BUSHFIRE RISK AT THE RURAL/URBAN INTERFACE

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Abstract

Living in a bushfire prone area provides many lifestyle advantages but also presents a risk to life and property. This paper describes the development of a model to predict the potential risk of loss of a specific house at the rural/urban interface.

The three fundamental mechanisms of attack have been considered: embers, radiation and flame contact. The spatial and temporal properties of these attack mechanisms are combined with our evidence based knowledge of house loss. The probabilistic model takes into account a wide range of parameters such as vegetation, climatic conditions, topography, building design, human behaviour and other infrastructure elements close to the house. Each of these elements may play a role in mitigating or contributing to the risk of building loss.

The model uses the principle of aggregated probability of failure of each object that contributes to the risk of house loss. The outcomes of the model provides a risk estimation for any given building/environment/people scenario and allow us to determine the level of risk mitigation achieved by a specific strategy or combination of strategy. The application of this model will be tailored to fellow researchers, community education, policy developers, town planning, and regulation reform.

Introduction

The risk considered in this model has been defined as the risk of building damage to a point where it no longer provides a safe haven for occupants. The buildings exterior shell is considered an envelope, a breach of this by the mechanisms of bushfire attack is considered as an exceedance of an acceptable level of risk.

The most appropriate approach is to divide the risk event into two main aspects, these being likelihood and consequence (Australian standard for risk management, 2004). Likelihood refers to the nature, magnitude or persistence of the attack mechanism (measured in terms of the heat and intensity of both the flame front and the flux of embers incident before during and after the flame front activity), and the chance of an event occurring. Consequence is a measure of the outcome in relation to the objective, which is determined by the effect the bushfire event has on urban assets. Obviously consequence is highly dependant on the vulnerability a property has to the mechanisms of bushfire attack. The vulnerability depends on the building material and design, the proximity of surrounding combustible elements, the presence of human intervention (before, during and after the fire) and the environment in which the event occurs.

Two main definitions are considered to evaluate the probability of destruction of any specific house:
- Impact of ember attack, radiant heat and flame at the urban interface
- Vulnerability of the house in response to these attack mechanisms.

This paper will present in the first part the input parameter of the risk model. It will then focus on the assessment of house vulnerability based on statistical data sets from field and experimental investigations. This paper aggregates relevant material that could be used to underpin the risk model and draws conclusions as to the gaps that this data may not yet be able to fill.

Basis of the risk model

The objective of this model is to define the potential risk of loss of a specific house over the 50 year design life of a building.
The existing approach first assesses ember, radiant heat and flame attack. The information related to post bushfire surveys and to experimental work is used to support and calibrate the risk model. However there is still some lack of data and this is where expert knowledge is used.

Approach to assessing the risk of ember attack radiant heat and flame

The risk model takes into account existing approaches to quantify the flame and radiant heat attack.
Radiant heat flux and flame received by the house for many of the circumstances is based on Mc Arthur flame length and spread rate equations, Byram's equation and simple view factor models (Mc Arthur 1967, Byram 1959, Cohen 1996). The output of this model provides a level of radiant heat as a function of distance to the bush, type of vegetation, ground slope and weather conditions.

Ember attack on an urban interface may be quantified by defining its distribution and the duration, in which it persists, however these phenomena are complex to predict. Various research has been conducted to model the trajectory of embers, to predict the ignitability of different material, and to study the behaviour of embers in different types of vegetation (McArthur, 1967, Muraszev,1974 Albini, 1979, Ellis, 2000). These models are used to calculate the maximum distance of spotting during the fire event. Some work has been done to define an embers attack index based on the relative amount of embers being released and the duration over which it is being released (Tolhurst, 2003).

In this model the estimation of ember attack is based on density of embers received by a house within 50m from the bush. An empirical approach is used to evaluate the embers density, function of different parameters: wind speed, type of vegetation, and distance. Ellis and Tolhurst mentioned the importance of vegetation characteristic and fuel load to determine the firebrands density (Ellis, 2003, Tolhurst 2003). The distance from the bush is another parameter to consider as the embers density decreased as an exponential function of distance (Ellis, 2003).

