reporting System (AIRS), FIRS and in the case of commercial structures, Australian Bureau of Statistics ANZSIC classifications.

Determining the Costs of Structure Fires at the Macro level

The costs born by the community as a result of structure fires are many and varied. A framework is required to ensure that all relevant costs are considered.

At its most basic level, a common approach is to differentiate between direct and indirect costs. Direct costs are those that result from the physical destruction or damage to buildings, infrastructure, contents and the like. Indirect costs are due to the consequences of the damage and destruction and includes aspects such as medical costs, temporary lodging, time off work and similar.

The Cost to Community Matrix (*Table 2*) shows the framework used to arrive at the total cost to the community. The key components of this matrix are

- The Direct Cost of Damage to Property
- The Cost of Death & Injury
- The Indirect Costs
- Low Probability High Impact Event Allowance

The *Direct Cost Of Damage To Property* can be estimated by examining historical incidents (preferably a number of years of historical data to avoid the influence of atypical events (outliers). Much of the required information is contained within fire service incident reporting databases. Due to possible inaccuracies present in incident data bases, wherever possible incident data should be reality tested using other independent sources of information (*such as insurance industry data*).

Accidental Death and Injury statistics can be accessed from a variety of sources including fire incident reports, Coroner findings, Institute of Health and Welfare statistics and the like.

Quantifying the *Cost To Community Resulting From Accidental Death Or Injury* can be a difficult and emotive area. The preservation of human life is the primary objective of all fire services and clearly the most severe outcome resulting from structure fires is the death or severe injury of an individual. It can also be argued that human life is above any form of monetary valuation. Because of its importance in the development of government policy, the subject of valuing accidental death and injury has been researched extensively for many years. While a lot of valuable research into the costs of deaths and injuries resulting from fire has been conducted internationally, most of the research conducted in Australia has been related to other causes of accidental death and injury, most notably transport accidents and natural disasters.

Indirect Costs are environment specific and are expressed as a proportion of direct costs. Little work has been conducted in Australia to quantify the indirect costs of fire, however some valuable research has been undertaken in the United States.

The *Low Probability High Impact Event Allowance* attempts to allow for infrequent, events that have a major impact on the state. This is best assessed by analysing national data over a significant time period to better determine the types of environments that these events occur within and resultant outcomes.

Table 2 Determining the Cost to Community & Risk Environment Relativities – Key Elements & Matrix Calculation

Risk Env' Code	Risk Environment Description	Annual Structure Fire Incidents	Annual Fatalities	Annual Injuries	Cost of Deaths and Injuries ($million)	Direct Cost of Property Damage ($million)	Indirect Cost ($million)	High Impact Event Allowance ($million)	RISK - TOTAL ANNUAL COST ($million)	Percentage of State Structure Fire Risk by Risk Environment
		A	B	C	D (Derived from B+C)	E	F	G	H = D + E + F + G	
1	Agriculture	###	#.#	#.#	$	$	$	$	$	%
2	Commercial	###	#.#	#.#	$	$	$	$	$	%
3	Healthcare & Special Accommodation	###	#.#	#.#	$	$	$	$	$	%
4	Industry	###	#.#	#.#	$	$	$	$	$	%
5	Infrastructure	###	#.#	#.#	$	$	$	$	$	%
6	Natural Environment	na								
7	Public Accommodation	###	#.#	#.#	$	$	$	$	$	%
8	Public Assembly	###	#.#	#.#	$	$	$	$	$	%
9	Residential	###	#.#	#.#	$	$	$	$	$	%
10	Transport	na								
TOTAL	**State Structure Fires**	**#,###**	#.#	#.#	**$**	**$**	**$**	**$**	**$**	**100%**

Step 2 Defining 'Small Areas'

In developing small area risk profiles, decisions need to be made regarding the most appropriate geographic areas to use. Alternative geographic areas for quantification and mapping of small area structure fire risk include :

a) existing administrative boundaries (such as Postcodes, Local Government Areas or ABS Census Collection Districts);

