When Disaster Strikes:

Human Responses to Wildfires and Evacuation in the South of France and Australia

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DECLARATION

I certify that the work contained in this thesis, or any part of it, has not been accepted in substance for any previous degree awarded to me, and is not concurrently being submitted for any degree other than that of Doctor of Philosophy being studied at the University of Greenwich. I also declare that this work is the result of my own investigations, except where otherwise identified by references and that the contents are not the outcome of any form of research misconduct.

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ABSTRACT

The number of wildfires occurring globally is increasing, exacerbated by urbanisation and changes in weather patterns. People's safety is threatened by this growing problem. Consequently, researchers have conducted studies of wildfires and human behaviour in response to wildfire evacuations in regions such as Australia and the USA. Regions in Europe have received less attention, despite facing the same issues. In addition, due to the different methods and focuses applied in existing disaster research, it proves challenging to compare and utilise results of multiple studies when developing tools for community safety (e.g. evacuation simulation models, for use in planning and training). This research addresses these gaps by:

- devising a framework for data collection and organisation (CIBER-t)
- applying mixed methods and a research focus shaped by this framework
- collecting data from various sources (media, professionals involved in wildfire management, residents) in wildland-urban interface/intermix (WUI) areas in the European region of southern France
- identifying, quantifying and contextualising aspects of individual and group behavioural responses to wildfires in these WUI areas
- comparing the French data with new data from Australia, thereby building an understanding of behaviours that may be generalised or regionally-specific
- using the combined data to create regression models that predict behavioural outcomes such as the decision to evacuate and evacuation delay times
- considering the potential for regression and evacuation models to assist researchers, practitioners, policy-makers, and the public in improving community safety

Through qualitative and quantitative analysis, a representation has emerged of how people respond across different stages of a wildfire, external and internal factors influencing such behaviour, and vulnerabilities. The results also reveal that some but not all human behaviours can be generalised across regions. Therefore, this research expands the knowledge-base upon which to develop wildfire safety tools and measures, but highlights the need for further regional data and context.

CONTENTS

ABBREVIATIONS

AE – Actual experience survey

ASET – Available Safe Egress Time

AUS – Australia

BI – Behavioural itinerary

CIBER-t – Context, Information, Behaviour, Emotion, Risk, time

DM – Decision-making

ENT – Emergent Norm Theory

FC – First cues

H – Hypothetical-scenario survey

NC – New cues

PADM – Protective Action Decision Making

PWM – Professionals involved in wildfire management

RSET – Required Safe Egress Time

SoFR – South of France

WUI – Wildland-urban interface/intermix

INTRODUCTION

Chapter 1

This chapter firstly presents the research questions and objectives, followed by context and rationale for research on human behavioural responses to wildfires. Then it explores theories providing a foundation for the approach to this study. The thesis structure is described next, outlining each chapter. Lastly, readers' attention is drawn to the peer-reviewed publications where some of this thesis work can already be found.

1.1 Research questions and objectives

The main aim of this research was to identify, quantify and contextualise aspects of individual and group behavioural responses to WUI wildfires. Given that an understanding of human behaviour in wildfires is already emerging in places such as Australia and North America, but is missing from Europe, the latter geographical area was of primary interest for data collection. However, data was also collected from the former region. This offered the opportunity for cross-cultural analysis in this thesis, by allowing existing knowledge and new data on human responses to bushfires in Australia to be compared with data from the previously-unexplored yet fire-prone region of the South of France. By doing so, findings could be generated that offer a broader perspective on this subject matter. Such findings can benefit researchers, practitioners, policy-makers and the public. For example, policy and disaster management strategies, including the use of evacuation models for planning and training, can become better informed – with the support of geographically diverse data, involved persons can become aware of the range of behaviours, the ones which dominate situations, the ones which are more general and those which are more regionally-specific. In turn, a community's response to improving safety can be shaped accordingly, and the problem of wildfires and their impacts can be tackled in more holistic and effective ways.

To achieve the main aim, two research questions with accompanying objectives were posed:

(1) What motivates people to evacuate or stay-in-place?

Objectives relating to research question one:

1.1 To build a framework to define aspects of individual and group behaviour influencing decision-making in wildfire.

1.2 To explore the significance of key pre- and peri-event factors influencing behaviour in a wildfire.

(2) How long does it take people to start evacuating?

Objectives relating to research question two:

2.1 To define and quantify behavioural itineraries (actions completed during the response phase, thereby delaying evacuation).

2.2 To explore the effects of pre- and peri-event factors on evacuation delay time.

1.2 Context and rationale for the research

Urbanisation and climate change are thought to be the two biggest challenges of the 21st Century, and the adverse effects on lives and health brought about by these challenges have come under the focus of a trans-national community of scientists and governments (UNISDR, 2015). An intrinsic part of this focus is the intensifying and more frequent occurrence of natural hazards, which turn into disasters that result in human and economic losses (UNISDR, 2017a). Among the natural hazards that develop into disasters due to their interaction with communities, the most under-researched – especially across Europe – are wildfires. These are large uncontrolled fires that may spread rapidly over areas with vegetation and other fuels. As growing cities push the formation of communities further into natural territories forming the wildland-urban intermix/interface (WUI) (Cohen, 2000; Mutch, Rogers, Stephens, & Gill, 2011), and rural lands become abandoned resulting in changes to natural land cover, the incidence and severity of wildfires is exacerbated (Fox et al., 2015). This positions wildfires at the forefront of the urban sprawl challenge, calling for risk mitigation and management tools that consider present-day human vulnerabilities. It is important because vulnerabilities may influence people's motivations in how they respond to a hazard, and their performance once a decision to stay or evacuate is taken (Folk, Kuligowski, Gwynne, & Gales, 2019). One such type of tool with the potential to support a wildfire response, and hence community safety, are evacuation simulation models (e.g. Veeraswamy et al., 2018). However, in order to improve these tools, data collection is often required (Ronchi, 2017a). Yet, studies providing empirical evidence to assist understanding of human motivations and subsequent performance, i.e. the time taken to evacuate when facing a wildfire hazard, are still lacking (McLennan, Ryan, Bearman, & Toh, 2018).

Looked at in the context of other disasters (Table 1-1; summation of worldwide trends from EM-DAT, 2016), wildfires may at first appear less devastating when compared to the number of deaths caused by floods, storms and earthquakes, for example. On the other hand, there has been an observed rise in deaths from other types of disaster such as extreme temperatures, which may lead to wildfires. Nonetheless, natural hazards' impacts on communities should not be underestimated or judged using one-dimensional measures such as the number of fatalities. While there appears to be relatively less wildfire-related fatalities overall, increasingly more people are *affected* by wildfires (as well as by droughts and volcanic activity, two types of disaster that again may lead to wildfires). Researchers claim that the size and duration of a wildfire – two aspects often reported – are not measures indicating their effect on communities per se (Paveglio, Kooistra, Hall, & Pickering, 2016). So, once more, the impact of wildfires may be underestimated or misjudged.

Table 1-1 Disasters worldwide.

		Flood	*Hurricane*	*Drought*	*Land-slide*	*Earth-quake*	*Wildfire*	*Extreme temp.*	*Volcano eruption*
Occurred	2015	152	90	32	20	19	12	11	8
	2005-2014	171	99	15	17	25	9	24	6
Deaths	2015	3.3 K	996	35	1.3 K	9.5 K	66	7.3 K	0
	2005-2014	5.9 K	17.7 K	2 K	923	42 K	73	7.2 K	46
Affected	2015	27.5 mil	10.5 mil	50.5 mil	50 K	7 mil	494 K	1 mil	958 K
	2005-2014	85 mil	34.8 mil	35.4 mil	299 K	8 mil	193 K	8.7 mil	136 K

Disaster-related data such as that reported above should be interpreted cautiously, for several reasons. It may bias understanding of the importance of or need for research, because reports of mortality rates and economic losses exclude individuals affected otherwise, e.g. by trauma. For instance, in Canada, between 1980 and 2007, there were no direct wildfire fatalities yet there were around 547 evacuations and approximately 200,000 people evacuated (Beverly & Bothwell, 2011). It would be remiss to believe that evacuation amounting to the size of the population of, say, Nottingham (UK) or Padova (Italy) would have been without repercussions for wellbeing. In addition, Australian insurance data report hailstorms and cyclones as the most devastating disasters in terms of building and crop losses, and other business disturbance. However, data from other sources indicate bushfires as being the most devastating for human life, which is often not reported by insurance companies and thus distorts the perception of the disaster

(Keating & Handmer, 2011). Often even the data that feed into disaster databases depend on different criteria for the size of an event and its consequences (Guha-sapir, Hoyois, Wallemacq, & Below, 2017a) and make studies of disaster implications more complicated. Keating (2011) rightly notes that certain events are not included in databases because they have not been reported by the media. Even when events do get press coverage, they may be left out. For instance, in their statistics, the Centre for Research on the Epidemiology of Disasters (CRED) (Guha-sapir, Hoyois, Wallemacq, & Below, 2017b) did not include wildfire events occurring in the South of France and Spain in 2016, where 10,000 and 2,000 people were evacuated respectively in August and September that year (Independent, 2016; Express, 2016a).

Finally, some conflicting perspectives exist that obscure the representation of disasters and their impacts. One example would be reports of falling numbers of wildfires and related fatalities in Europe due to the development in fire management (Schmuck et al., 2015) released right before two consecutive disastrous fire seasons (2017–2018). Data collected from media sources and articles shows that there have continued to be lives claimed in Europe (The Guardian, 2017a,b; The Guardian 2018b), as well as in other geographical regions, even when European evacuation numbers seem small (BBC News, 2014; CBC News, 2016; Express, 2016b,c; CNN News, 2016; The Guardian, 2016; EcoWatch, 2016; The New York Times, 2017a,b,c; DW, 2017; El Universal, 2017; The Weather Channel, 2017; Libertad Digital, 2017; CBC News, 2017b; The Local, 2017; The Independent, 2017a,b,c; The Telegraph, 2017; BBC News, 2017; Express, 2017; CNN News, 2017b; The Guardian, 2018a,b; The Gazette, 2018; The Independent, 2018a,b; BBC News, 2018a,b; Insurance Journal, 2018; AccuWeather, 2018; DW, 2018; The Denver Post, 2018).

The above literature discusses wildfires and their human impacts but how do humans become victims of such fires? While studies on European population responses to wildfires have not been published to date (McLennan, Ryan, Bearman, & Toh, 2018), European Union members have already expressed concerns about human behaviour needing more attention with regards to wildfire risks (European Commission, 2018), as well as disaster risk reduction (EC, 2017; EFDRR, 2013). A disaster is a “combination of hazard and vulnerability” (Kelman, Gaillard, Lewis, & Mercer, 2016, p.130) and WUI residents’ vulnerability is often seen to be provoked by the wild-urban “clash” (Modugno, Balzter, Cole, & Borrelli, 2016). Such a clash can be linked with inconsistent regulations for urban development, and the everyday needs of individuals. For instance, some wildfire-prone WUI areas develop in a more sporadic way compared to planned urban environments. Regulations limiting the spread of built-up areas are often merely catching up rather than setting a precedent (Fox et al., 2018). Therefore, people requiring a place to live may move into areas in close proximity to dense vegetation. Here, wildfires can more easily originate (through various means including human action, e.g. careless disposal of smoking materials, arson) or spread (through various means including human inaction, e.g. failing to clear or prune available fuel sources). Moreover, such areas may be inadequately served by road infrastructure, limiting residents' egress as well as the emergency services' ingress. For instance, new egress routes planned after one Canadian wildfire highlight the inadequacies of previous planning (CBC, 2017a). In addition, extensive research on human behaviour in other disasters shows that individuals tend to act on their own 'agenda' when it comes to responding to, for example, evacuation warnings (Dash & Gladwin, 2007; Drabek, 1986). People take too long to understand the risks that they are facing, delay evacuation, evacuate when it is not needed, and create bottlenecks in fire hazard areas (Martin, Bender, & Raish, 2007).

If, in a wildfire also, an individual initially fails to realise that they are at risk and subsequently makes a less-than-perfect decision regarding whether and when to evacuate – and many other individuals do likewise, in an area with access issues – then it is easy to conceive how lives could be threatened and lost. This situation therefore calls for a better understanding of:

(i) how and why people come to make decisions to evacuate, or perhaps stay-in-place, in wildfires; and importantly

(ii) whether any measures for risk mitigation and management can be taken to support effective decision-making, thereby avoiding or reducing fatalities in the future.

While some behaviours seen in disasters may appear illogical or irrational to practitioners and policy-makers, studies of human behaviour such as decision-making are in fact practicable. Scientists investigating numerous cases of emergencies have now established that certain ideas, promoted by Behaviourists up to the 1970s, such as "the majority of people act inappropriately and fail to respond in the way that is most likely to preserve life" (Unknown, 1969, p,121), are not entirely correct. This argument, related to the concept of mass panic, has been rejected numerous times, with evidence suggesting that individuals tend only to panic in exceptional life-threatening circumstances (Proulx & Sime, 1991). This repeated finding, and similarly-timed advancements in research methods, mean that human behaviour is easier to capture and more predictable than previously thought. Consequently, opportunities for quantifying human behaviour have been sought by researchers and tools for modelling evacuation in disasters have grown in number (Adam, Danet, Thangarajah, & Dugdale, 2016; Lovreglio, Ronchi, & Nilsson, 2016; Ronchi, 2017a; Veeraswamy et al., 2015).

Nevertheless, whilst a body of literature analysing human behaviour in disasters is growing, insufficient attention is currently paid to human behaviour in wildfire events. Wildfires have been brought to academic attention only relatively recently, presumably due to the growth of WUI populations and subsequent interest of governments. Thus, an effort to better understand the specifics of human behaviour in wildfires is needed to reach equilibrium with the available knowledge of human behaviour in other disasters. This would not only improve wildfire evacuation management, with the help of technology such as evacuation modelling, but also improve the safety of WUI residents and disaster management personnel through better informed policy and practice.

1.3 Theories

To best position this thesis in the field of human behaviour in wildfires, and to set up a study that informs and improves understanding of human behaviour, interdisciplinary theories used in sociology (including computational sociology, culture, and gender studies) and behavioural sciences (psychology, psychobiology, and cognitive science) were brought together to help build research questions and the approach to answering them. A starting position was social constructionism. It is a sociological theory that emphasizes the dependency of collective knowledge on its context (e.g. society, politics), hence the idea that reality itself is a social construct (Berger & Luckmann, 1967). It is a "sociological analysis of the reality of everyday life, […], of knowledge that guides conduct in everyday life" (Berger & Luckmann 1967, p.33), which in the context of disaster research, for example, would mean that a wildfire threat is socially constructed (i.e. it is perceived as well as "is", and resultant behaviours are subject to social influence at one level or another). As will be seen in later chapters, this is a dominant view of many contemporary researchers. Further, in human geography and disaster literature, scholars also identify the social construction of vulnerability, resilience, disaster, culture, gender (Zara, Parkinson, Duncan, & Joyce, 2016, Gustafson, 1998), and risk (Dash & Gladwin, 2007, Paveglio, Boyd, & Carroll, 2017a). For example, Paveglio (2017a) claims that place attachment is reinforced by the social construction of risk, which may pertain to gendered risk (Gustafson, 1998) and risk constructed by the elites (Vilain-Carlotti, 2017). Thus, since a disaster is the sum of a hazard and vulnerability to risks, it calls for qualitative research methods to deconstruct and understand what a wildfire hazard means to different communities. This can pave the way to understanding if and how wildfire responses will differ across regions.

Decision-making also requires positioning in its context. Social constructionism and emergent norm theories state that decision-making is influenced through interactions with other people, which result in the creation of norms and, through these norms, individuals make sense of a situation and act accordingly (Gwynne, Kuligowski, Kinsey, & Hulse, 2017). One decision-making model that reflects such a view is the Protective Action Decision Model (PADM) (Lindell & Perry, 2012). On the one hand, decision-making may become habituated to a certain degree, and the often subsequent institutionalisation of actions may mean that a 'social stock of knowledge' is formed, so situations do not need to be interpreted anew all the time (Gwynne, 2012). On the other hand, when a situation lacks precedent, Emergent Norm Theory (ENT) suggests that new behaviours will occur, transforming the future behavioural response (Gwynne et al., 2016; Kuligowski, 2011). At the same time, when institutionalisation is unsuccessful, and behaviours deviate from institutional expectations, changes may be required (either to the behaviours, the 'system', or both; see Bonkiewicz & Ruback, 2012).

Although social constructionism and ENT already highlight the inherent complexities of the study of human behaviour in disasters, scholars in disaster studies and sociology note that the field is constantly changing due to technological developments and the re-characterisation of social relationships (Ghisleni, 2017; World Disaster Report, 2014). Thus, a re-appraisal of the approach to studying human behaviour in disasters may result in a methodology for the current study that grasps and closely links (a) the fine-grained issues of decision-making, as well as (b) the larger-scale socio-cultural context of decisions.

Therefore, the foundation of this thesis is built on Michel de Certeau's 'Practice of Everyday Life' (1984). This examines much the same themes as in social constructionism and ENT but with a deeper emphasis on the *practices* in everyday life, which can help explore safety culture and wildfires. Across most of the disaster-related literature, a juxtaposition of *everyday life* (ordinary) and *emergency situations* (out of the ordinary) exists, defining 'emergency' as a deviation from the *usual,* even in terms of physical and psychological human reactions such as time distortion (Hancock & Weaver, 2005). A more symbiotic way to approaching wildfire disasters is the analogy of *wildfires as part of* *everyday life* (Eriksen & Gill, 2010a; Candea, 2008). For instance, wildfires are seen as a part of everyday life in WUIs due to fire hazards being intrinsic to residents' understanding of their environment (Hannah Brenkert-Smith, Champ, & Flores, 2012). Such latent risk also requires certain everyday practices of people – ones rooted in history, tradition, experience and institutional rules – such as:

- total fire ban days
- clearing 50 m of the vegetation surrounding one's property
- attending local fire prevention meetings
- having an evacuation plan, and finally
- experiencing a wildfire, which cognitively supports the recognition of cues and danger (Clode 2010, p.32).

This is not to claim that the individual, society and the system run in synchronisation. Rather, individual practices and institutions can sometimes conflict with each other and synchronise only once the development of the institution has become stable and people are thus able to 'catch up' and adapt (de Certeau, 1984).

De Certeau's philosophy touches upon the perception of risk, which influences everyday goals. In the case of a wildfire, goals are prioritised in order to prepare for this event, but everyday priorities can either impede or facilitate preparations (Clode, 2010, p.16). The philosophy also accommodates, at least to some extent, the influential research on gender and its effects on risk perception (Gustafson, 1998), as well as the transcendence of social roles into emergency situations (Drury, 2007). Additionally, it can prompt ideas for how types of mitigation actions can influence evacuation decisions (Paveglio, Prato, Dalenberg, & Venn, 2014). Not many researchers of disasters have explicitly referred to viewing their studies of human behaviour in emergencies through the lens of everyday practice in de Certeau's sense (see, for example, Eriksen & Gill, 2010). However, examples of available research pertaining to 'everyday life' and disasters shed light on the themes that surround the discourse of disaster responses and the connections between practices (Table 1-2).

Table 1-2 Everyday life in the disaster-related literature.

Author	***Which practice?***	***Quote***
(Quarantelli, 1980, p. 105)	Response to disasters	"[…] there are certain common phases upon the hearing or observing of danger […] common pattern is an initial disbelief, regardless of warning source. This is not a denial of reality […] but simply a continuation of the everyday assimilation of cues

Author	*Which practice?*	*Quote*
		to the normal which allows people to function without undue stress.”
(Barrett, 1997, p. 9)	Emotions and everyday life	“It is only when we regard the momentary ratings as sufficient estimates of everyday emotional experiences that we have grounds to claim that respondents’ beliefs about their own emotionality biased the retrospective ratings by having participants remember more emotion than they actually experienced.” (i.e. we need the everyday emotions to be able to define the emotions felt during an emergency)
(Fothergill, 1999, p.126)	Women’s roles in disaster in contrast to everyday life	“One way to understand women’s roles in all three spheres of social life - the domestic arena, the workplace, and the community - is to examine a disruption of their daily routines and explore the work and roles they take on when the social world is in crisis. One type of social crisis, a natural disaster, has been found to be a ‘realistic laboratory’”.
(Gustafson, 1998, p. 810)	Gender and everyday life	“Gender role theory sometimes tends to regard all gender differences (e.g., in risk perception) as the result of internalized role expectations, ignoring the activities, times, and places of women's and men's everyday life. On the other hand, a one-sided focus on this lived reality, or gendered practice, would reduce risk perception to risk exposure, ignoring the impact of the norms, values and world views of gendered ideology”
(Lindell & Perry, 2004, p.125)	Everyday practice in relation to expected risks	“[…] environmental threats can differ in their degree of intrusiveness, […] generated by the distinctive hazard-relevant associations that people have with everyday events, informal hazard-relevant discussions with peers, and hazard-relevant information received passively from the media”.
(Uriely, 2005, p. 203)	Tourists and everyday life	Tourist experience is seen as an “experience as contrary to the routine of everyday life is”; but “The notion of the tourist experience as disparate from the routine of everyday life has been challenged […] [by] the perspective of postmodern tourism” because of “the availability of various aspects of the tourist experience in the routine of everyday life”.
(Eriksen & Gill, 2010a, p. 1)	Culture and everyday life	“Bushfire is a topic that most Australians have an (often strong) opinion about, as the role of bushfires in Australian landscapes is tied to a range of emotions and experiences that are deeply embedded in traditions and everyday life.”
(Wachinger, Renn, Begg, & Kuhlicke, 2013, p. 1060)	Risk, experience and everyday life	“The experience of the disaster potential of tsunamis needs to be embedded within the narratives about everyday lives of people exposed to this risk.”
(Paveglio et al., 2014, p. B)	Everyday life: Itinerary (i.e. individual preparatory	“Researchers and policymakers currently have insufficient understanding about what everyday actions residents intend to take if they evacuate or choose to remain at home during

Author	Which practice?	Quote
	actions) in response to disaster	wildfire events, and whether these strategies fall into the categories discussed above.”
(Eriksen, 2015)	Preparedness and everyday life	“Why do people fail to deal with fire risk? […] For example, women may deprioritise wildfire preparation because of the pressure of everyday tasks. […] People may be highly aware of the risk of wildfire but do little to prepare because of other everyday priorities, […]. Factors such as a sense of community can provide strong incentives to engage with and prepare for wildfire”
(Handmer & O’Neill, 2016, p. 61)	Evacuation decision making in respect to the everyday life	“A major challenge to […] leaving early ‘just in case’ on all days of extreme danger becomes […] too disruptive to peoples’ lives and livelihoods and so people increasingly risk staying in the fire danger area.”
(Handmer & O’Neill, 2016, p. 61)	Policy changes and everyday life	“Policy changes have also occurred in response to the fires and the Commission’s recommendations. […] ‘Prepare, act, survive’ […] approach […] [still] had trouble coming to grips with the everyday complexity of living in a fire risk area […].”
(Sword-Daniels et al., 2016, p. 11)	Uncertainty and everyday life	“Uncertainty is lived and experienced […] internalised and becomes embedded within decision-making and social norms over time […] it accepts uncertainty as a persistent condition of daily life in many forms, scales and levels of conscious and unconscious decision-making. It lies on a continuum from (often decontextualized) epistemic knowledge to everyday practice guided by instinct.”
(Ronchi, 2017a, p. 331)	Everyday practice in computer modelling	“‘The impact of a natural event on any given community […] is […] determined by everyday patterns of social interaction and organization…”; “In another evacuation application an existing model was used to define the household activity-based travel patterns of a normal working day. This allows to capture the background traffic besides the real positions of people at the moment of the warning, based on their predicted activities.”

So, guided by de Certeau’s (1984) theory on everyday practice, a series of factors relating to the pre- and peri-event stages of disaster responses were unearthed (Table 1-2). The main elements that dominated in the examples included culture, demographics, preparedness, experience, actions, emotion, risk and policy; these will be expanded upon in the literature review chapter. In addition, an example of everyday life within an application of evacuation modelling was found. For this reason, the literature review that follows took on an interdisciplinary approach, drawing upon peer-reviewed publications on fire safety, the natural environment and forestry, human psychology in emergencies, human behaviour in disasters, risk assessment, and software development for disaster management. The approach taken in the literature review was to adopt alternative micro-theories where the more macro everyday practice connections fell short, and to gather rich evidence of qualitative and quantitative studies on or relevant to human behaviour in disasters. Out of this review, an original research framework developed, which went on to support the current study of human behaviour in wildfires.

1.4 Thesis structure

Chapter 2 – From wildfire to disaster: Review of the literature

This chapter reviews the literature along three main axes relevant to human behaviour in urban-scale evacuation. Firstly, WUI wildfire disasters where urban-scale and built environment evacuations are compared, and the main principles and conditions for wildfire evacuations are established. Then, human behaviour in disasters, presenting the main findings from other studies, which focuses on the main factors linked to decision-making (e.g. age, gender, culture, group behaviour). Finally, technology-supported wildfire response is reviewed, where theory and practice are explored through the lens of available tools for evacuation and disaster management. A review of tool capacity and potential aims to shed light on existing drawbacks and possible improvements for the quality of data used in evacuation models.

Chapter 3 – Research scope

Here, the literature review findings are summarised and the focus of the current study defined. The newly devised framework, called CIBER-t, is presented. The WUI and the geographic context of the two study regions are introduced. Also, this chapter establishes the study hypotheses, which set out to answer the research questions.

Chapter 4 – Methodology

This chapter outlines the research methodology employed, demonstrating the benefits of mixed-methods research. Methods for the qualitative and quantitative analysis in this thesis, and their convergence into research design, are presented together with ethical considerations.

Chapter 5 – Qualitative analysis: observations of behaviour

Through the application of the CIBER-t framework to media content, bushfire survivors' statements, and semi-structured interviews with professionals involved in wildfire management (PWM) in Australia and the South of France, this chapter identifies the main drawbacks of looking at decontextualized data and further investigates human behaviour in wildfires and evacuations.

Chapter 6 – Quantifying human behaviour

Quantitative results are presented following analysis of questionnaire data from civilians residing in wildfire-prone areas. Here, aspects of behavioural responses to wildfires and associated factors are identified, including planning for wildfires, individuals' immediate responses during wildfires, initial intentions and ultimate decisions to evacuate/stay-in-place, emotion and perceived risk. Behavioural itineraries are also identified and evacuation delay times analysed. Similarities and differences across the two study regions are reported.

Chapter 7 – Application of results: predicting human behaviour

With the help of regression analysis, this chapter identifies significant predictors of wildfire decision-making and evacuation delay time. Regression models using merged data from both study regions are generated. Subsequently, an illustrative model of human behaviour for application to evacuation modelling is presented. This chapter finally brings together premises from the literature review and the results from the current study and uses triangulation to explore what has been learned about human behaviour in wildfires.

Chapter 8 – Conclusion

Following an overview of the research methods, novel findings, and limitations, conclusions are drawn about this thesis' original contribution to the knowledge-base, the fit of the framework newly developed in this thesis, and how others can benefit from this expansion of knowledge. Recommendations are given for further research.

1.5 Peer-reviewed publications

Parts of this thesis are already available in the following peer-reviewed publications (Appendix K). The journals they are published in are currently Quartile-1 for the subject category 'safety research'.

Vaiciulyte, S., Galea, E. R., Veeraswamy, A., & Hulse, L. M. (2019). Island vulnerability and resilience to wildfires: A case study of Corsica. *International Journal of Disaster Risk Reduction*, *40*. http://doi.org/10.1016/j.ijdrr.2019.101272

Vaiciulyte, S., Hulse, L. M., Veeraswamy, A., & Galea, E. R. (2021). Cross-cultural comparison of behavioural itinerary actions and times in wildfire evacuations. *Safety Science, 135*. https://doi.org/10.1016/j.ssci.2020.105122

LITERATURE REVIEW

Chapter 2 From wildfire to disaster: Review of the literature

This chapter explores the relationship between climate and wildfire phenomena, and subsequently defines WUI vulnerability to wildfire hazards within the unique socio-cultural context. As a result, discussion of evacuation, where necessary drawing on research about responses to other disasters, takes place. To contextualise evacuation, this chapter also reviews and condenses the literature on the main factors affecting human preparedness, responses and risk perception in disasters. Finally, an overview of the role of technology in supporting the response to WUI wildfires is presented, exploring the potential of evacuation modelling tools for disaster preparedness and response.

2.1 WUI wildfire disasters – causes and response

“Hazards may be natural, but disasters are not. Disasters arise as nature and society interact; they are mediated by human settlement and behaviour.” - Warner and Engel (2014, p.1)

Wildfires are rapidly claiming their place among other highly devastating disasters caused by natural and anthropic activity across the world, although disasters are *not natural* (UN, 1974; IFRC, n.d.). Nevertheless, wildfires may be seen as a *niche* topic for several reasons. Firstly, as with any natural phenomena, a wildfire hazard becomes a threat once it directly or indirectly (through cascading problems such as flaming debris, smoke and landslides) endangers human habitats and livelihoods (AghaKouchak, 2018). Some arbitrary definitions of *disaster* make it difficult for many wildfires to ‘qualify’ as disasters (e.g. 10 people killed, 100 reported missing; Guha-Sapir, Hoyois, Wallemacq, & Below, 2016). Wildfires are most prominent in WUI areas, where wildland intermingles with urban structures – often this area can be relatively modest in size, compared to the pathway of a hurricane, which could cause distress for around 7 million people (CNN, 2017a). Secondly, it could be argued that a wildfire is less likely to become a disaster in the first place, since it can be supressed at its initial stage. Nevertheless, the dynamics of wildfires are changing and concerns about the implications of climate change on disasters show that people consider wildfires a potential risk which will continue to grow with time (EFDRR, 2013).

2.1.1 Climate and wildfires

Climate change effects and some of its causes have been continuously linked to more frequent wildfire occurrence (IPCC, 2014; NASA, n.d.; The Guardian, 2017b). Overall, wildfires are accountable for some 3,431 million tons of CO_2 (Bobrowsky, 2013, p.347), although currently there are no exact figures of how much CO_2 wildfires have emitted since 2007 following extreme events such as Australia's 2009 Black Saturday and Canada's 2016 Fort McMurray wildfires, due to aggregated data for all burning biomass (FAOSTAT, 2019). These CO_2 emissions from wildfires can cause serious implications for individuals' health, and alter their behaviour (Lahm, 2017; Public Health, Oregon, n.d.; The Sun, 2016). CO_2 emissions are also linked to increasing average global temperatures (IPCC, 2014; 2018). In one of the study areas of this thesis (South of France), the annual temperature in the towns of Bastia and Ajaccio in Corsica increased by 1.5 °C between 1971 and 2010 and is anticipated to continue rising (Garbolino, Sanseverino-Godfrin, & Hinojos-Mendoza, 2015). In turn, and as the following paragraphs will explain, this heat is likely to lead to greater wildfire occurrence.

While wildfires are classified under climatological hazards (Bobrowsky, 2013), the term *disaster* – aside from its statistical definition (Guha-Sapir et al., 2016) – defines "an event or situation that severely disrupts normal socioeconomic activities and causes damage and possibly casualties" and "… seriously disrupts the functioning of a community or a society" (Bobrowsky, 2013, p.176). Thus, a disaster can occur following a natural hazard (Fig. 2-1).

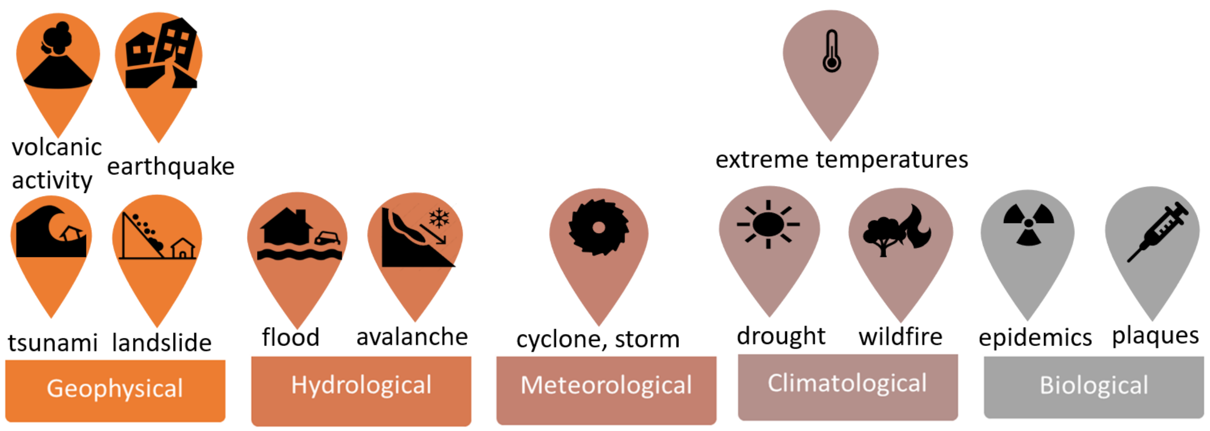


Fig. 2-1 Natural hazards and disaster potential.

A wildfire hazard (a.k.a. *forest fire*, *bushfire*, or *vegetation fire* depending on the geographical context) is essentially an uncontrolled fire, man-made or naturally ignited, in an area with vegetation and its five most important criteria are: (1) onset speed, (2) duration, (3) predictability, (4) potential for warning, and (5) scope of impact (Bobrowsky, 2013). The specifics of these criteria are highly dynamic – depending on (a) weather (wind speed, direction, relative humidity, and precipitation), (b) topography (hills and slopes, valleys and saddles, where the spread of fire increases, decreases or stays the same depending on the shape of the terrain), and (c) environmental elements (i.e. available fuel) (E-PPR.EU, 2016).

Wildfires can burn on the surface of the ground, within the ground, or on the top of trees ('crown fires'), depending on where the fuel is present (Viegas, 1998). Under the most unfavourable circumstances, a flaming front may turn when the wind changes, meaning that the scope of the fire can increase with the change of wind direction. This means that surrounding communities become at imminent risk, since preceding areas of vegetation can start heating up to 500 °C (932 °F), warmed and dried by the flaming front, making further combustion more likely (E-PPR.EU, 2016). The air too will be similarly heated, and the human skin pain threshold is only around 43-45 °C, with skin burning at around 44 °C (Heus & Denhartog, 2017). Furthermore, smoke spread will be increased by wind.

The unpredictability of a wildfire makes the potential for warning complicated. Less recent studies report several different wildfires destroying hundreds of houses within two to five hours (Cohen, 2000). Therefore, the warning time and potential scope for protective action will be determined by how well the risks are communicated as well as the reaction of individuals taking protective action.

If a warning and protective action do not take place in time, there can be consequences for human health as well as lives. Researchers have gathered evidence that carbon released from wildfires, and smoke, may have severe short- to long-term effects on individuals (Johnston et al., 2015; Mott, Meyer, Mannino, & Redd, 2002). In addition to affecting respiration, carbon monoxide and particulate matter (PM) may also impair mental acuity, cause headaches, eye irritation and fatigue in the short-term (Lahm, 2017; Public Health, Oregon; The Sun, 2016). Such effects are dangerous in emergency situations, where individuals must be able to perceive and act adequately. However, it is difficult to determine when PM will cause these effects upon exposure (O'Neill, Lahm, Fitch, & Broughton, 2013), which makes it challenging to safeguard the public from high PM concentrations, especially because they are difficult to spot visually. Nonetheless, health organisations warn that individuals with asthma, chronic respiratory diseases, or cardiovascular disease, persons over 65 years old, pregnant women, infants and children, and even healthy individuals can suffer adverse effects from exposure to wildfire smoke (Air Now, USA). Individual psychological well-being can also be affected as a result of a wildfire's effects on property damage, injury and/or other losses (Paveglio, Kooistra, Hall, & Pickering, 2016, p. 2). Anxiety has also been related to the experience of evacuation in a wildfire (Tally, Levack, Sarkin, Gilmer, & Groessl, 2013)**;** however, the cited study by Tally et al. (2013) has not been widely replicated, thus, more evidence is required to understand the potential effects of evacuation on people's health.

2.1.2 WUI definition and vulnerability

While the term 'WUI' allows an assumption of proximity between urban and wildland environments, there is no consensus over a precise WUI definition. Different studies, depending on the subject field, offer either simplistic or more complex descriptions of the term (Badia, Serra, & Modugno, 2011; Darques, 2015; de Torres Curth, Biscayart, Ghermandi, & Pfister, 2012; Modugno, Balzter, Cole, & Borrelli, 2016; Stewart, Radeloff, Hammer, & Hawbaker, 2007). Most of the aforementioned research agrees that, firstly, WUI requires a more local rather than standard definition and, secondly, it is a dynamic concept that changes over time due to increasing populations in WUI geographies (Badia et al., 2011). The definition provided by the most recent Modugno's (2016) publication on European WUI areas described it as "the transition zone between cities and wildland, where structures and other human development meet un-development [of] wildland or vegetative fuels" (p.113). In addition, it is commonly agreed among scholars that WUI areas are increasing because of two reasons: change of land cover from agricultural to urban, and the expansion of cities at the expense of previously unused wildland areas (Fox et al., 2015; McCaffrey & Rhodes, 2009; Paveglio, Jakes, Carroll, & Williams, 2009).

Apart from the geographic features of the WUI, sociology also offers WUI definitions. Researchers have long argued that different WUI populations "include inherent social, economic, or democratic influence by communities" (early arguments in Drabek, 1986, later in Paveglio et al., 2009, p.1087). For example, Alavalapati et al. (2005) note that the variety of land and ownership types in the WUI means that populations with diverse values are coming into coexistence, often meaning "conflicts and tensions […] between these new and existing communities and cultures" (Alavalapati et al., 2005, p. 705). On the other hand, Brenkert-Smith et al. (2013) show that cultural and social ties within the community are a somewhat distinguishing feature of WUI residents. To this extent, Paveglio et al. (2009) suggest that individuals living in the WUI have certain characteristics, e.g. they possess special local spatial knowledge, are networked, and understand the wildfire risks. Nonetheless, a certain tension lies between the human and the wildland where the anthropogenic and natural elements meet (Gore & Kahler, 2012). Vulnerability may be more present within the WUI (Eriksen & Simon, 2016b) than has been historically argued (Darques, 2015) and needs a more in-depth investigation.

2.1.3 Disaster-induced evacuation

As an area of research, emergency evacuation and its implications is fairly recent (Li et al., 2015) but it continues to increase in complexity (CCCM Cluster, 2014). In the literature, evacuation is described as a complex process of moving people from peril to safety (Li et al., 2015), which could also be called *emergency migration*, *flight*, *mass departure*, *relocation* (Bobrowsky, 2013) or *withdrawal* (EMV, 2016) depending on the emergency context. The evacuation process can be broken down into separate elements, or stages, which are followed through every time (CCCM Cluster, 2014): (1) evacuation decision (made by emergency managers), (2) evacuation warning, (3) people's withdrawal from the hazardous area, (4) seeking shelter (e.g. temporary retreat to a public shelter, move to a relative or friend's home; Cohn, Carroll, & Kumagai, 2006), and (5) return to original location (Elliott et al., 2014). Evacuation in disasters can be voluntary/spontaneous, mandatory (ordered by the authorities), or advised (may precede mandatory). In addition, shadow evacuation (when not-at-risk individuals enter the evacuation flow) can complicate the process (Stein, Dueñas-Osorio, & Subramanian, 2010).

Previously, evacuation has been seen as the last-resort in the response to a disaster, where other measures were deemed to be inefficient (CCCM Cluster, 2014). It has often been used when the event either occurred or changed its course and exceeded the capacity to safely respond in a way other than departing from the area, although it has also been used in situations where environmental conditions supported predictions of an extreme event with adverse consequences (Cova et al., 2016). However, evacuation as the preferred response to a wildfire hazard is growing across North America and Australia (McLennan et al., 2018). Populations most at-risk are the first ones to receive evacuation orders; however, voluntary and mandatory evacuations can become intertwined (Beverly & Bothwell, 2011). Therefore, while an evacuation order may be issued, the population's response to such an order will depend on the prevailing local evacuation practice, and also experience of similar events (Drabek, 1986). When individuals are free to choose whether or not to evacuate, their own attitudes towards complying with official advice become essential (Lindell, Lu, & Prater, 2005). Moreover, a study by Cohn et al. (2006), which captured specific citizen attitudes, illustrates just how important the sense of having a right to choose is when it comes to one's own security, confirming that individuals do not welcome state intervention. Nevertheless, authorities do have a responsibility towards people's safety and security, and evacuation procedures are guided by, and should always adhere to, international human rights and international humanitarian law, which states that life, physical integrity and health are the priorities for any such operation (CCCM Cluster, 2014; Firesmart, 2013).

Universally, once evacuation is chosen, its success relies on the time available until probable impact, thereby making the response to an unfolding disaster extremely time-sensitive. However, different disasters will have different timeframes, defined from the moment of recognising the threat until the moment evacuation is complete. In hurricanes, for example, this period can last up to 36 hours (Fu, Wilmot, Zhang, & Baker, 2007). At the other extreme, in earthquakes, it can be up to one minute (USGS, n.d.). Studies of chemical-related events have shown people get ready to leave mostly within 15 minutes, but can also take up to 120 minutes (Gai & Deng, 2019). Generally, the total required evacuation time, from the moment of hazard detection to the moment people reach a place of safety, comprises what is known in engineering fields as the Required Safe Egress (or Escape) Time (RSET) (Gwynne, 2012; Kinateder, Kuligowski, Reneke, & Peacock, 2015; Proulx, & Cavan, 2006). If lives are to be protected, this must be less than the Available Safe Egress (Escape) Time (ASET), which is defined as the RSET plus a safety margin (Babrauskas, Fleming, & Russell, 2010; Proulx et al., 2006; Veeraswamy et al., 2015; Veeraswamy et al., 2018). The elements within RSET have grown in complexity since Tweedie et al. (1986) introduced a methodology review for emergency evacuation time estimation. An updated review of what RSET entails in wildfires and other disasters can be summarised as follows:

1.Detection Time – the interval of time between fire ignition and first detection of the fire by a human or technology (Proulx et al., 2006). It could be argued that in cases where technology detects the fire, there is an additional time until fire safety authorities become aware of this incident.

2.Notification time (Tweedie et al., 1986), *alarm time* (Guylène Proulx et al., 2006), or *warning time* (Lindell & Perry, 2004) – these three concepts entail an interval of time between fire detection and when a household or individual is first notified of the fire or the need to evacuate. Since this could occur via means other than an alarm (whether outdoors or indoors), it is more comprehensive to call it the notification time. Arguably, notification time could be twofold – first, a notification of fire and then notification of evacuation, if necessary. Thus, notification time depends on the authorities, unless an individual detects the fire himself/herself. Kim et al. (2006) showed that in a sample of wildfire events in California, USA, notification for protective action was given approximately within a 10 km distance to the fire threat, with fires moving on average at speeds of 0.05-2.37 km/h.

3.Mobilisation time (Tweedie et al., 1986) – this is considered to be from the moment people are notified (and acknowledge that) until they begin leaving their buildings. It could also be referred to as the *pre-movement time* (Proulx et al., 2006). However, some researchers prefer evacuation *delay time* (Olsson & Regan, 2001) or *pre-evacuation* time (Gwynne, Galea, Parke, & Hickson., 2003; Gwynne, Hulse, & Kinsey, 2016) since there are normally types of movement involved before a person makes a conscious and motivated decision to start evacuating (see also *initial response time* and *the time to start [evacuation];* Fahy & Proulx, 2001). While mobilisation time tends to be viewed in terms of the response of a population, to an incident where an authority prompts evacuation, the response of an individual (regardless of who or what prompts this) can be characterised by two components: recognition time and response time (McConnell, 2010).

3.1 Recognition time is the interval of time from when fire cues are first encountered (e.g. smoke seen, notification heard) until the individual perceives that something is happening;

3.2 Response time is the interval of time from when the individual starts taking action in response to perceiving the cues (e.g. seeking information, packing for evacuation, getting ready to defend the property if initially deciding that the best action is to stay-in-place) until the individual begins to leave the building.

4.Travel time (Proulx et al., 2006; Tweedie et al., 1986) – this is the time needed to reach a place of safety once purposeful movement towards it has started. In a wildfire evacuation, it would be the time needed to travel from the door of the building to the designated or individually chosen safe shelter area.

5.Confirmation time (Tweedie et al., 1986) – this refers to the time it takes to confirm that the population has been evacuated.

Across the literature, these five RSET elements have been quantified using a mixture of methods. In studies of building evacuations, the third element is considered the most crucial part for evacuation success or failure (Day, Hulse, & Galea, 2013). Points previously mentioned here about residents leaving too late (section 1.1) and the speed of wildfires (section 2.1) indicate that this element is also likely to be crucial in urban-scale evacuation. In this thesis, the more general term of evacuation delay time (sometimes abbreviated to delay time) is used for how long it takes people to respond to the fire and begin evacuating. It refers to mobilisation time and/or response time where applicable. However, since a precise delay time is often too difficult to capture (i.e. requires authorities to have recorded the entire event or residents to have looked at a clock at the start and end and remembered these times), a further alternative time is used as a proxy in the analysis in chapter 6, called behavioural itinerary (BI) time. It involved getting residents to break their response down into discrete actions and estimate the time committed to each. Their answers were then summed to give the total amount of time committed to each individual's response.

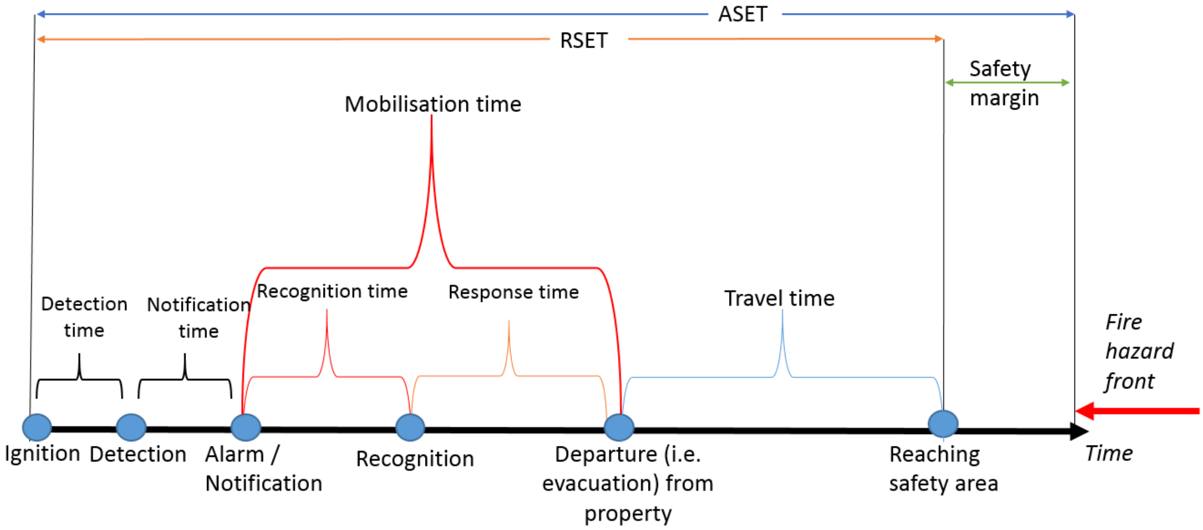


Fig. 2-2 RSET and ASET in wildfire evacuation.

Fig. 2-2 shows the RSET and ASET contextualised for wildfire evacuations. Usually, to determine all or certain evacuation element times, a formula, estimating the time from different components, is used. Lindell (2008), in his evacuation model for hurricanes EMBLEM2, adopted the following formula:

$$t_T = t_d + t_w + t_p + t_e \qquad [2\text{-}1]$$

where t_T is a household's total evacuation time, t_d is the authorities' notification time (or decision time in Lindell, 2008), t_w is the household's warning recognition time, t_p is the household's response time (or evacuation preparation time), and t_e is the household's travel time (Lindell, 2008).

A more recent contribution, for wildfire evacuations (Ronchi, Rein, Gwynne, Intini & Wadhwani, 2019), also identifies the main aspects of evacuation delay time:

$$t_T = t_d + t_{FDA} + t_{FDI} + t_N + t_{prep} + t_{foot} + t_{veh} + t_{ref} \qquad [2\text{-}2]$$

where t_T is the equivalent to the RSET for the population, and

- $t_d + t_{FDA} + t_{FDI} + t_N$ is the sum of t_d in Lindell's (2008) model, which includes the time from the incident start to the time the population is notified (i.e. t_d time needed for wildfire detection; t_{FDA} time needed to assess the situation; t_{FDI} time needed to control the wildfire; t_N time of population notification following an unsuccessful intervention)
- t_{prep} is the time needed for households to prepare to leave, which combines Lindell's $t_w + t_p$
- $t_{foot} + t_{veh}$ represent the time to move either on foot or into vehicles
- t_{ref} represents the final stage, reaching refuge.