The probability of house failure based on 4 main aspects

- The probability of failure due to embers entering the envelope
  The probability of ember entry is linked to the opportunity of embers entering through gaps in the structure and accessing combustible furnishings. The information collected on the main point of ignition was used to define the different vulnerable parts of the building. Different parts of the structure have been defined according to their likelihood to ignite due to the amount of combustible material present. The space considered, occupiable space, roof, subfloor and wall cavities are respectively ranked from most likely to ignite to least likely to ignite. For each part of the building we assess a 'gap factor' related to size and number of gap. It is assumed than the probability of ignition is link to the number of ember that could enter within the envelope (ember density model and gap factor) and on the action of occupant (occupant model).

- The probability of failure due to embers accumulating outside the envelope
  The probability of ember ignition against the envelope depends on the configuration (a measure of the structure's susceptibility for embers and debris to accumulate on horizontal projections, in re-entrant corners or crevices where localised flame attack is then likely to result) and combustibility (the ability of the material to support localised flame development, this property is linked to environmental factors such as temperature and humidity). In this example the probability of survival is based on the geometry and material of the structure (number of surface and typology of combustibility of different material commonly found in Australian house), embers density and action of occupant.

- The probability of failure due to envelop ignition or breaching by radiation from the bush
  This probability is based on radiant heat model and on information from our experimental work (Leonard 2005b, Bowditch 2005). Above a certain level of radiant heat received by the structure there is breach in the envelope which increases the probability of failure of the building.

- The probability of failure due to envelop ignition by radiation from surrounding burning elements

This identifies the relevance of surround elements such as outbuildings, stored materials, cars etc. The behaviour of these elements in a bushfire can be determined by experimental investigations (Leonard 2005b, Bowditch 2006)

The probability of survival of the house is based on the aggregation of these four aspects.

Evidence based statistical loss and experimental work to support the risk model - Response of the structure to the mechanism of attack

The vulnerability of the structure is based on the resistance of the structure to embers, flame radiant heat attack (linked to house placement material and design), the individual elements between the bush and the house that could contribute to or mitigate structural loss, the house vulnerability, and the influence of human behaviour.

Relative importance of bushfire attack mechanism

To better understand the mechanisms influencing house loss CSIRO-MIT has surveyed bushfires involving significant house loss from Ash Wednesday to recent investigation in the Eyre Peninsula.

Evidence of the mode of ignition in the Otway fire in 1983 came mainly from surviving house examination and interviews with eye witnesses (occupants and fire fighters), and is related to embers ignition. In the majority of cases, ignition appeared to have been caused by burning debris in the 1994 Sydney fire, although radiation heat and flame played a significant role in cases where the houses were directly abutting dense undeveloped vegetation (Ramsey, 1995).

Of all the houses assessed in the Duffy survey area after the 2003 Canberra fire, none showed evidence of flame or radiation attack from the fire front itself. Out of a total survey number of 229 houses, 106 (46%) were destroyed and 79 (34.5%) were damaged either as a direct result of ember attack or as a result of secondary element ignition leading to house ignition (Leonard, 2005). Ember attack was responsible for 65% of house loss, and 30% of house loss were via ember and some radiant heat from surrounding isolated vegetation or other elements (see Figure 1). Radiation from the main fire front was not sufficient to cause ignition or direct damage to the structures; however, it is likely to have played a role in increasing the likelihood of flame propagation as a result of ember attack. Convective heat (hot gases from the flame front) may have also contributed to increased risk in a similar way.