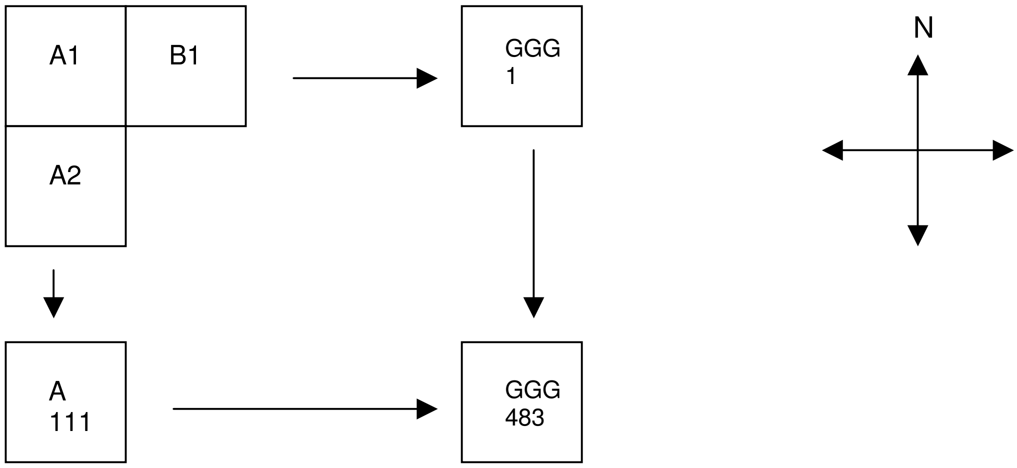
b) Small Area Grids (1sq km or less)

It was determined that a grid has several advantages over administrative boundaries for performing comparative risk analysis as

- a grid is easily interpreted and understood by all interested parties
- cells are uniform in size, ensuring valid statistical comparison of quantitative data across areas
- a grid is easy to disaggregate should a finer level of profiling be required in the future
- grid cells can be easily aggregated up to reflect any administrative or other boundary
- a grid maintains a consistent boundary and can therefore be used to produce historical 'risk-change' maps and calculations
- when mapped in GIS a grid clearly shows relative risk intensity

Figure 2 shows the approach taken to developing the grid standard utilising a state *Minimum Bounding Rectangle* (MBR).

Figure 2 Grid Creation & Referencing



Step 3 Disaggregating Cost to Community from State to Small Area

Disaggregating state wide risk down to the small area level (grid) involves three key steps :-

1 Determining The Proportion of State Structure Population Within Each Grid
2 Allowing for the Drivers of Fire Risk
3 Determining the Proportion of State Risk within each Grid using 1) & 2)

<u>Determining The Proportion of State Structure Population Within Each Grid</u>

The first step toward estimating the level of risk existing within each grid cell is to determine the proportion of state structures existing within each grid. This needs to be done independently for each of the eight identified risk environments.

In order to estimate structural population a decision needs to be made regarding the most logical measure of structure population for each risk environment; a measure that represents not only the number of structures but also the size of structures. For example, in residential environments, *number of dwellings* represents the most logical measure of structural density. In the case of Public Accommodation, bed numbers are the most logical measure of structure population (as accommodation facilities can vary significantly in size). In the case of Commerce, the number of employees is considered the best measure of structural population (again, because individual commercial structures can vary significantly in size).

Disaggregating Standard Geographic Data to Grid

Much of the data used to estimate the proportion of state structures existing within each grid is 'Polygon-based'. In other words, it relates to administrative boundaries that do not align to the grid cells. Examples include

- Census of Population & Housing Data – available at CCD (Census Collection District) level
- Business Employment Estimates – available at ABS Postcode level
- Agricultural Census Data – available at Statistical Local Area (SLA) level

Various techniques can be employed to disaggregate this information into the grid cells that lie within or across that area. Information such as cadastral boundaries, Address Points or geocoded Yellow Pages addresses by ANZSIC data can be very useful for this task.

Allowing for the Drivers of Structure Fire Risk

Apportioning state risk to grid based only upon the density of structures existing within each grid fails to consider other important factors that may be associated with increased or decreased risk.