These two formulas are complex in their timeline and granularity. For example, Ronchi et al. (2017a, 2019) consider recognition time and preparation time as one, while Lindell (2008) is less precise about the time factors involved from incident start to notification. However, this thesis is mostly interested in the element relating to t_{prep} and $t_w + t_p$.

As the *t*s in these equations are all dependent on factors (internal and external for the individual), Sorensen's (1991) review on evacuations offers some insights into what factors may affect the variation of timings within a single event. These factors can be broadly summarised into three elements:

(1) social and physical context:

- activity/occupation at the time
- social structure in terms of roles within the social setting
- connection to the social setting (closeness to family members/ neighbours/surrounding individuals)
- ethnicity
- physiological aspects
- geographical location in relation to the event
- environmental aspects, and other physical constraints that can prevent people from leaving

(2) informational context:

- warning channel
- warning context
- warning type

(3) risk perception:

- the real and/or perceived threat

A meta-analysis (Huang, Lindell, & Prater, 2015) found some of these factors to be insignificant in hurricane evacuations. However, a quantitative analysis testing for direct significant relationships between evacuation-related times and a wide-range of factors has not yet been conducted for wildfires.

Indeed, few researchers have collected quantitative data about the different RSET components in wildfires. Previous attempts to determine mobilisation times have rested on consultations with emergency managers only (Tweedie et al., 1986). There is also little research on how to gather time data, for even when the response element is encountered in surveys of survivors it may not be easy to ascertain related times (e.g. an interviewee in one study reports being told “you’ve got less than whatever, do your thing now”; McLennan, Elliott, & Omodei, 2012, p.921). Whilst time reporting is not a focus of qualitative studies aimed at informing policy-makers, these authorities cannot plan well for evacuation if they lack knowledge of likely delays, how long they may take, and therefore what role this could have on estimation of RSET. Faced with fire cues, individuals will assess their circumstances under the specific physical, environmental and other conditions (Dash & Gladwin, 2007; Lindell & Perry, 2012; Sorensen, 1991) and act accordingly. Having quantitative delay time data related to these conditions can assist modelling of past events and possible future scenarios, which would help prepare authorities and inform their decisions, and thus could prevent loss of life in wildfires. For this purpose, Czajkowski (2011) highlights the need for capturing microscopic household behaviours. While the importance of exploring household behaviour was established early on (Drabek, 1969), the disaster literature has also been criticised for the lack of a quantitative perspective, such as no reference to time committed to evacuation preparation (Sorensen, 1991), which is still typically the case in wildfire research.

In general terms, the aim to quantify response time can be summarised by the question of ‘who does what and how long it takes them to do it?’ (Gwynne, 2012). In the meantime, while a database of response times in wildfires is not yet available, urban-scale evacuation studies can benefit from experimental studies in the built environment. One example is Galea et al. (2010), whose overall evacuation equation [2-3] takes into consideration the RSET elements and how they interact:

$$RT = [NT + (NAT \times ATT) + (NIT \times ITT)] - [W \times X \times FOLmax \times ATT] +$$

$$+[Y \times Z \times TNT \times (ATT + ITT)/2] \qquad [2\text{-}3]$$

where: RT = Response Time (sec); NT = Notification Time (sec); NAT = Number of Action Tasks; NIT = Number of Information Tasks; TNT = Total number of tasks; ATT = Action Task time (sec); ITT = Information Task time (sec); FOLmax = Maximum number of overlapping tasks; W, X, Y and Z are constants.

ASET and RSET are at the core of planning for evacuations. In fact, individual characteristics coupled with external circumstances can have a major impact on RSET (Sorensen, 1991), making the ASET/RSET relationship different in each event (Babrauskas et al., 2010). While available data from office evacuations show that an individual may complete on average four tasks before they began to evacuate (Galea et al., 2009), individuals behave differently in the privacy of their homes compared to public spaces (Babrauskas et al., 2010; Gwynne et al., 2003; Proulx & Fahy, 1997; Thompson, Galea, & Hulse, 2018). Hence, urban-scale evacuation timings entail more variables than are currently explored, such as time committed to looking for pets, getting ready due to initially being asleep, or for collecting personal belongings found across an apartment or single-family home as opposed to an office desk (Babrauskas et al., 2010).

2.1.4 Emergency communication

Studies find that warnings are crucial in motivating residents to take protective action (McLennan et al., 2018; Strahan, Whittaker, & Handmer, 2018b). Advice or an order for specific protective action may be issued using a variety of media channels. Some earlier studies (Drabek, 1986) sought to understand which means of communication people use for receiving and sharing emergency information. Today it is understood that formal communication channels are not sufficient (Linardi, 2016). However, the crucial role is played by the message and, above all, the recipient, defined by their "social context and influenced by social-structural factors and ongoing social routines" (Cohn et al., 2006, p.40). Several theories exist that define types of effective disaster communication, with an emphasis on both the message and the receiver (Drabek, 1986, 1999; Martin et al., 2007). For example, while a message should entail a degree of "cognitive perceptions (vulnerability, risk severity, and efficacy)", the individual recipient of the message needs to be ready “to accept and act on a risk” (Martin et al., 2007, p.888). The messages that are most likely to have an impact on human behaviour, according to the PADM (Lindell & Perry, 2012), need to present information about ‘survival choices’ and be accurate, location-specific, consistent throughout their sources, and communicated by official sources or at least sources that are seen as credible by the population (Drabek, 1986). Several research studies highlight the importance of clarity and transparency in wildfire communication (Cohn et al., 2006; Handmer & Tibbits, 2005; Oloruntoba, 2013), and claim that the more the message is communicated, the more it is believed (Drabek, 1986).

Evacuation experiences in the 2009 Black Saturday bushfires in Australia, researched by Oloruntoba (2013), showed that the information from official sources did not achieve the required awareness in the affected communities. It was also found that, in earlier bushfire events, there were inconsistencies between promoting ‘staying and defending’ at the general policy level and urging people to evacuate on the day of the event (Handmer & Tibbits, 2005). Such critical appraisal of the 2009 events resulted in a detailed communications handbook, aimed at assisting Australian bushfire agencies in communicating wildfire hazards to the public (Australian Institute for Disaster Resilience, 2018).

However, the way the message will be interpreted or, in other words, what behaviour the message will provoke, will depend on the receiver, and often the urban-rural communities will display differences (McCaffrey & Rhodes, 2009). A study by McCaffrey and Rhodes (2009) highlights that differences between residents in urban and rural WUI areas lie in their approach to wildfires. Rural communities often have a higher level of awareness of the natural properties of fire, preparedness for fires, as well as a determination to stay and defend their property (McCaffrey & Rhodes, 2009). Subsequently, conflict in terms of urban-rural responses lies in the perception of messages and acting upon evacuation orders. On the one hand, Drabek’s (1986) review shows that small urban populations (e.g. in villages) are more likely than those in larger urban areas to disbelieve the disaster message, and hence are less likely to evacuate. On the other hand, those with greater ties to their families and greater involvement in their community will receive more messages, and thus will be more likely to interpret them as valid (Drabek, 1986). It is also argued that a difference in perceiving messages exists among individuals with different ethnic backgrounds and that communications should be adapted to reflect this diversity (Lindell & Perry, 2004; Perry, Lindell, & Greene, 1982). While most of the studies looked at information-perception differences within the same country, the varying response to messages across different ethnic backgrounds suggests that some cultural differences between countries/regions may also exist.

2.1.5 Wildfires versus other disasters

Since wildfire evacuation studies are scarce and limited to culturally similar countries, such as the USA, Australia and UK, the ability to generalise findings from other regions is questioned in this thesis. To explore the potential cultural-, individual- and policy-level factors that matter in evacuations, disasters from a wider geographical scope are looked at in this chapter. A starting point are similarities that ground the possibilities for comparison among disasters. At the macro level, these similarities include uncertainty, time sensitivity, anticipation, complexity, criticality, and assumptions (Drews, Siebeneck, & Cova, 2015). At the micro level, from the evacuees' point of reference, evacuation entails numerous 'situational constraints' (e.g. limited time for egress), problem solving (e.g. which items to take), and sense-making (e.g. beliefs held about the 'seriousness' of the evacuation order) (Cohn et al., 2006). It is beyond the scope of this thesis to conduct an in-depth comparative literature review on evacuation in different disasters; only points considered to be contributing to the overall understanding of evacuation in a wildfire disaster are discussed here.

Evacuation from storms to industrial hazards

One type of natural hazard similar to wildfires in its relative predictability are tropical storms. These storms can be predicted up to 36 hours in advance and, if a disaster is anticipated, require large-scale evacuation (Deely, Dodman, Hardoy, & Johnson, 2010). Nevertheless, literature shows that sometimes up to 25% of storm victims fail to evacuate (Ahsan, Takeuchi, Vink, & Warner, 2016). For example, people living on the coast of Bangladesh suffer every year during the cyclone season in April-May and in October-December. Despite their disaster experience, some individuals appear immune to safe decision-making. This illustrates the importance of assessing the reluctance to evacuate from coastal areas such as in Bangladesh, or other under-researched geographical areas, where a more localised perspective is required.

In the case of Bangladesh (Paul, 2012), there are certain determining factors that will act as a major hindrance to the evacuation process and to risk perception (World Disaster Report, 2014). To mention just a few, people may believe God or other spiritual beings are responsible for their fate, or they may own their property and also use it to make a living. An early, geographically-diverse attempt to understand what factors influenced evacuation during Hurricane Gilbert in Mexico, Cancun was made by Aguirre (1991). Aguirre highlighted the importance of the environmental circumstances on action taken, and the drawbacks of insufficient information dissemination prior to the hurricane. Importantly, however, Aguirre found that hotels were evacuated in an orderly manner, and well in advance, before evacuation of the general population was started. This suggests not only a segmented or staged evacuation strategy for different hazard zones that are applicable to wildfires (Li et al., 2015), but also segmentation of tourists versus the general population. While the tourists obeyed the authorities' guidance, some local populations failed to evacuate due to fear of looting (Aguirre, 1991).

Factors that affect evacuation decisions during hurricanes were assessed in a meta-analysis by Huang et al. (2015). This looked at studies of both actual hurricane experiences and answers to hypothetical scenarios and found the following:

- evacuation is related to being present in an at-risk area, and having a mobile home, but people are not always aware of being present in an at-risk area
- evacuation is also strongly related to the provision of an official warning but Lindell and Prater (2015) question the reliability of this factor on its own, since compliance to an order depends on personal factors such as risk perception; regardless, some individuals tend to comply with orders seamlessly
- environmental and social cues play a significant role in the evacuation process, which are likely indicators of the strength and proximity of the hurricane's landfall as well as strong indicators for evacuation; however, the 'rapid onset' itself is not significant
- perception of hurricane damage seems to be an important factor influencing evacuation; personal casualties score higher than material damage; however, job disruptions and being female were not shown to be significant in decision-making overall.

In addition to the factors reviewed by Huang et el. (2015), other studies have found the importance of time of day, the type of evacuation, and the environmental circumstances (Czajkowski, 2011; Fu et al., 2007). Furthermore, evacuation is found to be more likely if people have an evacuation plan in place, have evacuation experience, and young children are present in households (Dash & Gladwin, 2007). However, the likelihood of evacuation decreases when people feel that they should do what is best for them, even if authorities say otherwise, and also when families are of larger sizes (Dash & Gladwin, 2007). Both these reasons can stem from a distrust of local authorities

(Drabek, 1986) and logistical barriers, such as not having enough time to prepare a large family for evacuation, not being able to find accommodation for large groups, or not owning a large enough vehicle (Cote & McGee, 2014; Smith & McCarty, 2009).

In contrast to storms, less foreseen disasters are tsunamis and industrial disasters. Both events are rather rapid in their onset in the sense that they give a small window for evacuation. A study that first attempted to understand how individuals vary in their reception of a warning and the pace of evacuation was conducted by Sorensen (1991) in the aftermath of an industrial disaster. This case study of a hazardous materials' fire in Nanticoke, Pasadena showed that age and family size were not related to mobilisation time and, interestingly, perceived threat was not related either. While Sorensen's (1991) study does not indicate the actual time needed to evacuate in this specific event, such information was made available earlier by Tweedie et al. (1986), drawing on the expertise of Civil Defence Officers.

A connection between timing and behaviour in a large-scale evacuation was recently made by Charnkol and Tanaboriboon (2006) who analysed permanent residents' and transients' behaviour using a hypothetical tsunami evacuation event. The authors attempted to determine the speed of the evacuees' responses (fast, medium, slow) by asking them to estimate when they would have evacuated given various time intervals (60, 45, 30 and 15 min) before the tsunami was expected to hit. Note, this estimate was based on time needed for evacuation travel as well as preparation. The research showed that some of the factors observed elsewhere to make people more or less likely to evacuate (e.g. transient rather than permanent resident, larger family) are also factors that make people more or less likely to evacuate faster.

Evacuation from wildfires

Large information resources regarding human responses to wildfires became available when the Bushfire and Natural Hazards Cooperative Research Centre (BNHCRC) was established following the 2009 Black Saturday bushfires in Victoria, Australia. Studies contributing to BNHCRC covered fundamental themes such as community involvement in the bushfire response (Mclennan & Omodei, 2011), differences between communities in their individuals' responses (Morrison, Lawrence, & Oehmen, 2014), and how individuals make decisions to stay and defend their property, evacuate or shelter-in-place (McLennan et al., 2012; McLennan, Elliott, Omodei, & Whittaker, 2013c; McLennan, Paton, & Beatson, 2015a; McLennan, Paton, & Wright, 2015b). Nevertheless, authors of these studies have repeatedly emphasised the possible nongeneralisability of their findings beyond Australia due to its particular policies towards evacuation and property defence (McLennan, Paton, & Beatson, 2015a). Some have compared responses to Australian bushfires with that in North America, finding that the differences lie in wildfire response policies (Mclennan, Cowlishaw, Paton, Beatson, & Elliott, 2014). Same goes for some North American literature referencing Australian cases (Stephens et al., 2009). Thus, this suggests there might only be a certain degree of generalisation that can be applied when trying to understand human responses to wildfires and evacuation in other (currently neglected) countries such as those in Europe.

The existing qualitative and quantitative wildfire research, albeit with a focus on the USA and Australia, shows the main challenges and unintended consequences of human behaviour. For example, a study by Wolshon and Marchive (2007) analysed traffic flow issues (travel time) and noted a case of a 1991 California wildfire where egress complications caused delays in completing evacuation and subsequently a loss of human life on evacuation routes. The authors also emphasised the need to determine the warning time according to the WUI density, and the need to know how much in advance the evacuation warning should be given in order to "clear the subdivision as well as the number, arrangement, and capacity of evacuation egress points" (Wolshon & Marchive, 2007, p.74). Suggestions to improve road capacity included reducing the number of exiting vehicles at any one time (Wolshon & Marchive, 2007), and strategic placing of egress points, planned according to the needed capacity in the case of evacuation (Cova, 2005; Wolshon & Marchive, 2007). However, as noticed by Wolshon and Marchive, and other research (Veeraswamy et al., 2015), the uncertainty over wildfire speed and a lack of insight into who responds to a warning and at what time, complicates the very understanding of how to efficiently approach traffic planning in the event of a wildfire.

Although certain evacuation time analysis, essential for evacuation modelling, is present in literature on storms and industrial disasters (Charnkol & Tanaboriboon, 2006; Kang, Lindell, & Prater, 2007; Tweedie et al., 1986), studies on wildfire responses, as well as official policies, tend to simply define evacuation as 'early' or 'late' and the amount of available time as 'significant', 'moderate', or 'little to none' (Cova, Drews, Siebeneck, & Musters, 2009; Whittaker et al., 2016). Australian bushfire policy considers leaving early as the safest choice (McLennan et al., 2015b). This came after the findings from the 2009 bushfires, where 51% of respondents believed they left their property 'late' or 'very late', while 12% stayed because they felt it was already 'too late to leave' (Johnson, Johnson, & Sutherland, 2012). Nevertheless, such qualitative categories are not particularly useful for modelling human behaviour during an event or for anticipating the time-sensitive human response to an impeding hazard (Gwynne et al., 2003). The distinction between 'early' and 'late' is not well defined either; McCaffery and Rhodes (2009, p.14) interpret it as: "leave when we tell you to if not sooner". In contrast to 'early' (which should pose little to no risk), 'late' evacuation is considered to be the most dangerous option for protective action (Handmer & Tibbits, 2005). For instance, it was found that "a quarter of all deaths [in wildfires] between 1955 and 2008 were a result of late evacuations" (Beloglazov, Almashor, Abebe, Richter, & Steer, 2015, p.3).

The shorter the ASET in a WUI wildfire, the more likely that the last-minute 'safe' option is to not evacuate (Cova et al., 2009). Some of those who complied with the "prepare, stay and defend" part of the advice in the Black Saturday bushfires lost their lives due to overestimating their capacity to do this and ended up sheltering passively (Handmer & Tibbits, 2005). It is important to note this difference, that 'shelter-in-place' is passive and 'stay and defend' active (McCaffrey & Rhodes, 2009), and that these actions and evacuation require different environmental conditions to be present, a different level of individual preparedness, and different structural components. There are mainly three scenarios where shelter-in-place or stay and defend (collectively referred to in this thesis as 'stay-in-place') can be chosen over evacuation:

- when exit routes are blocked by fire and it is the only available option;
- when the margin of safety for evacuation is too small and evacuation becomes too risky (i.e. last-minute evacuations);
- when individuals choose to protect their property to improve the chance of its survival (Cova et al., 2009).

However, unless the structure of the property is built to withstand a wildfire front, leaving early should always be the main protective action option. The literature review by McLennan et al. (2018) suggests that planning and intention-setting before a wildfire, as well as risk perception during an event, likely influence decision-making but only after an evacuation warning has been given.

2.2 Human behaviour in disasters

"How many unfortunate people have perished in this disaster because of wanting to take his clothes, another his papers, another his money?" Rousseau (in Dynes, 2000, p.106)

Human behaviour in response to natural hazards ranges from full compliance to complete denial. Simulating such behaviour is only possible with the help of observations and other data. Knowledge of cognitive and emotional responses to emergencies, which influence the decision-making process, can help make sense of the available behavioural data.

2.2.1 Preparedness and response

Preparedness for a wildfire is closely associated to planning for what to do when disaster strikes, and is essential for human survival (Handmer & O'Neill, 2016). Different approaches to the effectiveness of preparation exist across the literature. For example, according to Drabek (1986), the level of preparedness of individuals and communities will depend on:

- socio-cultural factors
- whether community-wide preparedness initiatives are run
- local/state policies with regards to wildfire preparedness
- whether the family unit is willing to cooperate, and
- whether there are any factors influencing the planning stage, such as potential of looting if the plan is to leave early in the wake of a disaster.

Preparedness also plays a major role in resilience and adaptability (UNISDR, 2015). This, in turn, as noted by Jakes and Langer (2011), requires (1) local community networks, (2) experience and knowledge within the community, and (3) knowledge and capacity within the governmental institutions. Cultural adaptations are especially strong in fire risk mitigation and are well reflected in the variety of methods used in some countries (Emergency Management Australia, 1998).

However, more recent studies focus on the cognitive aspects of planning for wildfires and their implications for anxiety control, which have shown to matter somewhat more than planning on its own (Eriksen, Penman, Horsey, & Bradstock, 2016a). Thus, preparedness also means mental, physical and social preparedness efforts such as:

- awareness and recognition of wildfires
- knowledge relating to human and building survival
- careful planning for staying-in-place/evacuating
- personal safety

- ensuring the landscape or one's home surroundings are maintained appropriately, and
- a realistic understanding of the capacity for emergency service intervention and response (Clode, 2010).

Situations where preparedness was underestimated by individuals facing wildfire threats have largely brought injuries, loss of life and traumatising experiences (Kahneman, Slovic, & Tversky, 1974). The underlying difference between 'having a plan' and 'having no plan' is the following: during an emergency, an unprepared individual's ability to perceive information and understand directions may suffer and result in evacuation delay or death (Clode, 2010; Handmer & O'Neill, 2016). Nevertheless, the preparedness and subsequent responses to wildfires by people who perished in the 2009 Black Saturday bushfires have shown that having a plan does not necessarily result in appropriate protective action (Handmer & O'Neill, 2016).

Preparedness is also crucial for long-term post-wildfire effects on individual well-being (Paveglio, Kooistra, Hall, & Pickering, 2016). For example, Paveglio et al. (2016) concluded that individuals who were taken by surprise by the wildfire effects on their property and themselves experienced more negative effects to their well-being. In contrast, those who were better prepared and had wildfire experience were able to recover without much of a damaging impact to their well-being (Paveglio et al., 2016).

2.2.2 The immediate response of individuals

While preparedness for a disaster such as a wildfire is an intrinsic part of protecting lives, individuals' immediate responses to fire cues are equally crucial. Contrary to beliefs held about human reactions to emergencies, panic is rarely the immediate response (Proulx & Sime, 1991; Sime, 1999; Aguirre, 2005). Usually, it is disbelief or denial (Cohn et al., 2006; Drabek, 1986). However, despite that, research in building fires suggest that the time when cues such as a warning are transmitted is also often the beginning of the evacuation phase (Galea et al., 2010), although not consciously thought of that way by individuals in the situation. The latter point is supported by the fact that human beings are known to have an overall delayed physical reaction to outside factors due to their physiology (Jain, Bansal, Kumar, & Singh, 2015).

To better understand what an immediate response to a wildfire hazard consists of, it is useful to start at the neurological level of an individual. Clode (2010) reports that neurological mechanisms are responsible for the ways that humans respond to life- and property-threatening circumstances. Simply put, two systems in the human brain respond to events: the neocortex, which manages *conscious control* over behaviour, and subcortical systems, which mediate more *instinctive, emotional* and *unconscious behaviour* (Clode, 2010). The conscious part assesses information based on past experiences and, if such experience cannot be found, an individual will consider the situation as ‘normal’ (Clode, 2010). This is observed in the form of ‘denial’ and the ‘normalcy bias’ (Kuligowski, 2013), provoked in initial encounters with hazard cues. For instance, one bushfire survivor reported hearing “a sound like a 747 jet with backfires. At the time I said to [anon.] not to worry […]. Later I realised the sound I heard was the fire front and […] trees or gas bottles exploding.” (VBRC, 2009). Additionally, when a pattern of ‘false alarm’ experiences is formed, a so-called ‘cry wolf’ effect means that people will likely start distrusting cues warning of an emergency (Atwood & Major, 1998). When the motivation behind such distrust was investigated, individuals indicated it was associated with a fear of ‘loss of face’, appearing unreasonable, and feeling as if their “emotional and behavioural” actions had been wasted (Atwood & Major, 1998). However, it is claimed that disaster response training “provides the brain with a past experience on which to base its response to fire” (Clode, 2010, p.38), making community learning/drills an essential part of disaster preparedness.

2.2.3 Acknowledgement and confirmation of cues

After multiple ‘loops’ of milling and/or information searches are performed following receipt of cues (Gwynne, 2012), a person will become alarmed and completely disengage from their pre-emergency activities (Bourque & Russell, 1994; Drabek, 1986; Galea et al., 2010). At the point of milling/information-seeking, an individual may still interpret the situation as a false alarm and not disengage (Proulx, 2001), or return to their activities (Galea et al., 2010), albeit with somewhat higher levels of alertness. A person may also decide to *‘wait and see’* how the situation will develop (Mclennan & Elliot, 2013a, 2013b). Such ‘wait and see’ behaviour is seen as a need for ‘proof’ (e.g. sight of flames) before a decision to evacuate is taken. This is explained by the two brain systems’ different reactions to cues such as the presence of smoke versus actual fire (Clode, 2010). So, the cortex is for the most part bypassed in the presence of actual fire, and people instinctively respond to threats without further doubt. However, individuals may also experience generally counterproductive physiological responses induced by fear that hinder their ability to focus on protective actions (Clode, 2010). One example is tunnel vision, a focussing of attention on the threat itself, while another is freezing, and occurrences of people standing watching fire have also been observed as a common response (The Sydney Morning Herald, 2018).

Once the threat is identified as real, an individual initiates purposeful protective action and preparation to evacuate/stay-in-place begins. Nevertheless, in practice, the distinction between acknowledgement of cues and purposeful movement with the goal to evacuate is rather blurred (Drabek, 1986). For example, an individual can wait for more information while at the same time packing bags in preparation for the worst-case scenario. Moreover, if further cues fail to prove the seriousness of the situation, the intention to evacuate may be abandoned.

2.2.4 Evacuate or stay-in-place?

For people to respond to a wildfire, they must decide whether evacuation or staying-in-place is the safest viable option (Cova et al., 2009). Although policies in wildfire-prone regions may instruct PWM when to inform communities to evacuate, communication failures may mean such a decision will need to be taken by individuals themselves. To do this, the situation's dynamics must be assessed. For example, a wildfire threat can vary from very low to extremely high, depending on the flame height (Cova, Dennison, & Drews, 2011). Individuals will likely perform several 'information' tasks and possibly a few 'action' tasks also (Day et al., 2013) before the decision to stay-in-place/evacuate is taken. Then, people will undertake preparation activities, e.g. packing valuables, preparing the car for travel, etc. (Cohn et al., 2006; Proudley, 2008). Those individuals who are not at home at the time of an evacuation warning will normally ask for permission to leave work after having considered whether their leaving work will have an effect on their co-workers (Wilkinson, Eriksen, & Penman, 2016).

A person's motivation for evacuation is best summarised by the type of information they receive about the likelihood and consequences of the disaster, and the possibility of negative effects on themselves following these consequences (Drabek, 1986). However, motivations, or more simply reasons, for evacuation or staying-in-place can be numerous. From what is known so far in the literature, a motive could be summarised as an individual wanting to make the right decision, which is also influenced by economic reasons such as having the funds to leave and stay away, as well as wanting to protect family members, wanting to survive, and wanting to protect one's property. Nevertheless, motivations or reasons for certain decisions cannot always be pinned down. Certain predetermined beliefs or emotional states felt during an emergency event, such as anxiety, a rush of adrenaline, or fear, can well be what prompts some decisions. Therefore, more internalised motives need to be explored in order to obtain a full view of human decision-making in wildfires.

Risk perception, emotion, and motivation in decision-making

So far, throughout the overview of preparedness and response, risk has emerged consistently as a factor. *Risk* is claimed to be a socially-constructed notion that only exists within the boundaries of the society, at the same time dependent on both *culture* and *individual subjectivity* (Doyle et al., 2014; Bobrowsky, 2013; Kahneman, 2010; Kahneman et al., 1974). Cultural and individual understandings of risk may govern different aspects of life. For example, the objective risk of a wildfire depends on climatological, anthropic and environmental aspects (explained in-depth in section 2.1). However, knowledge of this risk often requires expertise to gather and interpret relevant information and may be beyond the realms of interest if unrelated to the everyday practices of people. On the other hand, individual attitudes to a disaster and the real-time perception of risk arguably depend on a person's own attributes, the media salience or other people's influence in one's life, as well as beliefs about the locus of control (LoC) over how one's life events turn out, among other things (Bobrowsky, 2013; Slovic, Finucane, Peters, & MacGregor, 2004; Kinateder et al., 2015). Nevertheless, while individual attributes matter, research has shown that individual preferences in decision-making can shift drastically and in fact be manipulated (Kahneman & Tversky, 1979), making it challenging to derive personality archetypes for predicting evacuation/staying-in-place (Strahan et al., 2018b).

Thus, while risk is considered to be socially-constructed, it also seems to be dynamic and situational. For example, Champ (2016) presented findings from a study where individuals, who had lost their homes in a wildfire, thought that the probability of a wildfire and possible consequences to their newly-rebuilt homes had gone down after the last fire (Champ & Brenkert-Smith, 2016), manifesting a form of 'risk denial' (Sjoberg, 2000). Similarly, even if knowledge of the objective risk may remain with people after a disaster, their personal risk perception is argued to be somewhat detached from the action to mitigate it (Sjoberg, 2000). For example, findings in Australian bushfire studies showed that people fail to assess the risk and take measures, even though they recognise the need to learn and the potential areas for improvement (Dwyer & Hardy, 2016). Therefore, as risk perception plays an important role in wildfire preparedness, more evidence is needed to understand how risk is involved in emergency decision-making.

In decision-making in emergencies, two theories are often employed when analysing human responses (Cahyanto, Pennington-Gray, et al., 2014). Firstly, rational choice, or utility theory, is considered, which insists that people will make decisions according to the utility of these decisions, including financial utility (Pabst, Brand, & Wolf, 2013). However, experiments on stress and decision-making emphasise risk aversion in loss-framing situations where individuals under stress are less likely to make risky decisions when it comes to losses compared to people who are not under stress; this is largely attributed to the role of negative emotion that stress induces (Pabst et al., 2013). Thus, prospect theory (which is based around subjective pain and pleasure) instead of utility theory may be a more appropriate way to approach human decision-making in wildfires. As Kahneman summarises: “people make judgements and decisions by consulting their emotions” (‘affect-heuristics’, originally conceptualised by Slovic; in Kahneman, 2010, p.139). Research has found that individuals who reported intending to leave in the event of a wildfire were more emotionally aroused, rating higher in anxiety, than those who reported intending to stay-in-place (McLennan et al., 2015a), although these emotions could be the result of the decided intention rather than what informed it. Another widely used but more complex theory, bounded rationality, acknowledges that a rational response to an emergency will be mediated or limited by several overarching factors, including: attitudes towards or beliefs about the event (Bobrowsky, 2013); “available information, cognitive resources, and the finite amount of time to make a decision” (Kinateder et al., 2015, p.10); and motivation, cognition, appraisal and knowledge of the situation and beliefs about oneself (Lazarus, 1991). That said, irrational behaviour (competitive, selfish or counter-intuitive behaviour such as pushing other people or refusing to move to safety when in imminent danger) has been largely accepted as being a very rare behavioural response (Aguirre, 2005; Proulx & Sime, 1991).

To some extent within bounded rationality theory, motivation can be seen as driven by the above-mentioned factors, which are subsequently appraised and re-appraised according to the situation (Lazarus, 1991; Lazarus & Smith, 1988). Motivation equips a person with an understanding of what is generally important, whereas appraisal of the situation helps them understand the personal significance of the event to their well-being. This is accompanied by an emotional response and available knowledge also comes into play (i.e. the absence of adequate knowledge about a hazard results in more trust being placed in the authorities to handle the hazard and lower perceptions of risk; Siegrist & Cvetkovich, 2000). Re-appraisal supports coping with the situation and has many ‘loops’ (depending on a situation’s dynamics); it can also become more sophisticated thanks to knowledge (Lazarus, 1991; Lazarus & Smith, 1988). Consequently, a person ends up making a decision that seems to be the most appropriate at a given moment (Fig. 2-3).

It is said that appraisal functions as a heuristic-systematic process, where it is assumed that information about the environment/event is processed systematically, heuristically, or a combination of both (Kinateder et al., 2015; Trumbo, 1999; cf. the discussion of a two-system approach in section 2.2). Heuristics refer to shortcut-related decision-making, are seen to be 'automatic' and comprise different types (e.g. affect, anchor, availability, representativeness, proximity). They are also used to explain certain biases such as the normalcy and optimistic biases (Kahneman, 2010; Kinsey, Gwynne, Kuligowski, & Kinateder, 2018). Systematic thinking, on the other hand, is slow and requires certain cognitive 'effort', which may not be at one's disposal in emergency situations. For example, under time pressure, when a possible threat is perceived, the subcortical system (amygdala) will activate an 'automatic' emotional response (fear) prompting protective action (Greenfield, 2000).

Thus, an individual's cognitive-emotional processes may influence risk perception (framing a situation in terms of potential pleasurable gains and painful losses) and affect the behavioural response. Researchers (Lindell et al., 2016; McLennan, Elliott, & Beatson, 2013b) have already tried to measure emotional responses experienced during disasters, but no clear links with behavioural decisions have been drawn as of yet.

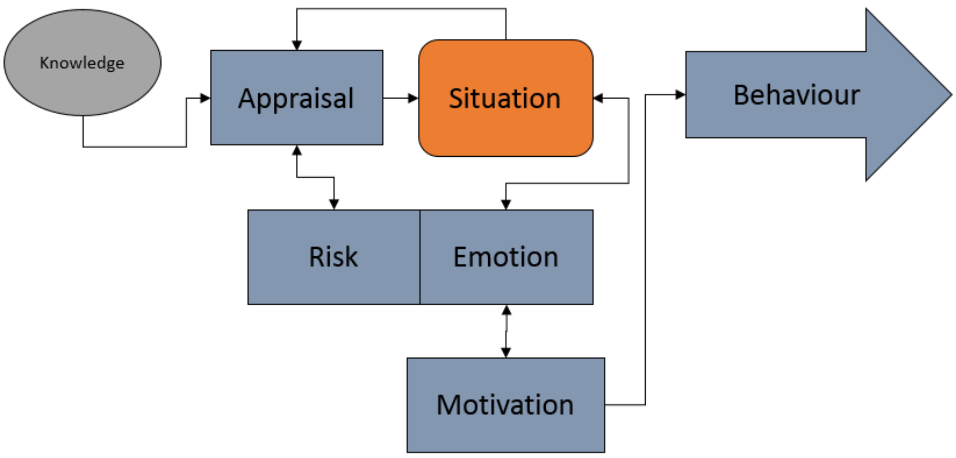


Fig. 2-3 Adapted from Lazarus (1991); since there is no direct effect of appraisal, situation, emotion and motivation they are double-arrows showing the interconnectedness and dependency on each element in any one moment.

It is found across the literature that in order to predict, represent and model human behaviour, complex behavioural responses should be simplified into their main elements. The PADM (Lindell & Perry, 2012) (Table 2-1) summarises a thought process that translates into protective behaviour. In Lazarus's cognitive appraisal process (Lazarus &

Smith, 1988) there are two steps, namely: is the event positive or negative and will it have significance for oneself, and what are the consequences of the event and how does one feel about that? The PADM, which has been adapted more specifically for disasters, consists of three pre-decisional and five decision-making steps (Table 2-1). Emotional aspects are omitted. However, perception of the stimulus is followed by paying attention to it, as well as understanding it, and deciding when to take action – elements that were not present in the previous work by Lazarus.

Table 2-1 PADM steps (Lindell & Perry, 2012).

1	Perceiving the stimulus (fire cue)
2	Paying attention to the stimulus
3	Comprehending the stimulus
4	Does it pose a threat to oneself?
5	Do I need to take action?
6	What can be done?
7	What is the best way to do it?
8	When should I do it?

While risk perception is an important part of the appraisal process, researchers continue to face the challenge of measuring risk (Day et al., 2013; Kinateder et al., 2015; Kahneman, 2010). The challenge is twofold: risk is inherently subjective (Kahneman et al., 1974), and attempts to measure it can conflict with research ethics (Day et al., 2013). The most widely used way of trying to measure risk is the *risk-as-feelings* approach that follows a psychometric paradigm (Kinateder et al., 2015), which taps into anticipatory emotions such as fear, anxiety, dread, and worry (Loewenstein, Weber, Hsee, & Welch, 2001). This approach allows researchers to somewhat observe the connection between emotion induced by environmental threats and subsequent action; although the feeling of risk can also be influenced by personal beliefs about being subordinate to nature (Berry, Segall, Kagitcibasi, 1997), i.e. by having an external LoC (Kinateder et al., 2015). The different aspects of risk perception also suggest that the feeling of being able to cope with an emergency may not be constant throughout the process of evacuation/staying-in-place. Changing external stimuli (e.g. presence/absence or intensity of cues), and the internal stimuli they may evoke (e.g. memories of previous experiences), can arouse different emotions ranging from positive to negative (Terpstra, 2011). Thus, emotion and risk perception should also be looked at as dynamic, and measured for different event stages (Galea et al., 2009).

Nonetheless, retrospective research that examines the changes in risk-as-feelings across a disaster is limited (Day et al., 2013; Knuth et al., 2014a), especially so for wildfires. Similarly, research rarely attempts to connect emotional responses to subsequent or accompanying behaviour in disasters (Knuth et al., 2014a; earthquake study in Lindell et al., 2016). Where such research is available, culturally-diverse case studies that explore emotional reactions during different stages of a disaster are scarce (a US case study on information and risk perception in a hurricane evacuation can be found in Burnside, Miller, & Rivera, 2007; Knuth et al., 2014a). In addition, researchers tend to focus on catastrophic events, which leads to a bias towards extreme (and perhaps solely negative) emotion, as discussed in the introductory chapter 1.

Culture and practice of safety

Safety culture is believed to be one of the core elements influencing risk perception and subsequent responses to an emergency (Galea et al., 2010; Ahsan, Takeuchi, Vink, & Ohara, 2016). Kinateder et al. (2015) reflects that 'safety culture' is a process where certain behavioural norms are instilled into people by institutions. At the same time, 'safety climate' represents the community's perception of official policy and of practices (both those engaged in by authorities and related agencies, and those engaged in by the people) (Kinateder et al., 2015). This suggests that a two-way process between the community's knowledge and institutional policies should be established, as in de Certeau's philosophy of everyday practice, where policy influences culture and culture influences policy (de Certeau, 1984). In a positive safety culture and climate, this would indeed happen, with good communication leading to a strong awareness across all levels of the risks, and communities and authorities working collectively, in harmony, to reduce and manage the risks. However, the coherence between policy and practice may often depend on the number of years lived in proximity to a WUI, and subsequent awareness of the wildfire risk, protective action and mitigation knowledge (Carroll, Cohn, & Blatner, 2004; Paveglio et al., 2009). Other cultural aspects have been shown to affect the way individuals respond to emergencies and stressful situations, such as tradition and religious beliefs (Jogia, Kulatunga, Yates, Wedawatta, 2014; Paveglio et al., 2017a). While these may involve authorities or institutions other than those related to the government, they nonetheless help form people's everyday lives and act to influence perceptions of risk and associated actions. Thus, seeing culture as an everyday practice of a 'regular' individual (Wild, 2012) helps organise ideas on what safety culture is and why behaviours may differ across geographical areas.

However, if safety culture can be shaped by different authorities/institutions, with some affecting all the population and others affecting just sections of the population, at what level should cultural effects be explored? How meaningful would it be to discuss, say, 'national' culture when exploring human behaviour? Several critiques have been raised over this in the literature (Lindell & Perry, 2004; Boccagni, 2008; Minkov & Hofstede, 2012; World Disaster Report, 2014). An answer is difficult to find currently. Minkov and Hofstede (2012) argue that within-nation variance usually exists because of differences in the predominant daily practices, and it is possible that sub-group existence can undermine the concept of 'national' culture. Nevertheless, the authors also argue that cultural differences on a large scale make it possible to distinguish between countries. Their findings, as well as those of Inglehart (in Boccagni, 2008), show that while sub-cultures can be strong, mainstream culture prevails.

Theories regarding culture have maintained that quantitative methods are not the most suitable means of inquiry (de Certeau, 1984). Few have tried combining qualitative and quantitative methods to shed light on cultural differences in disaster responses. One such attempt was made by the BeSeCu project (Knuth et al., 2014a; Grimm, Hulse, & Schmidt, 2012). There, qualitative and quantitative data collection approaches were adopted to understand whether a standardised questionnaire could be developed to capture intercultural differences in human behavioural responses to disasters. The resultant BeSeCu-S questionnaire, for use with survivors, has contributed to the understanding that emotional states should be measured for different stages ("beginning, realisation, evacuation, and aftermath"). Also, in line with other research (Elliott et al., 2014), it found that peri-event emotions and cognitions (distress, not perceiving ones' self to be able to control the situation) were associated with post-traumatic stress indicators. However, the tool was highly exploratory, and the disasters on which it was tested did not include wildfires; in fact, the authors suggested that the questionnaire's effective use might be limited to smaller- rather than larger-scale evacuations (Knuth et al., 2014a). Thus, cross-cultural comparisons of the responses of those who have actually experienced a disaster should be further analysed.

Gender and age vulnerability

Studies of gender in disaster responses have somewhat shifted their focus from female gender as a vulnerability factor (Fothergill, 1996; 1999), and from recovery-phase roles where "women clean up at home while men work on more visible town projects in the public sphere" (Fothergill, 1999, p. 135), towards analysing the differences and similarities between males and females, and gender's effect in the light of more modern social trends (Eriksen, 2014; Whittaker et al., 2016). That said, gender equality may not be likely in disaster responses, due somewhat to cultural factors (Zara et al., 2016). For decades, disaster studies have been preoccupied with finding gender to be a predictor of disaster responses, albeit with contradictory success. According to Gustafson (1998, p.805), "neither social reality nor scientific knowledge about that reality is gender-neutral". Gustafson's argument is true to the extent that even cultural studies, while not discussing *gender* as *sex* (Minkov & Hofstede, 2012) and therefore positing physical differences, nevertheless talk about such things as "emotional gender roles". That is, e.g. how roles such as being a caregiver at home, or being a breadwinner, make one feel as a woman or man, respectively. Thus, exposure to socially-constructed gender roles and division of labour may have an impact on individuals' sense of vulnerability and consequently their risk perception and actions (Whittaker et al., 2016). Gustafson (1998) explains that, on a day-to-day basis, gender roles may be adopted based on economic (income) or familial (parenthood) factors. It can be inferred that, in emergency situations, these roles do not change but rather are reinforced. Research by Eriksen et al. (2010b), which looked at bushfire experiences, preparedness and knowledge, illustrated tendencies that were prominent in earlier research by Enarson and Morrow (1997) and Fothergill (1999), i.e. greater helplessness, apathy and denial in the context of females' experiences of and attitudes towards bushfires were mostly a cultural outcome.

However, quantitative findings from disaster studies have shown weak links between evacuation behaviour and gender (Adeola, 2009; Handmer & Tibbits, 2005). That is, while certain qualitative links between gender and disaster responses exist (Dash & Gladwin 2007; Whittaker et al. 2016), there is no significant quantitative evidence of a gendered relationship with aspects such as wildfire awareness, planning and preparation (Huang et al., 2015; Whittaker et al., 2016). Additionally, Whittaker et al. (2015) analysed gendered bushfire responses based on the Bushfire CRC study interviews. While the authors noted that women were more prone to leave and men to stay and defend, it was not always the case and the opposite was also observed. The same inconsistency in findings can be noticed when looking into one of the aspects that motivate protective behaviour: risk perception. On the one hand, some quantitative studies find that females perceive risks as higher than males, including experiencing a more intense risk-as-feelings state (Champ & Brenkert-Smith, 2016; Loewenstein et al., 2001; Prati, Catufi, & Associate, 2012). At the same time, experiments on monetary gains and losses have not observed gender differences in risk-taking (Pabst et al., 2013). However, qualitative studies have shown that males and females give priority to different risks due to their consequences having different personal meanings (Gore & Kahler, 2012; Gustafson, 1998). Thus, when it comes to disaster responses within a mixed household, gender effects are yet to be understood (Zara et al., 2016).

Whilst vulnerability associated with gender continues to be debated, two other vulnerable groups have been identified across the literature: the elderly and children. There are a few reasons why these groups are considered vulnerable. Firstly, for their frailty regarding environmental effects. For example, the elderly and children's physiological functions are more vulnerable to radiant heat, hence these two age groups are also frequent victims of heatwaves across the world (Clode, 2010). Individuals of older age are also prone to having cardiovascular problems that intensify with heat and smoke produced by biofuels (Cova et al., 2009). Secondly, both groups are influenced, albeit differently, by their cognitive abilities. While children have the capacity to follow simple instructions, and are capable of comprehending danger and fear, they are "more at risk of freezing [still] or implementing an inappropriate strategy (such as hiding during a structure fire)" (Clode, 2010, p.37). The elderly, on the other hand, are affected by cognitive deterioration over time, especially due to cases of dementia (Christensen, Richey, & Castaneda, 2013; Proulx et al., 2006), which may lead to an inability to make rapid decisions and longer response times. Another issue for the elderly would be their decreased sensory capacities, which may prevent them from hearing a warning (Sorensen, 1991), thereby delaying evacuation until it is too dangerous to leave. These are some of the reasons why the elderly and children should be and often are evacuated early and must be advised against sheltering indoors or being exposed to smoke for extended periods of time.

Nevertheless, some studies have highlighted conflicting findings, stating that age itself may not have an effect on evacuation decisions (Huang et al., 2015; Smith & McCarty, 2009; Drabek, 1986, p.79) but rather illness, such as Alzheimer's, and lower income/dependence on state benefits, are better predictors of behaviour (Christensen et al., 2013). In addition to this, older individuals as well as children are likely to be more severely affected by post-traumatic stress, including the elderly being less capable of coping with short-term and especially long-term displacement following evacuation (Jogia, Kulatunga, Yates, Wedawatta, 2014; Viswanath et al., 2013). This is one of the reasons why the elderly and children's classification as 'vulnerable' also influences the behaviour of other individuals in their environment. As the Bushfire CRC study (Victorian

Bushfires Royal Commission, 2009b) showed, individuals' actions were highly influenced by their commitment and responsibility to dependents, including children, the elderly and those with disabilities. However, the decisions and actions of individuals with any disabilities such as mobility impairments have been less explored in wildfires, but in other contexts (Petrolia & Bhattacharjee, 2010; Shields et al., 2009).

2.2.5 Anticipating and forging appropriate wildfire responses

Given that human behavioural responses to disasters are said to be influenced by a myriad of factors such as risk perception, culture, and gender, it is naïve to expect that people will always engage in appropriate protective actions (Bonkiewicz & Ruback, 2012). However, it is believed that policy largely guides behaviour (Aguirre, 1991). For instance, various wildfire hazard slogans exist, aimed at the public, with advice for self-protective behaviour. Examples include: 'Stay and Defend or Leave Early' in Australia, where people are categorically advised against waiting to see how the bushfire situation unfolds; 'Ready, Set, Go' in the USA, where evacuation is a common practice; and 'Your safety is your responsibility' ('Tu seguridad es tu responsabilidad') in Spain, where mixed practices of evacuation and confinement exist. Such slogans, however, are absent in the South of France, since the focus here is on wildfire prevention, and personal security outdoors, hence the only detailed advice about protective action involves sheltering indoors (PPFENI, 2012).

Wildfire management practices, such as leaflets and art about fire prevention and response, is present across the globe where such hazards are prominent (Emergency Management Australia, 1998). Nevertheless, it has been argued (Mclennan & Elliot, 2013a) that the extent to which people actually wait and see how the event will unfold is still overlooked in Australia. Moreover, there is even less evidence on this aspect of human behaviour in Southern Europe and other regions. One way to anticipate behaviour in a particular community may be to ask people about their intentions regarding their wildfire response; this method is said to confidently explain 28% of variance in behaviour (Sheeran, 2002). More studies have shown that a person's intended actions and their actual behaviour are mostly consistent (Huang et al., 2015; Kang et al., 2007), especially so if the person has control over their behaviour (Sheeran, 2002). However, Whittaker et al. (2016) found a gender influence on intention: women were more likely to change their actions away from their intentions. In addition, research has found that people may know what they should do but their knowledge may not directly manifest into action (Bourque

& Russell, 1994). Thus, researchers agree that past behaviour may better predict future behaviour than intentions (Ouellette & Wood, 1998; Sheeran, 2002). However, Ouellette (1998) has specifically shown that in cases where the events are only occasional, as in the case of a disastrous wildfire event, past behaviour is not necessarily the most reliable predictor. Thus, intention may remain the best available predictor, especially if past behaviour is lacking (i.e. where individuals have never experienced a wildfire before).

Another way to anticipate the course of human behaviour in a wildfire may be to forge certain behaviours over time. It is an idea derived from theories on the intention-action relationship, where 'cognitive rehearsal' may well be related to learning how to respond to a wildfire event (Clode, 2010; Ouellette & Wood, 1998; Sheeran, 2002). In fact, in practice it is believed that a "well-trained and prepared population can help save lives and be very useful during evacuations" (CCCM Cluster, 2014, p.46). Thus, a number of online learning tools is available for adults (E-PPR.EU video material, n.d.; SIKANA video material, n.d.; Prepare in the Event of a Natural Disaster, n.d.), some of which can also provide guidance and information during disasters (I-REACT application, n.d.). Additionally, simulation of events is possible through virtual reality or desktop applications (BBC News, 2018c; "Evacuation Challenge", n.d.; Fire Adapted Communities, 2017; Padgham, 2016) including children's learning platforms (UNISDR, "Stop Disasters", n.d.; World Bank, 2017;). However, research on the feasibility and effectiveness of such methods is scarce. As explained by Clode (2010), certain individual traits will call for certain strategies (interventions) to successfully appeal to these traits, and these subsequently will play a role in how effectively behaviour can be changed in the direction that is seen as most appropriate by authorities and associated agencies.

