Findings of Studies of Houses Damaged by Bushfire in Australia

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Abstract

Bushfire impact on the urban interface over the past seven decades has taught us many lessons, much of which have invoked change in behaviour, community understanding and policy. The principles of how bushfires impact on the urban interface are now well established; however, the prediction of the synergistic effects and specific risk of these attack mechanisms is not well quantified. Re-exploring the basics and considering the findings from recent survey initiatives will help further progress in mitigating the risk posed by bushfires reaching the urban and peri-urban interfaces. The recent ACT bushfires highlighted how predictions of bushfire impact based on the past two decades are not adequate for predicting potential loss. We now must broaden the range of considered factors influencing risk. Beyond this, there is an ever-increasing need to consider mitigation strategies in the broader ecological and socio-economic value systems.

General Lesson from Past Research

When bushfires become so large that they cannot be suppressed until weather conditions become more favourable, they are perceived as catastrophic events, exceeding man's ability to control that which has the potential to threaten life and livelihood. When the smoke clears, we see a mixed picture of loss, adaptability and survival, and we begin to measure magnitudes of loss.

For the first 150 years of white settlement in Australia, the destruction of houses in bushfires was taken as inevitable, and few efforts were made to investigate or improve the performance of buildings in bushfire-prone areas. The lessons learnt in the wake of the 'Black Friday' bushfires of 1939 brought sufficient order to bushfire prevention and suppression, that the community could begin to look towards solutions for minimising the destruction of houses in bushfires. The required knowledge was gathered piece by piece from the studies of a series of bushfire disasters over the next six decades.

Communities that live in bushfire-prone areas are slowly coming to terms with bushfire behaviour and the risks involved, despite media proliferation of images of the most extreme aspects of these events.

Research in recent times has assisted in bringing about a fundamental change in the community's view of bushfire attack on buildings. Prior to this time, there was a widespread community belief, reinforced by the news media, that bushfires moved at the speed of express trains, that houses exploded into flames and burnt down in minutes, and that there was not much that could be done to prevent this. Whilst direct flame contact and radiant heat play a part in the ignition and destruction of buildings, research has shown that the majority of houses destroyed in bushfires actually survive the passage of the fire front only to burn down in the following hours due to fire spread from ignitions caused by windborne burning debris.

Mitigation of the risks to building damage can be achieved with a balanced approach between construction methods and clearance of fuel load around the structure. This, however, generally only has a significant effect during the few minutes it takes for the fire front to pass.

Showers of burning debris, on the other hand, may attack a building for some time before the fire front arrives, during its passage and for several hours after. This long duration of attack, to a large extent, explains why burning debris is a major cause of the ignition of buildings. If no one is present to extinguish these small ignitions, they can grow to involve the whole building. People who are well prepared and who return to their houses after the passage of the fire front can, in many cases, successfully defend them.

It has been found that burning debris can ignite buildings in a number of ways:

- It can, with other windborne combustible debris, pile up against combustible materials used at or near ground level such as stumps, posts, subfloor enclosures, building facades and steps.
- It can accumulate on combustible materials used for decks, verandahs, windowsills and pergolas.
- It cans lodge in gaps in and around combustible materials used for exterior wall cladding, and window and doorframes.
- It can gain entry to the interior of a building through gaps in the structure greater than 2 m. Once inside the building, the burning debris could ignite furniture, fittings and other contents.

The risk from ember attack is influenced by a number of factors:

- The number of embers.
- The quality of embers.
- The amount of combustible windborne debris present during the ember attack.
- The duration of the ember attack.
- The building design.
- The type and condition of the vegetation surrounding the building.
- The ground fuel around the structure.
- Suppression activities before, during and after the ember attack.

It is important to determine whether a building will trap this burning debris and, if so, whether there will be sufficient quantity in a location to cause ignition of the building. Furthermore, it is important to know whether those ignitions will lead to continued burning and destruction of the building. Building design is just as important as material selection when we are aiming to mitigate the risk posed by bushfire.