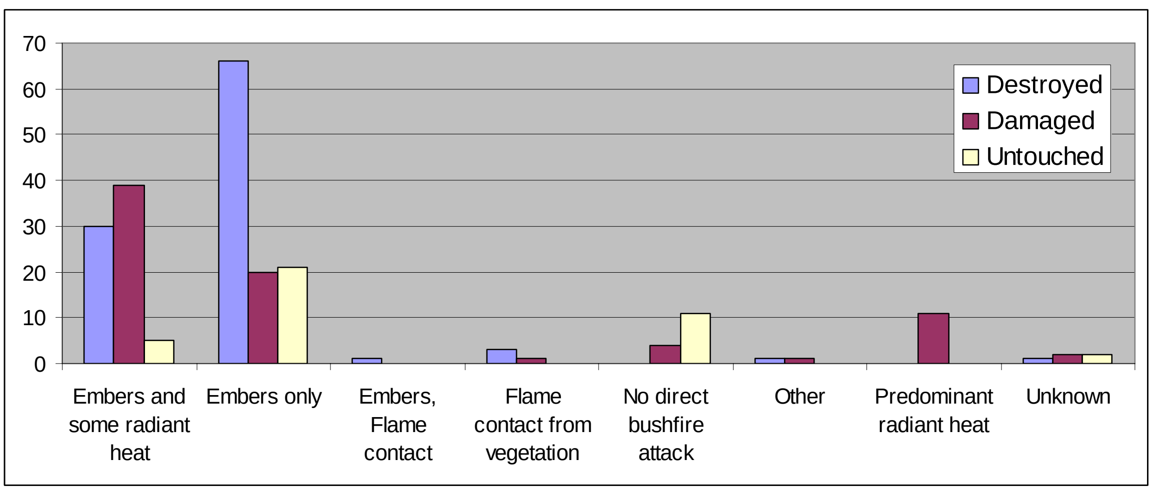

Figure 1 Mechanism of bushfire attack for surveyed area of Duffy (Canberra fire, 2003) – Expressed as a number of houses destroyed

Ember attack has been demonstrated as the main cause of house loss. However the impact of radiant heat on a house not only supports the ignition of flammable material on the structure, but may also create openings by causing failure of windows, which facilitates the entry of embers into the structure.

The synergistic effect of these two mechanisms of attack increases the potential of house loss, especially if the ignited points are not extinguished quickly.

House vulnerability to ember attack

Once the ember density is defined, the probability of ignition of the house depends on the number and quality of the firebrands to ignite the combustible material they reach. Two opportunities for ignition are possible: the probability of ember entry in the main envelope and secondly the probability of embers ignition against the envelope and the probability to sustain this ignition witch could lead to a breach in the envelope.

The results from post bushfire surveys show some of the main point of accumulation and entry (see Table 1). This table provides an interesting profile of the most susceptible aspects of external building elements. Timber decks (19%) were most prominent feature involved in direct ignition by embers, followed by eaves and gutters (17%), and window frame (10 %). This information is useful to understand the weak point of the house, but the lack of data on completely burnt houses has to also be considered.

Table 1 Summary of observed ignition point of survived houses recorded in Otways 1983, Sydney 1994 and Canberra 2003 post bushfire surveys

Evidence of ignition	**Number**
Timber decks	19
Eave fascia boards and or gutters	17
Timber window frames	10
Timber stairs	9
Timber door frames	7
Rough saws western red cedar cladding	5
Gapped board around stumps	5
Exposed timber beams (eave structure)	4
Verandah, supporting beam	4
door mat	3
Fabric verandah roofs	3
Timber shingle roofs	2
Plastic roof panel	2
Internal house	2
Verandah/Pergola	2
Timber frame behind A/C	2
Bitumen roof membrane	1
Canvas awning	1
Timber wall, supporting beam	1
Plastic verandah roof	1
Weather boards	1
Total	101

House vulnerability to radiant heat and flame

From a house’s perspective, radiation and flames present risk based on the level of radiant heat exposure as well as the time for which this exposure occurs (Leonard 2004).
There have been a lot of studies conducted on building material flammability for other purposes but there is little work done on the ignition of different material under bushfire conditions.
Research in CSIRO MIT have been done to evaluate the performance of glazing system, this research provides a better understanding of the parameters and levels of radiant heat that could lead to a window failure (Bowditch, 2005). Current research is developed to understand the performance of timber decks in bushfire.