2.3 Technology-supported wildfire response

"Science and technology revolutionize our lives, but memory, tradition and myth frame our response." - Schlesinger Jr. (in Shalowitz, 2019)

Technology currently assists with some of the main challenges faced by incident commanders and other PWM more generally: i.e. wildfire monitoring, emergency communication, and emergency response. Detecting the wildfire early, and understanding and predicting the fire's dynamics (e.g. location, size, speed, time until impact), is aided by automatic terrestrial and aerial systems in addition to human surveillance efforts (Slavkovikj, Verstockt, Van Hoecke, & Van De Walle, 2014; Veeraswamy et al., 2015). However, much of the decision-making is still largely dependent on the incident commander's knowledge, experience and assessment of the event, which includes decisions about the protection of vulnerable populations, knowledge of the populations' general locations (e.g. at home, at school, at work) at a given time, and predictions about where the populations will move (Li et al., 2015; Veeraswamy et al., 2015). Nonetheless, current advancements in technology suggest that such decision-making can be made with technological assistance too, since individual movement strategies are rather stable (González & Hidalgo, 2008; Song, Zhang, Sekimoto, & Shibasaki, 2014; Wang, Ye, & Tsou, 2016). However, there is no evidence of such use in practice yet, at least not in the geographical areas studied in this thesis. In addition, populations immediately at-risk can be determined by wildfire trigger zones and with the support of wildfire detection and fire propagation modelling systems (Finney, 2004; FireSmart, 2013; Li et al., 2015; Mahmoud & Chulahwat, 2018; fiResponse™); thus, PWM are able to anticipate fire movement and issue evacuation warnings with considerable confidence.

Available technology also allows a diversity of ways to communicate emergency warnings to populations. For instance, there are early warning systems (EWS) (CCCM Cluster, 2014), geo-targeted warnings, and staged-evacuation warnings (Cova et al., 2016b; Li et al., 2015). Attributes of the physical, social, or built environment can also be used to delimit target zones and reach the communities at risk; this can include the provision of risk area maps, if residents are able to identify their respective areas (Cova et al., 2016a). Additional proposals for technology's use in assisting wildfire responses are also on the rise, especially involving social media users (Slavkovikj et al. 2014). Wang et al. (2016), who built further on Slavkovikj et al.'s (2014) research, analysed and largely confirmed the usefulness of the information communicated through the social media channel Twitter during a 2014 California wildfire.

However, the technology-related focus of this thesis is on evacuation modelling for the purposes of planning and training (to assist prior to an event occurring) and the emergency response (to provide real-time assistance). The aim and challenge of sophisticated wildfire evacuation models, recognised by researchers, is to simulate interactions "between natural, built and social systems" (Cova et al., 2016a, p. 2), using computer modelling that represents human factors (Bernardini, D'Orazio, Quagliarini, & Spalazzi, 2014). Some research has shown substantial advancements in this area (Lämmel, Grether, & Nagel, 2010). Modelling human behaviour in wildfires highly depends on available and transparently-collected research data (both benchmark cases as well as data collected as part of tool development), which are translated into simplified behavioural models where some uncertainties remain (SFPE, 2019). However, one of the most prominent challenges remaining is the gap between social science and engineering studies in terms of converging their respective knowledge and approaches for the development of evacuation modelling (Trainor, Murray-Tuite, Edara, Fallah-Fini, & Triantis, 2013). This often means that data – which has either been collected retrospectively about real-life events using post-disaster surveys or from built environment evacuation trials (experiments) for purposes other than modelling – do not always correspond to the needs of modellers (Gwynne et al., 2003). Thus, to improve the quality of these behavioural models and, subsequently, the reliability of the simulations, there is a need to review the range of system specifications and potential data collection requirements.

2.3.1 Disaster evacuation modelling

In recent years, there have been a number of attempts to model household and pedestrian evacuations in disasters, including wildfires (AFAC, 2015; Beloglazov et al., 2015; Bernardini et al., 2014; Cova & Johnson, 2002; Li et al., 2015; Veeraswamy et al., 2018; Zia, Farrahi, Riener, & Ferscha, 2013). These studies have widely influenced and promoted the understanding of the importance of human factors (including in relation to ASET/RSET) when planning for safe evacuations of WUI communities. At the time of writing, several researchers are aiming to integrate fire, pedestrian, and traffic tools into a single modelling tool. These include the Fire Safety Engineering Group (FSEG) (Galea et al., 2017), with their agent-based evacuation modelling tool urbanEXODUS, and an open-source project WUI-UNITY (Ronchi, Gwynne, Rein, Intini, & Wadhwani, 2019), among others (e.g. Beloglazov et al., 2015). While the *pedestrian* sub-model focuses on human behaviour outside an individual's home, the broader *human behaviour* sub-model is of interest to this thesis due to its encompassing of behaviours taking place inside the home, prior to commencing evacuation. Nevertheless, both types of sub-models are said to require more reliable data on such things as behavioural itineraries, evacuation delay, mobilisation, and travel time, as well as decision-making (Gwynne, 2012; Gwynne & Hunt, 2018; Folk, Kuligowski, Gwynne, & Gales, 2019). This is especially the case for urban-scale evacuations rather than those of a single building (Ronchi, 2017a). In fact, various authors (Cova et al., 2009; Cova & Johnson, 2002; Dennison, Cova, & Mortiz, 2007) have pointed out a number of potential drawbacks that result from looking solely into the outdoor logistics of evacuation rather than into the indoor activities of households and individuals concerning evacuation. For example, setting the vehicle departure time delay to, say, 25 minutes assumes that this specific time is the population's mobilisation time (Cova & Johnson, 2002). However, such speculative assumptions fed into a model are often either based on data collected under non-emergency circumstances or include estimations of behaviours that have not been tested (Cova & Johnson, 2002; Lovreglio, Ronchi, & Nilsson, 2015). This results in parameter inconsistency due to a lack of available data. This is seen further with some models setting a five minute response time (Veeraswamy et al., 2015) and others setting it at one hour (Li et al., 2015). Nonetheless, there are some studies that have looked explicitly into the issue of information spread and, whilst not about wildfires, they can perhaps inform modellers, to some extent, of the evacuation delay time (Rogers & Sorensen, 1991).

One way to arrive at more accurate evacuation delay time estimations is to look at what constitutes the evacuation delay, which can be expressed in the form of a behavioural itinerary (set of actions), and time taken for this itinerary (Table 2-2). Beloglazov (2015) made these considerations, albeit without accounting for those individuals who would be leaving on foot versus other forms of transport, and with the assumption that individuals know where they are going and which roads can be used. In addition, Beloglazov's (2015) model does not consider agents' individual and household characteristics that define the delay time. In fact, the author argues that for evacuation delay time, assume the following: the less time available between the warning and required evacuation (e.g. 2 hours), the less time residents will take to leave their homes. While this example is logical and contributes to the advancement of models, it must be noted that this assumption is rather coarse, and delay time may vary by community. Thus, more studies on delay time distributions are needed.

Based on Kuligowski et al. (2017) and Fahy et al. (2001), there are effectively 4-5 main elements comprising evacuation models that account for human behaviour. While these elements are mainly related to building evacuation, they can serve as a starting point for understanding what information needs to be collected by researchers and successfully applied to urban-scale evacuation models. These elements are then elaborated by drawing upon the latest available review of WUI evacuation modelling system specifications by Ronchi (2017a) (Table 2-2). Those specifications were originally posed as system requirements for a potential pedestrian model but have been reframed in this thesis to anticipate the data requirements for wildfire evacuation models. Data collected with regards to model specification can eventually rely less on specific past events and be sufficient to model responses to wildfires that have not yet happened, assuming that the socio-cultural and policy context is represented within the dataset. Although addressing all system specification aspects is extremely challenging within one research project, a framework may help with how to approach data collection, dynamically including/excluding elements, thereby assisting questionnaire design (whether for surveying the public or PWM) – essentially a framework could help disperse the research burden across several waves of data collection or projects with a particular focus on pre-, peri-, and post-disaster stages, respectively.

Table 2-2 shows the factors of particular interest to evacuation modellers, regarding whether individuals will stay-in-place/evacuate, where they will choose to go, and evacuation delay times. While some information, such as travel speed, can be calculated according to road speed limits, and available shelters are often modelled as pre-determined from discussions with PWM (Shahparvari, Chhetri, Abbasi, & Abareshi, 2016), data on human behaviour are scarce and often complex to represent. To date, there are empirical, engineering and predictive agent-based models (ABMs) that vary in the degree to which the modeller decides the parameter relationship (Gwynne, 2012), and the ways in which agent decision-making is represented (Gwynne & Hunt, 2018). In the ABMs of interest to this thesis, an agent is an individual. In the literature on modelling, agents are defined as autonomous, social, react to external information, exchange and store information, and are goal-oriented, thus can act in line with internal objectives as well as available information and external conditions (Gwynne, 2012). Empirical and engineering models are the most commonly used, where the relationship between parameters is either based on the empirical data and translated into functions to represent the relationship, or is manipulated by the modeller to test certain “scenario conditions” (Gwynne, 2012, p.7). Predictive models are the most complex ones, where the social and physical surroundings of individuals affect behavioural responses based on individual attributes. The advantages of ABMs largely favour their use, since they can closely represent reality, population heterogeneity, environmental dynamics, social interactions among evacuees, and evacuee behaviour based on available information (Gwynne, 2012). Nevertheless, ABMs do not yet offer the full solution to issues that are being simulated and more research needs to be done to advance them (Macal, 2016).

Table 2-2 Evacuation modelling and human behaviour - system specification.

Modelling element	Element specification (Kuligowski et al., 2017; Fahy & Proulx, 2001) adapted to WUI	Detailed system specification developed for WUI evacuation (Ronchi, 2017a)
1. Mobilisation time	Time needed to leave the property from the moment the individual was notified of the hazard (e.g. wildfire).	How much time is needed to: respond to wildfire information and complete evacuation preparation tasks, as well as move from the building to a vehicle, board the vehicle, travel with the vehicle, leave the vehicle, access refuge location by foot or a vehicle, stay at refuge location?
2. Travel movement characteristics	Of the individuals (or population if it can be extrapolated), including pedestrian travel speed on different terrain; can also include vehicle speed under different conditions, which can subsequently be affected by group behaviour.	Here the requirements would be around understanding how information impacting travel will affect evacuee decisions. Will other evacuees affect the individual's behaviour? Is the evacuation destination choice a formal or informal shelter? Which routes will be taken? What will be the speed of travel? Will there be any delays or flow constraints? How will evacuees interact with emergency procedures?
3. Available egress routes, and the choice of routes	Those that are: (1) available for egress, (2) free to use without any obstructions, (3) chosen by evacuees for the reason of being familiar, and (4) the consequent action by evacuees in cases where the chosen route is obstructed.	Routes chosen would be affected by the fire behaviour model; the questions here are related to route choices either made before the trip or 'en route', which may depend on risks encountered on the road.
4. Population characteristics data	Such as census data and other information that can enrich the understanding of population distribution and potential decision-making.	There is a need for: diverse population data; understanding the effects of physical impairments and cognitive/sensory impairments on movement; understanding fatigue; information on experience of wildfires and previous evacuations; understanding social groups' behaviour; individual demographic attributes and their socio-economic conditions, as well as their relationship to the property; individuals' responses to wildfire information (transmitted face-to-face or otherwise), as well as situational awareness; how evacuees will interact with organisational/social structures; risks felt by evacuees; how evacuees make decisions/what their adaptive responses are to events.
5. Behavioural itineraries (BI)	Which are often part of more sophisticated evacuation models. Such itineraries represent the tasks performed during the mobilisation phase by individuals or groups, often referred to as 'actions during evacuation' (Fahy & Proulx, 2001), and constitute the aforementioned 'delay time' in built environment evacuations. However, BI can only be useful if it tracks both the action and the time spent undertaking that action (Kuligowski et al., 2017).	What are evacuee tasks? Do people use a vehicle for evacuation? What are the individual roles when in the vehicle? What is the vehicle capacity? How long does it take to board the vehicle? When does the vehicle leave? Does the vehicle encounter any difficulties, such as damage, fire, lack of fuel? How does reduced visibility, elevated temperatures, irritant gasses impact evacuee performance and well-being?

Other types of disaster preparedness and response tools are virtual reality (Feng, González, Amor, Lovreglio, & Cabrera-guerrero, 2018) and smart-environment-enabled serious games (SGs) (Bacon, MacKinnon, Cesta, & Cortellessa, 2013). These tools either analyse human behaviour by collecting data on their decision-making while using SGs and/or train first responders by presenting them with emergency situations (Drury, 2007; Feng et al., 2018). Since the evacuation modelling reviewed in this thesis is aimed at end-users, namely PWM, this approach is also taken while reviewing SGs. The current development of SGs offers a training environment for multiple types of disaster, allowing first responders to interact virtually with their teams to achieve goals such as protecting life, providing public information, and supporting self-help for communities, among other things (Bacon et al., 2013). Thus, it potentially opens up the ability to bring culturally diverse decision-makers into a single environment to solve issues, leading to support for response efforts in extreme events. For example, it could potentially give a chance for an Australian incident commander to observe and react to a French community's behaviour during a wildfire evacuation, thereby testing their response to an unfamiliar situation in a safe virtual environment.

Overall, simulations used for planning ahead versus in real-time differ in their granularity and the level of realistic representation, including the level of information on human behaviour used. Among the many existing variations on which behavioural aspects are considered in the models, there are several that are built on cognitive and emotional behaviour studies and those are presented in the next section.

2.3.2 Human behaviour modelling

Behavioural aspects can be represented within the model to varying levels of detail, depending on the capacity of the model as well as the available data. However, very detailed models are scarce for urban-scale wildfire evacuations and are more dominant for evacuations of built environments such as offices, where extensive research has been done (SFPE, 2019). A sample of comprehensive models is reviewed here to understand some of the different approaches to human behaviour modelling.

On the one hand, there is no shortage of approaches to distilling human behaviour for the purpose of urban-scale evacuation. One of the early detailed decision-making models, called an 'ethnographic decision tree' and based on hurricanes, was developed and tested by Gladwin and Peacock (2001). It is a binary outcome (evacuate/not-evacuate) model, incorporating individual characteristics such as older age, as well as the social and physical context, information availability, availability of prospective shelters, and interaction with officials. In the model, which highly reflects the PADM, decision-making is triggered by seven questions; if the first five are answered negatively, then no action is taken in response to the event. The drawback of applying this ethnographic decision tree, or the PADM, to wildfires is the absence of time: i.e. the amount of time that passes during the mobilisation stage under different circumstances has not yet been recorded in wildfire evacuation studies. In addition, whilst evacuation modelling will take into account "the time of day, length of time spent in a region, and whether a mandatory evacuation order was issued" (Dixit, Wilmot, & Wolshon, 2012, p.162), it does not say how these factors will affect the speed of evacuation.

Another approach to modelling human behaviour in wildfires specifically was offered by Adam et al. (Adam, Beck, & Dugdale, 2015; Adam, Danet, Thangarajah, & Dugdale, 2016), who proposed belief, desire and intention (BDI) as being the basis for behaviour in bushfire evacuations. The BDI approach is built on philosophy as well as psychology studies (Padgham et al., 2016; Lazarus, 1991). The theory states that if it is possible to determine an individual's goal in a situation, then it is possible to make assumptions about the sense-making of that individual, when he/she is exposed to certain cues (Lazarus, 1991). In the context of evacuation models, the goal would be to save one's self and loved ones and protect one's property. However, instead of observing agents' behaviour, which would depend on individual characteristics, Adam et al. organise the population into seven archetypes that follow practical reasoning depending on their beliefs, desires and intentions. These archetypes were developed from a series of interview analyses, which also shows the capacity of the BDI model to consider qualitative research methods. The authors state that the archetypes are likely to change where, due to circumstances, people switch their behaviour; the model also acknowledges the impact of stimuli and emotions on behaviour (Adam et al., 2015). Thus, the BDI model remains complex, and is based on Australian populations. Moreover, it has not yet been fully validated by other case studies.

Research on built environment evacuations, on the other hand, has contributed to rather sophisticated egress models, especially with the inclusion of case studies that allow for large-scale analysis, such as the 9/11 World Trade Center disaster (Day et al., 2013; Kuligowski, 2011; Liu & Lo, 2011). Gwynne (2012) and Kuligowski (2011) emphasized that both qualitative and quantitative performance of agents is important in tackling safety procedures. Subsequently, a new model, called the EDK, developed by Kuligowski (2011) and built on by Gwynne (2012), stems from symbolic interactionism and social constructivism – theories claiming that an individual's understanding of their environment is constructed through interaction with other individuals and that existing institutionalised roles pre-determine behaviour (Dickinson, Brenkert-Smith, Champ, & Flores, 2015; Gwynne, 2012). The EDK further takes into account the PADM, where an individual's action depends on the interaction between external and internal processes (Lindell & Perry, 2012), and ENT, according to which new norms may emerge from such interactions in order to guide behaviour in emergency situations. Based on the model elements, people will: (1) either continue their activities or look for more information; (2) if they find more information that suggests specific protective action, they will undertake it; (3) otherwise they will continue as normal until they receive additional cues and then take protective action (Gwynne, 2012). Gwynne (2012) highlights that early responders should be of specific interest to researchers. In 9/11, the main reason why early responders were more sensitive to the situation was their cognitive processes such as risk perception (Day et al. 2013).

To tackle how to represent cognition in an evacuation model, Zia et al. (2013) have offered an approach of distinguishing agents who have access to full information from those who have incomplete or limited access to information. This makes the modelling of social influence easier as agents with limited information are coded to follow other agents in their vicinity who supposedly have more information. Moreover, Zia (2013) developed an urban-scale evacuation model oriented to certain human behavioural aspects that determine the course of evacuation. This so-called 'aspect-oriented modelling' (AoM) similarly looks at individual, social and physical aspects, as well as information source and credibility. However, the model uses fewer characteristics but acknowledges some important developments of technology over the recent years that may have an impact on information dispersion (Zia et al., 2013). For example, information dispersion depends on the social relations of individuals and individuals will have their own characteristics (the authors mention 'technological and humanistic', meaning that smart phones will work in addition to biological sensory perceptions). Importantly, such individuals will be bounded to a *space*, and this will change/affect the agent's mobility in cases where the agent is attached to that space (Zia et al., 2013).

Aspects of group behaviour present their own specific challenges, and these are also addressed in modelling. Drawing upon aspects of human behaviour in crowds, Aguirre (2005) presented predictors of social behaviour that can help evacuation modelling. However, Aguirre stated that there is a lack of empirical research to show how these predictions determine the "timing of evacuation behaviour and the movement of evacuating collectivities" (Aguirre, 2005, p.124). The predictors include:

- the presence of competing interests for domination within the group, such as a dominant decision-making figure or social roles
- the size of the group – the larger the group, the greater the delay in deciding which protective action to choose
- whether the crowd begins to group into formations – a crowd moving directionally creates a flow
- whether the group is heterogeneous – either in demographics, physical capacity, or shared experiences
- resource availability – the more resources that are available to the group, the slower the evacuation, which leads to the assumption that more information may not necessarily mean a clearer understanding of risk and may increase ambiguity
- understanding one's own physical capacities – seeing one's own vulnerability due to gender, age or other reasons, may result in perceiving cues such as smoke or fire as more dangerous and subsequently lead to efforts to avoid the hazard

With the availability of detailed system specifications for evacuation models, and with theories of human behaviour that are systematised and translated for use in models, there is still a need to understand which tools offer wildfire evacuation response support to date.

2.3.3 Tools for modelling wildfire evacuations

In order to improve existing evacuation modelling using new research data on wildfires, it is important to understand the platforms and specific tools for potential data application, as well as their capabilities, in this regard. An extensive review of evacuation tools and their capabilities has already been conducted by Ronchi (2017a) with the aim of building an integrated fire and evacuation model. Thus, only a small selection of tools is provided here as an example: urbanEXODUS and webEXODUS, the integration of the IN-PREP training and response platform and Pandora$^+$ training tool into urbanEXODUS and webEXODUS, as well as the Community Emergency Response Model (CERM). CERM was chosen due to its validation efforts showing a capability to accurately simulate past events (AFAC, 2015), and the others were chosen due to the full access available to involved experts and developers and relevant projects that may benefit from these tools. While open-source software such as GAMA, or BLOCKS ("Congress proceedings: Australasian Simulation Congress," 2016) are available, such software relies on little quantitative human behaviour research and thus are beyond the scope of this thesis. The models that are reviewed here aim to improve their representation of autonomous human behaviour with the help of additional data, because much of the current configurations are manually represented by the end-user (Gwynne & Hunt, 2018).

On its own, webEXODUS is operating as a geographic information system (GIS) and has a web-based graphical user interface (GUI), making it portable and suitable to be used during a wildfire incident (Veeraswamy et al., 2018). Although webEXODUS is much like urbanEXODUS (a licensed software by FSEG, Greenwich, UK) in that it can be used for planning and preparation, urbanEXODUS is a desktop-based evacuation simulation tool allowing users to compare multiple evacuation scenarios (Veeraswamy et al., 2018). In both EXODUS versions, agents move from a built environment into the street network. Firstly, urbanEXODUS can help PWMs plan for future incidents, e.g. via traffic management/modelling, shelter planning, and design of warnings during incidents. While the end user provides population data, characteristics, the nature of alarms, and similar information, the simulation tool can provide the evacuation outcomes based on such details. EXODUS can also be integrated into training tools such as Pandora^{+} or IN-PREP (explained later in this section). The capabilities of the tool are reviewed based on content from the manual for buildingEXODUS (also explored in depth in Galea et al., 2011). This building evacuation tool has been extended to simulate an urban-scale evacuation and has similar model specifications to the urban tool. Its future development requirements have been determined through consultation with modellers and available publications (Lawrence, Filippidis, Veeraswamy, & Galea, 2016; Anand Veeraswamy et al., 2018).

Capabilities of webEXODUS and urbanEXODUS

Context	*Individual cognitive context*	Agents are aware of the shortest route to the nearest exit, or the shortest route to an exit that has been assigned by the end user; agents move following the potential map.
	Physical context	Models physical attributes but not trickled down to vision and hearing; agents with the same 'gene' attribute values respond/stick/evacuate together, etc. (i.e. group); physical elements that are important for evacuation modelling, such as roads, buildings, parks, other open space elements, are modelled; areas that cannot be populated, such as rivers, are ignored; at urban-scale, buildings are treated as coarse nodes, thus little attention is put into the internal workings of individual households but,

		nonetheless, a research version exists that allows the specification of flow rates for occupants exiting the buildings.
Information	*Information type/source*	Not directly modelled but some aspects can be modelled using existing functionalities; specified by the end user.
Time	*Evacuation delay time*	Delay time is specified before starting to evacuate from the property; delay times can be assigned to agents so a desired delay time distribution can be applied for agents exiting buildings; EXODUS can provide a breakdown of the delay time, average walking speeds, and distance travelled by the agent.

Requirements for further development of urbanEXODUS

Context	*Individual physical context*	Understanding of whether vulnerable people or households (elderly, young, families with children, single-person households, and transient populations) leave earlier/later, or evacuate/stay-in-place compared to non-vulnerable populations.
	Individual cognitive context	Understanding of the role of having a plan in delay time; understanding of the influence of past wildfire experience on the decision to evacuate/stay-in-place.
	Physical environmental context	Understanding of the impact of environmental cues, such as fire, embers and smoke, on decision-making and delay time; understanding of whether issues on the road result in individuals returning home.
Information	*Information content/type*	Understanding of the impact of information, e.g. an evacuation order, on decision-making and delay time.
Behaviour	*Response intention and execution; Travel itinerary execution*	Understanding of who intends to evacuate/stay-in-place and whether intentions are realised as actions subsequently; understanding of the impact of fire severity as well as available information on destination choice.
Risk	*Perception of imminent and long-term risk*	Understanding of how utility losses affect the decision to evacuate/stay-in-place.

Time	*Evacuation delay time*	Estimation of time required to board a vehicle (the time required to load important belongings and for people to board it).

As for the advancement of webEXODUS, the main development and potential use of the tool could be in providing training scenarios. Here, predictions – with a reasonable level of accuracy – for the influence of environmental cues, preparedness levels and evacuation warnings on the behavioural responses of the population would be most beneficial.

Both Pandora+ and IN-PREP can be enhanced by webEXODUS, which can augment these tools by providing the evacuation simulation dimension that is currently lacking. Pandora+ is a training tool that helps PWM handle crisis situations and can be used for evacuation-related issues during fire incidents, and train PWM in different locations. This training tool uses artificial intelligence (AI) that draws on a knowledge-base to present the trainees with decision-making points and subsequently reacts to these decisions (Bacon et al., 2013). IN-PREP (An INtegrated next generation PREParedness programme) is a platform that aims to improve the effective capacity of an inter-organisational response in complex environments (i.e. collective responding to a variety of disasters) and facilitate planning for crisis management in Europe (Cordis, 2017). Unlike Pandora+, IN-PREP involves coordination of organisational efforts across all levels and can be used before as well as during a disaster (Cordis, 2017).

Capabilities of Pandora+ and IN-PREP

Context	*Individual physical context*	Not explicitly represented by groups such as the disabled, elderly, etc., although it is possible to do so; currently represented by gender.
	Environmental physical context	Fire, smoke, embers, a lack of visibility and the interaction of these conditions with evacuees are not currently considered (although a version of the built environment tool, buildingEXODUS, makes these considerations).
Information		Notification rates based on the number of officers available to warn people and notification method.

Requirements for further development of Pandora+ and IN-PREP

Context	Integration of the role of citizens (i.e. they may also be volunteers or sources of information) in IN-PREP; improving and developing the

responsiveness of the environment to the behaviour of the trainees; integration of webEXODUS within Pandora to train PWM involved in wildfire evacuation operations. For example, once fire data, the initial distribution of the population, population characteristics, and other parameters are specified by the end user, this would trigger a certain proportion of agents (individuals) to leave the area. Depending on the circumstances, PWM would choose additional ways of informing people, such as issuing an evacuation warning, meaning that additional proportions of individuals would subsequently leave their location.

CERM

Supported by AFAC (Australasian Fire and Emergency Service Authorities Council, Australia), CERM claims to have adopted the most extensive view of human behaviour to date. The basis for this model is the cognitive risk model that defines the likelihood of individuals staying-in-place/evacuating and the moment at which the decision is taken, although the rules pre-determine the decision-making of households based on available data (AFAC, 2015). Data sources for CERM include post-event surveys, census statistics and information from Australian state emergency services. This model has been validated using such data from different bushfires over the period of 2005-2013, with 96%-100% agreement between CERM predictions and survey findings over whether occupants stay-in-place or evacuate, plus 91%-96% agreement for where occupants go. The main benefit of CERM is the ability for PWM to look at how certain inputs affect the outputs of the simulation.

Capabilities of CERM

Context	*Individual cognitive and physical context*	Preparedness, prior experience, self-efficacy levels and intentions; “change-of-mind” moments; awareness, motivation and action based on risk perception (comprised of threat, vulnerability and uncertainty); normal day-to-day activities; demographics; community profiles (community profile variables are unknown in the presentation of the model).
Information	*Information source*	Social media, radio, TV, mobile phone according to common use in populations.
Risk	*Perception of*	Threat = level of perceived threat to the lives of the individual and their household members (influencing

	imminent and long-term risk	factors: bushfire severity, likelihood of impact, time to impact; e.g. severe fire => higher threat). Vulnerability = level of perceived vulnerability to harmful effects of bushfire (influencing factors: age, gender, family structure, self-efficacy, prior bushfire experience and exposure, prior preparation, preference for staying-in-place /evacuating, resource failures, proportion of other residents leaving, presence of PWM). Uncertainty = level of uncertainty surrounding understanding of event details (e.g. severity of fire, time to impact, likelihood of impact, prominence/specificity/trust in communication and warning).
Time	*Evacuation delay time*	Timing or sequence of decisions is not included due to a lack of data.

Requirements (as provided in the model report) and suggestions for development of CERM

Context	*Larger sample size*	Overall, the sample size for the data used in CERM is often smaller than needed for validation (N = 300+).
	Physical environmental context	Explore the effects of environmental conditions on decision-making; collect post-fire survey data from medium and small fires to counter the current trend of surveys normally collected from large fires; understand the behaviour of tourists/transients by determining their relationship to their property/location.
Behaviour	*Behavioural itinerary; Grouping (joining-up) behaviour*	Obtaining response phase behaviours; exploring group behaviour; asking what occupants do if they are not with their families when they decide that leaving is the best option: do they go to where the others are (e.g. back home if at work) or have they agreed in advance to meet at a designated place of safety in the event of a bushfire?
Risk	*Motivation*	Obtaining reasons for behaviours.
Time	*Evacuation delay time*	Timing and sequence of decisions.

Chapter Summary

As the introductory Chapter 1 showed, the risk of wildfires is increasing, subsequently requiring more frequent consideration of community evacuation as a response, which could be supported by evacuation modelling tools. Nevertheless, human responses to wildfires and the effects on well-being are under-researched, possibly due to the relatively low economic and human costs involved compared with in other disasters. At the same time, where research is available, it mainly focuses on extreme wildfire events (Beverly & Bothwell, 2011; Eriksen, 2015; Ganteaume & Jappiot, 2013; Gazzard, 2014). This has resulted in most available research on wildfires and WUIs focusing on disasters in North America and Australia, whilst wildfire-prone regions in Europe lack scholarly attention.

Chapter 2 of this thesis sought to better understand the context in which wildfires become disasters, what is the current evidence of human behaviour in response to wildfire and how such information could be used to simulate urban-scale wildfire evacuations. It was shown that dry, hot conditions needed for a wildfire hazard to appear and grow put WUI residents living near flammable vegetation at-risk. Adverse wildfire effects to humans range from temporary cognitive impairment to physical and psychological injury to fatality through exposure to smoke, radiant heat and flames. Limited capacity to predict wildfires impacts the potential for giving warnings and limits ASET, making survival highly dependent on both authorities and individuals taking timely action. Nevertheless, available data on evacuation-related times are currently limited to industrial disasters and storms. One element of wildfire evacuation where time data are particularly needed is the interval between receiving fire cues and starting evacuation. The literature review has shown that evacuation delay time may likely be affected by the social and physical context, available information and risk perception. This was further explored with the help of literature and revealed the importance of individual characteristics, as well as cognitive and emotional aspects that influence wildfire preparedness, immediate responses, acknowledgement of fire cues, the evacuation/stay-in-place decision, ingress attempts and future evacuation. The literature review has shown that, across these stages, personal risk perception, emotion, and motivations were all relevant to decision-making. In addition, gender, age and other vulnerabilities, as well as the social (solitary individual versus a group) and cultural context (policies, practices), were seen to influence decision-making and motivations for protective action.

Although more information is urgently needed about the performance of response actions in wildfires, the scope of evidence of human behaviour in wildfires is limited.

Important factors that emerged from the literature are summarised in Table F 1 and Table F 2 (Appendix F).

One potential solution for better preparedness and response to wildfire disasters is the use of technology-enabled evacuation modelling. It was shown that including human behaviour into evacuation models has limitations due to a gap between the data available and the data required for simulations. This literature review showed the relationship between the theoretical specifications and practical capabilities of certain models, helping shape the scope to which this thesis can contribute. For example, certain requirements for human behaviour data to be used in the modelling of wildfire evacuations, in order to improve them, have been identified from this. These requirements for potential improvement can be grouped around six themes:

- *context* (i.e. environmental, social, individual cognitive, and individual physical context);
- *information* (i.e. information source, channels, and information content) and its effects on decision-making are also aspects which, while not necessarily modelled explicitly, are desirable for end users to know;
- *behaviour* of at-risk populations, for which data is currently scarce (i.e. individual and group behaviours, response actions);
- *emotion*, while conspicuous by its absence and presumably seen as too complex to be represented in evacuation modelling currently, is nevertheless influential and this is acknowledged in the literature that reviews behavioural models;
- *risk* in evacuation modelling is expressed via perceived threat, individual vulnerability and event consequence uncertainty, demonstrating that perceived risk levels are important to evacuation modelling;
- *time*, for which data is again lacking, was also acknowledged as requiring more ‘itemised’ measurement (i.e. in the form of timings of behavioural itineraries comprising evacuation delay).

IMPLICATIONS FOR RESEARCH

Chapter 3 Research scope

The first part of this chapter summarises the outlook of the current study. It also presents the framework (CIBER-t) developed for researching human behaviour in wildfires, based on the literature review findings. Then, two study areas – the South of France and Australia – are explored, including their WUI and climatic contexts, and the current wildfire challenges. Finally, the study hypotheses are outlined in relation to the research questions and objectives.

3.1 Setting the study outlook

Wildfires and the threat they pose to people's health and lives are a global problem, particularly given the increasing number of people living in WUIs, and the increasing size of WUIs. At the same time, human behaviour in wildfires and associated evacuations has received little research attention compared to other disasters. Where such research exists to date, it has focused on incidents in Australia and North America, while Europe remains relatively overlooked.

It is beyond the scope of this thesis to study behaviour in wildfires on a global scale. Instead, attention is focused on collecting and analysing data from one wildfire-prone European region, the South of France. Data was also collected and analysed from Australia, to serve as a comparison set. Thus, it would be possible to gain insight not only into the types of behaviour people display but also improve understanding as to whether such behaviour can be generalised or whether it might be specific to a particular culture/geographical area.

Moreover, wildfire-related human behaviour can span several phases: prevention, response and recovery. Again, it is beyond the scope of this thesis to attempt to conduct an expansive study. Thus, the focus was on response behaviour. This in itself covers a broad timeframe: behaviour prior to a wildfire occurring ('pre-event', e.g. having a plan of what to do); behaviour during a wildfire ('peri-event', e.g. sensing and reacting to environmental or social cues; preparing self, property and others for evacuation; moving to a place of safety), and behaviour in the more immediate aftermath of a wildfire ('post event', e.g. reflecting upon one's actions and whether they would be repeated in a future event). While the research collects data on behaviour across this timeframe, the period during a wildfire was of primary interest to the analysis because it can directly contribute to evacuation modelling (i.e. by quantifying evacuation decisions and delay time).

Furthermore, given the potential applications of the data (e.g. enhancing the development of agent-based evacuation models; training and supporting PWM in their wildfire planning and real-time response efforts to save lives), this thesis focused primarily on the behaviour of civilian individuals. Social aspects, such as the presence and responses of others (e.g. family members, neighbours, emergency service personnel attending the scene), were acknowledged from the individual level, i.e. whether and how the presence/responses of others affected the individual's response.

3.2 CIBER-t framework

The literature review revealed that attempts have already been made to bring together various diverse research findings to develop behavioural (conceptual and computer) models for building evacuation and other disaster mobilisation simulations (Gwynne, 2012). However, it also revealed that some gaps remain and that no standardised practice or tools appear to exist for researching human behaviour in wildfires and associated evacuations. Thus, one objective of this thesis was to first construct a research framework that could assist the collection and organisation of such behavioural data. This was done. The framework was built with the support of the main themes that emerged throughout the literature review. For the purpose of facilitating its use, i.e. ease of remembrance, the framework was called CIBER-t (Fig. 3-1).

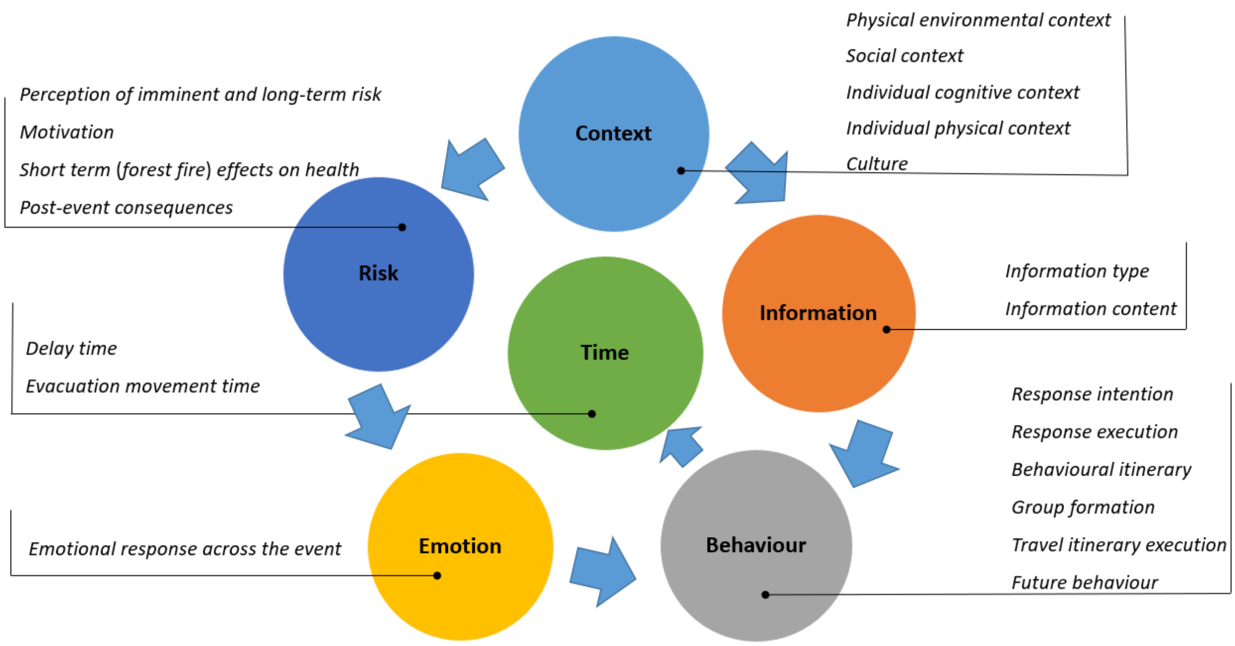


Fig. 3-1 CIBER-t framework developed from the literature review, with examples.

The literature review revealed that *context* often consists of an individual's previous knowledge and experience, and their social and environmental context (e.g. being at home versus work, feeling close to others in the community, gender roles, dependents, smoke density, proximity of the flames), among other things. *Information* in this framework groups together all available information sources – prior to the event and during – plus includes information content (e.g. does it specifically mention evacuation routes or protective action?). Human *behaviour* is often referred to in the literature as an itinerary of actions, and can be perceived as both appropriate and inappropriate. It can also be intended and/or actualised. Based on the review, it has been concluded that people's behaviour will depend on the surrounding context, the information they receive, their perception of risk and the emotion they feel in the moment. Thus, states relating to *emotion* (i.e. feelings such as fear, and cognitive and physiological states associated with emotional arousal such as optimistic, alert) were also seen to be important, and dynamic across the event. In addition, *risk* was seen as an influence on behaviour in relation to feelings as well as to perceiving one's vulnerability, associated to e.g. one's gender or having children present in the household. Finally, evacuation delay *time* is very important yet has either been arbitrarily guessed, collected empirically but not attached to the population demographics, or often absent in more qualitative studies of human behaviour. When delay time has been calculated, it has varied highly among individuals. While the usual 'S' shaped evacuation curve occurs over time, people tend to adapt their response pace to the severity of the hazard and the available time until potential impact (Sorensen, 1991). Therefore, it is crucial to also look at the factors that impact delay time, and not just delay time itself.

Thus, while existing behavioural models used for simulating human responses to disasters do not include all aspects involved in wildfires, the CIBER-t framework provides a comprehensive yet simple-to-use overview of aspects via which relevant data can be identified for collection and organised, and so could help inform models. To empirically ground the usefulness of the CIBER-t framework, data addressing all of the elements of it need to be collected.

3.3 Forest fires in Southern Europe

Wildfires occur yearly throughout Southern Europe (where they are often referred to as forest fires). In the 10-year period from 2000 to 2009, around 57,000 wildfires occurred annually in south-western European countries such as Italy, France, Spain, Portugal, and Greece (Ager et al. 2014). To put this into perspective, in the USA, the 10-year average for the same period was 78,437 fires, and in Australia calculations were over 50,000 fires per year (Australian Government, 2009). This shows that the wildfire issue is not isolated to any single region of the world. While the fires occur yearly between March and October, some wildfires have occurred in countries where they are not usual, leaving trails of damage throughout (Schmuck et al., 2015). Extreme weather anomalies and low precipitation has resulted in several wildfires in the Scandinavian and Baltic regions of Europe in 2014, 2018-19 (BBC, 2019; The Local, 2018; The Independent, 2018a,b), as well as caused an unprecedented number of deaths (over 100 people) during the course of two events that occurred in Portugal in 2017 (ABC News, 2017).

The European database EFFIS shows that, from 1980 onwards, Southern Europe experienced several increases in the overall average number of wildfires, which peaked in 2005 with 75,382 fires. Subsequently, declines occurred, with the overall average number of wildfires reaching a low of 23,425 fires in 2014. However, since then, increases have again been experienced, with 48,136 fires recorded in 2017 (European Commision, 2018). The total burnt area in Southern Europe has also been increasing since 2014, covering 895,738 ha in 2017. Of the countries in this region, France has observed a relatively more stable trend in the total number of wildfires experienced across the decades, with 5,040 fires recorded in 1980 and 4,403 fires recorded in 2017. Likewise, the burnt area for France has remained relatively stable, with 22,176 ha affected in 1980 and 26,378 ha affected in 2017 (European Commission, 2017b).

It is important to note that, over the past 46 years, due to urbanisation and other environmental changes (UNISDR, 2017b), the statistical data for fire occurrence and burnt areas will have different underlying circumstances, some of which will depend on human interference with nature (e.g. prescribed fires, arson) while some of them will not (e.g. drought, fuel availability, lack of precipitation, extreme temperatures). Nonetheless, WUI areas have grown significantly throughout Europe, especially throughout the Mediterranean. Unfortunately, at the same time, research predicts that climate change will have a significant effect on lengthening the fire season, with increased fire danger days in this region expected in the future (Fox et al., 2015; IPCC, 2014; IPCC, 2018). As part of the Mediterranean region, Corsica is the fourth largest island in the basin. As will be shown, Corsica shares wildfire risk challenges with the rest of the South of France and wider Southern Europe. In addition, it is an interesting area for safety culture research. Therefore, Corsica was chosen as a case study for the qualitative analysis, whereas data collection was expanded to the rest of the South of France for more powerful statistical (quantitative) analysis.

The number of wildfires experienced in Corsica every year from 1995 to 2009 rounded up to 536, while the burned area varied from a mean fire size of 7.9 ha to a maximum of 5,532 ha burned in a single event (Ager et al., 2014). However, over the period of 2014 to 2018, there were around 1,603 wildfires in Corsica (some data, however, is still unprocessed by the database http://www.promethee.com/incendies). The 'hotspots' can be seen in Fig. 3-2. It is estimated that, out of 360 Corsican communes, 200 municipalities are particularly exposed to wildfires (Garbolino et al., 2015). Nonetheless, no study exists to date that has analysed the effectiveness of wildfire responses in the South of France.

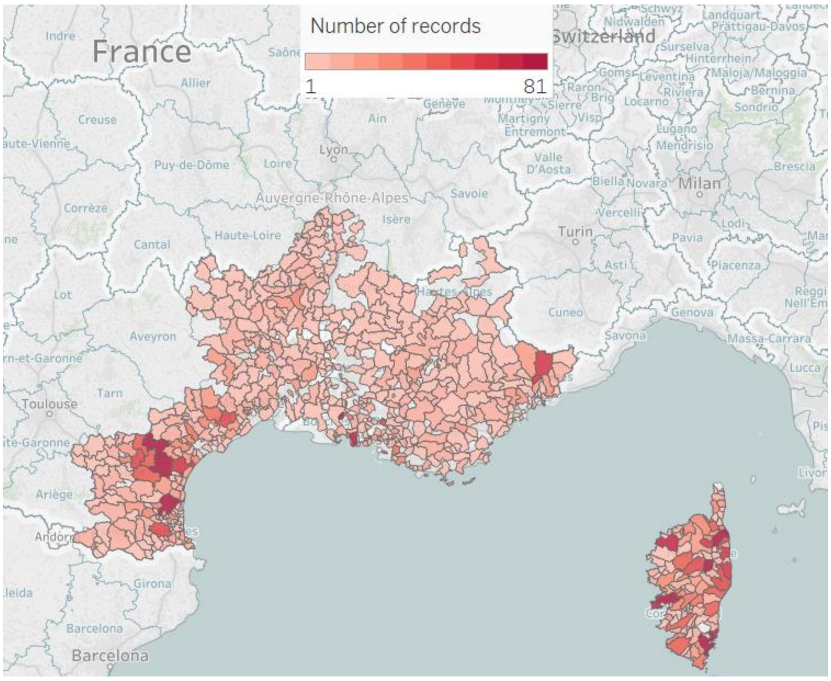


Fig. 3-2 Wildfires in the South of France, including Corsica, in the period of January 2014 – January 2018 by administrative unit *commune* (French for *township*). Data source: http://www.promethee.com/incendies.

With cool winters and hot, dry and windy summers, Corsica's vegetation types are typical examples of the rest of the Mediterranean land cover in terms of their nature and, importantly, combustibility. This means vulnerability (Fig. 3-3). However, it is predicted that due to changes in land use and climate change, ecosystems will also change in the areas that are not yet exposed to wildfires, bringing even higher vulnerability as a result (Garbolino et al., 2015).

Corsica, with a population of 0.3 million inhabitants has only 2% of the island covered by urban or other anthropic areas (Ager et al., 2014). Yet, in summer peak periods, the population almost doubles. This makes Corsica an interesting area to study WUIs, with associated wildfire risks similar to the rest of Southern Europe where such a peak in the population is also experienced during the summer season. The driest region of Balagne, as well as being one of the more largely-populated regions in Corsica, is also the most susceptible to wildfires.

Fig. 3-3 WUI at-risk, Corsica, France. By Patric Botey, SIS 2B, undated.

Other parts of the South of France are where the most wildfires take place on the mainland, particularly in the regions of Bouches-du-Rhône and Var. Bouches-du-Rhône and Haute-Corse (the northern part of Corsica) are the two French regions where there has been the largest fire occurrence, while Corse-du-Sud (the southern part of Corsica) has suffered the largest burned area by such fires. Coupled with the WUI proximity to occurring wildfires (Modugno et al., 2016), these French regions have high probabilities of fire affecting people, their livelihoods and infrastructure. However, French incidents are not widely reported by the English-speaking media in Europe and the real effects of WUI fires on people's well-being need to be further explored.

In fact, the Mediterranean region is said to be "a privileged area for a broad scale study and for observing city-fire interactions" (Darques, 2015, p.11). Modugno et al. (2016) carried out a probability analysis for Europe and concluded that frequent large wildfires occur mostly near WUI areas in the countries Albania, Bulgaria, Cyprus, France, Italy and Spain; this was due to large WUI areas in peri-urban environments being clustered around the Mediterranean region. In France, the WUI definition is as follows: "the overlay of a buffer zone of 100 m around urban settlement; 200 m around vegetation areas" (Modugno et al., 2016, p.115).

Historically, the formation of the WUI in Southern Europe has been a result of urban sprawl that is not associated with individuals wanting to live close to nature, but rather a balancing decision about where there is less congestion and land prices are lower (Badia et al., 2011). Vilain-Carlotti (2017) identified the specific issues surrounding the modern wildfire risk in Corsica. First, the change in economic sources from agriculture to tourism has formed the current view of pastoral fires as harmful to the aesthetics of the environment. Without such land management, vegetation grows uncontrolled. Second, the 'face' of the territories has also changed from more concentrated town clusters to isolated homes in the forest, with an increased risk of wildfire exposure. At the same time, developments in the communications infrastructure, improved roads and technology, and the decentralised availability of employment have all contributed to the growth of WUIs as permanent homes for people. Thus, WUI population growth in the South of France is more sporadic than that in the USA and Australia (Biasi, Colantoni, Ferrara, Ranalli, & Salvati, 2015).

3.4 Bushfires in Australia

Similar to in Southern Europe, the number of catastrophic fire danger days is predicted to rise in Australia, especially in densely populated areas (Dwyer & Hardy, 2016). The state of Victoria was chosen as a case study area in Australia due to the availability of previous studies, data and facilitating institutions, making it a reliable reference. So far, 2015 has been the hottest year on record for Australia, and the 5th hottest year in Victoria (Australian Government, Bureau of Meteorology, 2019). However, while hot weather and drought exacerbates the risk of wildfires (or bushfires as they are called in Australia), research shows that only 6% of all bushfires start naturally, with around 50% being due to arson or other suspicious activity, 35% being accidental, and the remainder being due to re-ignition or other causes (Australian Government, 2009).Fig. 3-4, shows the spatial occurrence of bushfire 'hotspots' in Victoria over the period of 2013 to 2017.

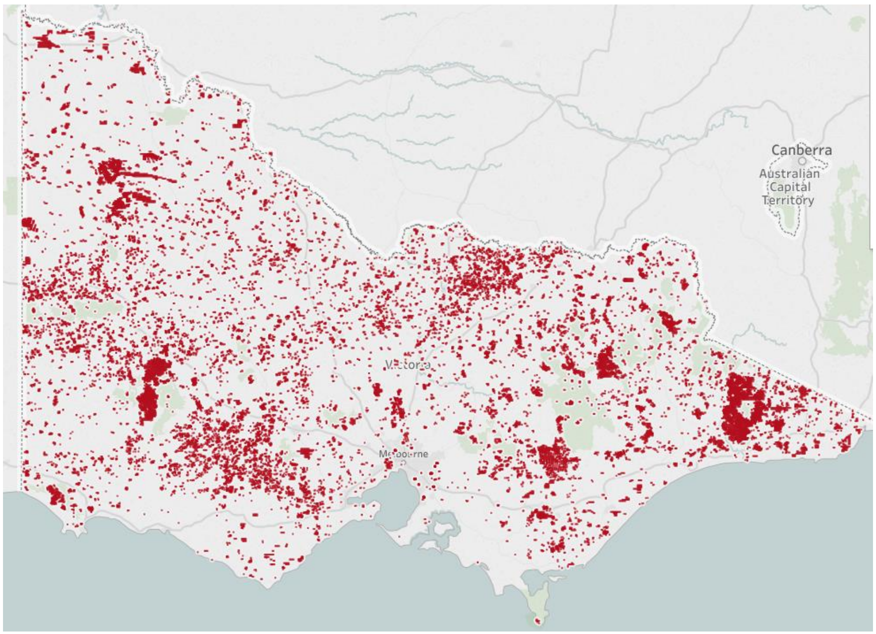


Fig. 3-4 Victorian Bushfires 2013 to 2017 – location for each bushfire 'hotspot'; source: https://sentinel.ga.gov.au/#/, historical data set 01.01.2013 to 17.12.2017.