Survey work has revealed that many houses are ignited from radiation and flame contact from adjacent burning buildings or features such as timber fences. The radiation exposure from adjacent burning structures may be for a significantly longer period (an hour or more) than the minutes it takes for the fire front to pass.

Research has clearly identified the mechanisms of bushfire attack on buildings, and has given direction to designers, architects and regulators working to improve the performance of buildings in bushfire-prone areas. It also formed the basis for the building-related components of Australian Standard 3959, *Construction of Buildings in Bushfire-prone Areas* (Standards

Australia 1999). This acknowledges that a house does not need to be built like a concrete bunker to withstand a bushfire. Various, less severe, approaches can play a major role in mitigating the impact of a bushfire attack. These include modifying, where possible, the proximity to and type of vegetation around a building, protecting windows, and modifying the design of a building to reduce its susceptibility to debris build-up. The selection of external construction materials that will resist ignition from ember attack is a part of this process.

In the areas of people and property protection, much is already known about the way buildings are attacked and how human activity can influence the survivability of structures. However, the issues of human decision-making and behaviour have only begun to be explored by researchers expert in these disciplines.

It is important to consider that bushfire is only one of a wide range of factors influencing the design of the urban and peri-urban interface. It is important to integrate measures designed to reduce the risk of building loss in a manner that is balanced against other risk mitigation strategies, whilst preserving physical, social and lifestyle values. Traditional value systems that people use to judge their lifestyle are potentially hampered by the use of prescriptive regulations.

It is clear that risk mitigation strategies for life and building survival form part of a much bigger picture – the future research challenge is providing an integrated approach.

Risk – The Way We Look at Bushfires

From an individual's perspective, the potential for the total loss of one's home and direct risk to life is a daunting one. In many bushfire-prone areas, this perceived risk is not eclipsed by any other form of natural disaster. In many cases, an individual's perceived risk is much higher than the actual risk. This situation implies that there is an element of 'mythology' surrounding the event. A discussion of the influence of perceived risk is covered in a later section.

Understanding the risk

It is well understood that, under certain weather conditions, conventional suppression activities cannot prevent a bushfire reaching the urban interface, and that fuel-reduced zones are able to reduce the propagation of the bushfire front under the more extreme of these conditions. Thus, it is imperative that the communities living at the urban interface are knowledgeable of the potential hazards and are well prepared for bushfire impact.

There are many strategies that can be adopted to reduce the risk to life and property at the interface. It is clear that one generic approach is not suitable for all areas. It is also important to note that there are many value systems to be considered. The ideal outcome is one where the community understands the real risk of bushfires and voluntarily adopts strategies to minimise this risk, with due consideration of all the value systems important to them.

Influence of perceived risk

An inaccurately perceived risk develops through poor information transfer to the community relating to fire behaviour and the relative risks. The media has been seen to portray the most extreme aspects of an event without providing a balanced appraisal of what actually occurred.

Another way this imbalance can occur is when an individual overpredicts the frequency at which a fire event will occur. The situation is exacerbated when the individual has lived in an area a relatively short time compared to the frequency of the fire event.

It is clear from our extensive surveys that perceived risk varies from one extreme to the other in a given community. These factors can be explored more extensively by investigating previous reports by McArthur (1982) and Ramsay and McArthur (1995).

It is clear that biased risk perception influences human actions, and can cause actions that increase risk to life or create an overcommitment to risk aversion. In all these cases, more comprehensive information transfer is the solution.

Factors that have changed relative risk level

Effects of brigade activities. Since the inception of rural fire brigades in the 1940s and the formalisation of bushfire research in Australia, much has been achieved in mitigating risk to life and property (Leonard & McArthur 1999).