Element between the house and the bush

The surrounding environment (type of vegetation, etc.) and details of outbuildings (type, degree of damage, and materials of construction) both contribute to mitigate or lead to house damage or loss.

Ramsay reported that for the Otway and Sydney fires the amount of vegetation around the house was found to influence house survival. Houses were more likely to be destroyed as the vegetation around them became thicker and the proportion of trees to shrubs increased (Ramsay, 1994). Overhanging trees appear to increase the risk to the house, due to the deposition of material on and immediately around the structure (Leonard 2005).

In each of the survey investigations it is observed that outbuildings like garage and shed are more readily ignited than homes. They present more gaps and openings and are more susceptible to ember ignition. The risk outbuildings pose to homes is a function of proximity to the home, outbuilding design, size, and material. Investigations have shown that outbuildings are more readily lost compared to the main structure and represent a significant impact mechanism for house loss (Leonard 2005).

Recent CSIRO MIT experimental work have investigated the performance of the many commercial fencing as protection for houses from radiant heat, burning debris and flame impingement during bushfires (Leonard, 2005b). In a number of cases the fences are responsible for spreading the flame between houses as was observed in the Canberra fires.

Human activities

The results of post fire investigation have shown the importance of human behavior before during and after the bushfire. A house is more likely to survive with someone around. Occupants and brigade members are in almost all case able to easily suppress an ember attack on the house, which has been demonstrated as one of the main mechanisms of attack. Fire service intervention is important for house survival, as they are significantly better equipped and have the ability to actively defend against more aggressive attack scenarios.

The Table 2 shows the importance of people presence. The information is based on the fire fighting activities carried out during and after four major bushfires. The action of occupant is important to reduce the impact of embers attack that persists during several hours after the fire front passage. The information should be used with caution as there is a bias introduced by the lower number of known occupant behaviour for destroyed houses, and a bias introduce by the sample of house surveys, which is not completely random for each fire. However, the interviews of people who had stayed with their house have broadened the general understanding of the mechanisms of bushfire attack.

Table 2 Fire fighting activities carried out during and after the bushfire event/house loss (summary of the Otways 1983, Sydney 2001, Canberra 2003, Wangary 2005 data)

Effectif %column % row	**Someone present (fire brigade, occupant, other)**	**No one present**	**Unknown**	**Total**	**%**
House destroyed	24 13% 8%	68 77% 22%	217 63% 70%	309	50%
House damaged	105 56% 61%	8 9% 5%	60 17% 35%	173	28%
House untouched	57 31% 42%	12 14% 9%	68 20% 50%	137	22%
Total	186	88	345	619	.
%	30%	14%	56%	100	.

The probability of having your house destroyed is 13% when someone is present and 77% if no one is present (see Table 2). This is a 5.7 times greater chance of a house being destroyed if no one is present.

Conclusion

Both the study of infrastructure element performance and post fire investigation have increased our knowledge of attack mechanisms, environmental conditions, house design, surrounding design and human behavior. These results are used to refine and calibrate the risk model. In some cases data is not available to support an essential aspect of the risk model, in this situation expert knowledge is used to define the main parameters and the different scenarios used in the model.

The input parameters for the probabilistic risk model for individual houses have been defined. The model will define the risk of loss for a specific house, and then different scenarios can be used to determine the level of risk mitigation achieved by a specific strategy or combination of strategy. For example what would be the impact on the total risk if the house is design with a timber deck and metal fence? The results provide the necessary information to assist the occupant to make appropriate cost effective solution. The outcomes of this risk model will be useful as a tool for community education, policy development and town planning.

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