Australia is seen as extremely prone to bushfires (Oloruntoba, 2013). With over 50,000 fires every year (Australian Government, 2009), WUI areas in Australia, with narrow or outback roads, leading to and from a town (Fig. 3-5), are at high risk both in social and economic terms.

Fig. 3-5 WUI and a single in-out road in Fairhaven, Victoria, Australia. By CFA South West community safety, 2018.

Clode (2010) concluded that over 1.5 million homes in Australia are about 700 metres away from potential bushfires, which is 20% of the homes in the country. Research on Sydney's WUI has shown that the probability of fire increases with proximity to urban structures, but this depends greatly on weather conditions and topography (Price & Bradstock, 2013).

Australian vegetation varies throughout the country due to its diverse climate zones, ranging from equatorial in the north, to tropical, subtropical, dessert, grassland and temperate in the south east and south west. Victoria's is both grassland in the north and temperate along the length of the state. In common with the South of France, Australia has the Mediterranean-type climate that is prone to wildfires (Keeley, Bond, Bradstock, Rundel, & Angeles, 2012). Winter here lasts from June through to August and Summer runs from December through to February, with mild temperatures in Victoria in Winter (min 6 °C / 43 °F, max 14 °C / 57 °F) and warm in Summer (min 16 °C / 61 °F, max 26 °C / 79 °F). The region experiences its driest months in winter, with most fires occurring from December to May. While some vegetation fires can be supressed at their origin, other types of vegetation such as Eucalyptus Angustissima trees pose a real threat when ignited, since these trees can burn to over 1,200 °C (2,190 °F) and are highly explosive, fuelling the surrounding branches (Oloruntoba, 2013).

Conversely, the probability of losing a property to bushfires in any given year in Australia is 1 in 6500 (McAneney, Chen, & Pitman, 2009). Such a seemingly low probability may feed into reluctance by individuals to prepare for unexpected extreme bushfire events, which since 2001 were the leading (note, not the primary) cause of injuries and death in Australian WUIs (Clode, 2010). One of the most destructive bushfires in Australian history occurred in February 2009. This bushfire event, named Black Saturday, claimed 173 people's lives and destroyed over 3,000 structures, out of which 200 were private homes (reported in Crompton, McAneney, Chen, Pielke Jr, & Haynes, 2011; Stephenson, Handmer, & Haywood, 2012; Australian Roundtable, 2016). It also burned 24,470 acres, resulting in a total estimated tangible economic loss of around 3 billion USD (Stephenson et al., 2012; Australian Roundtable, 2016). Some intangible losses were also reported; although they are more challenging to quantify, they could likely constitute almost the same amount of economic loss as tangible costs (Australian Roundtable, 2016). The intangible costs, which lack longitudinal studies to fully explore them, include mental health consequences among individuals, family conflicts and violence, and exacerbated risks of diabetes and other diseases (Australian Roundtable, 2016). In the context of urban-scale wildfire evacuations, the 2009 Black Saturday incident marked not only great loss and damage within the WUI, but also an opportunity to further research the circumstances and individual preparedness and responses to wildfires.

In addition, an insufficient perception of risk relating to bushfires is likely due to migration from urban to rural areas in Australia, where people arrive without the necessary knowledge for risk management in the WUI (Eriksen & Gill, 2010a). This also has implications for changing land use and a lower quality of land maintenance in the long-run (Eriksen & Gill, 2010a). In fact, the National Strategy for Disaster Resilience in Australia explicitly points out the issue of urban development in at-risk areas, which creates pressures and high expectations for services and facilities (Council of Australian Governments, 2009). Such changes in urbanisation thus contribute to individual and community vulnerability (Council of Australian Governments, 2009).

It seems rather straightforward that anthropic activity in the wildlands poses a risk of fire to communities. For this reason, active engagement in the processes of fire preparedness and mitigation is crucial, and the emphasis on such measures – as well as 'shared responsibility' across communities, businesses and governments – has increased highly across Australian policies compared to a decade ago (Australian Government, 2013). Previously, fire suppression activities were prioritised in Australia over preparedness and mitigation, which was said to be the result of a lack of funding towards "community safety measures" (Clode, 2010).

3.5 Study hypotheses

Two main research questions were posed in the current study, with the aim of advancing understanding of human behaviour in wildfires and evacuations:

(1) What motivates people to evacuate or stay-in-place?

(2) How long does it take people to start evacuating?

The CIBER-t framework helped organise the subsequent analyses around the relevant components that should be studied to answer these questions. For example, ‘behaviour’ in the form of deciding to evacuate could be influenced by other themes such as ‘risk’ (e.g. perceiving danger) and ‘context’ (e.g. staying in a temporary residence and therefore having little attachment to that property). Thus, variables identified in the literature review as being relevant to the CIBER-t themes were extracted and specific hypotheses constructed around them for the quantitative analysis. Prior to that, the qualitative analysis would provide context for the answers to the questions.

However, the CIBER-t themes and many of their related variables are temporal, and may arise multiple times in a disaster’s timeline. For instance, danger could be perceived not only during a wildfire but also prior to one by the fact of living in a WUI. Likewise, decisions about protective action could be made once, following the receipt of initial cues, but could also be made more than once, following the receipt of further cues and after the outcome is realised. Thus, the hypotheses were adapted to cover pre-, peri- and post-event stages of a wildfire.

The study hypotheses, relevant to research question (1), were organised into their wildfire stages:

Pre-event

(i) pre-event risk perception
(ii) planning

Peri-event

(iii) immediate response of individuals
(iv) intention
(v) evacuation decision
(vi) evacuation destination choice and ingress attempt

Post-event

(vii) future decision

Given their chronology, it was hypothesised that many of these responses could have a sequential effect leading up to and away from the evacuation decision. Where deemed appropriate, more direct associations with the evacuation decision were tested. In addition to the above, two other types of peri-event response were considered in relation to question (1) and hypotheses were constructed under the following heading:

(viii) emotion and perceived risk

One response aspect requiring a set of hypotheses was considered in relation to question (2):

(ix) evacuation delay time.

Each hypothesis relevant to these nine headings is accompanied by a brief comment, which outlines the context from which the hypothesis arose, i.e. whether directly from the literature review or from an as-yet unexplored but logical assumption made following the review. Note, some hypotheses were re-visited and re-imagined following data collection.

3.5.1 Pre-event risk perception

The following variables are hypothesised to be significantly associated with the pre-event perception of being at-risk:

1. Dependents.

Wildfire effects are especially hazardous for more vulnerable populations. It is therefore assumed that knowledge of this may in turn affect the risk perception of individuals who have vulnerable persons in their care.

2. Information sources that an individual engages with before a wildfire.

While effects of hazard knowledge on peri-event risk-as-feeling have been explored (Kinateder, 2016), it is still unclear whether information received before a wildfire affects the perception of pre-event risk.

3. Involvement in community risk mitigation.

This is based on the assumption that being involved in community efforts to mitigate risks will raise awareness of the risks and therefore affect pre-event risk perception.

4. Medical conditions.

Previous research, albeit not on wildfires, produced inconclusive results (Kinateder et al., 2015). This hypothesis re-visits the subject, following the assumption that those with medical conditions (e.g. mobility issues, cognitive impairments) will see themselves as vulnerable and therefore more at-risk.

5. Property insurance.

Individuals motivated to have their property insured against wildfire damage will likely know the objective wildfire risk and therefore this is assumed to affect whether they personally feel at-risk.

6. Property type.

This hypothesis stems from the assumption that family houses (as opposed to other types of property such as apartments) are not only more common in at-risk WUI areas but also have more to lose given their greater size, and thus it logically follows that greater risk will be perceived by the residents of these properties.

7. Gender.

Findings show that higher risk levels are felt by females and that there can be gendered distinctions for specific types of risk (Gustafson, 1998; Kinateder et al., 2015), and so a relationship between risk perception and gender is expected here too.

3.5.2 Planning

The following variables are hypothesised to be significantly associated with having a plan of what to do in the event of a wildfire:

8. Pre-event risk perception.

The literature identifies having a plan as emerging from feelings of being at-risk (Eriksen et al., 2016a).

9. Information sources that an individual engages with before a wildfire.

Preparedness, according to Jakes and Langer (2012), is strongly associated with networks and knowledge. Thus, it is expected that a relationship between planning and information sources will be visible from participants' responses.

10. Age and gender.

Age and gender could be vulnerability factors that heighten pre-event risk perception and thus subsequently motivate planning. For example, older residents may have lived longer in the area and so have better awareness of the wildfire risk, which may lead to them having a plan. Similarly, females may be more sensitive to the risk (Champ & Brenkert-

Smith, 2016; Loewenstein et al., 2001; Prati, Catufi, & Associate, 2012) and so also be more prepared.

11. Experience of wildfires.

The more an individual has experience of hazards, the more likely they are to be aware of and recognise the risk one poses (Eriksen et al., 2016a, 2016b; Knuth et al., 2014a). Awareness and recognition of hazards have been shown to influence preparedness (Clode, 2010); therefore, a relationship between experience is expected here.

12. Property insurance.

This hypothesis stems from the assumption that if an individual has considered the possible threat to their property and taken out insurance then they are also likely to have considered the threat to lives and have a plan.

13. Community closeness and general involvement in community risk mitigation.

According to Paveglio et al. (2017a), a community's shared experience of wildfire hazards may motivate collective action (Paveglio et al., 2017a; Paveglio & Edgeley, 2017b). If individuals feel part of their community and display involvement with them, they may also have a plan for themselves.

14. Property attachment.

Since tourist evacuations have been found to be prompted by the involvement of lodgings staff (Drabek, 1999), it follows that transients (less attached to their temporary residences) will be less likely to have made a plan themselves, in contrast to permanent residents who will have lived in the area longer and be more attached to their properties.

15. Pet ownership.

Individuals are also likely to be attached to their pets, who they will have made plans for when away on holidays, for example, and therefore it is assumed that having pets will be associated with planning for the event of a wildfire too.

16. LoC.

Having an external LoC means believing that what happens in life is largely in the hands of external forces – including e.g. deities, authorities, fate, chance – rather than one's self (Rotter, 1966). If an individual holds such a belief, then it is assumed they will be less motivated to plan for a wildfire.

3.5.3 Immediate response

The relationship between individuals' immediate response (e.g. passively waiting for versus actively seeking more information to confirm that something is happening) and the listed variables is expected to be as follows:

17. Having a plan.

This hypothesis stems from the assumption that individuals with a plan will have gone through the cognitive process of identifying what cues represent a fire and deciding what response is required as soon as such cues are encountered.

18. Gender.

While risk perception is likely to be affected by an individual's gender, disaster research suggests that not all types of behavioural response will be similarly affected (Huang & Lindell, 2016; McLennan, 2013a, 2013b), thus immediate responses are not expected to be significantly associated with gender.

19. Environmental cues.

Since environmental cues, such as the presence of smoke or flames, may be the first thing to alert an individual to a fire and also have a physical affect, it is assumed that they will be an important factor for the type of immediate response displayed to a wildfire.

3.5.1 Intention

The variables hypothesised to be associated with individuals' intentions are similar to those for the (ultimate) decision regarding whether to evacuate or stay-in-place (see section 3.5.5), given that the decision-making process is practically the same for both. Intentions differ from the evacuation decision in two main ways: the time during the event when they occur (intentions being formed earlier, in some cases prior to any visible signs of fire or other factors coming into play); and intentions may not be binary (i.e. individuals could initially decide to wait and see how the situation unfolds before ultimately choosing to evacuate/stay-in-place).

3.5.2 Evacuation decision

The relationship between the decision to evacuate or stay-in-place and the listed variables is expected to be as follows:

20. Intention.

While some intentions may not be actualised, it is nevertheless assumed that an individual's initial intention will be significantly associated with the ultimate evacuation decision (e.g. intend to evacuate, then more likely to decide to evacuate ultimately; intend not to evacuate, at least not straight away, then more likely to decide to stay-in-place ultimately).

21. Having a plan.

Preparedness in the form of a plan has been linked with the evacuation decision (Burnside, Miller, Rivera, 2007; Drabek, 1986; McLennan et al., 2013b, 2013c; McNeill et al., 2015), and so it is hypothesised that having a plan will be significantly associated with the decision here also.

22. Pre-event risk perception.

A study by Stein et al. (2013) states that "general sensitivity to risk is a stronger predictor of evacuation behaviour than perceived risk from storm surge alone" (p.331), meaning that risk's influence on decision-making may start before the event of a wildfire, pre-disposing people towards evacuation.

23. Gender.

While bushfire research (McLennan, 2013b, 2013c) shows a higher proportion of men stay-and-defend, this result was not significant, and a meta-analysis on hurricanes agrees with this finding (Huang & Lindell, 2016). So, gender is not expected to be significantly associated with this stage of decision-making in the current study.

24. Age.

The meta-analysis on hurricanes also found that age was not significantly associated with the evacuation decision (Huang et al., 2016). Thus, a similar outcome is expected here.

25. Dependents.

In Drabek's (1986) findings, having young children present in the household increased the likelihood to evacuate, although Huang et al.'s (2016) meta-analysis findings did not show this factor to be significant. So, again, no significant association is expected here.

26. Pet ownership.

The relationship between pet ownership and the decision to evacuate was not significant in McLennan et al.'s (2013c) study, although generally the results across disaster research are conflicting. Thus, a significant association between having pets and deciding to evacuate or stay-in-place cannot be ruled out.

27. Experience of wildfires.

The relationship between previous (hurricane) experience and the decision to evacuate was not significant in Huang et al.'s (2016) meta-analysis. Again though, the results on previous experience across disaster research are generally conflicting.

28. Environmental cues.

Those who evacuate have been more likely to report an environmental trigger (McLennan et al., 2013c); additionally, environmental cues were found to be a significant factor for the evacuation decision in the meta-analysis on hurricanes (Huang et al., 2016). Thus, a significant association between encountering environmental cues initially and deciding to evacuate is expected here.

29. LoC.

The findings across the literature are varied, perhaps in part because some researchers touch upon this subject but do not explicitly measure LoC. However, Drabek (1986) found that religious beliefs decreased the likelihood to evacuate and so a significant association between LoC and the evacuation decision is expected here.

30. Community closeness.

A significant association between the decision to evacuate and close community ties was observed in Drabek's (1986) work, and so is expected here as well.

31. Fire safety knowledge.

McLennan et al. (2013c) observed a significant association between deciding not to evacuate and having fire safety knowledge (gained through e.g. training or practical experience with fires), and so such an association is expected here too.

32. Property attachment.

Drabek (1986) observed that living in a residence for less than five years increases the likelihood to evacuate. So, a significant association between deciding to evacuate and lower property attachment (i.e. living in a temporary residence) is hypothesised.

33. Household size.

Although some research has shown that the size of families affects evacuation decisions (Dash & Gladwin, 2007), the meta-analysis by Huang et al. (2016) found otherwise, and so household size is not expected to be associated with the decision to evacuate.

34. Property insurance.

While McLennan et al.'s (2013c) findings on insurance and the evacuation decision were not significant, it is hypothesised that a different outcome will be observed if the assumed relationship between pre-event risk perception and insurance is correct.

35. Official warnings that mention evacuation.

In Drabek's (1986) study, evacuation advice received from an official source increased the likelihood of evacuation; also, in Huang et al. (2016), an official warning was significant. Thus, the decision to evacuate is expected to be significantly associated with receiving an official warning that advises evacuation (or, if worded more strongly, orders evacuation).

36. Grouping behaviour.

While families have been observed to seek to unite with members before leaving the evacuation area (Hsu & Peeta 2013, Stern, 1989), it is also important to understand whether grouping behaviour is associated with the evacuation decision itself.

37. Seeing others evacuate.

Several findings show that seeing others (e.g. neighbours) evacuate increases the likelihood of evacuating one's self (Drabek, 1986; Huang et al., 2015; Stein et al., 2010), and such a result is expected here also.

38. Fire proximity.

In one study (McLennan et al., 2013c), a greater fire hazard was associated with the decision to evacuate. However, it may be difficult to objectively determine the severity of the hazard that an individual encountered at the time. A possible alternative way of looking at this might be to consider how close the wildfire was. Thus, it is hypothesised that closer proximity to the wildfire will be significantly associated with the decision to evacuate.

3.5.3 Evacuation destination and ingress attempt

The following variables are hypothesised to be significantly associated with the chosen evacuation destination and attempts at ingress following evacuation commencement/completion:

39. Fire proximity.

Leaving late was observed to result in sheltering in cars and open areas (McLennan, Elliott, & Omodei, 2012), and since closer fire proximity may also indicate little time available for evacuation, it is expected to be significantly associated with the choice of evacuation destination.

40. Evacuation route knowledge.

It is assumed that individuals will choose their evacuation destination in a similar way to how they do when evacuating buildings – i.e. stay with the familiar (Kuligowski et al., 2017). Thus, those with limited knowledge of the routes (e.g. locals who have not lived in the area long, tourists) may choose to go somewhere close to hand that they know of, if they know of any such place at all, while others with greater route knowledge may display choices that are more varied and further afield.

41. Varied motivations.

While researchers highlighted some time ago that ingress attempts occur and need attention (Drabek, 1999), this issue remains one to be explored further. Motivations for such behaviour are assumed to be varied and perhaps similar to motivations for grouping behaviour (Wilkinson, Eriksen, & Penman, 2015). Examples include a desire to check on/protect things of sentimental value that were left at home (e.g. pets, property to which individuals are attached), or a (perhaps mistaken) confidence of being able to predict/handle what will happen if heading back into the hazard zone (e.g. through having fire safety knowledge or previous wildfire experience).

3.5.4 Future decision

The relationship between the decision to choose evacuation in the future (if a similar event occurs) and the listed variables is expected to be as follows:

42. Evacuation decision.

Ouelette's (1998) studies on past behaviour and its influence on future behaviour, and Burnside et al.'s (2007) findings showing that those who evacuated before are more likely to evacuate again, lead to the hypothesis that, in the current study, individuals' decision to evacuate during the event will be significantly associated with the decision to evacuate in future.

43. Gender.

Since gender is not predicted to be significantly associated with the evacuation decision made during the event, it is assumed that gender will also not be associated with the decision to evacuate in future (at least not directly; however, see Injuries below).

44. LoC.

It is assumed that an external LoC will be significantly associated with the decision to evacuate in future, given the existing hypothesis about LoC and evacuation decision.

45. Injuries.

If any adverse effects on well-being were experienced (e.g. due to initially deciding to wait and see until confronted with a severe fire or deciding to stay-in-place) and disclosed (e.g. perhaps more by females who might discuss vulnerability), then it is assumed that individuals will decide to evacuate in future.

3.5.5 Emotion and perceived risk

The following variables are hypothesised to be significantly associated with individuals' emotional states and perceptions of risk during the wildfire:

46. Evacuation decision.

Lewis et al. (2011) claim that people's decisions are not purely rational and will be affected by emotion and, in their study, those who intended to leave rated higher in anxiety. In addition, higher emotional reactivity was reported by those who intended to leave in McLennan et al.'s (2015a) study. Thus, it is hypothesised that the decision to evacuate will be significantly associated with higher ratings of negative emotion.

47. Future decision.

The decision to evacuate/stay-in-place will have led to either a positive or a negative experience for individuals, and theory claims that a person's memory of experience will carry an emotional 'affect' (Slovic et al., 2004). This emotional memory could result in a change of behaviour in subsequent events. Thus, it is assumed that emotion may be connected with the decision to evacuate/stay-in-place in future.

48. Stage of event.

Previous studies have shown that survivors' self-rated levels of emotion and perceived risk can vary across different types of disaster (Grimm et al., 2012) and across different stages of a disaster (Knuth et al., 2014a). However, neither study looked at wildfires. It is therefore hypothesised that emotion and perceived risk ratings will significantly fluctuate throughout a wildfire event.

49. Gender.

In their earthquake study, Prati et al. (2012) have shown that women will feel more afraid than men. In addition, Grimm et al.'s (2012) study found females reported feeling more emotional stress, if not more risk. Other studies have shown that males supress their emotions more than females (Melka et al., 2011) and perceive less risk than females (Champ & Brenkert-Smith, 2016). Thus, it is expected that female gender will be significantly associated with higher ratings of emotion and perceived risk.

50. Experience of wildfires.

Research has shown that previous experience of a disaster can subsequently influence pre-event factors involving risk (Eriksen et al., 2016a; Knuth et al., 2014b). It is assumed in this hypothesis that experience will also influence peri-event perceived risk and, since emotions are associated with risk perception, that peri-event emotions will be influenced as well.

3.5.6 Evacuation delay time

The following hypotheses are based largely on Sorensen's (1991) study (Table F 1, Appendix F), unless otherwise specified, and embellished according to the CIBER-t framework to include more untested variables.

51. Female gender will be associated with shorter delay times.

52. Gender will also be associated with the types of BI actions performed.

While Whittaker et al. (2015) reported mixed findings for whether females were more likely to evacuate and males more likely to stay-in-place, it is nonetheless hypothesised that gender differences will be seen regarding BI actions, e.g. those related to protecting property.

53. Having fire safety knowledge will be associated with shorter delay times.

54. Larger properties and households will be associated with longer delay times.

55. Information type (environmental cues) and content (referencing ASET) will be associated with delay time.

56. Elderly age or medical conditions will be associated with longer delay times.

57. Closer fire proximity will be associated with shorter delay times.

METHODOLOGY

Chapter 4

This chapter presents the methodology used in this thesis to answer the research questions and test the hypotheses. It starts with an overview of the criteria for the study analysis, setting the motivations for the thematic qualitative research, as well as the design for the semi-structured interviews, and then discusses the more quantitative research involving the residents' survey. The chapter concludes with ethical research considerations. The research design, including the aims, methods and analysis sources, is briefly outlined in Figure 4-1.

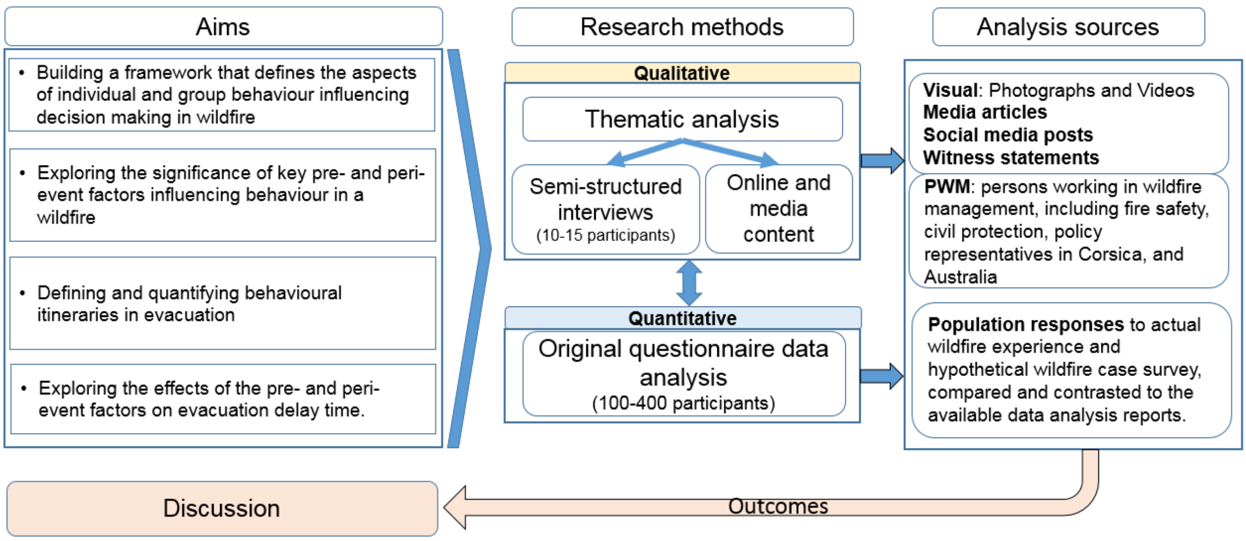


Figure 4-1 Human behaviour in wildfire evacuations: research design.

4.1 Qualitative methods: cross-cultural comparison and thematic analysis

The theory underpinning this thesis broadly views quantitative research in human behaviour as insufficient. As de Certeau believes: “The power of its calculations lies in its ability to divide, but it is precisely through this analytic fragmentation that it loses sight of what it claims to seek and to represent.” (de Certeau, 1984, p.VIII), implying that quantitative research (on its own) lacks the detail that binds meaning to the results. Therefore, a mixed-methods approach was taken as it is used in research with similar complexities (Bamberger, Rao, & Woolcock, 2015), as well as in areas where topics involving diverse human behaviours are explored (Eriksen, Gill, & Bradstock, 2011). The study areas of Victoria, Australia and the South of France were to be compared with respect to human behaviour in wildfire within the context of the local safety culture. Therefore, a cross-cultural study was seen to be the most suitable approach. Such a task requires a certain level of equivalence (Buil, de Chernatony, & Martinez, 2012). At the same time, safety culture and implications of policy for human behaviour become more evident when they are contrasted between study areas, thus complete equivalence was not believed to be required at this stage (see Berry, 1969). For example, there is a general lack of data on human behaviour in wildfires and therefore comparing two or more specific events is unattainable without compromising on the sample size. Nevertheless, certain measurement equivalence levels (Buil et al., 2012) were taken into consideration:

1. *Data equivalence*: data were collected from regions in France and Australia that share a Mediterranean-type climate and where communities live closely to vegetated areas prone to wildfires (Keeley et al., 2012).

2. *Construct equivalence:* the context of both case studies was examined to understand local historical wildfire issues, the forecasted severity of the problem, and policies on wildfire preparedness and response, including evacuation and staying-in-place approaches. Research enquiries were conducted in English and French, where possible. Collaborators from the study regions were asked for feedback and other native-speakers were consulted to confirm that the terms used in the PWM interview questions and residents' survey were unambiguous.

3. *Measure equivalence:* When it became clear that two versions of the residents' survey would be appropriate – one for individuals with actual experience of a wildfire and one for individuals with less recent/no experience, instead answering about hypothetical wildfire scenarios – efforts were made to align the variables and questions of both surveys, and assure their translation quality. Pilot testing was conducted first before large-scale data collection began.

4. *Sampling equivalence:* a non-probabilistic sample was used for the survey in both study regions. In particular, non-probabilistic sampling was chosen due to difficulty in reaching survivors, because there is no publicly-available list of affected individuals and their contact details, which is partly explained by survivors wishing to avoid press intrusion. Where such (private) lists may exist, they only record individuals who have evacuated and/or accessed official shelters. As for the qualitative analysis, non-probabilistic sampling was used due to the need to collect data from a particular group of individuals with particular professional experience, i.e. PWM. Non-probabilistic sampling has also been suggested for cross-cultural studies (Buil et al., 2012), which is preferred given one of this thesis' aims is to explore whether behaviours can be generalised or not.

5. *Data collection equivalence:* data were collected for about three months in each case study, employing the same strategies and the same channels each time in an effort to achieve a very similar sample size.

Furthermore, results were reviewed and discussed with interested parties from another part of Europe (Spain), for several reasons including to check their reliability, potential interpretations and applications beyond the study regions. The methodological steps are summarised in Figure 4-2 and it is suggested that any future study attempting to replicate the current one should follow these same iterations. Also note that other practitioners were consulted during stages of the study, e.g. software developers and end users, such as the urbanEXODUS and buildingEXODUS working group (http://fseg.gre.ac.uk), to inform the requirements for data that could be successfully used in evacuation modelling.

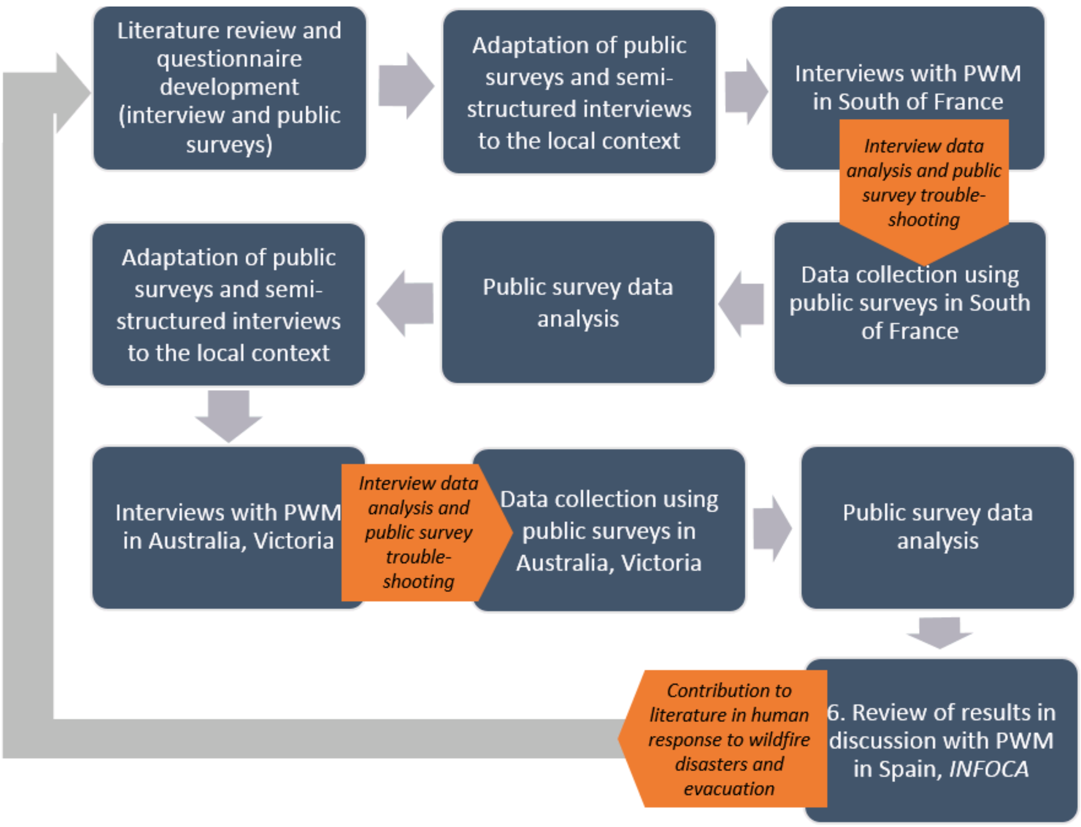


Figure 4-2 Iterative process needed for cross-cultural comparison.

The comparison between the two study areas was essentially made with the help of thematic analysis, used to reduce and clarify data in the public domain, as well used to analyse the answers from interviews with PWM (Gale, Heath, Cameron, Rashid, & Redwood, 2013). Public-domain data included video content, news articles, and bushfire survivors' statements. While wildfire-related news articles were continuously monitored through the news media channels online, some historical information was also searched for online and at public libraries. The search queries were made of the following words: (*what?*) wildfire, bushfire, forest fire, feu/incendie de forêt, incendios forestales + (*where?*) France, Spain, España, Australia, Europe + (*when?*) 2014-2018 + evacuation, évacuée, desalojados.

While the grand-themes in the CIBER-t framework were always in mind, thematic analysis still allowed for the revelation of new patterns that may not have been discussed in the literature (Shoemaker & Reese, 1996), allowing meanings unique to the qualitative data types to be unpacked.

4.1.1 Semi-structured interviews

Access to PWM was facilitated by the GEO-SAFE project (Cordis, 2017). GEO-SAFE aims to share knowledge and practices between European and Australian academic and fire-related organisations to help develop tools and other solutions for fire suppression, fire propagation, the protection of life and assets, and wildfire response training. The project recognised that such solutions would require input regarding human behaviour and thus an opportunity was created for this thesis to contribute to the project – partner organisations would assist with such things as facilitating access in return for the thesis results being shared with them. However, the thesis remained a stand-alone activity. The construction of the research aims, hypotheses, framework, study design and materials, and the conductance of analysis were all independently led.

Participants for the interviews were sampled purposefully (Wilkinson et al., 2016). Sampling stopped when 'saturation' was observed, i.e. when participants' responses no longer deviated from each other, and therefore no new themes were arising from the data (Fusch & Ness, 2015). Semi-structured interviews were conducted with PWM (N = 18), who at the time of the interview were employed as firefighters, incident commanders, police officers involved in evacuation coordination, civil protection coordinators, evacuation operations officers, forest fire prevention officers, forestry protection and preservation officials, as well as individuals with decision-making authority such as government representatives and others responsible for residential areas, i.e. campsite owners. The interviews lasted 30-45 minutes and aimed to capture common patterns of adult and child behaviour in wildfires, and allow for the discussion of the context of such behaviour (cultural, policy, historical, etc.). Interview questions were designed to reflect the main human behaviour issues arising from the literature and were translated from

English into French to better access French interviewees' knowledge and experience. See Chapter 5 and Appendix B for further details.

4.2 Quantitative methods: residents' survey

Members of the public residing in at-risk areas were surveyed with an online questionnaire. Two versions of the survey were created for this research: an actual experience survey (henceforth AE) and a hypothetical-scenario survey (H). The AE and H surveys were completed by similar numbers of participants in total (AE: N = 382; H: N = 380). Data collection lasted 3 months in each study region. The aim of the survey was to identify and quantify patterns of residents' behaviour in wildfires.

4.2.1 Survey question topics

Following the review of the literature, modelling requirements, and the subsequent generation of study hypotheses (Chapters 2 to 3), as well as the review of existing disaster survey materials (Chapter 4), and the qualitative analysis of the publicly-available and interview data (Chapter 5), survey question topics were decided upon. These are organised according to the CIBER-t framework (Appendix D, Table D 1). The question topics were designed to gather data to address relationships between the most important pre- and peri-event variables relating to: (1) pre-event risk perception; (2) planning; (3) immediate response; (4) intention; (5) evacuation decision (evacuate or stay-in-place); (6) evacuation destination choice and ingress attempt; (7) future decision; (8) emotions and perceived risk; and (9) evacuation delay time.

4.2.2 Experience and hypothetical-scenario survey designs

The AE survey asked participants to describe a recent wildfire experience. However, not everyone residing in an at-risk area will have actually experienced a wildfire either in recent years or at all. Yet the attributes and behaviour of less experienced individuals are still very much of interest. Moreover, research conducted before an event rather than after may unlock issues that may otherwise have been rationalised in post-event surveys (Dash & Gladwin, 2007). So a second, H survey was created also. Previous disaster research, albeit on hurricanes, suggests that hypothetical and actual human behavioural responses are consistent (Huang et al., 2015). However, hypothetical-scenario studies are currently rare in wildfire evacuation research and, where some do exist, they are problematic to compare because of different variables, measures, and contextually-unrelated samples. For this reason, the AE and H surveys were built around similar variables wherever possible and were aimed at the same region's population, in both Australia and the South of France.

In the H survey, participants were randomly presented with one of three wildfire scenarios (involving environmental cues only, social cues only, or environmental plus social cues), which were developed following interviews with PWM. The hypothetical scenarios presented situations with gradually escalating circumstances. At each stage of escalation, participants were asked what their response would be. The full extent of the scenarios can be explored in the Note section of Table H 6 (Appendix H). Accompanying the scenarios were visuals (e.g. photographs showing smoke, fire, embers, neighbours evacuating). The use of visual tools have been found to heighten the perception of risk and could be expected to yield more realistic results compared to when no images are present (Xie et al., 2011).

According to Bourque (1997), a standardised survey can be used as a tool to understand human behaviour before, during and after disasters. Importantly, it can provide researchers with an opportunity to compare samples across time, space and events (Knuth et al., 2014a; Grimm et al., 2012). This thesis also draws on the practice of standardised instruments, such as those used in assessing survivors' experiences in the BeSeCu study (Knuth et al., 2014a). For example, those authors used a 5-point Likert scale (1 = not at all, 2 = a little, 3 = moderately, 4 = quite a bit, 5 = extremely) for assessing emotional distress. Such scales are a useful tool as it has been shown that the intensity of emotion – even when predicted only – is a more accurate measure than a general emotional response on its own (Levine et al., 2018). In addition, Likert scales have been tested to work well when translated into French (e.g. Brunet, St-Hilaire, Jehel, & King, 2003), and so were considered to be a good fit for this thesis' purposes. A 4-point scale was adopted (Table 4-1), where the *not at all* option was coded as '0' to represent the absence of the state in question, and all other options coded as positive integers. The European Social Survey questionnaire in French was also consulted for other standard terminology (IPSOS EES Questionnaire, 2014).

Table 4-1 A 4-point Likert scale in English and French, and coding.

English	Coding	French
Not at all	0	Pas du tout
Very little	1	Dans une faible mesure
Somewhat	2	Dans une certaine mesure
To a great extent	3	Dans une grande mesure

Scale items about responses related to emotional states were created using a combination of Mood Adjective Checklist (MAC) measures (Lindell et al., 2016; Matthews, Jones, & Chamberlain, 1990). Peri-event risk perception items pertained to the individual and others separately as Sjoberg (2000) claims that risk to others is felt greater than personal risk.

The design of the survey in this thesis moreover builds on the 2009 Black Saturday bushfires questionnaire example (Handmer, 2009). That questionnaire was used to capture human behavioural responses quickly after the event, although the purpose of that survey was largely an official inquiry into the event carried out by the Victorian Bushfires Royal Commission (VBRC) in Australia. It resulted in the original analysis of the Black Saturday survey being mostly descriptive rather than inferential, although later studies have used the raw data further to support various research themes. Thus, 38 questions from the Black Saturday survey were adapted to this thesis' aims and became part of the survey design. The full AE and H questionnaires can be seen in Appendix D.

Several novelties were introduced to improve the richness of survey data. For example, the questionnaire was intended to capture individuals' experiences, thus multiple respondents per household were allowed, unlike in some other disaster studies. Visual aids reflecting national context were included, such as images of local architecture and similar. In addition, knowing that humans struggle to objectively assess distance and size (e.g. using numbers alone) when visibility is poor (Kahneman, 2010), the AE survey used images to help determine visibility levels experienced during the wildfire event. A way of better capturing self-reported times was also tested. If AE participants (those who evacuated) provided both the time of encountering the first fire cues and the time they left their location, then the period in between could be calculated to give a measure of evacuation delay time. However, this was not always the case. Thus, participants were also asked to estimate the time committed to each of their behavioural itinerary actions, and these were summed to give a BI time that could also represent evacuation delay time. It was also possible for H participants to estimate BI times.

Finally, a few commonly-studied variables were not used in this research, such as income (Mozumder et al., 2008), because people may find questions on this intrusive and because home size and insurance can be used as proxy for income. In addition, the question of race is illegal in France and therefore was left out of the survey. In contrast to the Bushfire CRC questionnaire, attitudinal questions did not include the answer option "I don't know" (DK). Not only can this sometimes be confounded with other states, e.g. I don't remember" (see the CRC questionnaire), it can also cause 'survey satisficing' (Krosnick, 1999), where a participant's capacity to answer is attenuated by an 'easy' option, one which does not stimulate the thought processes enough. However, for factual questions, such as “Was your property insured against wildfires?”, an “I don’t know” option was presented.

4.2.3 Testing and translating the survey

The suitability and comprehension of the survey questions was pilot tested in the UK initially. First, they were shown to a few individuals who had been through a disaster of any kind, such as a flood, earthquake or a wildfire. This was done at the university, in face-to-face meetings. Their feedback on the range and appropriateness of answer options was considered. Secondly, classroom-based testing took place with 24 participants at the University of Greenwich in February 2017. In order to check the usability and logics of the online survey, these participants were assigned a computer and one of four constructed backgrounds, with individual and environmental details to help guide their responses (varying in their supposed age, number of dependents, mobility impairments, availability of vehicles, and a wildfire scenario with varying wildfire proximity). All these pilot participants were recruited via an electronic advertisement asking for volunteers with or without disaster experience to trial a research survey. None of the pilot participants took part in the main survey study that followed. Both stages of testing ensured that any discrepancies in the English version could be avoided, technical issues such as web browser compatibility problems were mitigated, survey logics were correctly in place, and any questions that were not comprehensive enough could be identified and modified. Importantly, survey completion time was found to be within the recommended maximum timeframe of 30 minutes (Cahyanto, Pennington-gray, et al., 2014). While long surveys can result in participants ‘dropping out’, overall, no extensive evidence exists to say that shortening the completion time in itself will be sufficient to avoid *response fatigue* or *response burden* (Rolstad, Adler, & Rydén, 2011). Therefore, this survey attempted to maintain a balance between a generally tolerable completion time and being sufficiently in-depth to ensure validity and reliability.

Given that French is the official language in one of the study areas where interviews and surveys were administered, the survey and interview questions were first translated into French and then back-translated into English by different bilingual individuals – a practice successfully adopted in a previous cross-cultural study (Knuth et al., 2014a). Moreover, open-ended questions were avoided in the survey unless otherwise seen to be vital, and a PWM who was bilingual, was usually present during the interviews to assist with translation where necessary (the author of this thesis has some fluency in French, but it is not their first language).

4.2.4 Survey sampling methods and participant engagement

Firstly, as preparatory work, information sought via online media and newspaper archives was used to determine the locations of wildfires occurring in the past three years. This served to determine which populations could be later targeted for participation in the online surveys. In both study regions, prospective survey participants were recruited through snowball sampling initially. That is, organisations known through GEO-SAFE to have had direct contact with survivors of wildfires in the target areas, either due to their involvement in disaster response or disaster research, were asked to nominate or advertise the survey to their relevant contacts, then those contacts were asked to promote the survey more widely to further contacts of their own, and so on. Additionally, individuals named in newspaper articles and for whom contact details were in the public domain (e.g. managers of affected businesses) were approached in a similar vein. As well as this, recruitment took place through other channels, including having an article about the research featured in a regional newspaper; asking local universities to send electronic notifications to all staff and students advertising the survey; asking local community or public-gathering spaces to display flyers and cards to promote the survey to visitors; and reaching out to target populations through social media using geo-targeting tools. Participants who clicked/went online and entered the link to the survey landing page self-selected which of the available surveys they should complete depending on their language preference and wildfire experience. Social media accounts on Facebook and Twitter platforms were also created to help disseminate the survey. Making information regarding the research publicly available helped increase participation and interest because trusted local organisations agreed to share the posts and individuals could engage by reading further information, posting comments, liking the posts, and so forth. Adopting an electronic, online method for administering the survey across multiple computing and mobile devices also offered advantages, i.e. provided a paperless solution and lowered research costs (e.g. no postage fees; physical travel to affected or at-risk residences, sometimes in difficult-to-reach locations, was not necessary). PWM were consulted first to ensure that internet was an available and widely-used utility across target areas.

Participation was anonymous. Data collection was carried out during the wildfire seasons in each region, which past disaster studies have shown to be a good time to capture participants' attention, since many individuals are actively interested in the ongoing phenomena (Cahyanto, Pennington-Gray, et al., 2014).

4.2.5 Survey analysis

Both descriptive and inferential statistical methods were used to analyse survey questionnaire data. Descriptive statistics present an overview of the responses, such as their frequency. For the inferential analyses, several methods were employed to test hypotheses and determine the existence and direction of significant relationships between variables. In some cases, e.g. where cell sizes involved in a particular piece of analysis were relatively small, non-parametric inferential tests were used and alternative descriptive statistics are reported (e.g. median and interquartile range [IQR] instead of mean and standard deviation [SD]). IBM SPSS® software versions 22 and 25 were used to perform the statistical tests. Effect sizes, denoting the magnitude or strength of relationships, were also calculated using this software.

Measuring association between variables

To investigate relationships between nominal categorical variables, such as gender and evacuation decision, or having a plan and evacuation decision, the *chi-square test* was typically used. Any results showing $p < .05$ led to the conclusion that there was a significant association between the variables (rejecting the null hypothesis that the variables are independent) (Field, 2015). This was the case for all inferential tests. Nevertheless, it was borne in mind that such results should be treated as indicating a level of probability worth paying attention to rather than a certainty, and also that results should be considered in their context (Vidgen, Yasseri, 2016). The direction of the relationship between nominal categorical variables was determined by examining the accompanying descriptive statistics.

Several assumptions for the chi-square test needed to be met (Field, 2015). Firstly, the independence of the entities in the sample, meaning that each individual could only belong to one of the categories per variable. Secondly, sufficient cell sizes were required; if the expected value < 5 then results of a Fisher's exact test were presented instead. The effect size here was Cramer's V since it is suitable for crosstabs with two or more categories per variable; its values range between 0 and 1. Where variables had more than two categories, multiple comparison post-hoc tests were performed to locate which cells exactly were significantly different, and an adjusted *p*-value using the Bonferroni correction was applied accordingly.

Exploring differences between groups

When investigating a significant relationship between either a continuous (e.g. delay time) or ordinal (e.g. level of emotion or perceived risk) variable and a categorical variable with two or more categories (a.k.a. groups), ANOVA and the non-parametric *Mann-Whitney U* and *Kruskal-Wallis tests* were used. Data were first inspected visually to determine whether a parametric or non-parametric test was more suitable, depending on if the parametric test assumption about normality was met. If it was judged that the data was not normally distributed, a non-parametric alternative to ANOVA was used first. Nonetheless, ANOVA can be rather robust to violations of normality and its results are more easily interpreted (Field, 2014), and so this test was run subsequently. Where the ANOVA results did not differ from the non-parametric test results, they have been reported. The effect sizes here were (partial) eta squared and the correlation coefficients Pearson's r/Spearman's rho, all of which range between 0 and 1 (correlation coefficients can also range between 0 and -1 for negative relationships). Multiple comparison post-hoc tests were again run, with the Bonferroni correction applied, when there were more than two groups.

Emotion and risk: differences within individuals and principal components

Emotions experienced by an individual are seen as dynamic, in that they adapt to changing circumstances (Salzman & Fusi, 2010). Perceptions of risk can likewise be dynamic. Thus, *Friedman's test* was utilised to detect changes in self-reported emotion and perceived risk over time for AE participants.

Exploratory *principal component analysis* was also performed on the emotion data to investigate whether participants' emotional responses could be 'boiled down' into a smaller set of core components. The idea was that any core components could then be entered subsequently in regression models instead of the multitude of more precise emotional states, thereby helping keep variables to a more manageable number (see section 6.4 for further details). Similar reductive analysis of emotional responses was first conducted by Lindell et al. (2016) when investigating immediate responses to earthquakes in Japan and New Zealand. That study adapted the MAC to measure the emotional responses and found three items each loaded most strongly on three factors or components, which those authors called *hedonic tone*, *tense arousal*, and *energetic arousal*.

Predicting behavioural outcomes

Finally, to predict decision-making and delay time, various regression models were built and tested. The odds ratio (OR) was the effect size used in this case. An OR equalling 1 means the odds of the outcome of interest occurring are the same whether a variable is present or absent (e.g. whether female or not, gender does not significantly predict the decision to evacuate). An OR greater than 1 (ranging to infinity) means the presence of a variable increases the odds of the outcome occurring, while an OR lower than 1 (ranging to 0) means the presence of a variable decreases the odds. Regression findings were subsequently utilised to create a more illustrative type of model – a decision tree – for model validation (Gwynne & Hunt, 2018) and potential application in evacuation modelling. See Chapter 7 for further details.

4.3 Study design considerations

The interviews with PWM and the AE survey relied on participants remembering their experiences of wildfires that may have occurred several years ago, and/or may have been traumatic, meaning there is a chance that some answers could have been affected by impaired memory. Nevertheless, other disaster research has indicated that retrospective interviews and self-report questionnaires can provide detailed accounts and reliable data (Kinateder et al., 2015; Knuth et al., 2014a, 2014b). With regards to time data, it was believed that breaking the response phase down into discrete BI activities could help minimise the underestimation of time as participants would be able to see what was involved. At the same time, a certain degree of unreliability can be expected when participants are asked to estimate the time committed to activities, as time perception in humans is not precisely a "chronometric record of events" (Hancock & Weaver, 2005, p.194). Thus, it was expected that, when asked about durations, there would be individual differences in estimations or rounding of times (Proulx & Fahy, 1997), especially in more obviously emergency situations in the AE survey (Edwards & McCormick, 2017) or, in the H survey, if participants had never undertaken a chosen activity before. Nonetheless, the alignment of the AE and H survey questions gave an opportunity to compare estimations between the two groups, and thus an opportunity to see if the time data differed widely or was similar. Additionally, the inclusion of ASET-related information in the H survey offered the opportunity to see if the summed BI times were within the given timeframe or extended beyond it.