It is clear that firefighting agencies have become very effective in their ability to prevent initial fire starts from reaching unmanageable proportions. For example, as far back as Ash Wednesday in 1983, the brigades (in this case the Country Fire Authority (CFA)) were effective in quickly controlling most of the 95 fire starts occurring on the day: 88 of these fires were contained to within 100 hectares, while 7 fires burnt out extensive areas of bushland, with 5 of these latter fires being responsible for major house loss. Even with this level of effectiveness, firefighting initiatives were closely reviewed, with the result that the CFA was comprehensively re-equipped with new and better designed vehicles and equipment. Communications equipment and procedures were upgraded and tactics were revised so that the service could cope better should a similar situation arise.

Since 1986, in conditions that have sometimes matched the 1961/62 and 1976/77 fire seasons, there has only been one fire that has involved major house loss. That was in the Dandenong Ranges in Victoria in 1997, when 40 houses were lost.

Strategies have also been adopted in recent years where brigades are purchasing firefighting aircraft for fast response to initial fire attack to even further reduce the number of fire starts reaching unmanageable sizes.

Effect of community understanding of bushfires

Research has shown that the community's understanding of a fire event is continually improving, and that they play an ever-increasing role in reducing their own risk to life and homes. This is a very difficult aspect of a fire event to quantify without detailed and consistent survey initiatives. We are working towards formalising this approach so that we can measure improvements from future initiatives.

Current programs focussing on community education include:
- The Community Fireguard Program.
- The Brigades in Schools Program.

- Operation Bushfire Blitz (Hill, 1998); AS 3959 and associated handbooks.
- Educational videos and texts (e.g. Webster 1986).
- A broad range of information leaflets.
- Television advertising campaigns.

Whilst these initiatives are effective, they require constant updating as new information comes to light. It is also necessary that accurate information is made freely available to the public through the most effective means. This will be achieved by strengthening links with the above-mentioned education programs, and incorporating previously purchasable information into freely accessible web-based community education programs.

Other initiatives involve liaison with police and emergency services regarding their strategies, and the use of product endorsements and the certification of specialised builders and landscapers who can supply appropriate bushfire-resistant outcomes.

Effect of prescriptive standards on house loss. Prescriptive requirements such as AS 3959 and the NSW *Planning for Bushfire Protection* booklet (NSW Rural Fire Service 2001) influence house design and human behaviour in two ways: firstly, in their mandatory adoption in the relevant areas and, secondly, their use as advisory documents for individuals who elect to modify or build their house for improved bushfire resistance. Many of our recent survey initiatives have shown that this elective process has seen a reduction in house loss, while we are yet to have a house prescriptively built to these requirements receive a bushfire attack.

What is the real impact?

This is an extremely complex issue and falls outside the scope of this paper. The losses felt by individuals, communities, industries and the Australian economy are diverse and have many peculiarities. The following references discuss these issues also realising the benefits of new outlooks, opportunities and economic growth:

- For micro- and macro-economic loss of bushfire events, see Healy *et al*. (1985).
- For insurance losses, see Walker (2002) and McArthur (1982).
- For house loss and deaths, see Leonard and McArthur (1999).
- For other losses, including intangible losses, see Ramsay and McArthur (1995).

What are the variables?

The following list provides a broad classification of the factors that require consideration when assessing the overall risk to life and property (to develop a comprehensive risk-based model, these factors need to be broken down much further):

- Building position (proximity, slope and orientation to bush, access).
- Building design characteristics (what are the most vulnerable aspect of design).
- Building materials (e.g. roofing type, wall materials, glazing type and area).
- Human behaviour during the event (brigade and occupants, including their level of understanding and awareness).
- Vegetation type and relative proximity (does the vegetation form an effective wind barrier/ember trap).
- Proximity to adjacent structures that may form a secondary exposure.

- Placement of combustible and non-combustible elements (e.g. fencing).
- Type and condition of forest fuel load (fuel load level, orientation, species, elevation, size, moisture content).
- Localised weather conditions (wind, temperature and humidity history).
- Likelihood that neighbouring houses will develop into fully involved house fires.

How are these risks minimised?