In order to uncover these factors, analysis should be undertaken to compare the frequency and severity of historical structure fires that occur in various geographic regions to the characteristics of those regions. Where relationships exist between frequency and a characteristic, it is assumed that the characteristic is a *Driver* of structure fire and the risk profile of the effected grid cell is adjusted accordingly. Characteristics examined are specific to each risk environment, but may include

- Demographic / Social Factors (*eg. age, income, language, disabilities*)
- Geographic Factors (*eg remoteness*)
- Industry Types (*eg. ANZSIC industry types*)
- Structure Type (*eg age of structure, building materials used, fire suppression*)

Correlation Analysis

Correlation analysis is a useful means for determining whether a particular characteristic is related to structure fire risk. Where a significantly high correlation exists it can be said that there is a statistical relationship between the characteristic of interest (Driver) and fire risk, although this does not necessarily imply causality.

Geography for Analysis of Drivers

The geographic area used to perform the correlation analysis needs to be large enough to capture a significant number of events but small enough to maintain characteristic diversity between areas. For fire incident data the 1 sq km grids are too small (as the number of incidents is very small or non existent, placing doubt on the accuracy of the dependant variable). Also, some characteristic data is more easily accessible at Postcode, SLA or LGA level. The analysis will be undertaken at either Postcode, SLA or LGA depending on the availability of data and the number of incidents.

Creating an Index Score that Reflects Per Structure Risk

Regression can be used to define models relating the number of incidence per head of structure population to area / structural characteristics. Once defined, the models can then be applied back down to the micro grid level (assuming the relevant data is available or can be estimated at the micro level). By comparing the resultant prediction of incidents per head of structure population at grid level to the state average, an index score (or weighting) can be derived that communicates the per head of structure population risk for each grid.

Calculating the Proportion of State Risk within each Grid for each Environment

The estimated structure population of each grid multiplied by its index score (weighting) is used to determine the proportion of state risk existing within each grid.

Calculate the Total Structure Fire Risk Within Each Grid

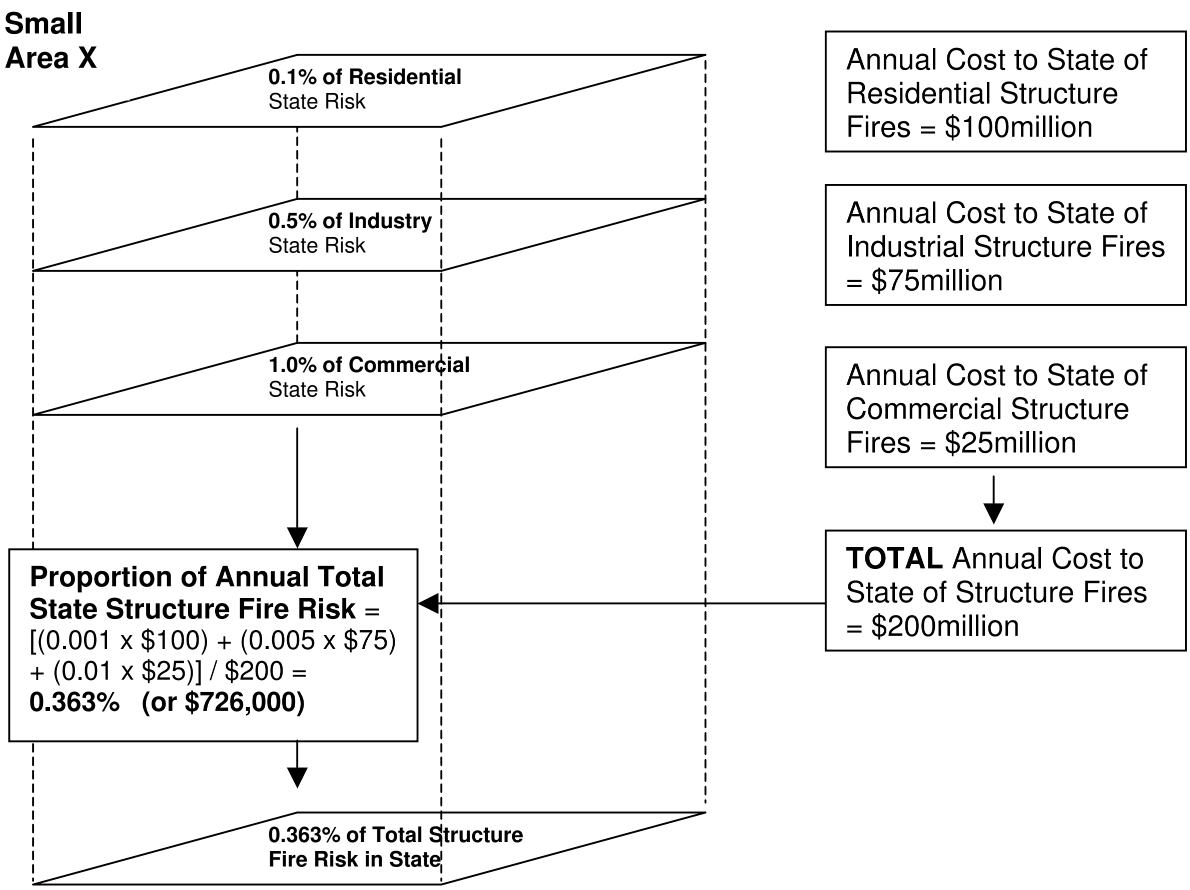
The proportion of total structure fire risk within each grid is calculated using