Finally, a non-response bias, due to sensitivities attached to past wildfire experiences, was another consideration for this research. All that could be done here was to employ as many different channels for participant recruitment as feasible and assure participants of anonymity. This issue, along with the language barrier in the study area of the South of France, limited the possibility of conducting in-depth interviews and focus groups with wildfire survivors.

4.4 Ethical considerations

4.4.1 Participant vulnerability and researcher's risks

People who suffer a loss or damage to their home due to a fire can experience severe trauma, potentially lasting for a significant period of time (Carroll, Morbey, Balogh, & Araoz, 2009; McConnel & Boyce, 2012). Such trauma will have an impact on mental health and can be a cause of post-traumatic stress disorder (PTSD). The psychological vulnerability of individuals may manifest during participation in research due to recalling the fear experienced in the event, followed by the stress experienced during the evacuation. Additionally, for those who lost their homes, "chronic stressors" may be experienced due to having to rebuild homes (Bourque & Russell, 1994). It is similarly possible for first responders to develop PTSD after attending scenes of horror and devastation (McFarlane, 1986). Thus, participant vulnerability must be taken into account when carrying out interviews with PWM and targeting individuals for self-administered surveys. The researcher should prioritise efforts to mitigate and neutralise any potential psychological distress to participants.

For this reason, the rules of ethical conduct in interviews and surveys, as outlined by the British Sociological Association's (1994) statement on ethical practice, were followed meticulously. For example, it was important to remain vigilant for signs of distress when dealing with the participants face-to-face in interviews; the author of this thesis was prepared to pause or change topic to something neutral, or even postpone the discussion to another time if requested. Participants were reminded from the outset of their right to withdraw from the interview at any time without giving reasons, and this would have been reiterated if hesitation to continue had occurred. Furthermore, an adequate closure phase for appraising the participant that their provided information was very helpful was always included; such action can leave participants feeling empowered and brighten their mood. Similar steps regarding withdrawal and appraisal were employed with survey participants also. Both sets of participant were provided with a participant information sheet/webpage and an opportunity to ask questions prior to providing their informed consent and commencing participation, and both were advised that if they had any concerns about revisiting their experiences then they should speak with their GP or a counsellor. Online questionnaire participants were also directed to their local Red Cross support services.

Finally, although vicarious traumatisation is a possibility when exposed to others' accounts of disaster experiences, there was no signs of distress from interview participants and there were no significant risks posed to the author of this thesis while carrying out the research. Nonetheless, awareness was made at the outset of available support contacts and close collaboration with GEO-SAFE partners while abroad helped ensure personal safety was not put in danger when visiting wildfire-prone areas.

4.4.2 Data collection and storage

No personal information identifying individuals was collected in the survey. Likewise, secondary data obtained from the public domain were anonymised (e.g. social media account usernames and names of newspaper interviewees were removed). Following the Data Protection Act (GOV.UK, 1998), all hard copies of data containing personal details, such as interview notes and informed consent forms, were kept in a lockable compartment, while any electronic data with personal details were saved directly to a secure University of Greenwich server in the UK.

Chapter summary

A mixed-methods design was adopted and is especially relevant when the risky and sensitive nature of the research topic does not allow for an examination of emergency behaviour ‘in situ’ (Proulx et al., 2006; Creswell, 2014). A triangulation method was used in this thesis, following the CIBER-t framework that emerged from the literature review. Personal accounts of PWM were designed to be captured through semi-structured interviews, while actual responses of wildfire survivors and potential responses of relatively inexperienced individuals living in at-risk areas were designed to be collected via online questionnaires. The data would also be compared and contrasted with publicly-available information collected online and from local sources throughout field studies lasting a duration of several months each in Corsica (France) and Victoria (Australia). Analysis of the results of this research would be followed by a consultation and review with PWM in Andalusia (Spain). Such a combined approach would allow the author of this thesis to construct a broad, realistic view of human behaviour in wildfires and thus increase the credibility and validity of the research results (Shannon & Hsieh, 2005). In turn, this would allow the potential application of findings to be proposed, e.g. in evacuation modelling.

ANALYSIS

Chapter 5 Qualitative analysis: observations of human behaviour

This chapter presents the qualitative findings on human behaviour in wildfires from data that is publicly available - i.e. detailed accounts in newspapers and online media, citizens' videos and survivors' statements posted online - as well as from semi-structured interviews with PWM. It provides an overview of the use of such qualitative information in research and outlines its limitations.

5.1 Media and witness reports: sensationalism and the 'self'

When coding the qualitative data using thematic analysis (see, for example, Joffe, 2012), the CIBER-t framework was used (for full information see Appendix G). The grand themes of context, information, behaviour, emotion, risk and time were used to organise wildfire-related data, and then the analysis further split these themes into emerging topics.

Analysis conducted on data from online news media was used to gauge the extent to which survivors' experiences are represented and match the current literature on behavioural responses. In total, 29 online articles from global media sources were chosen randomly. These dated from May 2016 to March 2018, as well as from June 2009 (Black Saturday bushfires), and reflected on some 12 different wildfire events across Europe (including the South of France), Australia, USA (California), and Canada (Fort McMurray). The findings are summarised in Appendix G, Vignette G 1.

Video footage was also analysed to better visualise interactions between individuals and fire cues. In total, 32 video clips were chosen, entailing news pieces that included individual testimonies, news coverage from wildfire events, and personal video material made available on social media. Observations of individuals' behaviours when faced with smoke, flames, and wind, plus their interactions with other people, are summarised in Appendix G, Vignette G 2.

A qualitative review of news stories from the three years leading into the start of this research (2014-2015, 2015-2016, 2016-2017), filed in the French regional newspaper 'Corse-Matin', returned fruitful results with regards to the detail, frequency and tone in which Corsica's wildfires are reported. Firstly, wildfires were a major topic during the annual wildfire season (July-September), usually taking up to two pages and including reviews of fire service operations and adversities. It was noted that these stories always paid respect to the work of the fire services. Once every wildfire season, a newspaper weekly supplement called 'settimana' or 'Hebdo' was also included, which contained extensive coverage of wildfire issues. The topic of clearing or 'débroussaillement' (the legal obligation to remove or reduce vegetation within 50 metres of building structures) was covered in 2014; fire fighters' work with a focus on its risk, called 'the anatomy of the fire', featured in 2015; and a review of the wildfire risk, in the context of environmental sustainability and climate change, featured in 2016. The main findings of the newspaper analysis are summarised in Appendix G, Vignette G 3.

Australian bushfire experiences have been largely documented by the Bushfire and Natural Hazards Cooperative Research Centre (BNHCRC) studies (Victorian Bushfires Royal Commission, 2009b). Materials from this research centre have supported the development of the questions asked of participants in this thesis: i.e. in the residents' questionnaire and the PWMs' interviews. Whilst obtaining raw data from BNHCRC studies was constrained by bureaucratic difficulties that were beyond the control of the author of this thesis, publicly-available survivors' statements published online by VBRC (2009) allowed an independent analysis of survivor experiences. A total of 80 (females = 34; males = 46) random survivors' statements were reviewed and organised according to the CIBER-t framework. The advantage of using such secondary qualitative data was the access to sensitive information that would have otherwise been beyond the capacity of this research (Long-Sutehall & Addington-Hall, 2010). The summary of the findings is in Appendix G, Vignette G 4.

The analysis of all the above helped test and gauge the importance of the elements within the CIBER-t framework. No new elements emerged, reinforcing the framework's structure. The themes arising from this chapter's analysis are summarised in Table 5-1, with overlapping themes highlighted in grey.

Table 5-1 Summary of the main themes arising from the qualitative findings (I).

Theme source / CIBER-t	**Online media/video footage**	**Newspapers**	**Survivors' statements**
Context		Safety culture	Safety culture
	Smoke		Smoke
	Fire		
	Heat		Preparedness
	Other cues		Lifestyle differences
	Social + environ. cues		Community closeness
	Physio. + cog. Effects	Physio. + cog. effects	Medical conditions
	Traffic conditions	Traffic conditions	Locals v outsiders
	Emergency services		Experience
Information	Information content	Information content	Information content
	Type of information		Type of information
	Information source		Information source
	Information availability		
	Late information		Contrasting information
	Directions		Non-verbal information
	Protective action announcement		Way of delivering information
Behaviour	Shelter		Shelter
		Ingress attempts	Ingress attempts
	Inappropriate behaviour	Inappropriate behaviour	Inappropriate (and appropriate) behaviour
	Driving behaviour		Driving behaviour
	Safety-related behaviour		Responsibility towards others
	Putting out fire		Behavioural itinerary
	Forced to flee		Evacuation decision triggers
	Running	Motivations for decisions	
	Evacuation means		Change of plan
	Indecision		Seeking information
			Waiting for information
Emotion	Fear	Fear	
	'Panic'	'Panic'	'Panic'
	Calmness		Calmness
	Terror		Distress
	Helplessness		
	Surprise		Shock
	Alertness		Difficulty recalling emotion
	Various feelings		
	Repetition		
Risk	Cognitive bias		Cognitive bias
	Death		Not taking risks
	Property damage		Pre-event risk
	Uncertainty		
Time	Fire arrival time		Fire arrival time
	Quick turn of events		Mobilisation time
	Unexpected amount of time needed		

5.2 Interviews with PWM: contextualising the community

To improve the understanding of human behaviour in wildfires within a region-specific context, this section presents the findings from the semi-structured interviews with PWM in Corsica (the South of France) and Victoria (Australia).

In Corsica, participants were contacted and recruited with the help of GEO-SAFE partners SDIS 2B (now known as SIS 2B), the fire and rescue service serving the northern part of the island (SIS 2A serves the southern part). In Australia, interviewees were recruited directly via electronic communication. The participants voluntarily agreed to share their observations of the wildfire threat to their respective communities, their observations of adult and child behaviour in wildfire evacuations, and wildfire response planning. Typically, the interviews lasted for 30-45 minutes; field trips to locations affected by fires and evacuations were occasionally added on. The interviews were digitally recorded with participants' consent and handwritten notes were also taken. In Corsica, the PWM (n = 8) from across the island were: a representative for the National Forestry Office (Office National des Forêts), a SDIS director, a fire officer at an operations command centre (CODIS) whose duties included prevention work, two incident commanders whose duties included managing evacuations, the mayor of a commune, a chief of the civil security reserve (Réserve Communale de Sécurité Civile; volunteers force), and a campsite owner. In Victoria, the PWM (n = 10) were: a police officer involved in emergency response coordination and a senior sergeant, whose duties included incident control; a community programmes' coordinator for emergency planning in environment, land and water (DEWLP); as well as a community programme director responsible for education and research for communities (AFAC); a community safety and resilience director, and a community safety manager, both working in developing and maintaining Community Information Guides for bushfires (CFA); a learning and development manager, representative of local government council; an emergency management coordinator (EMV) and two Victoria State Emergency Services representatives (VICSES). Further context for French and Australian PWM is shown in Fig. 5-1 and Fig. 5-2, with institutions of interviewed representatives highlighted in colour. The interview questions can be found in Appendix B.

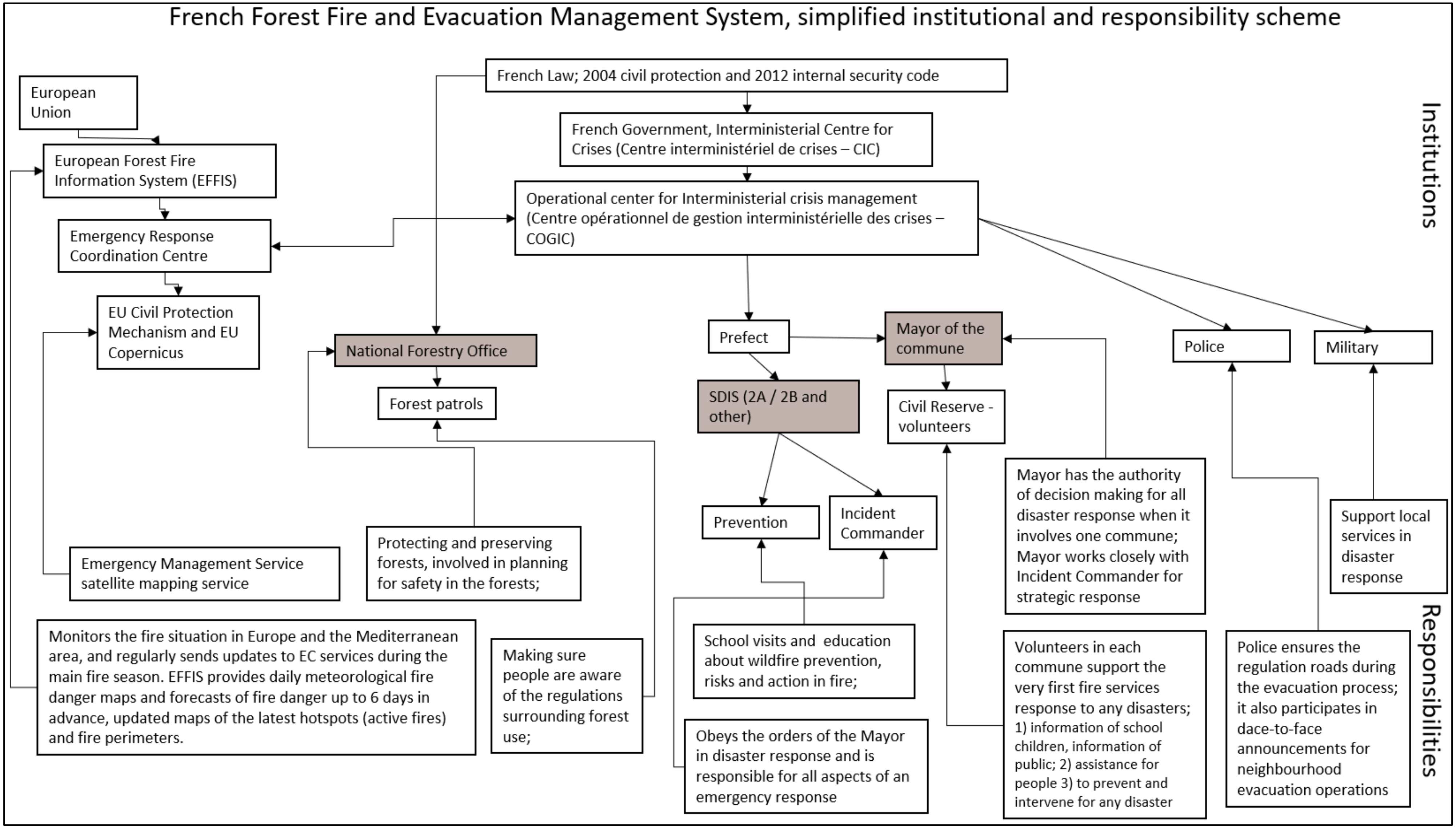


Fig. 5-1 French forest fire and evacuation management system: simplified scheme of institutions and responsibilities.

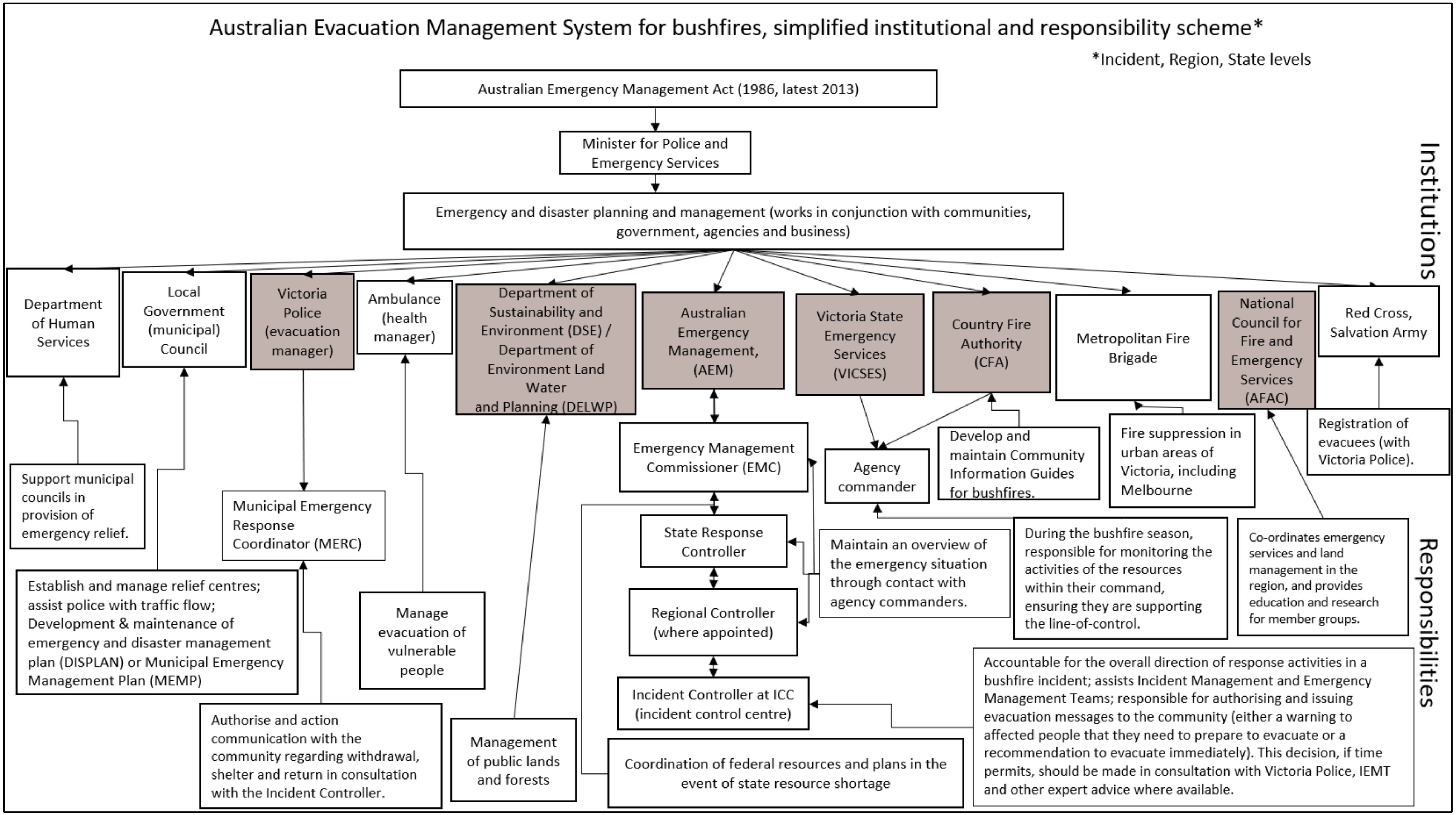


Fig. 5-2 Australian evacuation and bushfire management system: simplified scheme of institutions and responsibilities.

5.2.1 The case of Corsica: vulnerability, resilience and safety culture

There were several benefits to interviewing PWM in Corsica. First, they made it possible to gauge the level of consistency between official policy and general practice, and facilitated sense-making of lengthy official documentation published in French. Second, the interviews opened up discussion about risks and safety culture, resilience, and also support from the mainland and EU – a topic that has not been mentioned in wildfire research to date. Third, first-hand accounts of experiences with a wildfire response helped shed light on human behaviour and deeper questioning could take place as to why such behaviour may occur. Finally, the interview process was also used to review the residents' questionnaire methodology, aligning it to the local context. Findings from the thematic analysis of interviews are summarised in Appendix G, Vignette G 5.

Interviews with the Corsican PWM suggested that the island is an interesting case study for wildfire research. Since Corsica is an attractive holiday destination for people from mainland France, as well as from the rest of Europe, the population in peak summer periods (July-September) almost doubles. Local school holidays also coincide with these peak periods (July-August), when families often choose to go camping. It was conveyed by one of the interviewees that, in general, thinking about the wildfire risk is not people's priority, since culturally the focus is on socialising and entertainment. However, with the growing number of transients there is also a growing risk of wildfires:

"*As there is a lot of people [in summer] there is a lot of imprudence; they do BBQ and they don't know that it's dangerous to make fire here and so the fire can start and grow and every year there is a big fire; also another reason for wildfire is because of hunting – people hunt here but they cannot do it everywhere [due to legal restrictions] so they would be upset and would burn the area; it's a local specificity*" – operations/prevention officer.

To a certain degree, Corsica is seen to be self-sufficient when facing any risk, although not in the case of a series of disasters. The reason for self-sufficiency is the available expertise of firefighters in this disaster-prone southern region and the training that they, as incident commanders, receive in mainland France:

"w*e don't have structures and materials and proximity with the rest of France to be well prepared as them, so the South of France [on the mainland] would find it easier than us. North of France will have the infrastructure and not the people who are trained*" – incident commander.

The presence of this wildfire risk is particularly important when considering the urban development. People must have permission to build houses in Corsica and, often, they insist of doing so in the high-risk areas in the forest. In such cases, construction permission is not granted. However, it was also noted that people have now started building wooden structures, which are very vulnerable to fire. While a certain safety culture is acknowledged by PWM in Corsica, the growth of urbanisation and tourism seems to interfere with the natural patterns of this culture:

"*Culture of [being aware of and managing] risks begin at school and it is better understood by adults if they have the first information very early [on in life]. Children talk also to their parents what is good and what is not good and presumably it has a bigger effect.*"– civil security reserve chief.

"*It's our culture – people are sensitized of wildfires, they know what they have to do. We have more problem with summer vacationers than local people*" – incident commander.

Wildfire response: confinement over evacuation

Generally, in Corsica, evacuation as a response to a wildfire is seen as the last resort while the preferred response is 'confinement', i.e. staying-in-place (or, more specifically, sheltering-in-place). However, exceptions are made for vulnerable groups, such as children and older people. These groups would be evacuated first in advance and it would be the responsibility of the mayor of the commune to identify households where vulnerable people reside (Corsican communities can be very close, and the mayor is often familiar with the population). Sheltering indoors is also a preferred option after the evacuation of homes is chosen. The evacuation destination will usually be a safe structure in town, rather than any place outside of the area or outdoors. This is mainly due to three reasons: (1) people's homes and other town buildings, such as churches, are typically architecturally-robust stone structures that are capable of withstanding fire; (2) narrow roads, varied topography (hills and slopes), as well as vegetation close to the roads, present challenges for travel; and (3) most campsites and town surroundings are cleared and thus adequately prepared for facing a fire, making it relatively safe for people to stay-in-place. Nevertheless, it has to be noted that structures such as camper vans, cars, tents and wooden homes are seen as unsuitable shelters, thus people are confined within other structures such as any concrete/stone buildings or swimming pool areas. Another option for residents of campsites is confinement on the beach, if one is nearby. For areas that are not cleared, such as forests, shelters are available and marked, and are used as assembly points from which individuals can be rescued by PWM transport before the fire front arrives.

Safety management

Corsica (and France in general) places a heavy emphasis on prevention and mitigation, as well as strategic firefighting, to protect tourists' and the general population's safety. These aspects are detailed across several publicly-available plans: the departmental file for major risks called DDRM (Dossier Départemental des Risques Majeurs, 2015), the communal informative document on major risks called DICRIM (le Document d'Information Communal sur les Risques Majeurs, 2017), and a forest fire protection plan called PPFENI (Plan de Protection des Forêts et des Espaces Naturels Contre les Incendies, 2006-2012). Nevertheless, several points are noticeable: (1) formal plans about major hazards are extensive but plans specifically about wildfire hazards fall somewhat behind; (2) much detail is provided about what to do before a fire starts or has reached residences but less detail is provided about what to do when a fire arrives or if evacuation is deemed necessary; and (3) cooperation from people at-risk is essential to make the most of the fire safety plans (e.g. clearing 50 m around structures, collaborating with neighbours when the 50 m overlaps or stems into a territory beyond one's ownership). People are also asked to be vigilant in times of a total fire ban (July-September), and familiarise themselves with available information about how to respond including the instruction to follow authorities' orders (Appendix A, Fig. A 4 and Fig. A 5).

5.2.2 Bushfire response in Australia – changes and challenges

Interviews with Australian PWM revealed an intricate and complex relationship between the law and bushfire response, providing an overview of the roadmap for future changes and challenges. Findings from the thematic analysis of interviews are summarised in Appendix G, Vignette G 6. Australia consists of several federal states, and diverse policies exist across the country with regards to bushfire management. For example, New South Wales can legally force people to evacuate, whereas in Victoria the law gives the population a choice whether to comply or not with evacuation orders. The starting point to a bushfire response is preparedness. This belief is reflected in official slogans ranging from "prepare, stay and defend or leave early" (Victorian Bushfires Royal Commission, 2009b) to "Prepare. Act. Survive." (McLennan et al., 2015b) – note the change away from mentioning stay-and-defend as an option since the Black Saturday bushfires. According to one interviewee, the director for community safety, local government has an emergency management plan and subsequently identifies who the key people are within the emergency services, who in turn identify key community representatives. Thus, preparedness depends highly on strong community ties. In fact, in their National Strategy for Disaster Resilience (NSDR) in 2009, and later in 2013, the National Emergency Management Committee (NEMC; now ANZEMC to include New Zealand along with Australia) emphasised a shared, although not equal, responsibility between PWM and communities (Council of Australian Governments, 2009). This was repeatedly emphasised by the interviewees.

In line with Victoria's Bushfire Handbook (ed. 5.1, 2019), interviewees also emphasised that evacuation procedures are strongly linked to legislation. Evacuation approval is issued by the 3rd level incident commander and the police implement the order by carrying out the evacuation procedure; the Country Fire Authority (CFA) gets involved if police resources are scarce. However, all PWM agreed that evacuations are a relatively new practice, and much of the experiences that were shared were individual and often personalised:

"my mother is now retired and living in that house, she's mentally capable but not physically capable because of her age now, she'll leave early. And that's what we say, leave early; if tomorrow's a really bad fire day, she's got a little bag, USB sticks and all her photos and all the things she wants she puts in a car and goes and visits a mate for the day. So, she's made this decision. I think we've educated my mother well, nagging at her to do that" – police sergeant.

In fact, community-wide evacuation is still considered a challenge as only smaller communities have ever been evacuated in the past. Thus, the human costs and the necessity to evacuate are continually questioned:

"…the bigger question we need to ask ourselves these days: do we need to do an evacuation, or do we in-vac as I call it, get people to shelter-in-place, or do we just ask people on an urban interface to go one street in and get away from the fire? We've learned that from healthcare counterparts that for nursing homes and the elderly, there's a greater chance of loss of life while evacuating…" – police sergeant.

Often, however, the capacity of the PWM to support the community in their own homes is extremely limited:

"Lorne has 2 fire trucks and 600 residents, people are not aware of that and think the fire truck will come and save them. It is quite confronting when you're asked to evacuate for a reason" – police sergeant.

The WUI and its complicated topography presents risks both for bushfires and for evacuation, as getting trapped on the only road leading out of the city is a possibility:

"…in the area where it [the fire] was, there is a lot of volcanic rock, so the roads […] wind around quite a bit, you could have a ride […] 10 kilometres and you still don't get a side road to come onto to leave that direction" - learning and development manager.

The dynamics of WUI communities and their socio-economic challenges were also said to complicate evacuation. Nevertheless, the interviewees claimed that vulnerable groups, such as those communicated in the Victoria state demographics and fire safety report (DEWLP, 2016), but not including the indigenous populations, do not necessarily possess deterministic characteristics that would affect evacuation decision-making (although they may be more/less reluctant to leave).

The issue of 'pecuniary interest' (based around the notion that people have a right to enjoy their property without being impeded by the state) has played a big role within Victoria in decisions to stay-in-place and has become a challenge in situations where evacuation would be highly recommended:

"…a law here called 'pecuniary interest', so, people don't have to leave, it's not mandatory, if you are on your property. You can't be outside of your area and come back in because police will stop you at a roadblock, but if you're on your property you can't be made to leave. To some degree at your own peril; if you were to lose your life, it was your decision to make that, and you're entitled under the current law to do that…" – police sergeant.

The work of first responders in more 'challenging' communities to overcome reluctance to leave is somewhat stymied by this fact that the law protects people's right to stay-in-place if they wish. However, it has been admitted by the Australian Institute for Disaster Resilience (AIDR), who released the latest Public Information and Warnings Handbook (Australian Institute for Disaster Resilience, 2018), that certain persuasion strategies have been employed in warning message construction:

"we're getting better at constructing warnings around using some of the thinking that comes from marketing, you know, about why people choose to buy coca cola; it's this whole notion of compliant behaviour: how do you get people to do what you want them to do? And there's a lot of lessons to be learned from marketing, and so how you construct a message around that is very important to whether people will choose to act" – community safety and resilience director.

5.2.3 Regional comparison of the experiences of PWM

Interviews with both study regions' PWM have revealed that rather opposite policies regarding protective action exist: stay-in-place is preferred in the South of France, while evacuation is preferred in Australia, yet the reverse action is preferred in each region for vulnerable groups. However, practices to date are dissimilar in terms of preparing communities for risks (e.g. public educated from a very early age via schools versus community meetings for interested adults). Thus, several cultural differences are expected when comparing the survey data from residents in the South of France and Australia. These differences are likely to be related to *preparedness* and *response*. However, some similarities reflecting shared human factors are expected also. Differences and similarities between interviews with French and Australian PWM can be seen in the themes arising from qualitative research, summarised in Table 5-2; overlapping themes are again highlighted in grey.

Table 5-2 Summary of the main themes arising from the qualitative findings (II).

Theme source / CIBER-t	Corsica interviews	Victoria interviews
Context	Property attachment	Property attachment
	Experience	Culture
	Attitudes of locals	Community type
	Attitudes of tourists	
	Dependents	
Information	Information source	Information source
	Information availability	Warning messages
		Communication barriers
		Reliance on authorities
Behaviour	Inappropriate behaviour by…	Inappropriate behaviours
	Adult locals	Appropriate behaviours
	Adult tourists/transients	Behavioural itineraries
	Children around firefighters	Shelter
		Evacuation
Emotion	Stress	
	Fear	
	'Panic'	
Risk	Risk awareness	Risk awareness
	Risk mitigation	Risk mitigation
		Credible risk
Time	Door-knock time	Door-knock time
	Assumed RSET/ASET	Warning time
	Travel time	Response times
		Mobilisation time

Chapter Summary

Certain limitations to online and print media content suggest the need for additional data. For example, media accounts published by more global news outlets rarely revealed the safety culture (e.g. few, if any, provided details about national policy and practice relating to evacuation/stay-in-place), which made most of the news seem de-contextualised. They also lacked detail for inferring the reasons behind certain outcomes. In addition, extraordinary (i.e. sensational) cases have been reported often, which may exaggerate experiences; one example was the report about a family driving around for nearly 20 hours looking for shelter.

Additional sources of information in the public domain, i.e. video material, particularly that made available on social media (Twitter, YouTube), suggested that people are often captivated by the sight of smoke plumes and flames visible in the distance, and may stay and watch, at least for a while. However, it is generally difficult to assess the distance between those filming and the fire (did the person shooting the footage zoom in prior to pressing 'record'?). The video material was often assumed to be shot for 'entertainment' purposes (therefore arguably unnecessary and lacking benefit compared to filming for the purpose of informing the authorities). Moreover, videos that included commentary rarely contained any narrative that would allow researchers to make sense of the event-related intentions of the person filming, leaving much of the details 'behind the scenes'. In addition, video material from this thesis' study areas was very limited at the time of analysis, and so the findings relied more heavily on videos from other countries.

Thus, the behaviours highlighted by these data sources may not necessarily reflect the behaviours of wider populations likely to frequently occur in the areas of interest. For this reason, themes were further extrapolated with the support of newspapers in Corsica (the South of France) and survivors' statements from the 2009 bushfires in Victoria (Australia). Together, these sources provided better information about elements such as context (e.g. safety culture) and internal states (e.g. emotions and risk perceptions influencing behaviour). However, the newspaper articles still lacked a certain range and depth, shared some of the limitations of the online media, and there was no direct French comparison for the bushfire survivor statements.

The interviews with PWM were conducted to help achieve a better degree of contextualisation of human response to wildfires than was possible with publicly available information. As in de Certeau's work, resistance (within communities) to the system (authorities' policies and practices) is a recurring topic in the interviews with PWM in both study regions. The PWM share a common struggle in convincing people, albeit often to different ends, e.g. to take appropriate action to shelter rather than attempt to defend property by tackling fire (in Corsica) and to evacuate early if at all (in Victoria). At present, it appears that less thought has been given to evacuation in the French region and so one of its major issues would be in considering and predicting what will motivate evacuation. In contrast, in the Australian region, evacuation is very much in the minds of professionals now at least but one of the major issues there is how to get residents to start leaving more quickly. So, a better understanding of what people do and how long they take to do it is much needed.

Overall, the PWM observations with regards to human behaviour in wildfires, and especially the likelihood of some inappropriate behaviour, seem to be in line with other findings in the literature on human behaviour during emergency events. Nevertheless, no knowledge system is exhaustive (Kelman et al., 2015), in that the experiences of PWM are contained within their practice. Their observations are based on how people behave in the presence of authority such as firefighters or police officers. There is less insight available into what people do when such social influence is not present. Moreover, external observations can only assume not reveal the thoughts and feelings experienced by residents. Thus, a better understanding of people's internal processes and what motivates them – gained through surveying residents directly – could help the development of strategies to influence behaviour if it needs changing, thereby supporting wildfire response operations. It could also help couch behavioural responses in better terms (e.g. avoid the misleading 'panic', which was used liberally by some PWM as well as in the media and other publicly-available accounts analysed in Chapter 7).

Chapter 6 Quantifying human behaviour

This chapter presents the survey findings, firstly by describing the samples who completed the AE and H surveys in the South of France (SoFR) and Australia (AUS) and comparing them to the available descriptive data from other research, showing a reasonable agreement among the data. Then, inferential statistical test results present the findings regarding hypothesised relationships between variables and inform of the similarities and differences between the study regions. Significant associations are shown for variables related to: pre-event risk perception and planning; immediate responses to wildfire cues; initial intentions regarding what decision to make about protective action; ultimate decisions to evacuate/stay-in-place; evacuation destination choices and ingress attempts; decisions related to future possible wildfires; emotions felt and risk perceived at key moments; and evacuation delay times. With some regional differences, the overall results show the importance of context (physical environment and social context), information (seeking it), and behaviours (performing more actions) which also often played a role in evacuation delays. All related data tables are provided in the Appendices.

6.1 Descriptive statistics

The AE and H surveys were completed by similar numbers of participants in total (AE: N = 382; H: N = 380), although there were somewhat more participants completing the survey about their actual experiences in the Australian region (AUS-AE: n = 201; AUS-H: n = 157) and somewhat more answering about hypothetical scenarios in the French region (SoFR-AE: n = 181; SoFR-H: n = 223). The level of wildfire experience was similar in the study regions: the majority of AE participants (SoFR: 63%; AUS: 71%) had experienced a wildfire more than once and the majority of H participants (SoFR: 75%; AUS: 78%) had never experienced a wildfire. Most SoFR-AE participants described an experience with a wildfire that occurred within the most recent two years (2016-2017), while AUS-AE participants tended to describe experiences from 2014-16 as well as from 2009. For both of these regions, these periods coincide with major wildfire incidents.

Note that some survey questions were multiple choice; where that was the case, the reported percentages – representing the frequency with which each answer was chosen by participants – therefore do not add up to 100%. Also, certain questions could be skipped by participants (e.g. if sensitive or not applicable to their choice of protective action) and, thus, in cases where there were some missing values, the percentages had to be calculated for those who did answer.

The location of participants was identified from their self-reported geographical position using an interactive map within the questionnaire. Participants in SoFR were spread across the mainland and Corsica, while the majority of AUS participants came from the state of Victoria (Fig. 6-1).

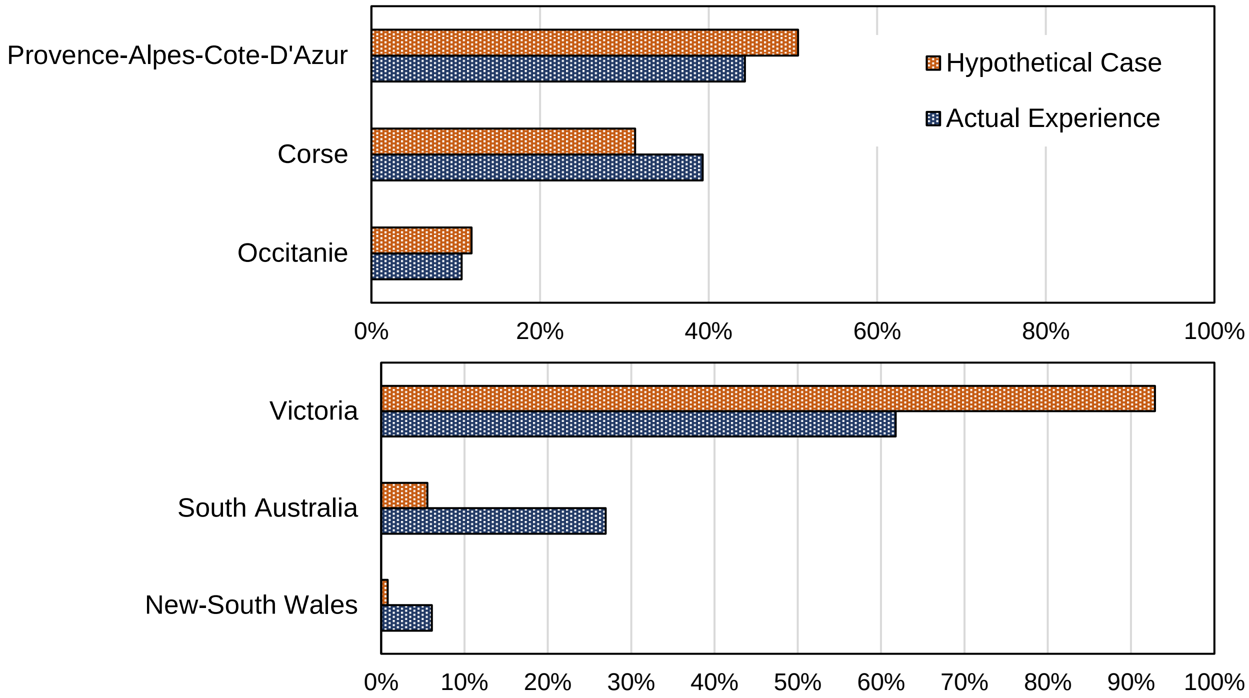


Fig. 6-1 Main locations of survey participants in SoFR (top) and AUS (bottom).

Using the interactive map data, a series of geographic area snapshots were taken that helped identify the types of WUI that participants came from. As methodology for categorising WUI types has already been developed by Lampin-Maillet et al. (2010), it was possible to simplify the information at hand using categories that may work better for satellite images than aerial shots (Appendix J, Table J 1). Finally, several cross-checks were performed to verify the simplified typology, mainly to check the credibility of the geographical location based on other information provided by the participant (i.e. someone living in an urban environment would be expected to have no livestock). In addition, Spanish PWM at *INFOCA* were consulted over the simplified categories, who agreed that such classification in principle can support studies such as this thesis.

The remainder of this section presents an overview of the participants' context (both internal and external variables), information (received before and during the event), behaviour (exhibited in response to wildfire), and their emotion and risk. This is done using descriptive statistics in the first instance to show differences in the responses between the regions, while the next section presents an in-depth analysis of relationships between the variables. A mixture of tables and figures is used, where figures mainly represent a multiple-choice response and / or require additional discussion.

Context

- **Household size**

Most prominent among the SoFR and AUS samples were households comprising 2-3 persons. There were slightly more single-person households in SoFR (Fig. 6-2).

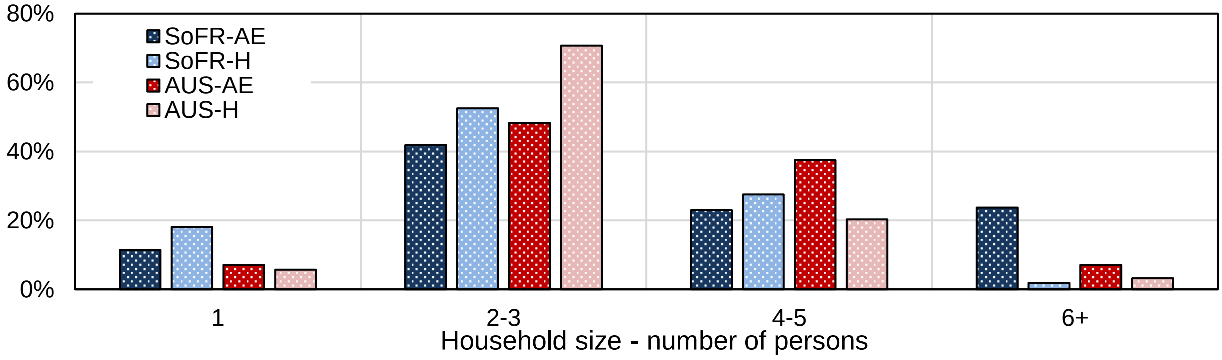


Fig. 6-2 Household size in SoFR and AUS.

- **Children and other dependents**

The majority of participants reported having no dependents in their household, although around a third of participants in each group reported having to take care of children. More SoFR-AE participants had elderly persons in their care than did any other group (Fig. 6-3). In contrast, more AUS-AE participants had adults in their household with known physical or mental conditions that are likely to be seriously aggravated by the presence of smoke/flames.

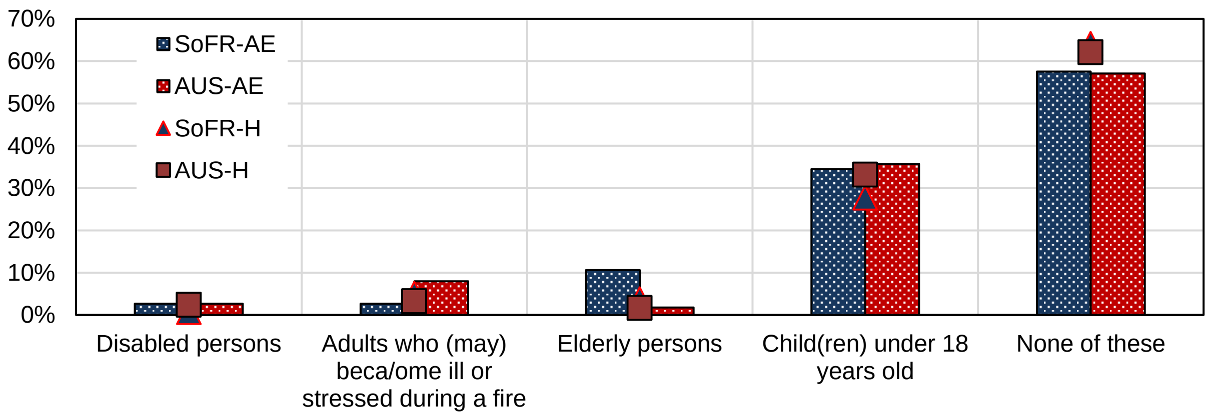


Fig. 6-3 Type of dependents in the household.

- **LoC**

While a lower percentage of participants in SoFR than in AUS had a strictly internal LoC (i.e. believed that they controlled the wildfire consequences to them and their property), a number of participants believed that control rested both internally and externally, selecting more than one locus. Of the external loci, spiritual beings were selected rarely across all samples. Interestingly, much higher percentages of participants in the AUS-AE/H samples believed that the emergency services had control while SoFR-AE/H samples were more inclined to believe that outcomes were due to chance (Fig. 6-4).

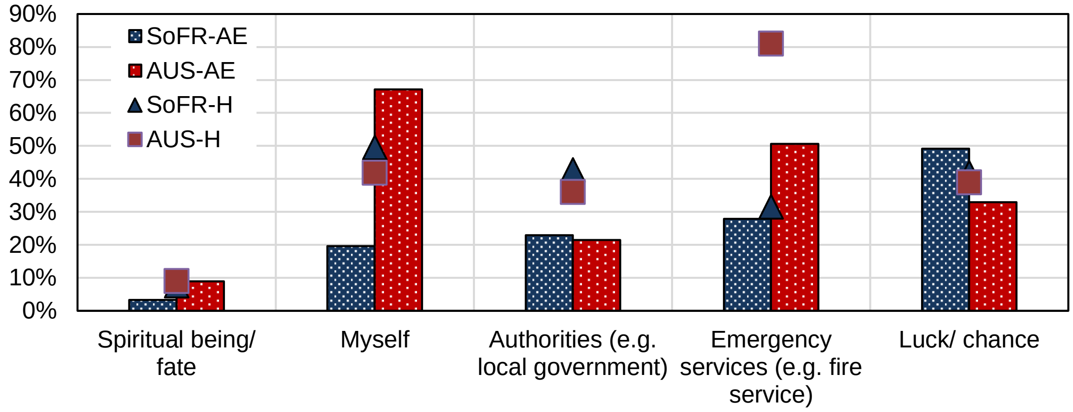


Fig. 6-4 Locus of control.

The remaining variables in relation to individuals' pre- and peri-event context are presented in the table Table 6-1.

Table 6-1 Context-related variables, descriptive statistics.

VARIABLE	SoFR		AUS	
	AE	H	AE	H
Gender				
Male	50%	45%	39%	32%
Female	50%	55%	61%	68%
Age				
Mean	42.50	43.23	48.69	44.82
SD	14.74	13.71	13.46	12.57
Range [min-max]	18-71	18-75	18-78	22-74
Property type				
Camper	5%	1%	3%	1%
Apartment/Flat	17%	44%	1%	15%
Family house	76%	55%	90%	84%
Outdoors (never entered a property)	2%	n/a	6%	n/a
Property attachment				
Temporary residence (part-time)	29%	14%	12%	14%
Permanent residence (full-time)	57%	84%	75%	86%
Other	14%	2%	12%	0%
Insurance				
No	6%	3%	0%	8%
Yes	39%	68%	87%	46%
Medical conditions				
Yes	9%	6%	15%	14%
No	91%	94%	85%	86%
Pets and livestock ownership				
Yes, livestock	2%	0%	4%	2%

VARIABLE	SoFR		AUS	
	AE	H	AE	H
Yes, pets and livestock	5%	3%	31%	9%
No animals	41%	54%	16%	34%
Yes, pets	52%	43%	49%	55%
Closeness to the community				
Low (not at all or very little)	42%	37%	29%	47%
High (somewhat or to a great extent)	58%	63%	71%	53%
Involvement in community risk mitigation activities				
No	83%	92%	53%	86%
Yes	17%	8%	47%	14%
LoC				
Internal	5%	50%	24%	65%
External	95%	50%	76%	35%
Having a plan				
Plan	14%	13%	62%	38%
No plan	51%	64%	15%	46%
Knows what to do	36%	23%	23%	17%
Merged category				
Plan/ knowledge	50%	36%	85%	55%
No Plan	51%	64%	15%	46%
Fire safety knowledge				
No	86%	60%	77%	93%
Yes	14%	14%	23%	7%
Evacuation route knowledge				
Not at all	24%	29%	5%	31%
Very little	14%	24%	11%	26%
Somewhat	20%	29%	20%	18%
To a great extent	42%	19%	64%	25%
Visibility during evacuation				
Good visibility	42%		47%	
Poor visibility (5 – 15 m)	47%		27%	
Reduced visibility (50 – 100 m)	11%		27%	
Visibility when staying in place				
Good visibility	50%		18%	
Poor visibility (5 – 15 m)	27%		56%	
Reduced visibility (50 – 100 m)	23%		27%	
Event consequences				
No	72%		66%	
Yes	28%		34%	

NOTE: regional differences highlighted in colour

Information

- **Information (preparation) sources**

In the 12 months prior to the described (AE) event or the (H) survey, most participants had gained information from at least one source about preparing for wildfires. These information sources were most often the television, radio, and internet. Social media and newspapers were also quite common sources. However, AUS participants were much more engaged with consulting the Government's website and attending community meetings while SoFR participants were more likely to report that they had received no information at all about preparing for wildfires (Fig. 6-5).

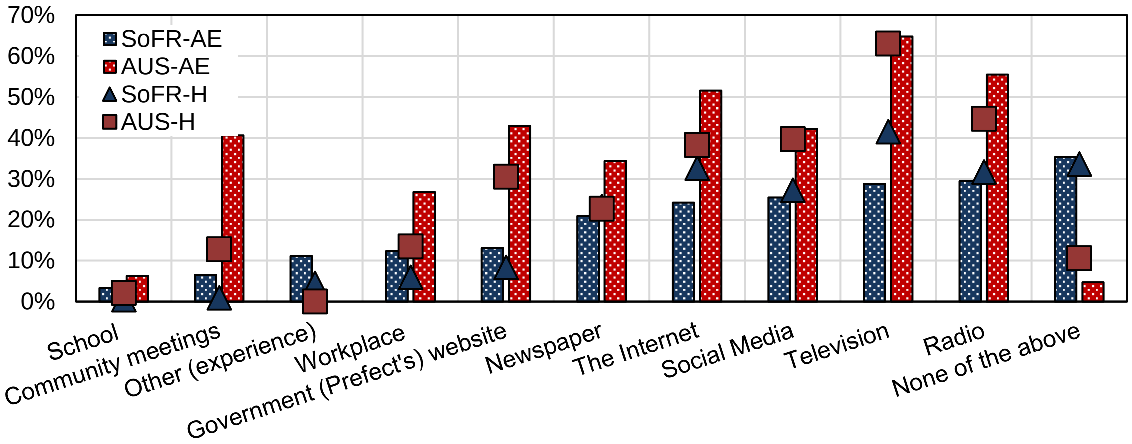


Fig. 6-5 Information (preparation) sources.