During extreme fire weather days, there are two main risk minimisation strategies: one is to prevent the fire reaching an asset or community, and the other is to take measures to prevent risk to life or structural loss given that a fire does reach it.

The first strategy can be influenced by reducing the number of fire starts that reach unmanageable sizes (however, it is recognised that under certain weather conditions, it becomes virtually impossible to perform this task) or by providing extensive fuel-free buffer zones around an asset.

For the second strategy, there is a very broad range of tactics to be employed to mitigate the risks posed by bushfire attack. Many of these tactics are well understood and utilised, some are not and warrant investigation, while a few are poorly understood and require further observation of bushfire events to understand their impact. Synergistic effects between these strategies have not been fully investigated, nor have the relative effects on all other value systems.

The real challenge is to perform this risk minimisation process efficiently and holistically. This is clearly not achievable with current risk model approaches. Future collaborative research initiatives aim to rectify this (see section 'Where is the research going?'). For a detailed description of strategies, please refer to AS 3959 (Standards Australia 1999) and Ramsay *et al.* (1987).

Rather than accepting the current risk level, we can aim to minimise it in a number of ways. Hence, it becomes necessary to understand the effectiveness of the various alternatives, for example:

- Education initiatives.
- Insurance incentives for individuals undertaking risk reduction initiatives – this can become a key motivator for education initiatives.
- Supporting community-based education initiatives.

Preliminary Findings From Recent ACT Survey Initiatives

Scope of survey initiative

CMIT surveyed the worst effected areas of Duffy following the Canberra bushfires, concentrating on urban design, ignition mechanisms and local vegetation. The intent was to identify the combination of bushfire attack mechanisms and contributing factors that played a part in house involvement. Typical contributing factors included vegetation type and density, local geography, site layout, house design and firefighting intervention. Over 200 untouched, damaged and destroyed houses were surveyed in the Duffy region. Also high-resolution aerial photographs were taken of all the effected areas.

Key findings

Analysis of the data to date has indicated that no houses in Duffy were directly impacted by flames from the fire front itself. The distance between the main forest fuel and the houses was sufficient to prevent radiation from the flame front directly igniting these structures. The primary attack mechanism was from embers. The general town planning design of providing perimeter roads as a buffer zone between houses and forest fuels is considered to be a very effective measure to prevent direct flame and radiation impact. Houses in Duffy were particularly vulnerable to ember attack, as they had no specific design requirements to mitigate the entry of embers. Due to the fact that AS 3959 is not applied retrospectively, there were no houses in the Duffy area that had prescribed mitigation measures. The age of houses in the Duffy area was approximately 30 years. AS 3959 prescribes that houses within 100 m of forest fuels require specific measures to mitigate ember attack. This requirement would have significantly reduced the levels of house loss in Duffy, but would not have prevented loss altogether. It would also not prevent loss once a significant numbers of houses are alight beyond the 100 m perimeter.

The insured losses in the Canberra fires were comparable to the losses on Ash Wednesday with inflation taken into account, even though the numbers of houses lost was much less. In terms of insured losses, Ash Wednesday stands as Australia's largest bushfire event and sixth largest natural disaster. If the Ash Wednesday losses are indexed to inflation to today's prices, it represents a total insured loss of $300–350m (Walker 2002), with 1511 houses lost (Leonard & McArthur 1999). Canberra's total insurance loss is comparable to this level, with approximately 516 houses destroyed. There is a considerable increase in the asset value at the urban interface that needs to be considered for future policy. Thankfully life loss has not followed the same trend, with 75 lives lost in the Ash Wednesday fires compared to 4 lives lost in the ACT fires.

Structural loss so deep into the urban interface has not been observed since the Hobart fires of 1967.

The condition and type of vegetation in Canberra significantly exacerbated the progression of structural loss deep into urban areas. Extensive water restrictions and low rainfall left vegetation immediately around the structures in a very dry and susceptible state. This also led to the ground cover having very low moisture content and a greater thickness due to the lack of natural composting. Many of the vegetation types found in Duffy were highly combustible.