a) The percentage of state structure population within each grid, weighted using the analysis of drivers models

b) The relative cost to community of state structure fires across each of the eight identified environments

The approach is best conceptualised in the following diagram that displays the steps taken in determining the proportion of total structure fire risk in a fictitious area "Small Area X". This example displays only three different risk environments for ease of illustration.

Figure 1 Method For Determining Risk In Small Area X



Utility of Results

The resultant grid based estimates of proportion of state structure risk can be used for a variety of purposes including

- Thematic mapping to show the geographic distribution of risk
- Calculating the percentage of state risk contained within any area of interest
- Calculating the theoretical annual cost to community from structure fires in any area of interest
- Use the resultant percentage breakdown of risk environments for any area to drive the most appropriate mix of community education and safety programs
- Compare risk with service delivery performance at the micro level
- Set Appropriate and Equitable Response Time Standards
- Undertaking 'What if?' and Predictive Planning

The results can be easily incorporated into any standard GIS system, and may overlay a variety of other GIS information.

Limitations

Some limitations of this method include

- Disaggregation of information down to grid level can introduce inaccuracies;
- Data used is historical (representing a point in time), meaning that profiles may not represent an exact current picture;
- The allowance for high impact events (using national history) may not reflect the future probabilities of such events;
- Use of historical incident data to quantify the state wide cost to community is in fact measuring realised risk, a function of current service delivery standards, community attitudes and legislation;
- Descriptive data is more accessible for some environments than others, meaning that different levels of confidence in results apply to different environments;
- Analysis of Drivers is limited by available data, meaning that some critical factors that contribute significantly to risk cannot be tested or incorporated.

In Summary

This paper has outlined an approach for determining fire risk levels at the micro area level and has outlined possible utility of results and potential limitations. While the process is an involved one (much detail of which extends beyond the scope of this paper), the benefits of undertaking such research must outweigh the effort in production.

About the Author

Bruce Waddington is regarded as one of Australia's foremost geo-spatial modelling professionals.

Bruce Waddington founded Spectrum Analysis Australia in 1992 and since that time has provided expert consultancy in matters of strategic significance to many of Australia's largest organisations and government agencies.

Over the last 2 years Bruce has undertaken a number of important research projects for the fire services in Victoria, including developing the Strategic Location Plan (Fire Stations & Equipment) for MFESB as well as small area risk profiling and response time modelling for both MFESB and OESC.

Bruce Waddington continues to work closely with Spectrum Analysis as well as providing his own specialist consulting services.