First cues and fire proximity at the time of first cues are summarised in Table 6-2.

Table 6-2 Information-related variables, descriptive statistics.

VARIABLE	SoFR AE	AUS AE
First cues		
I had no advance warning, I saw/smelled the cues of the fire	73%	26%
I received an advance warning via media or someone else	27%	74%
First warning source		
Social/unofficial	13%	23%
Official/fire service	14%	51%
Environmental cues	73%	26%
First environmental cues		
Sight of embers	4%	14%
Sight of flames	24%	17%
Smell of smoke	46%	55%
Sight of smoke	74%	59%
Other	15%	0%
Fire proximity		
In the street	5%	7%
At the property	8%	3%
In residential area	30%	28%
Not reached residential area	57%	58%

NOTE: regional differences highlighted in colour

- **Information (first warning) content**

When receiving a (first) warning via social cues, such messages were reported to most frequently contain information about the fire's location (somewhat more so for AUS-AE), its severity (somewhat more so for SoFR-AE), and what protective actions to take in response to the fire. However, the warning less often mentioned evacuation specifically; when it did in AUS, it was more often a recommendation rather than an official order to evacuate (Fig. 6-6).

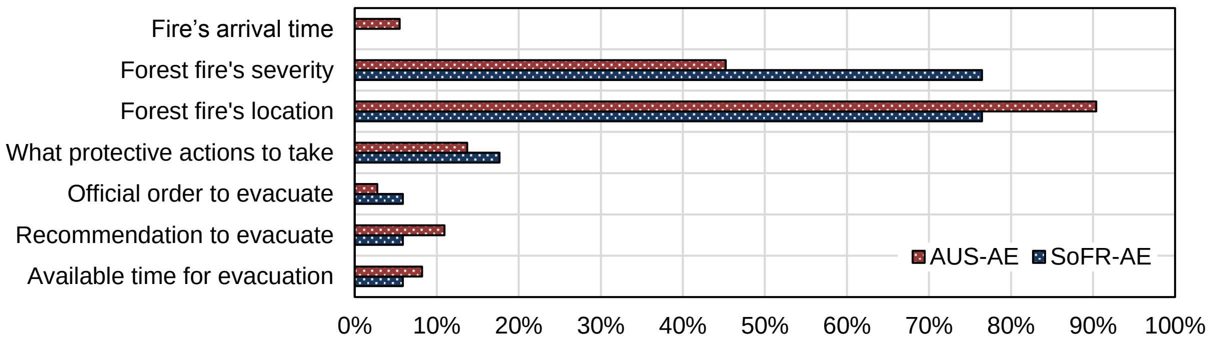


Fig. 6-6 Information (first warning) content.

- **New cues**

For those AE participants who subsequently received new cues (SoFR: 84%; AUS: 87%), these were mostly similar to the first cues (e.g. sight or smell of smoke, warned by emergency services). However, this time there were more participants who saw flames in SoFR (54%); the percentage seeing embers also grew slightly from 4% to 7% in SoFR and from 14% to 16% in AUS. There was also a number of participants who were now warned by friends and neighbours (Fig. 6-7).

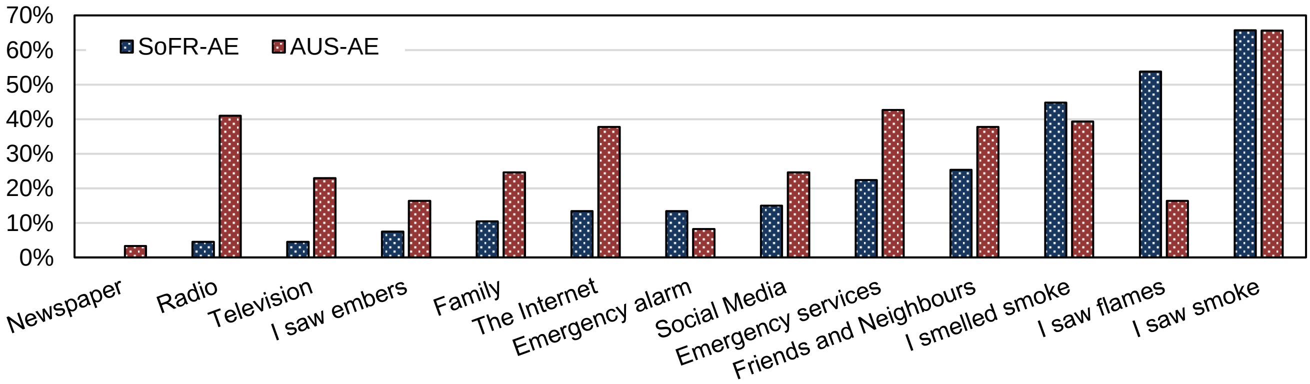


Fig. 6-7 New cues for AE participants.

- **Information (new warning) content**

As with the first warning, information about the fire's location, severity and protective actions were commonly provided in the new warning. Nevertheless, second time round, AE participants received more recommendations and orders to evacuate (Fig. 6-8).

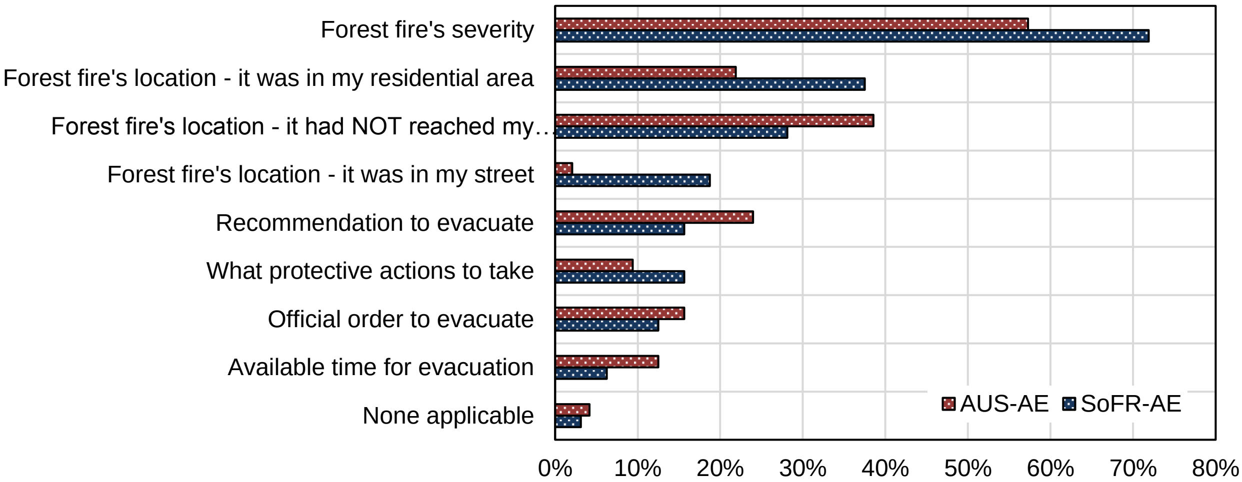


Fig. 6-8 Information (new warning) content.

Behaviour

- **Immediate response**

Once the first cues (environmental cues or social cues comprising a warning) were noted, the majority of AE participants in both regions (SoFR: 78%; AUS: 82%) reacted actively, i.e. reported that they either knew some protective action needed to be taken and commenced this or sought further information to help inform how they should respond. Far fewer participants in both regions reported reacting passively, i.e. either continued with their current activities or waited for more information to be provided (Fig. 6-9).

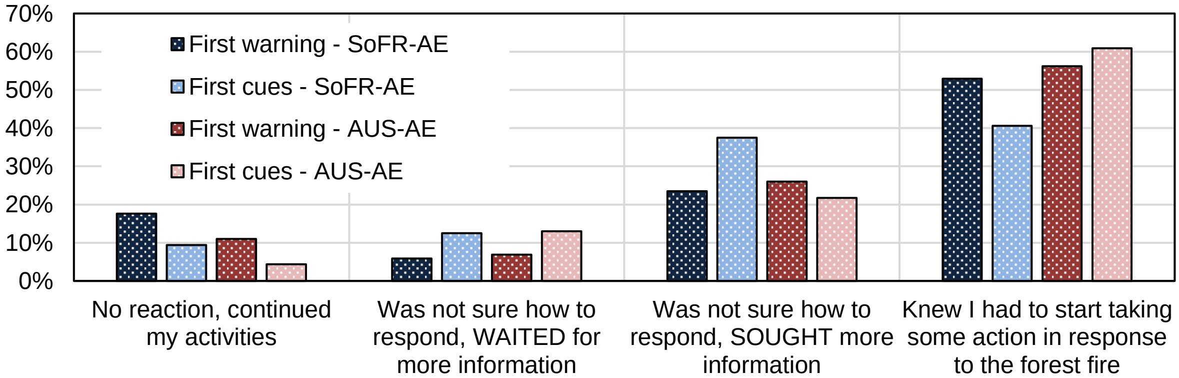


Fig. 6-9 Immediate response to first warning/environmental cues.

- **Intention and evacuation decision**

Ultimately, the majority of SoFR-AE participants stayed-in-place and around a third evacuated, whereas just under half of AUS-AE participants stayed-in-place and a slim majority evacuated. However, around a fifth of participants reportedly changed from their original intention during the event (Fig. 6-10).

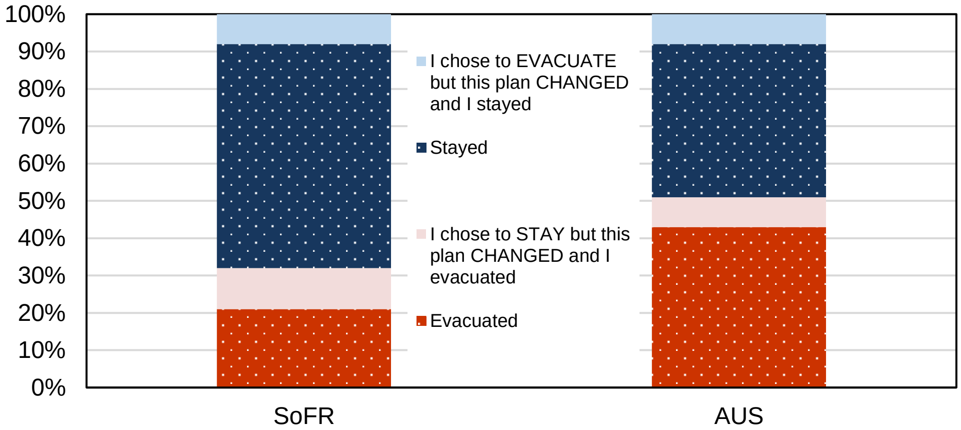


Fig. 6-10 Intention and evacuation decision (AE).

Since this study set out to explore how well responses to hypothetical scenarios reflect human behaviour in wildfire evacuations, some H survey data is also presented here. As mentioned in Chapter 4 (section 4.2.2), H participants were faced with one of three hypothetical scenarios (social cues only, environmental cues only, social + environmental cues) and decision-making was tested repeatedly as the situation gradually escalated in each. The following examples illustrate some decision-making trends observed in three different situations.

Firstly, where participants were warned via the media, receiving information about the fire but not an evacuation recommendation/order (in other words, a perhaps common type of advance warning), the greatest tendency in both SoFR and AUS was to not yet commit to a type of protective action and instead actively seek more information (although evacuation was perhaps more likely to follow):

"Imagine that you are at your usual residence. You learn from the TV, radio, Internet or similar that there is a forest fire in your area, and it is estimated to reach your town/village in 3 hours. What do you do?" (Fig. 6-11).

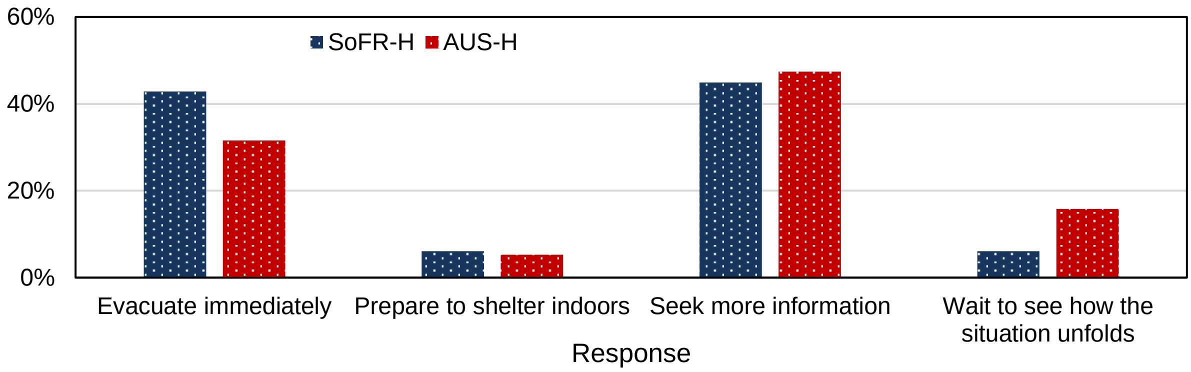


Fig. 6-11 Scenario 1 B.

Secondly, where participants first received an advance warning via social cues and subsequently received an environmental cue (i.e. the sight of smoke, so perhaps a common situation involving the receipt of new cues), the tendency in both regions was somewhat similar to that seen in the scenario above:

"*You learn from the TV, radio, Internet or similar that there is a forest fire in your area that is heading towards your town/village. You look through the window and see smoke plumes over the top of the trees. What do you do?*" (Fig. 6-12).

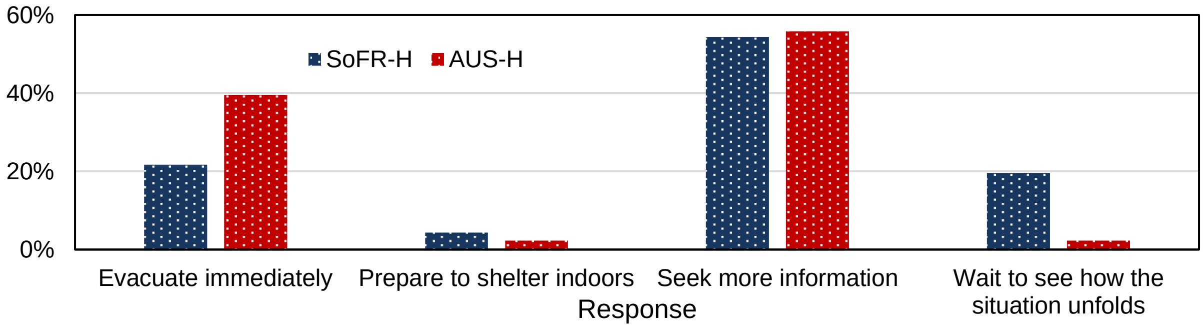


Fig. 6-12 Scenario 3 A.

Lastly, where participants received no advance warning and instead were faced with the fire front nearby (so perhaps a worst-case scenario, as reported by some AE participants), the tendency in both regions was to commit to a type of protective action; in AUS, there was a slight inclination towards evacuation over staying-in-place:

"You have not received any advance warning, but you look through the window and can see signs that there is a forest fire nearby, e.g. smoke, embers and flames. Your throat and eyes start to feel irritated and you feel unwell due to the smell and smoke in the air. What do you do?" (Fig. 6-13).

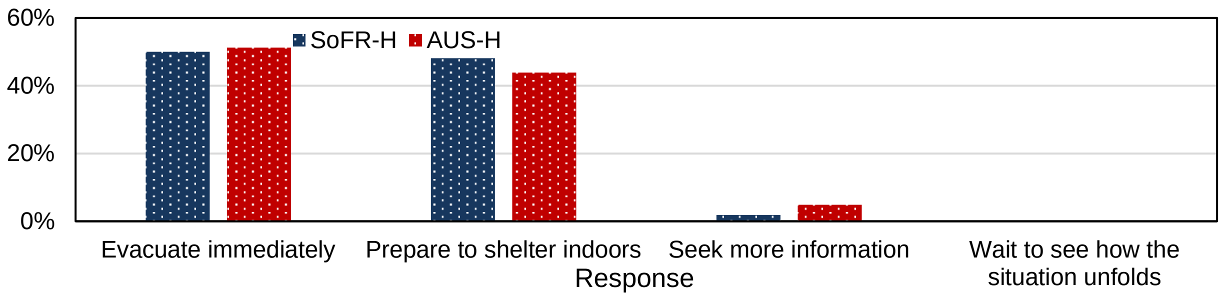
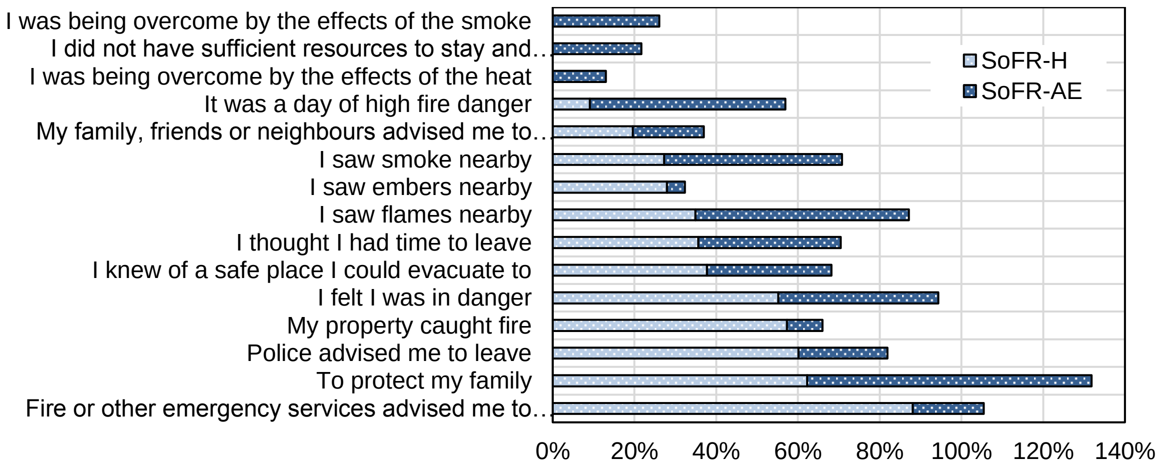


Fig. 6-13 Scenario 2 D.

- **Decision triggers**

In both SoFR and AUS, a desire to protect one's family was the main motivation for actual/hypothetical evacuation if looking at the AE and H participants' answers together. (Fig. 6-14). Looked at separately, this desire is still a main motivation for AE participants but not as much for H participants, who instead appeared more reliant on the emergency services making the evacuation decision for them. The social influence of non-officials (neighbours) in triggering evacuation appeared to be stronger in AUS than in SoFR.



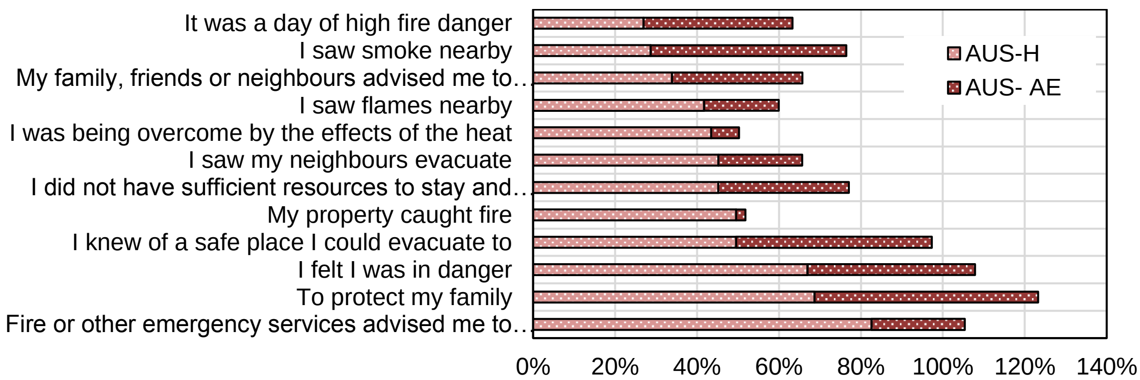


Fig. 6-14 Motivations in SoFR (top) and AUS (bottom) to evacuate.

- **Behavioural itinerary**

The activity most likely to be performed prior to evacuation in SoFR was shutting windows (AE and H), while in AUS it was getting pets ready to leave (AE) or packing money/one's wallet (H). In both regions, in general, activities were more often listed in H participants' behavioural itineraries than in AE participants' itineraries.

Table 6-3 Behavioural itineraries

ACTIVITY	SoFR		AUS	
	AE (%)	H (%)	AE (%)	H (%)
Use the bathroom (e.g. take a shower, use toilet)	0	10	9	32
Turn the gas off	31	67	27	58
Turn the air conditioning off	8	26	18	44
Tidy up the garden/ outdoors	12	11	13	23
Shut the windows	62	78	36	72
Prepare food/ drinks to take away with you	8	44	20	53
Pack personal belongings	38	76	53	70
Pack passport/ driver's license	23	28	44	30
Pack money/ wallet	38	67	64	86
Pack first aid items/ medication	8	49	40	61
Pack documents (e.g. insurance policy, birth certificate)	31	53	49	75
Pack children's items	23	29	20	35
Other miscellaneous activities	19	7	24	17
Open the gate to the residence	35	37	24	39
Load my vehicle for evacuation	-	-	69	78
Get pets ready to leave	50	46	71	71
Get dressed	23	40	18	48
Find out what neighbours are doing	15	7	33	48
Fill sinks/ bathtub/ building gutters with water	0	15	31	46
Eat	4	7	9	23
Check travel directions	15	29	33	57
Charge mobile phone	8	32	24	48
Call family and friends	46	37	51	57

Decision to form a group, move to shelter, return, and evacuate / stay-in-place in the future is presented in Table 6-4.

Table 6-4 Behaviour-related variables, descriptive statistics.

VARIABLE	SoFR		AUS	
	AE	H	AE	H
Grouping behaviour				
No	63%		51%	
Yes	37%		49%	
Evacuation destination				
Another building, such as a hall or church	5%	15%	8%	1%
Another residence nearby	21%	3%	13%	3%
I don't know	0%	13%	0%	11%
An open area, such as a beach or sports field	0%	30%	0%	31%
Other	21%	0%	11%	0%
Means of evacuation				
By bicycle	5%	3%	0%	2%
By motorcycle	0%	2%	0%	1%
On foot	5%	18%	1%	12%
Other	5%	2%	0%	0%
Using public transport	5%	4%	0%	6%
By car	79%	71%	97%	79%
Ingress attempt				

VARIABLE	SoFR		AUS	
	AE	H	AE	H
No	68%	20%	50%	51%
Yes	32%	80%	50%	49%
Future decision				
I would evacuate	24%		44%	
I don't know	34%		20%	
I would stay	42%		36%	
Changes in future decision				
Would take the same action	40%		60%	
Would take an opposite action	60%		40%	

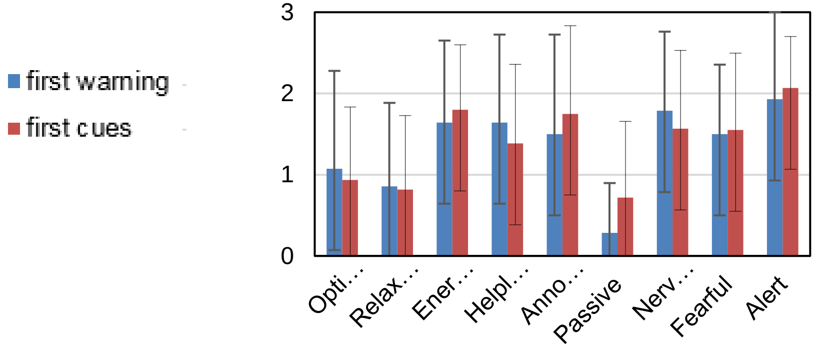
NOTE: regional differences highlighted in colour

Emotion and perceived risk

In both SoFR and AUS, participants rated their pre-event perceived risk (Table 6-5). AE participants, particularly those in AUS, perceived it to be lower. Risk, and emotion, were also rated either across different stages of the experienced wildfire (AE) or once the given wildfire scenario had peaked in escalation (H). When visually compared, AE participants' responses across the three different stages displayed a similar pattern in terms of the range of emotions and concerns felt but varied somewhat in the level to which they were felt, both according to the participants' circumstances and region (Fig. 6-15 to Fig. 6-20; errors bars based on SD). H participants' responses across the three different scenarios similarly had range and varied in intensity according to circumstances and region (Fig. 6-21 to Fig. 6-22).

Table 6-5 Pre-event risk, descriptive statistics.

VARIABLE	SoFR		AUS	
PRE-EVENT RISK	AE	H	AE	H
High (somewhat or to a great extent)	31%	58%	7%	70%
Low (not at all or very little)	69%	42%	93%	30%



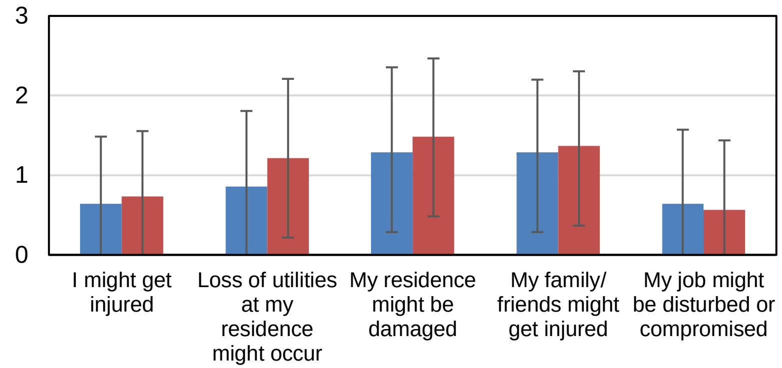
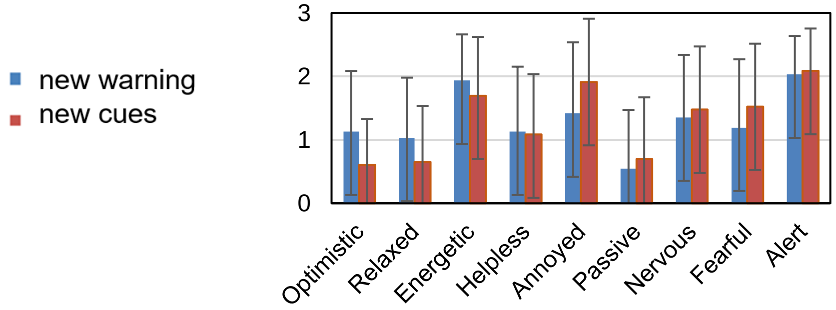


Fig. 6-15 SoFR-AE emotion (L), perceived risk (R): first warning/cues.



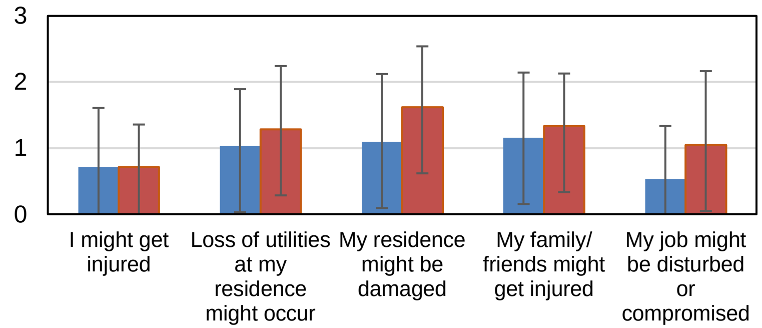
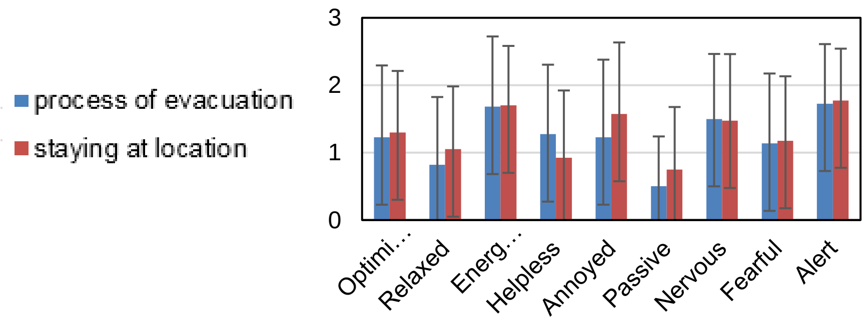


Fig. 6-16 SoFR-AE emotion (L), perceived risk (R): new warning/cues.



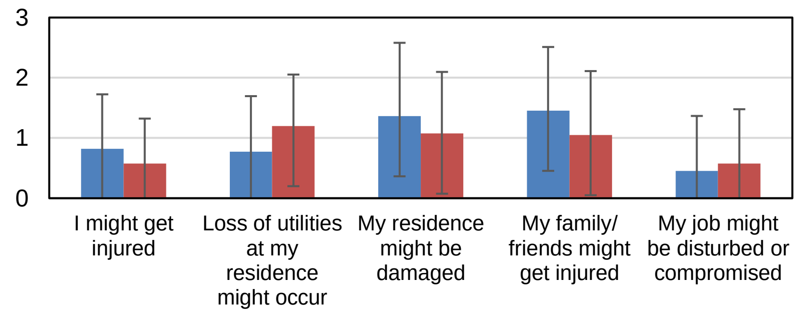


Fig. 6-17 SoFR-AE emotion (L), perceived risk (R): evacuation/staying-in-place.

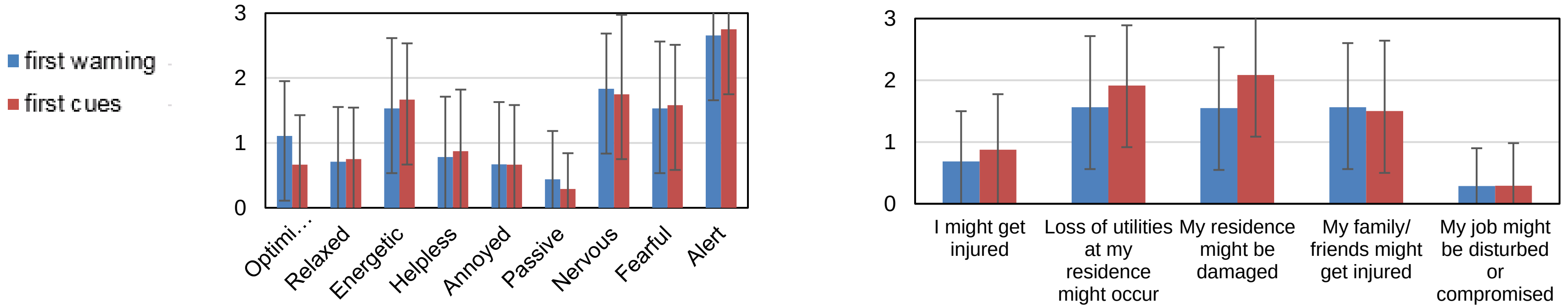


Fig. 6-18 AUS-AE emotion (L), perceived risk (R): first warning/cues.

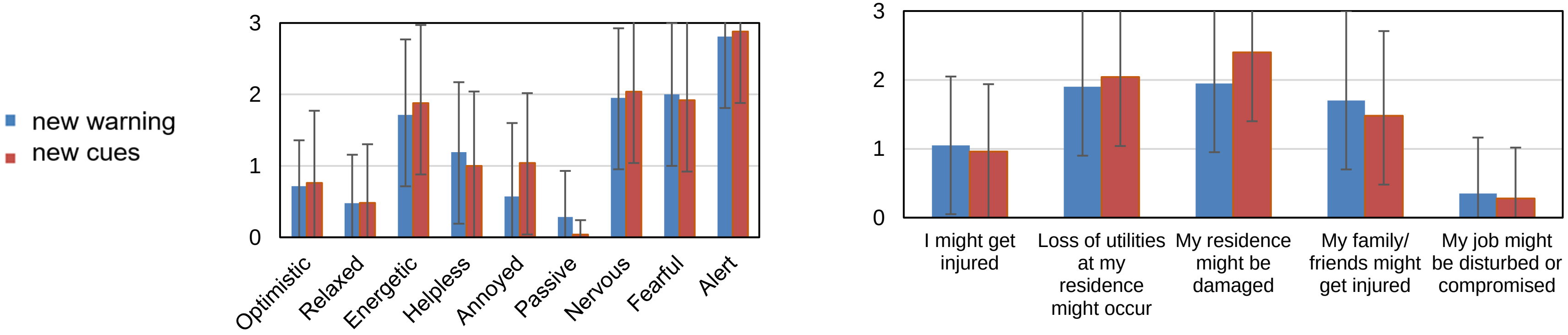


Fig. 6-19 AUS-AE emotion (L), perceived risk (R): new warning/cues.

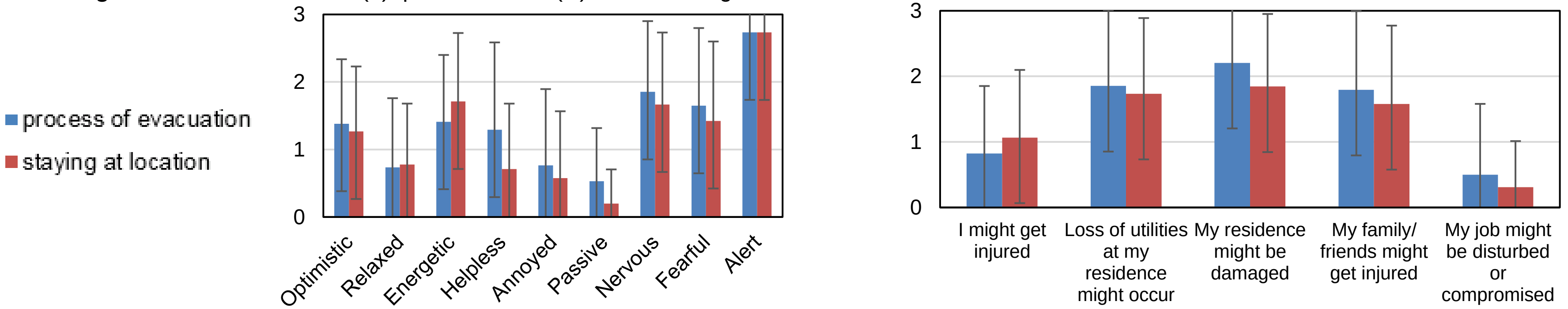


Fig. 6-20 AUS-AE emotion (L), perceived risk (R): evacuation/staying-in-place.

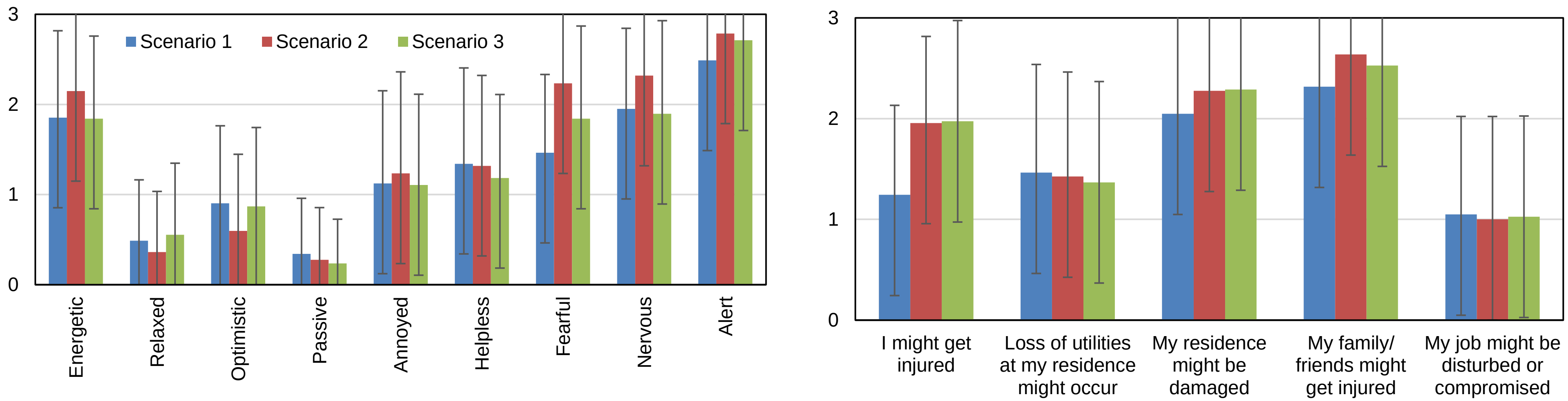


Fig. 6-21 SoFR-H emotion (L), perceived risk (R): across 3 scenarios.

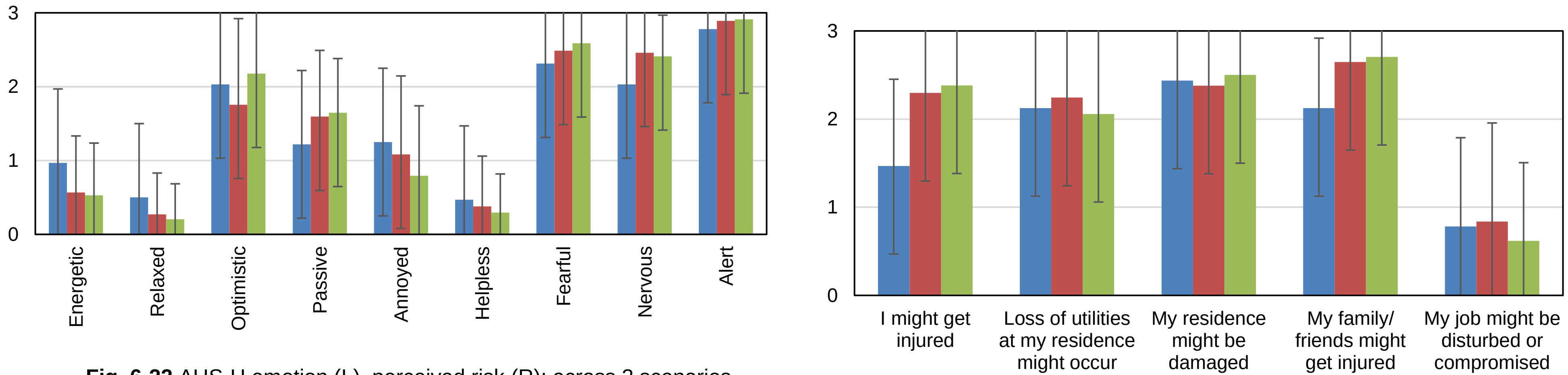


Fig. 6-22 AUS-H emotion (L), perceived risk (R): across 3 scenarios.

- **Times**

As anticipated, estimates for when key moments occurred were not always forthcoming from AE participants, and so the calculation of certain times was often impossible. For example, participants were not necessarily still at their homes when the fire arrived so could not always estimate the time of fire arrival. Moreover, participants could not always remember the time when they had received the first cues and/or when they left their residence (e.g. “[possibly left 1 hour later but] I’m not sure. It is all a blur now”) or could only remember in such general terms that it was not possible to make a calculation to any reasonable level of precision (e.g. only known that the participant evacuated on the same day they were warned of the fire). Time estimates were particularly missing for the moment when participants arrived at their evacuation destination. Hence, the analysis on times focused solely on evacuation delay time, as measured mainly via BI times, which were provided by AE and H participants (see section 6.5 for further detail).

6.1.1 Comparison of current and previous samples

As already mentioned, European regions such as SoFR have been neglected to date by researchers of human behaviour in wildfires. Thus, the current SoFR-AE sample can only be compared with the SoFR-H sample. Overall, there was good correspondence between the socio-demographics of both samples (e.g. similar in terms of participants’ individual, household and community characteristics such as gender, age, children and other dependents, pets, community closeness, etc.) and indicators of being prepared for a wildfire (i.e. both had received information, from similar sources, on wildfires, yet both also lacked planning and were less likely to be involved in community risk mitigation activities). In AUS, the AE and H samples were also similar to each other in these respects, although occasionally the correspondence between the two would not be quite as strong (e.g. most in AUS had a plan of some sort but this was more the case for AE than H participants: 85% vs. 55%). Where the AE samples in both regions noticeably differed from their H equivalents was on the issue of wildfire experience, which is to be expected given the instructions for which survey to complete.

AUS is one country that has received more attention from researchers on wildfires and evacuation. Moreover, this study drew upon the survey methods from previous research on the 2009 Black Saturday fires (BCRC, 2009) during the study design phase. Thus, several observations can be made where similar or the same questions were asked in both studies. For example, when it comes to the information (preparation) sources, BCRC-2009 results showed good correspondence with the current findings. For BCRC-2009, the percentage of permanent residents (full-time) was as high as 97%, compared to as high as 86% in this study (for AUS-H, and as low as 57% for SoFR-AE), meaning that the current survey reached more transients. Fire safety knowledge in this study was in line with that observed in the BCRC-2009 study. Reports of smoke and impaired visibility as difficulties encountered during the wildfire were also in line with the BCRC-2009 results (44% and 26%, respectively). The current findings on the first information type/source in AUS are compatible with that from BCRC-2009, in that a sizeable amount of participants received an advance warning via social cues; moreover, seeing/smelling smoke was common for those who first received environmental cues. Additionally, very similar percentages of AUS-AE participants reported staying-in-place and evacuating as in the BCRC-2009 study (46% and 54%, respectively). Overall then, there was no evidence to suggest that any of the samples in the current study were 'unusual', i.e. unrepresentative of the populations and fires from the two regions, at least those willing and/or available to be studied. There was also no evidence to suggest that opting to administer the survey online in the current study produced unrepresentative results given that the BCRC-2009 study collected data via postal survey (supplementing their interviews that resulted in qualitative survivor statements).

6.2 Before the wildfire

6.2.1 Pre-event risk perception and planning

Consistent with what was hypothesised, *pre-event risk* was perceived to be significantly higher by individuals who had received information about wildfires from *community meetings,* were *involved in community wildfire risk mitigation* activities, were *insured* against wildfire property damage, and resided in a *family house*. This was often more so the case for the H samples. In contrast, only AE participants' elevated pre-event risk was significantly associated with having *medical conditions* (mainly in SoFR sample). Dependents in the household and gender had little or no association with pre-event risk (see Table 6-6, plus Appendix H, Table H 1 for full statistical results). Participants of an older age were more likely to have a plan; so too were participants who had insurance against wildfire property damage. This was consistent across the study regions and survey samples, except for the SoFR-H sample*. Wildfire experience* was only a significant factor for planning in the H sample(where a lack of experience was associated with lack of any planning at all); likewise *involvement in community wildfire risk mitigation* (with informal planning in SoFR and formal planning in AUS). *Specific information (preparation)* *sources* were significantly associated with planning, although which types these were differed across AE and H participants, as well as across study regions, suggesting they might depend on context and personal preferences. However, the general trend was that participants who had gained information from a source tended more often to have given some thought to preparing for a fire, while participants not exposed to any of these sources tended to have no plan at all. Individuals with a high degree of *closeness to the community* were more likely to have a formal plan, but this was more the case in AUS than SoFR samples. Likewise, *pre-event risk perception* (perceiving higher risk), *property attachment* (being a permanent resident), and *'pet' ownership* (having pets and/or livestock) were all significantly associated with having a formal plan in the H samples, albeit only those in AUS. There was no significant association between *LoC* and planning in SoFR or AUS, only when the two regions' data were merged together. Gender did not have any significant relationship with planning (see Table 6-6, plus Appendix H, Table H 2).

Table 6-6 Tested hypothesised relationships with pre-event risk, planning.

	Statistically significant?		
Perceived risk will be associated with...	**SoFR**	**AUS**	**Merged**
Dependents	X	X	✓(AE)
Information (community meetings)	X	✓(H)	✓
Community risk mitigation involvement	X	✓(H)	✓
Medical conditions	✓(AE)	X	✓(AE)
Property insurance	✓(AE)	✓(H)	✓
Property type (family house)	✓	✓(H)	✓(H)
Gender	X	X	X
Planning will be associated with...			
Pre-event risk perception	X	✓(H)	✓
Information (any source vs. none)	X	✓	✓
Age	✓(AE)	✓	✓
Gender	X	X	X
Experience of wildfires	✓(H)	✓(H)	✓(H)
Property insurance	✓(AE)	✓	✓
Community closeness	X	✓	✓
Community risk mitigation involvement	✓(H)	✓	✓
Property attachment	X	✓(H)	✓
Pet ownership	X	✓(H)	✓
LoC	X	X	✓

6.3 During the wildfire

6.3.1 Immediate response

When faced with smoke/flames (Fig. 6-23), SoFR-AE participants were more likely to *react passively* (i.e. wait for more information, continue with current activities [no reaction]), compared to the AUS-AE sample. In contrast, AUS-AE participants were more likely to wait passively when seeing embers.

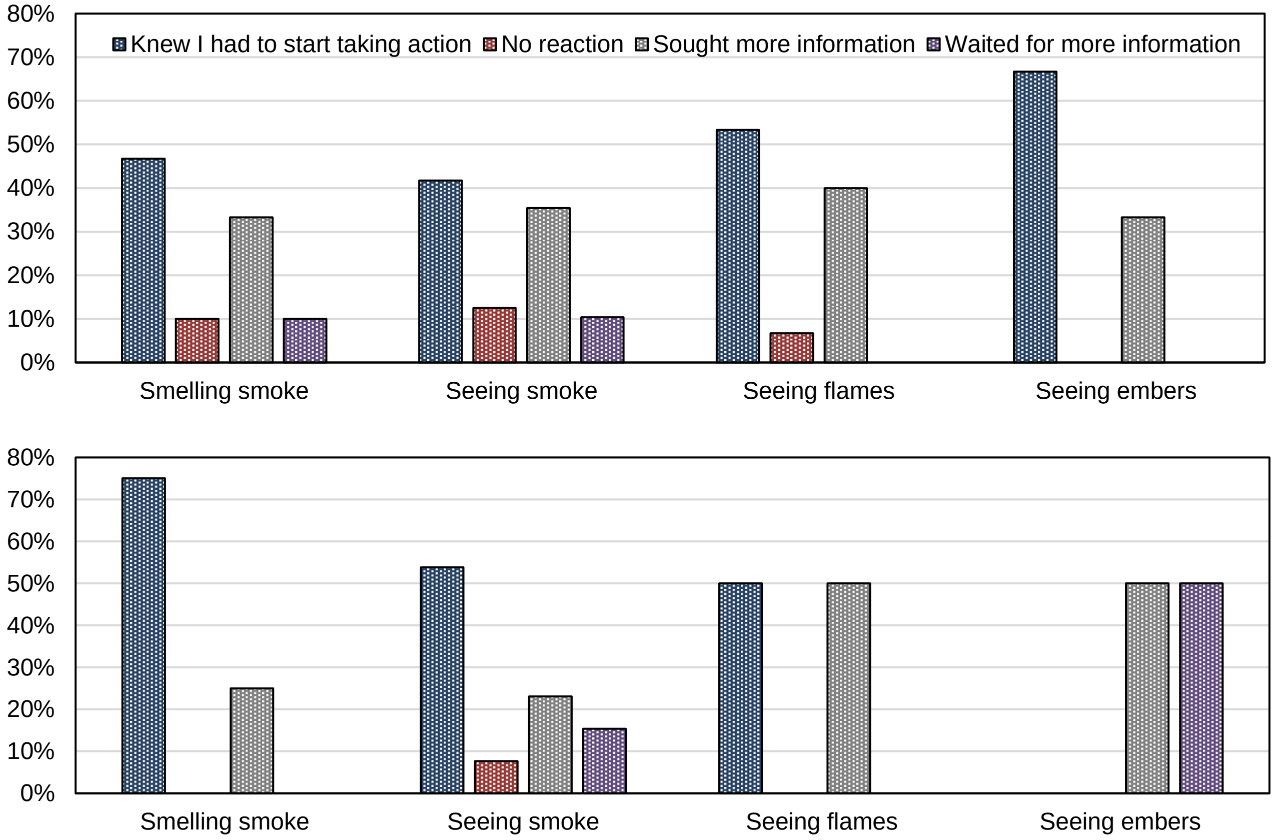


Fig. 6-23 SoFR-AE (top) and AUS-AE (bottom) immediate responses to environmental cues.

AE participants who *reacted actively* (knew something had to be done and commenced action, sought information) rated *visibility* as significantly worse compared to those who reacted passively, but only when the regions' data were merged. *Having a plan* (formal or informal) was significantly associated with *reacting actively,* although only for AUS-AE sample. For both regions, gender was not associated with immediate response (see Table 6-7, plus Appendix H, Table H 3).

Table 6-7 Tested hypothesised relationships with immediate response.