The low residence and brigade presence in the hours after the fire front had impacted contributed to the number of houses lost. These impacts endured throughout the afternoon and well into the night. We found many examples of community and agency suppression activities during this time, with many houses being saved. It was obvious that if no suppression activity had occurred during this time, house loss would have approached 100%. The presence of brigades and residents was low compared to bushfires in the previous decade. Traditionally it has been accepted that suppression activities by agencies and residents are sufficient to mitigate the spread of structural fires deep into urban areas. However, the house loss in Duffy stands as an isolated example of how this assumption is not always true.

Life loss was comparatively low compared relative to the number of structures lost in past bushfire impacts.

There was little evidence of houses in Duffy being structurally damaged by wind or mechanical impact from windborne debris.

The initial vegetation and structural fires in Duffy created an even more concentrated and enduring ember attack for those further downwind. The ember attack caused by persistent winds blowing over structural fires played a role in fire spread deep into urban areas. Some of the structural fires provided direct flame attack and radiation impact on adjacent structures. These impacts persisted for hours rather than the number of minutes it takes for a flame front to pass. This effect was exacerbated by the placement of relatively large houses on medium sized blocks, and the presence of timber fences and vegetation between the closely aligned structures.

The contribution/synergistic effect of a number of factors (as listed above) resulted in an extreme level of impact on the urban interface – an impact far greater than had previously been considered probable.

Where is the Research Going?

Aim

The aim of current CSIRO research into bushfires is to improve the awareness and understanding of the issues surrounding building loss in bushfires, through integrated research, communication and education. As well as reducing the direct loss of buildings in bushfires, the work should also generate an improved lifestyle for people living and working in bushfire-prone areas.

Risk-driven approach

This initiative will be facilitated by the development of a model that quantifies the relative bushfire risk and related value systems of any given property/building or community. Most of the important matters relating to hazard and hazard mitigation have been identified for input into this model. The application of this model will:

- Provide a risk estimate for any given building/environment/people scenario.
- Quantify the potential for mitigating risk for various features of building construction.
- Develop meaningful protocols for assessing building components and design.

Future research will develop a risk-based predictive model that, in its initial basic form, will provide guidance and justification for investigating gaps in our understanding of all the relevant issues. The risk model will evolve in subsequent years into an effective tool for use by many institutions and industries. Eventually it will become integrated into other, more broadly scoped risk models developed for overall bushfire risk management.

Future/ongoing research

Other areas of future/ongoing research will include:

- Improving timber deck design to minimise ignition by ember attack.
- Determining how more cost-effective glazing system designs can resist radiation and flame attack.

- Improving timber fire-retardant treatments to mitigate ignition of external timber elements of buildings.
- Understanding how to most effectively use naturally fire-resistant vegetation to reduce the risk of the ignition of structures.
- Assessing the usefulness of non-combustible solid-panel fencing systems in arresting ground fire spread and reducing radiant heat loading on buildings.
- Assessing the minimum design requirements and viability of using external sprinkler systems to minimise ignitions.
- Assessing the efficacy of roller shutters in minimising ignitions.
- Studying the impact of radiation on buildings from adjacent burning buildings.
- Studying the behaviour of domestic supply gas bottles in bushfires.
- Studying the performance of fence posts, and electricity and telephone poles in bushfires.

Beyond these research initiatives lays the more significant task of *utilising the body of knowledge to effect real outcomes in relation to building protection in bushfires.*

This initiative will provide advice that seeks to meet community expectations of aesthetics, functionality, cost and utility, while minimising the impacts on biodiversity. It is clearly understood that imposed regulations may represent an additional cost to the community in these areas. This initiative will endeavour to prescribe requirements only where absolutely necessary.

It is well understood that these education initiatives are intrinsically linked to community attitude and behaviour. Participants in the CRC for Bushfires will work closely with the human behaviour initiative so that its community-based outcomes are holistic and appropriately focussed.

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