	Statistically significant?		
Immediate response will be associated with...	**SoFR**	**AUS**	**Merged**
Having a plan	X	✓	✓
Gender?	X	X	X
Environmental cues (smoke) impacting visibility	X	X	✓

6.3.2 Intention

For both study regions, *having a plan* of any kind was significantly associated with an *intention* to *stay-in-place*. For AUS-AE only, having a plan of any kind was also significantly associated with an *intention* to *evacuate*, while having no plan at all was significantly associated with an *intention* to *wait-and-see.* In addition, for AUS-AE: being *older*, more *wildfire experience,* being a *permanent resident,* and worse *visibility* were significantly associated with an *intention* to *stay-in-place;* less *experience,* high *community closeness*, and receiving a *recommendation to evacuate* were all significantly linked to an intention to *evacuate*; and being a *temporary resident* was significantly associated with an *intention* to *wait-and-see.* For SoFR-AE, male gender and fire safety knowledge were significantly associated with an intention to stay-in-place, while female gender was associated with intended evacuation. Only when the SoFR and AUS were merged were remaining variables significantly associated with *intention* (see Table 6-8, plus Appendix H, Table H 4)*.*

Table 6-8 Tested hypothesised relationships with intention.

	Statistically significant?		
Intended action will be associated with…	**SoFR**	**AUS**	**Merged**
Having a plan	✓	✓	✓
Pre-event risk perception	X	X	✓
Gender?	✓	X	✓
Age?	X	✓	✓
Pet ownership	X	X	✓
Experience of wildfires	X	✓	✓
Environmental cues (received)	X	X	✓
Environmental cues (seeing smoke initially)	X	X	✓
Environmental cues (smoke) impacting visibility	X	✓	✓
LoC	X	X	✓
Community closeness	X	✓	X
Fire safety knowledge	✓	X	X
Property attachment	X	✓	✓
Property insurance	X	X	✓
Advance wildfire warning	X	X	✓
Official warning (recommending evacuation)	X	✓	✓
Official warning (ordering evacuation)	X	X	✓

6.3.3 Evacuation decision

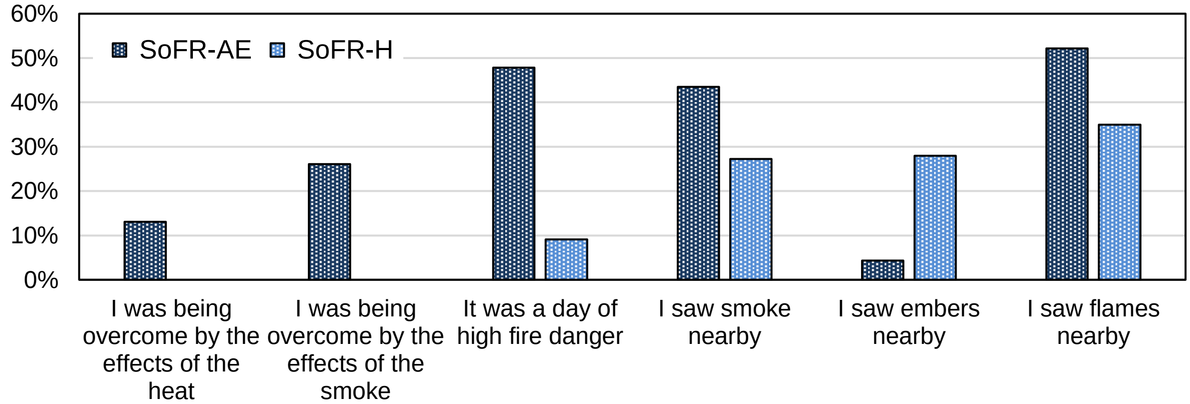
In both study regions, AE participants who initially *intended* to *evacuate* were significantly more likely to ultimately do so, while those who initially *intended* to *stay-in-place* were also significantly more likely to do so. Interestingly, those who initially *intended* to *wait-and-see* were significantly more likely to *stay-in-place* in SoFR whereas they ended up choosing evenly between *evacuation* and *staying-in-place* in AUS. *New warnings* containing an *evacuation order/ recommendation* were significantly associated with an ultimate *decision to evacuate* in both study regions also. *Warning content* that included mention of protective actions, as well as or instead of fire properties such as location, was significantly linked to the ultimate decision for SoFR-AE only. Also for SoFR-AE only, being *female* and the presence of *dependents* meant a *decision to evacuate* was significantly more likely, although efforts to *join up with others* if initially apart were significantly associated with a reduced likelihood of evacuating ultimately. Receiving initial *social cues* from an *unofficial* source (e.g. neighbours) was significantly associated with an ultimate *decision to evacuate*, while initial cues from *official* sources (e.g. fire and rescue service) were significantly linked with *staying-in-place*. Poorer *visibility* and closer *fire proximity* were only significantly associated with *evacuation* for AUS-AE. The remaining variables were either only significantly associated when using the merged data, or were not associated at all. In some cases (e.g. *age*), the lack of an association was consistent with the literature and, thus, hypotheses (see Table 6-9, plus Appendix H, Table H 5).

Table 6-9 Tested hypothesised relationships with evacuation decision.

	Statistically significant?		
Evacuation decision will be associated with...	**SoFR**	**AUS**	**Merged**
Intention	✓	✓	✓
Having a plan	X	X	X
Pre-event risk perception	X	X	✓
Gender?	✓	X	✓
Age?	X	X	X
Dependents (any kind)?	✓	X	✓
Dependents (children)?	X	X	✓
Pet ownership	X	X	✓
Experience of wildfires	X	X	✓
First cues	✓	X	✓
New cues	X	X	X
Environmental cues (smoke) impacting visibility	X	✓	X
LoC	X	X	X
Community closeness	X	X	X
Fire safety knowledge	X	X	X
Property attachment	X	X	X
Household size?	X	X	X
Property insurance	X	X	X
New warning content	✓	X	X
New warning (mentioning evacuation)	✓	✓	✓
Grouping behaviour	✓	X	✓
Fire proximity	X	✓	X

The H scenarios help to qualitatively explore decision-making further (some patterns are visible in Appendix H, Table H 6). For example, the most common initial response across all three scenarios and the two study regions was not one of evacuation; instead, participants tended to decide to first *seek information*. Additionally, in the *social cues* scenario, only a relatively small percentage of participants (c. 20%) in both study regions who did choose to *evacuate* at first changed their decision in later stages. Thus, the majority were relatively committed throughout to their decision to evacuate. In the *environmental cues* scenario, participants choosing to *evacuate* at first also tended to stay committed to this decision. However, regional responses to environmental cues differed somewhat; when confronted with nearby vegetation catching fire, most SoFR-H 'evacuees' now opted to call in firefighters. This was temporary, with evacuation becoming their more common decision again in subsequent stages when the effects of the fire escalated further. As for the third scenario, where both *social and environmental cues* were present, a relatively small proportion (c. 25%) of initial ‘evacuees’ in each region changed their mind and later decided to *stay-in-place (shelter)*. Thus, most again committed to their decision to evacuate. Further decisions of participants who first opted to seek information were similar in their patterns across both regions, especially when it came to sheltering and evacuation. In general, the decisions of SoFR-H and AUS-H participants were similar in their trends. However, in the two scenarios where environmental cues were present, the AUS-H participants who initially chose to shelter did sometimes briefly waver over this decision, unlike the SoFR-H participants. In the scenario where environmental cues were absent, there was no wavering from AUS-H participants as none of them initially decided to shelter, again unlike the SoFR participants.

Reported motivations for evacuation can provide further insight into environmental cues, their physical effects, and decisions. The H samples’ motivations suggest SoFR participants would tend to evacuate somewhat earlier and AUS participants somewhat later (Fig. 6-24). However, their AE equivalents responded opositely: those from SoFR reported a greater tendency to have decided to evacuate once seeing flames and being overcome by the effects of fire, and those from AUS more commonly reported evacuating upon the sight of smoke and an awareness that it was a high fire danger day, suggesting participants in AUS were more sensitive to environmental changes and their decision-making more affected in turn.



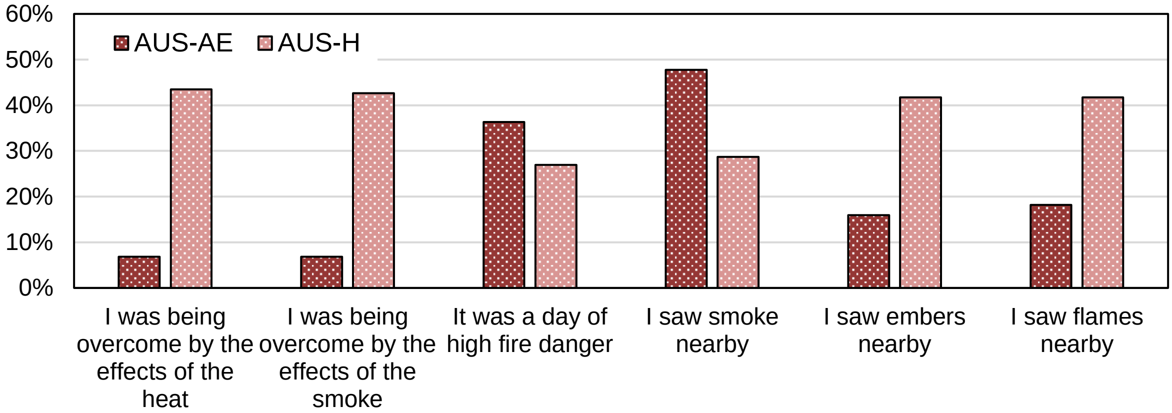


Fig. 6-24 Environmental-based motivations for evacuation in SoFR (top) and AUS (bottom).

6.3.4 Evacuation destination and ingress attempt

For the H (but not AE) samples, *route knowledge* was significant; i.e. participants who did not know where they would evacuate to were less familiar with the evacuation routes than were participants who specified an evacuation destination (SoFR: a church or hall; AUS: another town or village). AE participants' *evacuation destination* was not not significantly associated with *fire proximity* (see Table 6-10, plus Appendix H, Table H 7).

Table 6-10 Tested hypothesised relationships with evacuation destination.

	Statistically significant?		
Evacuation destination will be associated with...	**SoFR**	**AUS**	**Merged**
Fire proximity	X	X	N/A
Evacuation route knowledge	✓(H)	✓(H)	N/A

Yet Fig. 6-25 reveals that fewer participants evacuated to another town/village the closer the fire was; in cases where the fire eventually reached the property, participants often tended not to have left that property.

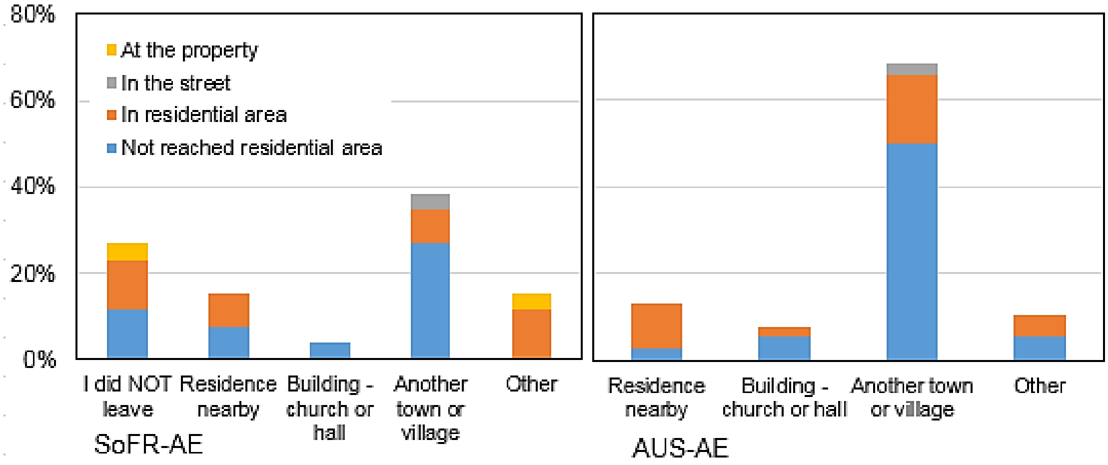


Fig. 6-25 Fire proximity and destination choice (*left*: SoFR, *right*: AUS-AE).

Several *motivations* were reported by AE participants who evacuated but then *attempted ingress*. Most often, they returned early because, in their view, the threat had passed (SoFR: 43%; AUS: 53%) but, in general, attempts tended to centre around a desire to check on the safety of things – usually property (SoFR: 29%; AUS: 35%) or, in AUS only, pets/livestock (SoFR: 0%; AUS: 41%). H participants most often envisaged attempting ingress to check on the safety of family/friends (SoFR: 28%; AUS: 25%), although perceiving the threat to have passed was also a commonly chosen motivation (SoFR: 25%; AUS: 24%).

6.3.5 Future decision

In both regions, AE participants whose *past evacuation decision* (i.e. past action) was to evacuate were significantly likely to repeat that decision in the *future*. *Females* were also significantly more likely to decide to evacuate in the future. An external *LoC* was significantly linked to future decision to evacuate, but only in AUS. In SoFR, a *future decision* to evacuate was significantly associated with *injuries* resulting from the wildfire (regardless of whether participants evacuated or stayed-in-place). On the other hand, a significant association was observed in both study regions between being female and reporting *injuries* (psychological and/or physical) (see Table 6-11, plus Appendix H, Table H 8 and Table H 9).

Table 6-11 Tested hypothesised relationships with future decision.

	Statistically significant?		
Future decision will be associated with...	**SoFR**	**AUS**	**Merged**
Evacuation decision (past action)	✓	✓	✓
Gender?	✓	✓	✓
LoC	X	✓	✓
Injuries	✓	X	✓

6.4 The role of emotion and perceived risk in wildfire responses

Firstly, it was hypothesised that emotions and risk would be felt differently depending on the *stage of the wildfire*. This was tested by exploring the H samples' responses to the different wildfire scenarios when they had escalated to their peak, as well as analysing the AE samples' responses across different event stages (receipt of first cues [FC], receipt of new cues [NC], following decision-making [DM] about evacuating/ staying-in-place).

The comparisons of emotion-related states and perceived risks across the H scenarios (Appendix H, Table H 10) showed some significant differences when environmental cues were present. For example, participants in both study regions reported feeling more fearful when environmental cues peaked (Scenario 2) than when social cues peaked (Scenario 1). The AUS-H sample also felt more helpless in the environmental cues scenario, while the SoFR-H sample felt more nervous and alert. When examining responses to Scenario 3 (social + environmental cues), SoFR-H participants felt significantly less energetic here than when faced with environmental cues alone, while AUS-H participants felt significantly more nervous and fearful here compared to when facing just social cues. Similarly, the perceived risk of injury (both to one's self and to family/friends) was significantly greater in Scenarios 2 and 3; this was usually the case in both study regions. So, overall, if a wildfire scenario involved environmental cues at all, its peak escalation evoked greater levels of emotion and perceived risk from H samples.

As for the emotion-related states of AE participants, the results revealed that they were dynamic across the three stages examined: receipt of first cues (whether a warning received via a social source or environmental cues), receipt of new cues, and following decision-making regarding evacuating or staying-in-place (Appendix H, Table H 11). Such dynamics were noted when looking at the sample as a whole in each region, as well as when looking at those who evacuated versus those who did not within each sample. In summary: the feeling of fear was often at its greatest upon receipt of the first cues and, for some in both regions, decreased significantly across subsequent stages; those who eventually evacuated in SoFR felt more annoyed when receiving the first cues; the feeling of helplessness, and in some cases nervousness, increased upon the receipt of new cues in AUS, while some participants in both regions now felt less relaxed; some AUS participants' concerns over the risk of losing utilities, their residence being damaged, and their jobs being disrupted, peaked upon the receipt of new cues; optimism increased in both regions when participants had made their ultimate decision, particularly when that was evacuation; and finally, in SoFR, participants felt less alert when having made their ultimate decision, particularly if that was to stay-in-place.

Secondly, *emotions* and *risk perceptions* were analysed in relation to the *future decision*. In comparison to those who would evacuate again, *evacuees* who would *choose to stay in the future* reported feeling significantly more *annoyed* after making their ultimate decision during their described wildfire; this was only observed in SoFR. In comparison to those who would stay-in-place again, *non-evacuees* who would *choose to evacuate instead in the future* reported feeling significantly more *energetic*, *helpless* and *fearful* after making their ultimate decision; this time, differences were only observed in AUS. Appendix H, Table H 12 summarises the feelings and concerns of evacuees and non-evacuees according to whether or not they would make the same decision again in the future. In addition, the *perceived risk of job disruption* differed significantly between those who would make the same decision again and those who would not. *Evacuees* who would *decide to stay in future* (in AUS) perceived a significantly greater risk of this kind, while *non-evacuees* who would *evacuate in future* (in SoFR) perceived significantly less risk.

Thirdly, *gender differences* in *emotion* and *risk perception* were looked at. The aim was to understand whether there is a consistent pattern of male-female responses in wildfires, regardless of circumstances. This was addressed by looking first at the H samples' responses, considering all wildfire scenarios equal (Appendix H, Table H 13). In both study regions, females reported feeling significantly more nervous and fearful, and significantly less relaxed, than males. Additionally, females in SoFR felt more helpless and less optimistic, and perceived a greater risk of residence damage, while AUS females perceived a greater risk of injury to one's self and family/friends.

When *emotions* and *perceived risk* were compared by *gender* in AE participants, significant differences were again found (Appendix H, Table H 14). In both regions, females reported feeling less relaxed and more helpless, nervous, fearful, and alert, plus they perceived a greater risk of residence damage and injury to family/friends, than did males. Additionally, females in SoFR reported feeling less optimistic yet perceived a lower risk of loss of utilities. Thus, overall in the H and AE samples, females appeared to feel greater negative emotions than males. Moreover, females appeared to perceive greater risk of the kind that poses a direct threat of harm (to persons and property), while males did not appear to perceive as much risk; when they did, it was risk of a more indirect kind.

Finally, *broader patterns of human responses* regarding *emotion* and *risk perception* were explored. The aim here was to identify if people's feelings and concerns when faced with a wildfire could each be "boiled down" into a small set of fundamental components. For example, it was already noted above in this section (on gender differences) that the different emotions felt could be grouped under the term "negative" for some participants as compared to "positive".

This analysis was done with the help of exploratory principal component analysis (PCA), which also provided factor scores that are used in a regression model later on in Chapter 7. PCA involves using mathematical procedures to reduce a number of variables into a smaller number of variables, ones which retain the majority of the information available in the original set, thereby explaining as much of the variance in the data as possible. The procedures involve testing the extent of the correlation between the original variables and each newly created variable (component); if there is a strong correlation, the original variables are said to “load” highly on the component. However, sometimes the loadings may not give a clear picture of which component the variables are supposed to comprise (e.g. if component 1 is imagined as being along the x-axis and component 2 along the y-axis, some variables may lie squarely in the middle of both axes while other variables may not lie near either of these axes). Therefore, a further procedure can be employed which involves retaining the position of the variables but rotating the axes to reveal a clearer picture (e.g. finding that each cluster of variables now more closely aligns with one of these axes). The researcher must then draw upon their professional understanding of the subject matter and common sense to interpret which of the identified components are important and should be kept (or otherwise rejected and the analysis re-run) and, subsequently, what these components represent.

In order to find the optimal loading strategy, one that closely resembled existing analysis published by Lindell (2016), albeit on hurricanes, and gave the most interpretable output, several rotation methods which allowed values to load maximally onto a component (Field, 2013) were tested:

- Principal component – Varimax – as used by Lindell (2016)
- Maximum likelihood – Varimax – as used by Lindell (2016)
- Principal axis factoring – Promax – as used by Lindell (2016)
- Principal component – Oblimin – as recommended by Field (2013)

The PCA analysis presented here was monitored to meet the following assumptions:

- KMO - Kaiser-Meyer-Olkin Measure of Sampling Adequacy > 0.6;
- Bartlett's Test of Sphericity *p* > .05;
- Correlation Matrix – correlations of 0.3 and higher;
- Eigenvalues > 1.0;
- Loading for sample size as follows: n = 50 loading >= 0.722; n = 100 loading >= 0.512; n = 200 loading >= 0.364;
- Rotated values here are all represented > = 0.3;
- Only rotated values are represented.

For emotions, two components were acceptable following the assumption of valence, i.e. emotions are along the spectrum of negative and positive (Salzman & Fusi, 2010). After applying four types of rotation on the SoFR data, the most robust results were produced by PCA with direct oblimin rotation (Field, 2013). However, across all types of analysis, a trend was seen of some strongly negative loadings. To achieve more clarity, three emotion-related states – “passive”, “relaxed”, “optimistic” – were reversed into “activeREV”, “tenseREV” and “pessimisticREV”. This was not reported as necessary in Lindell’s (2016) study, even though when a scale contained a negative emotion variable it seemed to affect the scale’s Cronbach’s alpha score (i.e. reliability score). This process, once tested on SoFR data, was readily applied to the AUS data based on the assumption that if the process worked for the first group of data, and if the constructs were reliable, then it should also be applicable to the AUS data.

Hypothetical Scenarios: Emotion PCA

When performing PCA on the H samples’ data, all scenarios were considered in one analysis. Initially, for SoFR-H, after considering all nine emotion variables, three components were extracted (variance explained = 63%). The analysis was re-run to extract two components to represent the positive/negative distinction of emotional valence. This time, three variables (energetic, annoyed, alert) showed poor performance (communalities < 0.3) (Field, 2010) – that is, not much of the variance in those variables was explained by the two components – and so these variables were taken out. After the analysis was re-run again, two components were extracted and accepted (KMO = 0.736, variance explained = 69%). They were interpreted as representing a “Negative State” and a “Positive Active Attitude”, respectively. Since the emotion “helpless” now loaded highly but negatively on the latter component, it was re-coded as “capable”. Scale reliability was tested using Cronbach’s alpha, and component (factor) scores were saved accordingly for each scale; put simply, factor scores are the participants’ original rating-scale scores re-calculated based on the loadings and then standardised. The tests of reliability suggest the H questionnaire captured negative emotional responses well. However, a low alpha value for Positive Active Attitude (reported below) raises doubt as to whether the H questionnaire was able to capture a good understanding of positive emotional responses in a wildfire event (Table 6-12).

SoFR-H components:

Negative State (1): Pessimistic, Tense, Nervous, Fearful (α = 0.830).

Positive Active Attitude (2): Capable, Active (α = 0.428).

Initially, for AUS-H, when all nine emotion variables were considered, two components were extracted automatically (variance explained = 53%). As ‘annoyed’ showed poor performance (communalities < 0.3), this variable was taken out and the analysis re-run. This second iteration produced satisfactory results (KMO = 0.710, $p < .001$, variance explained = 58%). However, the variables ‘alert’ and ‘energetic’ were also taken out since they were now effectively synonymous with the reversed ‘passive’ variable ('active') and their removal aligned the two components with that for SoFR-H, enabling a direct comparison across the two study regions (Table 6-12 and Table 6-13). In the final iteration, 66% of the variance was explained (similar as for SoFR-H). As before, the reliability tests suggest the H questionnaire captured negative emotional responses well but positive emotional responses less well.

AUS-H components:

Negative State (1)*:* Pessimistic, Tense, Nervous, Fearful (α = 0.793).

Positive Active Attitude (2)*:* Capable, Active (α = 0.275).

Table 6-12 Pattern Matrix: Final set of SoFR-H components.

SoFR (N = 143) Loading accepted when component value >= .512, KMO = 0.736	Component 1	2
PessimisticREV	**.798**	.132
TenseREV	**.829**	.117
Helpless (capable)	.360	**-.660**
ActiveR	.182	**.896**
Nervous	**.815**	-.194
Fearful	**.792**	-.101

Table 6-13 Pattern Matrix: Final set of AUS-H components.

AUS (N = 116) Loading accepted when component value >= .512, KMO = 0.687	Component 1	2
PessimisticREV	**.751**	.140
TenseREV	**.730**	.396
Helpless (capable)	.487	**-.643**
ActiveR	.243	**.802**
Nervous	**.770**	-.200
Fearful	**.847**	-.075

Actual Experience: Emotion PCA

The emotions reportedly experienced across the three wildfire stages (receipt of first cues [FC], receipt of new cues [NC], following decision-making [DM] about evacuating/ staying-in-place) were considered together for the AE samples. At first, six components were extracted for SoFR-AE (KMO = 0.660, Eigenvalue > 1, $p < .001$, variance explained = 77%). In line with the H samples' analysis, components were reduced to two and the analysis was re-run twice to achieve component consistency closer to that of SoFR-H.

For AUS-AE, eight components were first extracted (KMO = 0.690, $p < .001$, variance explained 79%). The analysis was re-run to extract two components, but the outcome was not satisfactory. As Table 6-14 shows, few variables loaded highly on one of these components. It was also noticeable that none loaded highly on component (2). Furthermore, both the AUS-AE and SoFR-AE loadings suggested that the components differed across the response stages.

Table 6-14 Pattern Matrix: SoFR-AE and AUS-AE PCA, initial comparison of components.

SoFR (N = 52) Loading accepted when component value > 0.722	Component		AUS (N = 69) Loading accepted when component value>0.722	Component	
	1	2		1	2
ActiveREV FC	.133	**.812**	ActiveREV FC	.073	.643
Alert FC	.638	.136	Alert FC	.125	.303
Annoyed FC	.199	-.641	Annoyed FC	.433	-.475
Energetic FC	.124	.570	Energetic FC	-.018	.110
Fearful FC	**.723**	-.265	Fearful FC	.700	.111
Helpless FC	.705	-.173	Helpless FC	.620	-.375
Nervous FC	**.731**	<.001	Nervous FC	.704	.078
PessimisticREV FC	.589	.005	PessimisticREV FC	.336	.304
TenseREV FC	**.784**	.125	TenseREV FC	.478	.492
ActiveREV NC	.103	**.776**	ActiveREV NC	.035	.699
Alert NC	.690	.001	Alert NC	.499	.102
Annoyed NC	.257	-.627	Annoyed NC	.491	-.473
Energetic NC	.164	**.753**	Energetic NC	.111	.203
Fearful NC	**.745**	-.233	Fearful NC	**.867**	.036
Helpless NC	.475	-.499	Helpless NC	**.727**	-.515
Nervous NC	**.808**	-.070	Nervous NC	**.865**	-.022
PessimisticREV NC	**.777**	.089	PessimisticREV NC	.460	.193
TenseREV NC	.582	.014	TenseREV NC	.573	.494
ActiveREV DM	-.070	**.738**	ActiveREV DM	-.024	.586
Alert DM	.581	.257	Alert DM	.286	.057
Annoyed DM	.174	-.577	Annoyed DM	.506	-.520
Energetic DM	.105	.660	Energetic DM	.109	.265
Fearful DM	.566	-.121	Fearful DM	**.804**	-.069
Helpless DM	.670	-.163	Helpless DM	**.738**	-.436
Nervous DM	.620	.052	Nervous DM	**.814**	-.032
PessimisticREV DM	.609	.020	PessimisticREV DM	.525	.136
TenseREV DM	.647	.212	TenseREV DM	.604	.153

Thus, a case-by-case component analysis was run for the emotions, looking at each response stage separately. Some discrepancies appeared in terms of consistency in variable loading (SoFR-AE: Table 6-15; Table 6-16; Table 6-17; AUS-AE: Table 6-18; Table 6-19; Table 6-20), with some but not all emotion variables performing well (communalities > 0.3) and occasionally loading highly on the opposite component. In general, there still appeared to be a clearly negative emotional state, seen across all three stages. However, for the first stage some participants appeared to experience an emotional state that was partially negative but also partially positive. This state seemed to represent vigilance, with participants anticipating and being unhappy about an approaching threat yet not willing to just give in and wait for its arrival, instead keenly monitoring for its presence. At the second stage, a wholly positive emotional state was experienced by some, seeming to represent readiness, with participants now being more informed about the threat and feeling able to face it. Nevertheless, by the third stage, a positive state was undetectable, with participants' decision-making about whether to evacuate or stay appearing to be dominated by negative emotions.

SoFR-AE components:

- **1st stage (FC)**

Negative State (1)*:* Tense, Nervous, Fearful (α = 0.795)

Vigilant State (2): Active (α = n/a)

- **2nd stage (NC)**

Negative State (1)*:* Pessimistic, Tense, Nervous, Fearful, Alert (α = 0.818)

Vigilant State (2): Active (α = n/a)

- **3rd stage (DM)**

Negative State (1)*:* Pessimistic, Tense, Nervous, Fearful (α = 0.806)

Vigilant State (2): Energetic (α = n/a)

AUS-AE components:

- **1st stage (FC)**

Negative State (1)*:* Helpless; Annoyed; Nervous; Fearful (α = 0.760).

Vigilant State *(*2)*:* Pessimistic; Tense; Active; Alert (α = 0.576).

- **2nd stage (NC)**

Negative State (1)*:* Tense, Nervous, Fearful (α = 0.850).

Ready State (2): Capable (α = n/a).

- **3rd stage (DM)**

Negative State (1)*:* Pessimistic, Tense, Nervous, Fearful (α = 0.867).

Table 6-15 Pattern Matrix: Final set of SoFR-AE components (FC).

Stage 1 - FC		
N = 74, value => 0.722	Component	
55% variance explained	1	2
PessimisticREV	.648	-.078
TenseREV	**.835**	.112
Energetic	-.003	.689
Helpless	.677	-.246
Annoyed	.267	-.664
ActiveREV	.083	**.793**
Nervous	**.794**	.035
Fearful	**.776**	-.126
Alert	.549	.387

Table 6-16 Pattern Matrix: Final set of SoFR-AE components (NC).

Stage 2 - NC		
N = 61, value => 0.722	Component	
59% variance explained	1	2
PessimisticREV	**.824**	.176
TenseREV	**.728**	.141
Energetic	.186	.681
Helpless	.482	-.569
Annoyed	.213	-.646
ActiveREV	.072	**.834**
Nervous	**.776**	-.110
Fearful	**.725**	-.294
Alert	**.742**	.005

Table 6-17 Pattern Matrix: Final set of SoFR-AE components (DM).

Stage 3 - DM		
N = 62, value => 0.722	Component	
59% variance explained	1	2
PessimisticREV	**.731**	-.292
TenseREV	**.782**	-.177
Energetic	.060	**.931**
Helpless	**.797**	-.097
ActiveREV	-.240	.587
Nervous	.719	.199
Fearful	**.728**	.058
Alert	.535	.475

Table 6-18 Pattern Matrix: Final set of AUS-AE components (FC).

Stage 1 - FC		
N = 96; value= 0.512	Component	
55% variance explained	1	2
PessimisticREV	.075	**.547**
TenseREV	.188	**.749**
Helpless	**.789**	.106
Annoyed	**.730**	-.351
ActiveREV	-.375	**.666**
Nervous	**.726**	.322
Fearful	**.658**	.366
Alert	.149	**.585**

Table 6-19 Pattern Matrix: Final set of AUS-AE components (NC).

Stage 2 - NC		
N = 81, value => 0.722	Component	
60% variance explained	1	2
PessimisticREV	.625	.057
TenseREV	**.856**	.195
Helpless (capable)	.448	**-.725**
Annoyed (comfortable)	.101	-.656
ActiveREV	.407	.692
Nervous	**.792**	-.344
Fearful	**.780**	-.318
Alert	.593	.052

Table 6-20 Pattern Matrix: Final set of AUS-AE components (DM).

Stage 3 - DM		
N = 79, value => 0.722	Component	
67% variance explained	1	2
PessimisticREV	**.795**	.194
TenseREV	**.850**	.203
Helpless	.642	-.549
Annoyed	.293	-.597
ActiveREV	.299	.708
Nervous	**.868**	-.110
Fearful	**.832**	-.188

Hypothetical Scenarios: Perceived Risk PCA

For SoFR-H, the perceived risk items loaded on two components, showing that two types of wildfire risk exist here – a risk of injury to persons, and a risk of disruption to the surrounding personal or professional environment (KMO = 0.644, variance explained = 62%) (Table 6-21). However, the reliability tests indicated, perhaps surprisingly, that risk perceptions regarding injury to persons generally were not captured well; this might reflect social differences across participants (e.g. some might have a large family or close network of friends while others might be more solitary, and therefore the focus of their respective concerns might vary accordingly).

SoFR-H components:

Injury (1): personal injury, family/friends' injury (α = 0.377).

Disruption (2)*:* residence damage, loss of utilities, job disruption (α = 0.645).

For AUS-H, after job disruption was eliminated due to showing poor communalities, the PCA returned only one component on which variables loaded effectively (KMO = 0.572, variance explained = 83%) (Table 6-21), meaning that the AUS and SoFR samples' perceptions differ in their components. It would appear that AUS-H participants were concerned that a wildfire could negatively impact their personal lives more generally.

AUS-H component:

Personal Life Impact (1): personal injury, family/friends' injury, residence damage, loss of utilities (α = .715).

Table 6-21 Pattern Matrix: Final set of SoFR-H and AUS-H components.

SoFR N = 143; KMO = .644; 62% variance explained; loading > 0.512	Component		AUS N = 115; KMO = .572; 83% variance explained; loading > 0.512	Component	
	1	2		1	2
Loss of utilities	**.894**	-.219	Loss of utilities	**.707**	.585
Job disruption	**.738**	.095			
Residence damage	**.580**	.357	Residence damage	**.767**	.475
Family/friends injury	-.131	**.866**	Family/friends injury	**.704**	-.592
Personal injury	.136	**.647**	Personal injury	**.773**	-.468

Actual Experience: Perceived Risk PCA

For SoFR-AE, items were forced to load onto two components. As in the SoFR-H analysis, the two components consisted of *injury* and *disruption*. However, not all variables loaded strongly and only the 3rd stage *disruption* component achieved KMO > 0.600 (Table 6-22; Table 6-23; Table 6-24).

SoFR-AE components:

- **1st stage (FC)**

Injury (1): my injury, family/friends' injury (α = .553).

Disruption (2): job disruption (α = n/a).

- **2nd stage (NC)**

Injury (1): my injury, family/friends' injury (α = .581).

Disruption (2): loss of utilities, job disruption (α = .297).

- **3rd stage (DM)**

Injury (1): family/friends' injury (α = n/a).

Disruption (2): loss of utilities, job disruption (α = .321).

For AUS-AE, items were also forced onto two components. Only the components in the first and second stages achieved KMO > 0.600, and in both cases formed *personal life impact* (Table 6-25; Table 6-26; Table 6-27).

AUS-AE components:

- **1st stage (FC)**

Personal Life Impact (1): personal injury, loss of utilities, residence damage, family/friend's injury (α = .721).

Disruption (2): job disruption (α = n/a).

- **2nd stage (NC)**

Personal Life Impact (1): loss of utilities, residence damage (α = .784).

Disruption (2): job disruption (α = n/a).

- **3rd stage (DM)**

Personal Life Impact (1): loss of utilities, residence damage (α = .819).

Disruption (2): job disruption (α = n/a).

Overall, it seems that there is a difference between the two regions' risk perception, with SoFR-AE participants focusing on the risk of disruption at the decision-making stage and AUS-AE participants focusing on the risk of their personal life being impacted in the first/new cues stages.

Table 6-22 Pattern Matrix: Final set of SoFR-AE components (FC).

Stage 1 - FC		
N = 74; KMO = 0.501	Component	
Loading value = 0.722	1	2
65% variance explained		
My injury	**.836**	.143
Loss of utilities	-.270	.679
Family/friends injury	**.784**	-.137
Job disruption	.238	**.808**

Table 6-23 Pattern Matrix: Final set of SoFR-AE components (NC).

Stage 2 - NC		
N = 59; KMO = 0.570	Component	
Loading value = 0.722	1	2
57% variance explained		
My injury	**.764**	-.114
Loss of utilities	-.042	**.768**
Residence damage	.671	-.049
Family/friends injury	**.790**	.208
Job disruption	.035	**.748**

Table 6-24 Pattern Matrix: Final set of SoFR-AE components (DM)

Stage 3 - DM		
N = 62; KMO = 0.602	Component	
Loading value = 0.722	1	2
59% variance explained		
My injury	.688	.123
Loss of utilities	-.004	.750
Residence damage	.681	.049
Family/friends injury	.913	-.149
Job disruption	.019	.779

Table 6-25 Pattern Matrix: Final set of AUS-AE components (FC).

Stage 1 - FC		
N = 96; KMO = 0.653	Component	
Loading value = 0.512	1	2
65% variance explained		
My injury	**.650**	.312
Loss of utilities	**.837**	.051
Residence damage	**.865**	-.058
Family/friends injury	**.586**	-.290
Job disruption	.002	**.930**

Table 6-26 Pattern Matrix: Final set of AUS-AE components (NC).

Stage 2 - NC		
N = 80; KMO = 0.698	Component	
Loading value = 0.722	1	2
64% variance explained		
My injury	.666	.236
Loss of utilities	**.833**	-.078
Residence damage	**.847**	-.195
Family/friends injury	.588	.069
Job disruption	.001	**.963**

Table 6-27 Pattern Matrix: Final set of AUS-AE components (DM).

Stage 3 - DM		
N = 79; KMO = .528	Component	
Loading value = 0.722	1	2
65% variance explained		
My injury	.659	.028
Loss of utilities	**.781**	.082
Residence damage	**.850**	-.132
Family/friends injury	.711	.014
Job disruption	.006	**.995**

6.5 Evacuation delay time

The aim here was to explore evacuation delay time curves, identify what individuals do prior to evacuating and how long it takes them, and finally determine which variables (see the study hypotheses in section 3.5.6) affect delay time.

6.5.1 Evacuation response curves

As mentioned earlier (see sections 2.1.3, 4.2.1, 6.1), *mobilisation time* was calculated from AE participants' estimates regarding when they received the first cues and when they left (if evacuees). *BI time* was calculated by asking AE and H participants about the actions they did/would perform prior to evacuating, the estimated time committed to each action, and then the times were summed resulting in an overall time for performing the itineraries. Again, mobilisation time is more commonly discussed in research but in reality, such data is scarce; BI time data was more available from participants in this study.

Fig. 6-26 and Fig. 6-27 show cumulative distributions of BI and mobilisation times taken from the residents' survey and other sources. The purpose of these graphs is to show the AE time data collected in SoFR and AUS and help put this into context by comparing it with other available time data related to large-scale evacuations. Two of the distributions were readily available in the literature: one synthetic mobilisation time distribution found in Tweedie (1986; nuclear power plant evacuation scenario), and one actual distribution derived from the Bushfire CRC household survey responses (Bushfire CRC, 2009; wildfire evacuations). The Bushfire CRC data had to be fitted as only fragments were available. Two additional mobilisation time distributions ('Spain 1' and 'Spain 2') were obtained via consultation with Spanish wildfire management organisation INFOCA (personal communication, anon. October 18, 2018; wildfire evacuation scenarios).

The BI time distributions from this study were noticeably different to the mobilisation time distribution from Bushfire CRC, ascending at a much greater rate compared to that (Fig. 6-26). Nonetheless, after 40 minutes, the AUS-AE distribution did start to diverge from the other time distributions and move closer to the Bushfire CRC distribution, which was also derived from Australian evacuees. When mobilisation times were compared (Fig. 6-27), some stark differences were particularly noticeable from 20 minutes onwards, with the distributions from Tweedie and Spain ascending at a greater rate and ending far earlier than the other distributions. The SoFR and AUS distributions were more similar to the one from Bushfire CRC. It is worth reiterating that Tweedie's distribution was meant for evacuation from an urban environment that was not a WUI, and from a nuclear hazard under an evacuation order. The issue with Tweedie's data is that it expects the vast majority of the population to evacuate within the first 60 minutes; based on the mobilisation times from SoFR and AUS, fewer than 50% of individuals actually do so. The BI times also warn that evacuation delays could be longer in some regions.

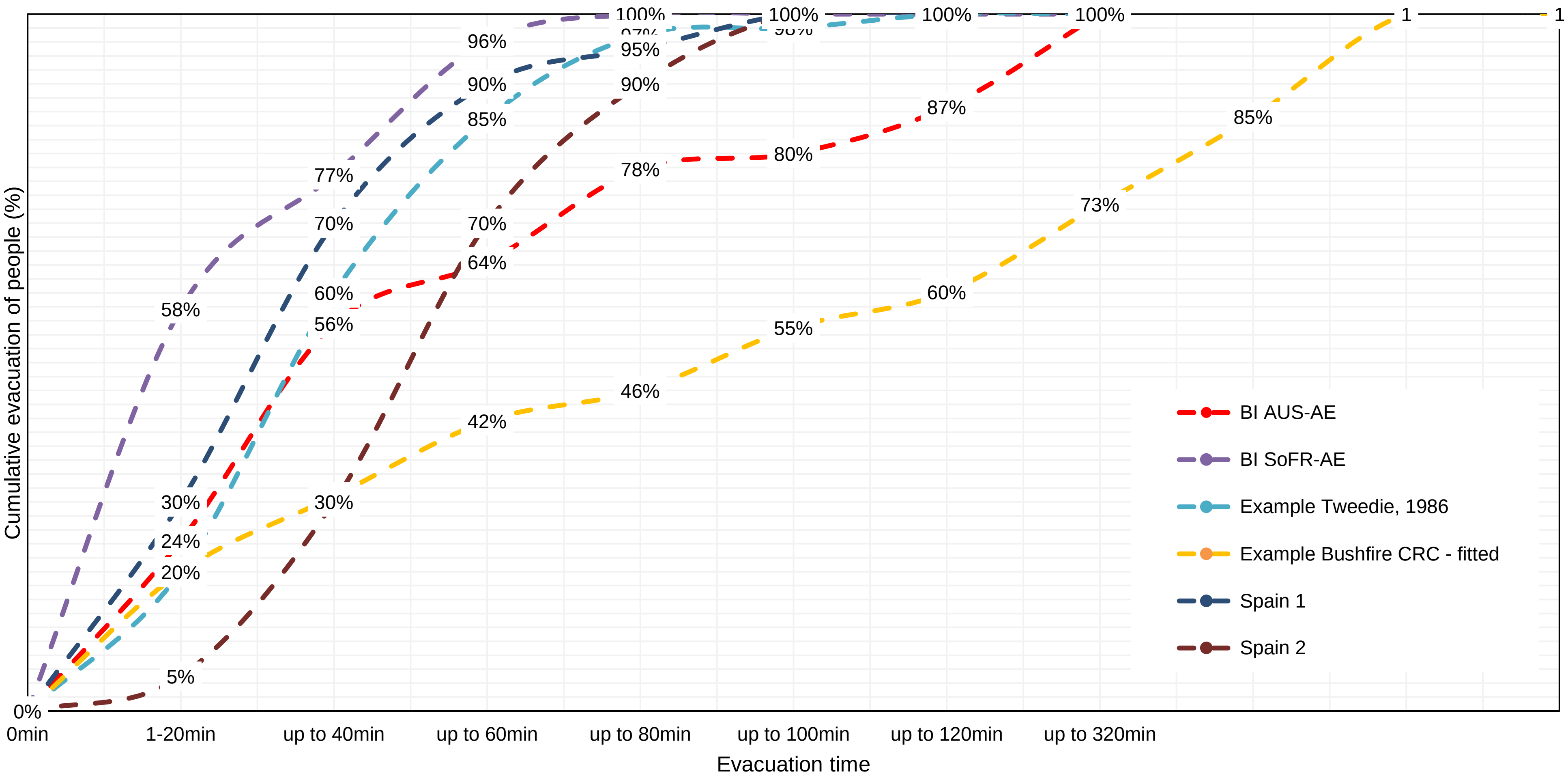


Fig. 6-26 BI time v mobilisation time cumulative distributions.

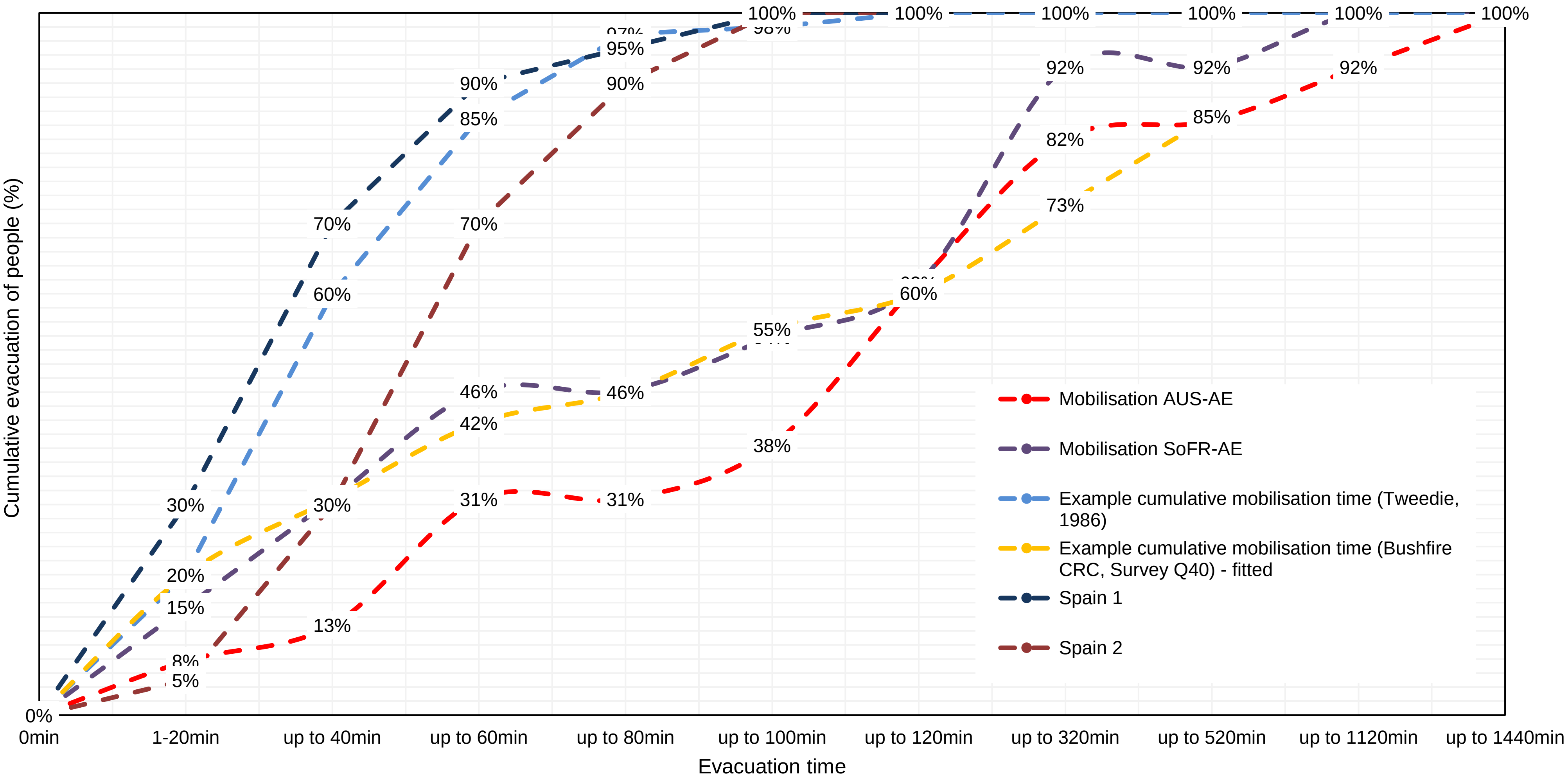


Fig. 6-27 Mobilisation time cumulative distributions.

A way to compare the distances between distribution curves was suggested by Galea et al. (2012; 2013) and Peacock et al. (1999), where two parameters are taken into account: (1) Euclidean Relative Difference (ERD) for assessing the average difference between the experimental data (or in this study's case, the newly acquired data from SoFR and AUS) and the model data (e.g. data from Tweedie and Bushfire CRC), with a recommended value of <= 0.25; and (2) Euclidean Projection Coefficient (EPC) for measuring the agreement between the experimental and model data, with recommended values between 0.8 and 1.2. The acceptance criteria for the ERD and EPC, set in the work of Galea et al. (2012), relate to maritime evacuation but propose the best accessible means of assessment to help understand whether all curves (from new data and from the literature) can be similarly regarded in evacuation modelling or whether a more specific approach is needed.

The results (Table 6-28 and Table 6-29) confirmed that, for BI time, there was more agreement between these distribution curves and Tweedie's data than with the data from Bushfire CRC. However, when it came to mobilisation time, the Spain 1 and 2 hypothetical data agreed better with Tweedie's proposed data, while the SoFR and AUS data based on real events corresponded with that from the Bushfire CRC dataset.

Table 6-28 BI time curve analysis using Galea et al. validation assessor.

BI Time case	Bushfire CRC baseline data[1]		Tweedie baseline data	
	Euclidian Relative Difference	Euclidian Projection Coefficient	Euclidian Relative Difference	Euclidian Projection Coefficient
AUS-AE	0.36	0.76	**0.14**	**1.10**
SoFR-AE	0.64	0.63	**0.16**	**0.94**
Spain 1	0.56	0.66	**0.06**	**0.98**
Spain 2	0.47	0.71	**0.14**	**1.04**

Table 6-29 Mobilisation time curve analysis using Galea et al. validation assessor.

Mobilisation time case	Bushfire CRC baseline data[1]		Tweedie baseline data	
	Euclidian Relative Difference	Euclidian Projection Coefficient	Euclidian Relative Difference	Euclidian Projection Coefficient
SoFR-AE	**0.17**	**1.04**	0.44	1.31
AUS-AE	**0.10**	**0.95**	0.33	1.23
Spain 1	0.50	0.70	**0.05**	**0.98**
Spain 2	0.41	0.75	**0.13**	**1.03**

6.5.2 Behavioural itinerary

BI times from the AE and H surveys can be compared overall, but also by grouping the discrete actions comprising itineraries into categories and then looking at how much

[1] Data has been adapted to meet the missing data point by taking the average of the two closest points of data.

time individuals commit to each category prior to evacuation, to understand where most time may be spent (lost). The five action categories were *seeking information*, *gathering belongings*, *protecting property*, *protecting life/health*, and *other miscellaneous* (e.g. eating a meal, using the bathroom). Note that since the window of opportunity for evacuating in a real-life wildfire would increasingly narrow, at varying rates for different individuals, H participants were informed that they only had a certain amount of time before they had to evacuate and were randomly assigned to either a 15-minute, a 30-minute, or a 60-minute evacuation delay group. The results (Fig. 6-28) suggest that with the exception of the 15 minutes H group, overall, SoFR participants tended to commit far less time to their behavioural itineraries than did AUS participants. For example, SoFR-AE participants committed 12.00 minutes (median time, IQR = 5.00-36.13) to their behavioural itineraries; this was around one third of the time committed by AUS-AE participants (Mdn = 34.50 min, IQR = 19.50-73.75). While the AE groups' median times were shorter than some of the H groups', it is nonetheless important to note that the interquartile ranges show some actually took much more time before commencing evacuation. That is, the middle 50% of SoFR-AE participants took up to around two-thirds of an hour while the middle 50% of AUS-AE participants took up to around one hour and a quarter.

Regardless of what region they were in, what questionnaire they completed, or what time pressure they were faced with, participants always committed a relatively greater amount of time to Gathering Belongings (i.e. this category was always first in the sequence of action categories to which they committed most to least time; see Fig. 6-29). Additionally, Protecting Property and especially Other Miscellaneous activities never dominated participants' time (i.e. these categories always came fourth and fifth in the sequence). In SoFR, the second most time was always committed to Protecting Life/Health, and the third most time to Seeking Information, regardless of group. In AUS, the 15 and 60 minutes H groups followed this same sequence, although the 30 minutes H group prioritised time for Seeking Information over Protecting Life/Health while the AE group committed equal time to both categories.

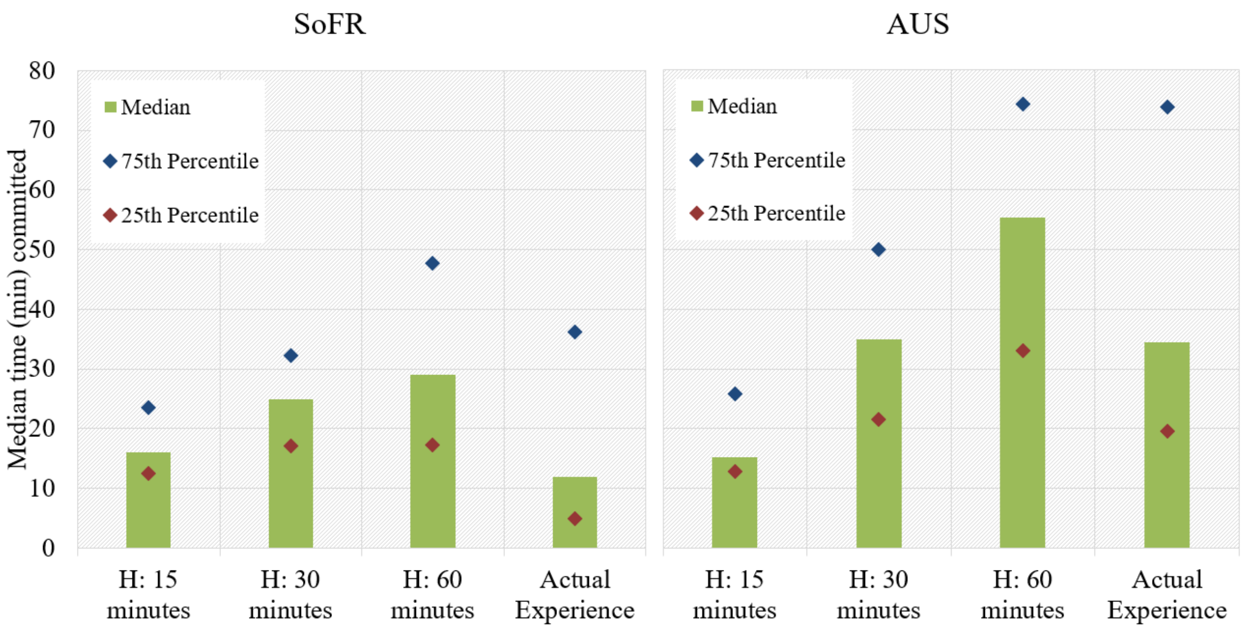
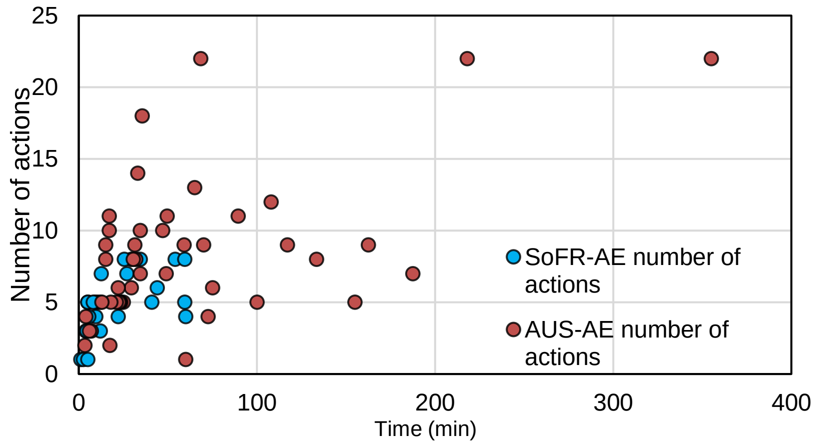


Fig. 6-28 Overall BI time by H and AE participants in each region; error bars represent the interquartile range.

Fig. 6-29 BI time (%) per action category by H and AE participants in each region.

Also, the *number of discrete actions* reported by participants was compared with *BI times* (Fig. 6-30) and found to be highly correlated in SoFR (AE: Spearman's rho = .67, $p < .001$; H: rho = .56, $p < .001$) and AUS (AE: rho = .46, $p = .002$; H: rho = .70, $p < .001$).



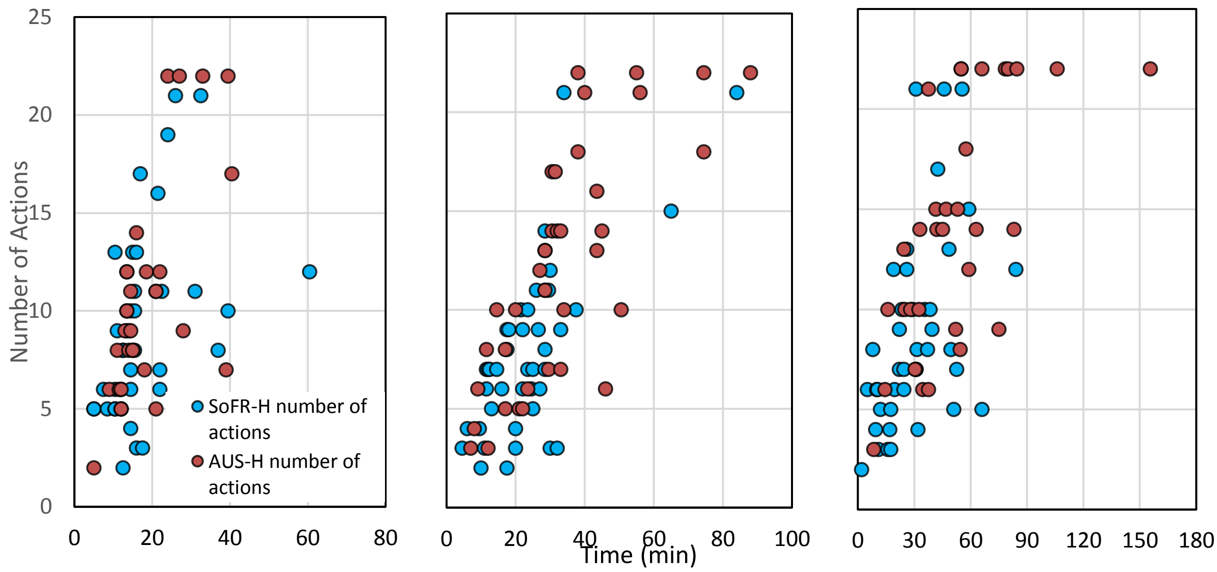


Fig. 6-30 BI times and number of actions for AE (top) and H (left to right: 15, 30, 60 min) samples.

6.5.3 Pre-event variables

Gender did play a role in *evacuation delay*, albeit not uniformly. Only SoFR-AE females undertook significantly more BI actions than males, although AUS-H females committed significantly more *BI time* to protecting life/health and seeking information than males, and both AUS-AE and H females took significantly longer than males to gather belongings. Nevertheless, in no region was *gender* significantly associated with overall *BI time*. AUS-AE participants who had *fire safety knowledge* committed significantly more *time* to performing their itineraries compared to those without such knowledge. SoFR-AE and/or H participants residing in a *family house* had significantly more *BI actions* and significantly longer *BI times* than those residing in other types of property, while the *number of actions* in SoFR-H participants' itineraries significantly increased along with their household size. However, *age* and *medical conditions* were not significantly linked to *BI actions or time* in either study region (see Table 6-30, plus. Appendix H, Table H 15 and Table H 16).

Table 6-30 Tested hypothesised relationships with evacuation delay.

	Statistically significant?		
BI actions overall will be associated with...	**SoFR**	**AUS**	**Merged**
Gender	✓(AE)	X	N/A
Fire safety knowledge	X	X	N/A
Property type (family house)	✓(AE)	X	N/A
Household size	✓(H)	X	N/A
Age	X	X	N/A
Medical conditions	X	X	N/A
BI times overall will be associated with...			
Gender	X	X	N/A
Fire safety knowledge	X	✓(AE)	N/A
Property type (family house)	✓	X	N/A
Household size	X	X	N/A
First cues (environmental)	X	X	N/A
Age	X	X	N/A
Medical conditions	X	X	N/A
Fire proximity	X	X	N/A

6.5.4 Peri-event variables

Next explored was whether *BI time* was affected by *ASET-related information*; that is, information about when the fire was expected to reach the individual's location or, in other words, the time available for evacuation to commence. Often, H participants complied with the time they were told was available to them before evacuation had to commence (Fig. 6-28). Nonetheless, some deviations were present. When assigned just 15 minutes, participants exceeded the time slightly in both SoFR (Mdn = 16.00 min, IQR = 12.50-23.50) and AUS (Mdn = 15.25 min, IQR = 12.75-25.75). Also, when assigned 30 minutes, AUS participants were excessive with their time (Mdn = 35.00 min, IQR = 21.50-50.00). The interquartile ranges are again worth noting as they show a substantial percentage of additional participants committed even longer times – in this case, greater excesses – than these medians indicate. In both regions, AE participants were grouped into those who reported knowing the fire reached their residential area versus those who did not have such knowledge. However, no significant relationship was found between a closer *fire proximity* and *BI times*, except for in one case: the AUS group who knew the fire got as close as their residential area had significantly longer BI times than the SoFR group with similar fire proximity knowledge. AE groups who *first learned of the fire via environmental cues* (so, again, an indication of closer fire proximity) did not seem to differ significantly in their *BI times* from those who received other cues initially. However, the AUS group whose first cues were environmental ones had significantly longer BI times than the equivalent SoFR group. So, in other words, AUS participants who could sense the presence of a fire nearby, and therefore had greater opportunity to understand how quickly it was approaching their residential area, took more time prior to evacuating than did SoFR participants who were experiencing similar conditions (see Appendix H, Table H 17).

Chapter Summary

This analysis of survey data from residents in two study regions provided insight into several areas. A mixture of contextual and risk-related elements was associated with pre-event perceived risk and having a plan for responding to a wildfire. Participants' immediate responses were mainly determined by the environmental conditions (physical context), and emotional states such as feeling fear were also prevalent around this time. Intentions were significantly associated with a wider array of variables, while ultimate decisions were frequently guided by intentions, with emotions changing around this time. Destination choices were largely constrained by the context, such as fire proximity. Ingress attempts appeared to be motivated by risk-related elements, with participants perceiving a lowered threat to themselves (without confirmation from official sources) but having concerns for the safety of loved ones/property in the hazard zone. Decisions about future responses to a wildfire were informed by personal characteristics such as gender and LoC, as well as past behaviour (and perhaps emotional memories of that), plus the experience of consequences such as injury. Relationships between variables were occasionally the same but oftentimes different for the two study regions; other times, the merged data would reveal a significant difference/association where data from an individual study region would not, suggesting that a larger sample size was needed to find a smaller effect. Finally, when evacuation delay time was analysed, the data suggested that, in some circumstances, delays could be longer than currently anticipated by researchers and longer than residents were warned was safe.

Chapter 7 Application of results: predicting human behaviour

The quantitative findings so far have shown significant associations between variables. This can help explain outcomes in previous wildfires. However, it is important to also plan ahead for future incidents: what might determine the likelihood of certain behavioural outcomes if another wildfire were to occur? To show how collected data can be applied in answering such a practical question, two types of regression techniques were employed. First, logistic regression to identify which independent variables are significant predictors of responses related to wildfire decision-making. Secondly, simple and multiple linear regression to predict evacuation delay time. This chapter then goes on to demonstrate how a regression model can help create another type of model, one that may be more easily understood by users (or developers) of evacuation modelling tools. Finally, the findings stemming from triangulation of the qualitative and quantitative analyses are appraised. This aims to give an overview of important behavioural motivations and their differences/ similarities across two study regions, and help inform policy-making and practice.

7.1 Decision-making before, during and after a wildfire

Regression analysis requires larger sample sizes because multiple independent variables are included in each model that is tested. In a previous large-scale study, the sample size for such analysis was suggested to be N = 300 (AFAC, 2015), which is larger than available in this study for a single region. Thus, the data from AE participants in SoFR and AUS were merged into a single sample, albeit for mostly illustrative purposes since some regional differences have been shown in Chapter 6. The results of the merged-data models that best predicted human behaviour related to decision-making are presented in the Appendix I, Tables I 1 to I 10, with "best" being evaluated via such metrics as the percentage of correct predictions (showing how well a model classifies cases from the independent variables into the correct outcome category) and R^2 values (showing how well the model explains variation in the outcome variable). The best models are the ones with higher metric values than other models tested for predicting the same outcome. However, the best models should also be acceptable – that is, make correct predictions the majority of the time (i.e. correctly classify far more than 50% of cases) or explain at least a small amount of variation (e.g. around 10% [.10] or more) (Bryman & Liao, 2019) in the highly complex human behaviour being studied as opposed to a negligible amount. A further criterion to being acceptable is that both the models themselves and some of the variables within them should be significant. Finding such models makes it possible to subsequently suggest illustrative models for application to evacuation modelling.

The variables for the binary logistic regression analysis were chosen with the help of the CIBER-t framework, as they were in Chapter 6. The variables were then fitted using hierarchical analysis (Field, 2015). In addition, the variables were analysed keeping the event stages in mind. That is, pre-event variables (i.e. pre-existing characteristics of the participant, their household and property) were first selected and tested for their capacity to form significant models to predict relevant event outcomes such as whether participants had a plan, whether they initially intended to evacuate, and whether they ultimately decided to evacuate (Fig. 7-1). Then peri-event variables relevant to certain moments during the event – i.e. upon receipt of the first cues, receipt of new cues, and having made the decision to evacuate – were selected and tested. In some of these tests, variables that were previously outcomes (e.g. having a plan) were now included as independent variables. Lastly, some variables relevant to the aftermath of the event (i.e. some peri-event decisions, the emotional and physical impact of the fire on the participant and their property, and some beliefs that may have been strengthened or altered by such impacts) were selected and tested for predicting the decision to evacuate in the future, if a similar wildfire were to be experienced again. This method of testing different models for different event stages was chosen to minimise the number of possible model combinations that would result from testing tens of variables in total, and to retain control over variable selection (Field, 2015).

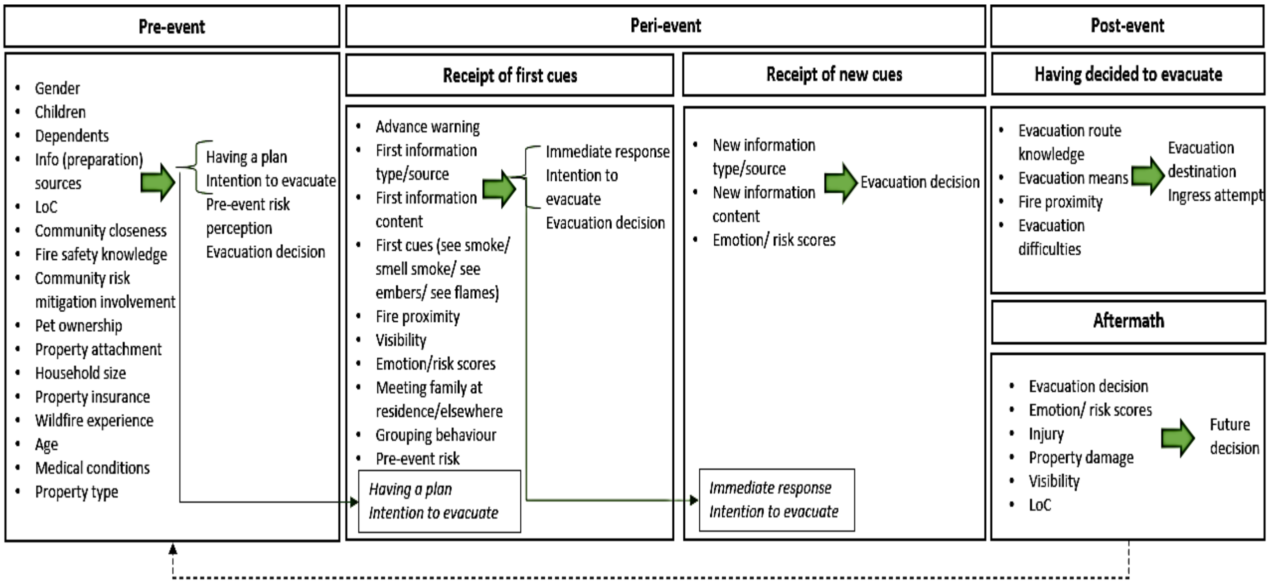


Fig. 7-1 Variable testing scheme for binary logistic regression.

The best model for predicting *having a plan* prior to the event (a significant model which correctly classified 77% of cases and explained 39% of the variation; Appendix I, Table I 1) contained three significant predictors that were pre-event variables: two related to involvement in community efforts (gaining information by attending community meetings, being involved in community risk mitigation activities) and one related to the participant's age (being older). Since H participants, like AE participants, were asked about pre-event variables and could prepare for a wildfire, their survey responses can also offer some insight into predictors of this particular outcome. Thus, separate testing was run with the merged H data. In the best model there, four variables significantly predicted *having a plan* (Table I 1). None were related to involvement in community efforts. Instead, two were related to what the participant had been exposed to (experienced a wildfire more than once in the distant past, received information more recently from any kind of source about what to do in the case of a wildfire), one was related to the participant's household (having pets/livestock), and one to the property (it was insured against wildfire damage).

The best model comprising pre-event variables for predicting the *intention to wait-and-see* during the event (Table I 2) included one significant predictor. This was related to the participant's planning (not having a [formal] plan). The *intention to stay-in-place* was significantly predicted by two pre-event variables: the participant's age (being older) and what the participant had been exposed to (received information more recently from their workplace about what to do in the case of a wildfire).

For predicting the *evacuation decision* during the event (Table I 3) – i.e. ultimately deciding to evacuate – the best model comprising pre-event variables had two significant predictors: one related to what the participant had been exposed to (less prior experience of wildfires) and one related to their household (having dependents).

Regarding peri-event variables, participants' *immediate response* during the event was best predicted by a single significant predictor: feeling alert (Table I 4). Participants who felt somewhat, or to a great extent, alert upon receiving the first wildfire cues were more likely to react actively and do something in response.

The *intention to evacuate* during the event was also best predicted by a single significant predictor (Table I 5). This related to social influence (i.e. the content of the first cues included a recommendation from authorities to evacuate). In contrast, the *intention to stay-in-place* was best predicted by two significant predictors: one related to the environmental conditions (experiencing poor outdoor visibility, i.e. not being able to clearly discern anything beyond 5-10 metres) and the other to the participant's emotional state (not feeling nervous to a great extent when receiving the first cues). The *intention to wait-and-see* was also best predicted by two significant predictors: one related to the participant's planning (not having a [formal] plan) and the other to the environmental conditions (not experiencing poor outdoor visibility).

The best model predicting the *evacuation decision* following receipt of the first cues was made up of two significant predictors (Table I 6). These were related to the participant's intentions (intending to evacuate), as well as to their household (no grouping behaviour, i.e. not trying to join up with others such as family members).

Following the receipt of new cues, however, the *evacuation decision* was best predicted by a model containing three significant predictors (Table I 7). Now, factors such as an earlier intention to evacuate were no longer determinants. Instead, evacuation was determined by social influence (the content of the new cues included an official order to evacuate), the participant's perception of risk upon receiving new cues (not perceiving a little risk of loss of utilities at the residence), and their emotional state in this same moment (feeling a little or somewhat helpless) .

After making the decision to evacuate, choices have to be made about where to go. The *evacuation destination* was significantly predicted by one variable (Table I 8), related to the environmental conditions (evacuation to a further away destination, i.e. another town/village, was more likely when the fire had not got as close as the participant's residential area). Again, H participants answered questions on where they would choose to evacuate to and how, so their merged data was tested once more. Here, *evacuation destination* was also best predicted by a single significant variable, albeit a different one (Table I 8), related to available transport (evacuation to another town/village was more likely when a car was the chosen means of evacuation).

Choices may also be made about going back to the residence, prior to this being officially announced as safe, and perhaps even prior to reaching the evacuation destination. However, no "best" model was found for predicting *ingress attempts* (Table I 9). For the merged AE data, a significant model was found, which contained a single variable (evacuation difficulties, such as encountering smoke and poor visibility while on the road), but this variable was not a significant predictor. For the merged H data, which was also applicable here, no model reached significance; the closest model to being "best" contained a single variable (evacuation means) but it was also not significant.

Lastly, participants' *future decision,* to evacuate if faced with another fire, was best predicted by a model with only one significant predictor (Table I 10). This was related to the evacuation decision made in the past described wildfire (to evacuate).

7.2 Evacuation delay time

As before, the AE data from SoFR and AUS were first merged into a single sample. Simple and multiple linear regression models were built as appropriate to predict evacuation delay (BI) time. The independent variables tested in the models are presented in Fig. 7-2. These variables were drawn from the study hypotheses (section 3.5.6) and from the outcome of preceding analyses on BI time (sections 6.5.3 and 6.5.4) and evacuation decision predictors (section 7.1). Again, variables were tested with different event stages in mind, looking at pre- and peri-event factors.

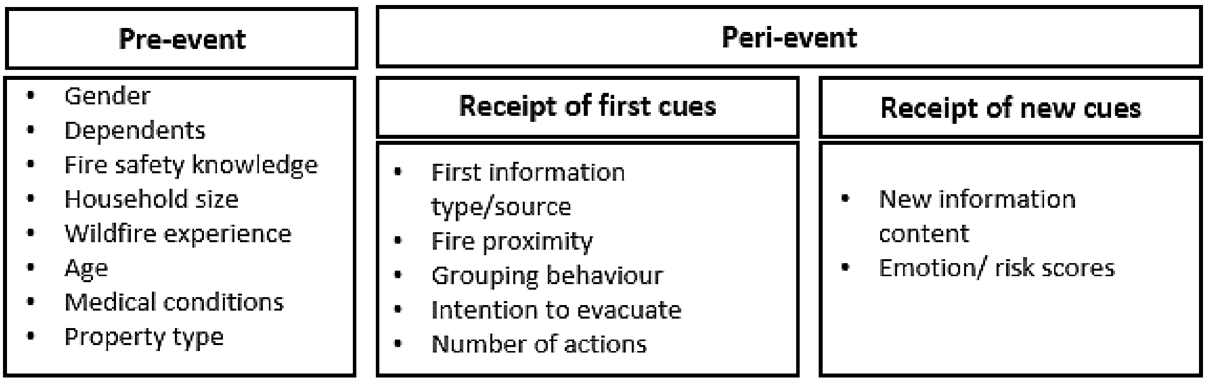


Fig. 7-2 Variable testing scheme for linear regression.

The following formulas were used:

Simple linear regression: $Yi = (\beta 0 + \beta 1\ Xi) + \varepsilon i$

Multiple linear regression: $Yi = (\beta 0 + \beta 1i\ X1i + \beta 2i\ X2i) \ldots + \varepsilon i$

where Y_i is the outcome (BI time, in minutes), $\beta 0$ is the intercept, $\beta 1_i$ is the predictor's unstandardized coefficient ('*B*'), and $X1_i$ is the value of the predictor (value = coded number if a categorical variable, observed number if a continuous variable). Additionally, ε_i is an error term.

The best model testing pre-event variables contained just a single significant predictor (Table 7-1). As such, the regression resulted in the following equation:

$$BI\ Time_{pre} = 39.93 + 65.52(fire\ safety\ knowledge) \qquad [10\text{-}1]$$

Fire safety knowledge was coded as yes = 1, no = 0. So, BI time was longer by almost 66 minutes for participants who had fire safety knowledge.

The best model testing peri-event variables contained two significant predictors (10-2). For this data:

$$BI\ Time_{peri} = 9.89 - 24.68(intention) + 7.34(number\ of\ actions) \quad [10\text{-}2]$$

Intention was coded as evacuate = 1, stay-in-place/wait-and-see = 0. So, BI time was shorter by almost 25 minutes for those with an intention to evacuate but increased by approximately 7 minutes for each additional action that was performed in itineraries.

Table 7-1 Simple linear regression analysis results for pre-event variables predicting BI time.

Regression predicting: BI time	**Intercept**	***B***	***SE B***	**Β**	***t***	***P***	**95% C.I. for *B***		**R^2**	**Model**
							Lower	**Upper**		
Merged data – AE	39.93								.14	p = .002
Fire safety knowledge: yes (vs. no)		65.52	20.26	.38	3.23	**.002**	25.03	105.99		

Table 7-2 Multiple linear regression analysis results for peri-event variables predicting BI time.

Regression predicting: BI time	**Intercept**	***B***	***SE B***	**Β**	***t***	***P***	**95% C.I. for *B***		**R^2**	**Model**
							Lower	**Upper**		
Merged data – AE	9.89								.38	p < .001
Intention: to evacuate (vs. any other)		-24.68	11.33	-.21	-2.18	**.033**	-47.29	-2.07		
Number of actions		7.34	1.24	.57	5.92	**.000**	4.87	9.82		

7.3 Illustrative human behaviour model

A way to apply human decision-making to wildfire evacuation modelling is proposed here. The regression analysis in section 7.1 shows there are several models that predict responses related to wildfire decision-making. There, the analysis was intentionally split into event stages, and showed that:

- The future decision (i.e. an individual would decide to evacuate if faced with another wildfire in the future) is determined by the ultimate decision made during the previous wildfire (i.e. the individual decided to evacuate)
- The ultimate decision made may be determined by the individual's general situation to date, if responding to the first cues (lacking prior fire experience; having dependents; seeing no need to join up with those household members, perhaps because they are already in their company; having an intention to evacuate), or be determined by their more current situation if responding after the receipt of new additional cues (now receiving an order to evacuate; not perceiving a slight risk of loss of utilities in this moment; beginning to feel helpless)

- An intention to evacuate is determined by initially receiving a recommendation to evacuate, while intentions to stay-in-place or simply wait before making a choice are determined by several different variables relating to the individual's general and current situation (including not having a plan)
- Having a plan may be determined either by being older and actively involved in the community response to wildfires, if the individual has experienced a fire more recently, or by having pets and being mindful of the risk of a wildfire despite lacking any recent experience (i.e. experienced multiple wildfires but only in the distant past; gained wildfire-related information in the last year; have property insured against wildfires)
- Finally, an individual's immediate response (reacting actively) is determined by feeling more alert, but this immediate response appears to stand alone rather than be related to preceding or succeeding stages of decision-making; in contrast, the choice of evacuation destination (further afield, by car) is naturally tied to an evacuation decision.

Chapter 6's analysis highlighted that regional differences may exist. Thus, users of evacuation models (whether they be practitioners, policy makers or researchers) should aim to collect local data to ensure the models are relevant to their circumstances. The nature of available data might vary based on the region's history of wildfires (e.g. if it has only recently become an "at-risk" area) or the end user (for example, researchers might have more access to data related to peri-event variables, while practitioners/policy makers might have more access to pre-event data, e.g. through population census). So, the above approach of breaking the models into stages could assist if model users only have data for part of the puzzle. However, if model users independently or collaboratively have data on both pre- and peri-event variables then a further round of testing is required here: to identify predictors of the ultimate decision to evacuate, the key outcome, with both types of independent variable tested together in the same model.

Such an integrated binary logistic regression model was tested. Pre-event variables (wildfire experience, dependents) were entered in Block 1, the peri-event variables relating to the receipt of first cues (intention, grouping behaviour) were in Block 2, and those relating to the receipt of new cues (order to evacuate; perceived risk: loss of utilities; feeling helpless) were in Block 3. The results revealed that while Block 2 was a significant improvement over Block 1, Block 3 was not acceptable. Therefore, Block 2 comprised the final model, one that successfully predicted 90% of cases and explained 76% of the variation (Table 7-3). It contained two significant predictors of the evacuation decision, revealing that peri-event variables had a relatively greater effect on decision-making.

To proceed with application of the results to evacuation modelling, firstly, certain population attributes would need to be pre-determined before an evacuation simulation could be run. As mentioned earlier, the pre-event variables could be determined via the collection of local data. Assumptions would need to be made about peri-event variables such as residents' initial intentions. These assumptions could be made with the help of data (local and/or from the research literature) on the factors that influence intention (see results of section 7.1). Grouping behaviour could again be determined by local population data. Furthermore, it could be explored via modification of certain aspects of the evacuation simulation (i.e. end users could select to run a scenario where a fire occurs early in the morning/late at night, when families would be more likely to be together, and compare this with another scenario of a wildfire evacuation occurring during daytime working hours, when household members would more likely be separated).

Table 7-3 Binary logistic regression results for final model predicting *evacuation decision*.

Regression predicting:	**Intercept**	**B**	**SE**	**Wald**	***p.***	**OR**	**95% C.I.for OR**		**Nag R^2**	**Corr (%)**	**Model**
							lower	**upper**			
Merged data - AE											
Evacuation decision	-1.51								.76	90	p<.001
Wildfire experience: >once (vs. once)		1.43	1.40	1.04	.308	4.16	0.27	64.34			
Dependents (vs. no dependents)		1.75	1.02	2.97	.085	5.75	0.79	42.02			
Intention:											
- To stay-in-place (vs. to wait-and-see)		-2.22	1.10	4.08	**.043**	**0.11**	0.01	0.94			
- To evacuate (vs. to wait-and-see)		5.14	1.88	7.47	**.006**	**170.24**	4.27	6784.1			
Grouping behaviour (vs. no grouping)		-2.99	1.24	5.83	**.016**	**0.05**	0.00	0.57			

The output for the probabilities for each combination of variables is in Table 7-4. The predicted probability (P) is obtained using the formula that converts odds to probability as follows:

$$P = \frac{\text{odds}}{(1+\text{odds})} \qquad [10\text{-}3]$$

Odds are calculated as follows:

$$Odds = e^{y} \qquad [10\text{-}4]$$

Where e^y is the exponential of y, and $y = B + b_1X_1 + b_2X_2 + b_3X_3$; where B represents the intercept of the model, and finally variables ($X_{1, 2, 3, 4, 5}$) are coded into 1 = yes; 0 = no.

Table 7-4 Probability table for the four variables in the final model.

(P)	Y	Odds	X_1 (Dependents)	X_2 (Experience)	X_3 (Intention to evacuate)	X_4 (Meeting family)
1.00	6.80	897.27	1	1	1	0
1.00	5.37	215.80	1	0	1	0
0.99	5.05	156.05	0	1	1	0
0.98	3.81	45.11	1	1	1	1
0.97	3.63	37.53	0	0	1	0
0.92	2.38	10.85	1	0	1	1
0.89	2.06	7.85	0	1	1	1
0.84	1.66	5.27	1	1	0	0
0.65	0.63	1.89	0	0	1	1
0.56	0.24	1.27	1	0	0	0
0.48	-0.09	0.92	0	1	0	0
0.21	-1.33	0.26	1	1	0	1
0.18	-1.51	0.22	0	0	0	0
0.06	-2.75	0.06	1	0	0	1
0.04	-3.08	0.05	0	1	0	1
0.01	-4.50	0.01	0	0	0	1

With the above information established, the regression model can then be expressed in graphical form to support evacuation modelling. A decision tree is one graphical option. It starts with an initial decision. The possible answers to this decision are represented by branches that lead down to resultant subsequent decisions, which then branch to other decisions, and so on until they reach the roots where no more decisions can be made. The outcomes are represented by values that are the probabilities. A full decision tree, based on the regression results here, would be too large to present, so a partial tree is illustrated in Fig. 7-3. Three dots refer to an unrepresented part of the tree. Here, the outcome is the probability of deciding to evacuate, ranging from 0 to 1. However, to simplify the interpretation, the values can be translated into a dichotomous evacuate/stay-in-place outcome, where 0 (stay) represents values $P < .5$, and 1 (evacuate) represents values $P >= .5$.

While full implementation of the results to evacuation modelling is beyond the scope of this thesis, end users can take advantage of the available data resulting from the regression models presented here. Moreover, the quantitative and qualitative analyses provided in earlier chapters can provide context for end users in the study regions of SoFR and AUS, which in turn can help guide them to generate and test further regression models/decision trees relating to various outcomes of interest, using this dataset and/or their own datasets collected locally.

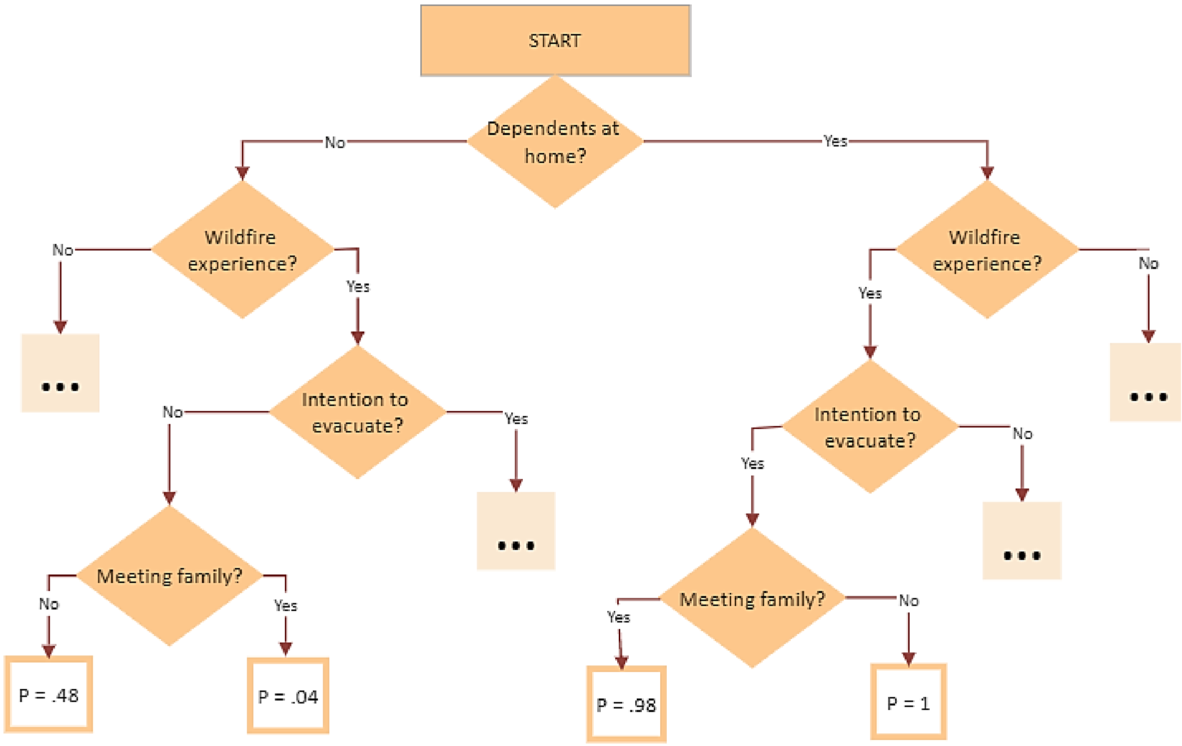


Fig. 7-3 Sample-predicted tree showing the probability of an evacuation decision.

The challenge for the implementation of such decision trees lies in determining the triggers to start the decision-making in an agent. Environmental conditions, such as the presence of smoke, embers or flames (section 6.3.3) have shown to be potential triggers for an evacuation decision in the AE and H samples studied here. Nonetheless, representing environmental triggers in an evacuation model may be challenging due to currently existing constraints discussed in Chapter 2.

7.4 Triangulation of qualitative and quantitative analysis findings

This section discusses the qualitative and quantitative results together, demonstrating the value that can be derived from media analysis, interviews with PWM, and interpretation of the quantitative analyses. This triangulation of study results shows what data may be useful for wildfire planning and response and can inform policy makers in programming community campaigns.

7.4.1 Before the wildfire

Pre-event risk and planning

In this study, *gender* did not seem to play a role in *pre-event risk perception*, i.e. females were not significantly more likely to perceive a higher risk of wildfires than males. This is in contrast to the findings of Gustafson (1998) and Kinateder (2015). Likewise, an expected relationship between having *dependents* and perceiving higher pre-event risk was not found. However, all other results on pre-event risk were consistent with the study hypotheses and literature that informed them. That is, higher pre-event risk was perceived by individuals living in a *family house*, those with *medical conditions*, those involved in *community risk mitigation activities*, and personal risk mitigation (i.e. had *property insurance*), plus those who gained *information from community meetings*. Thus, while it might be intuitive to think that people living in at-risk areas will naturally be aware of the risk posed to them by fire, it would appear that this may only be the case if it is communicated to them and/or reinforced via others with whom they have more direct and frequent interaction regarding their family and property vulnerabilities (i.e. fellow community members, doctors, insurance companies). Stein et al. (2013) have also warned that expecting communities to have well-formed pre-event risk perceptions is unrealistic. So, it should not be assumed that individuals will automatically perceive a greater risk of wildfires prior to one occurring, for the first time or again, if they reside in an at-risk area.

As hypothesised, perceiving greater *pre-event risk* was significantly associated with *having a plan*. So was being of an older *age*, having *pets*, being a *permanent resident*, having more *wildfire experience*, being *closer to the community* and involved in their *risk mitigation activities* and *community meetings*, and having *property insurance*. However, pre-event risk, being a permanent resident, and community closeness, were not significant predictors of having a plan. This suggests that planning for wildfires might simply be due to being a more conscientious and well-planned individual in life in general. So, for example, tourists/transients on the whole might be less prepared for what to do in the event of a wildfire due to being less familiar with their social and physical surroundings but such unpreparedness might be overcome individually by having the foresight to do some research into the area and its risks prior to arriving. Thus, while it would remain advisable for owners/managers of temporary residences to prepare plans on behalf of their guests to display/enact at the location, they could also point guests towards useful resources (e.g. foreign travel websites or insurance apps that provide safety advice for the relevant area) and encourage them to engage with these before arrival. However, the findings on *information* (*preparation) sources* showed that different groups gained information from different sources and so owners/managers should offer a variety to guests to increase uptake.

LoC appeared to play a lessor role in planning, while *gender* did not influence planning at all. However, it is worth noting several points in relation to LoC. Firstly, in both study regions, H participants were more likely to have an internal LoC and AE participants an external LoC. This suggests that LoC is not a persistent personality trait, as has been argued (Judge et al., 2002), but rather an attribute that can vary according to feedback. That is, when a wildfire occurs, this may reveal to individuals that such disasters are indiscriminate, severe, require the involvement of multiple agencies, and hence result in a shift towards an external LoC, at least in the short term. Without such feedback, individuals will retain a greater belief in their own capability to control wildfire outcomes. Secondly, when the SoFR and AUS data were merged, an external LoC was significantly associated with having no plan at all. This could appear to suggest that communities with a salient wildfire experience will contain more individuals with an external LoC and thus be less likely to plan for another wildfire in the future. However, the regression findings argue otherwise, with LoC failing to significantly predict planning. Thus, authorities should not fear an external LoC per se. However, an external LoC based around the belief that outcomes are due to chance is possibly one to beware. This was observed more frequently in SoFR, while planning (particularly formal planning) was less prominent in this region. The official policy in SoFR is ‘confinement’ (i.e. a more passive form of protective action). If residents interpret such policy as meaning that they play little part in wildfire outcomes then they could adopt a more *laissez-faire* attitude regarding planning.

7.4.2 During the wildfire

Immediate response

As hypothesised, *gender* and *immediate response* were not related whereas *having a plan*, as well as smoke-impaired *visibility* (when the SoFR and AUS data were merged), were significantly associated with immediately *reacting actively*. However, the main determinant of an active immediate response, revealed by the regression analysis, was a heightened *feeling* of alertness. These findings suggest that if individuals are convinced that the cues represent a real and present danger, then they will act. It would appear that: a plan helps by making individuals mentally prepared for what they will encounter and how they should respond in turn; larger quantities of smoke help by visually confirming the existence of a serious fire and highlighting the deterioration of the physical environment; while feeling alert likely indicates the triggering of psychological and physiological processes that help individuals perceive and monitor these environmental conditions, and facilitate decision-making about appropriate action – in other words ‘appraisal’ (Lazarus, 1991; Lazarus & Smith, 1988) or the steps of the PADM (Lindell & Perry, 2012). Conversely, the sight of flames (SoFR) and embers (AUS) were linked to *reacting passively*, suggesting that such *environmental cues* may overwhelm individuals, perhaps giving them the impression that the fire is too close, it is too late to take effective action, and so the situation is one they cannot cope with mentally or physically.

Intention

For the first time, *gender* was significantly associated with a behavioural response, *intention* (with females inclined to evacuate and males to stay-in-place). Another demographic factor, *age,* was more important: being older significantly predicted the *intention to stay-in-place*. Significant associations between this intention and having an internal *LoC* or *pets* (once data from the two regions were merged) suggest that older individuals might require more convincing to evacuate if such action is most appropriate – they may believe they can handle staying and defending what is precious to them but, if such beliefs are unrealistic then they may need conquering; alternatively, older individuals may be more inclined to evacuate if they are assured they will have assistance moving their animals or assured that shelters can accommodate the animals. If such things are actually feasible, then they will require advance planning.

Having a plan was significantly associated with the *intention to evacuate* and *to stay-in-place* but (no) planning was particularly impactful for the *intention to wait-and-see*. This suggests that if an individual lacks a plan, they are not more likely to consider staying-in-place over evacuating, they simply will take longer to make their choice. *Temporary residents* were significantly associated with the *intention to wait-and-see* and this is likely related to the lack of planning already discussed in relation to tourists/transients. The finding that receiving a *recommendation to evacuate* was the main determinant of an *intention to evacuate* indicates that intervention by others during the event, preferably early intervention if planning is lacking, could move an individual to consider evacuation.

Intending to stay-in-place was significantly predicted by having gained *information about wildfires from the workplace* and lower levels of *nervousness*, indicating that more information might currently be available to residents about staying, leaving them feeling more prepared for such action. This raises the possibility that if similar information were to be imparted about evacuation through formal channels and training then such protective action might be considered more widely. A further significant predictor of *intending to stay-in-place* was poor outdoor *visibility* while the opposite environmental conditions predicted the *intention to wait-and-see*. As already mentioned, sufficient levels of smoke may be required before individuals are prompted into reacting actively, while overwhelming conditions may inhibit individuals from thinking they can leave. Thus, these findings reinforce the need for planning – this may overcome the absence of any useful environmental cues and help prompt earlier action, before conditions become too much. Interestingly, this result about smoke stands in contrast to findings from building evacuation studies, where a willingness to move through smoke has been observed, even with minimal visibility (Richardson, et al., 2019). It is possible that knowing a place of safety and fresh air are only a short distance away in a building evacuation increases hope of being able to survive moving through smoke, while seeing one's entire physical environment blacken over with smoke in a wildfire may present a different prospect. Evacuation models with the capacity to account for environmental conditions such as smoke could be used to test for the threshold of where decisions shift away from evacuation towards staying-in-place; these would likely be most effective if they have greater visual capabilities (e.g. virtual reality).

Evacuation decision

Similar to McLennan et al.'s (2013c) study on the 2009 bushfires, this study also found that around a fifth of individuals changed their decision from their initial intention and ultimately took different action. Some changed away from evacuating; this highlights that ultimate action may depend on situational factors (e.g. the sudden arrival of the fire front forcing individuals to remain) and more data on fire behaviour is needed alongside data on human behaviour. However, most changes represented the switch from wait-and-see to a definite choice. Thus, these findings reinforce the need to understand and minimise evacuation delays. Nevertheless, around four-fifths of the overall sample in this study followed through on their *intention*, and this factor was the greatest determinant of the *evacuation decision*.

Overall, fewer people in SoFR than in AUS ultimately decided to evacuate and left their properties. In fact, the majority in SoFR stayed-in-place. Likewise, the majority in SoFR who initially intended to wait-and-see switched to ultimately deciding to stay-in-place. A change in this direction was not so prevalent in AUS. The percentages of AUS participants ultimately evacuating/staying-in-place were close to those in the BCRC-2009 dataset. These differences between regions could in part be due to SoFR individuals tending to become aware of the fire at a later stage, once *environmental cues* were present and becoming inhibitory. However, the patterns of decision-making also suggest that official policy may, again, be influencing behaviour. On the one hand, this is encouraging: if policy can help shape the safety culture and, in turn, individuals' behaviour, then it suggests that any desired changes in behaviour can be elicited by a change in policy. However, the interviews with AUS PWM showed that inconsistencies in 'the message' (i.e. authorities say evacuate, the law says individuals can stay) may dilute the impact of policy. Thus, for rules to have a greater impact, they should be congruous. Similar findings about message consistency have been found in studies of building evacuations (Kuligowski, 2011). On the other hand, there is a risk that a single consistent message (as in SoFR, where the receipt of initial *social cues* from the fire and rescue service was significantly associated with staying-in-place) could encourage inflexible thinking; if individuals tend to automatically follow the norm, then it could leave them unprepared for rapidly changing wildfire situations where a different kind of protective action is required.

Another issue regarding consistency is if evacuation is the message, and people follow this, but then the fire does not end up affecting the evacuated area. This can lead to a 'cry wolf' effect, which may explain why having more *wildfire experience* in this study meant individuals were significantly less likely to evacuate. Although wildfire experience was not ultimately found to be the most dominant predictor of *evacuation decision*, a similar 'cry wolf' issue was also signalled in the 2009 bushfire survivors' statements (VBRC, 2009), suggesting it is nonetheless worth bearing in mind. The challenge for PWM will be to find a balance between their stance of 'better safe than sorry' and residents' concerns about unnecessary disruption to their everyday lives and businesses. Effective planning may potentially minimise disruption.

As with wildfire experience, having *dependents* significantly predicted the decision to evacuate, although was not a dominant predictor in the final regression model for evacuation decision. The impact of having dependents might be greater in cultures where it is traditional to have several generations of a family live in the same household, although the dependency would be key rather than the *ages* of household members or the *household size* as neither of these factors were found to be significantly associated with the evacuation decision.

Indeed, many variables that were hypothesised to matter to the evacuation decision according to findings in the literature on disasters were found to be not significant in this study, reinforcing that wildfires are worthy of and require their own investigation. Interestingly, however, a number of the variables were found to be significantly associated with decision-making at an earlier stage, e.g. when forming intentions, thus the differences between behaviour in wildfires and other disasters may not be quite as great as such results would first suggest.

The effect of *gender* on *evacuation decisions* has been much contended across the disaster literature and the results in this study have not necessarily come close to more conclusiveness. While there was a significant association between gender and evacuation decision, this was only observed in SoFR (with females being more likely to ultimately evacuate than males) and gender was not found to be a significant predictor. *Pre-event risk perception* (higher perceived risk, higher likelihood of evacuating) was also found to be a significantly associated with the evacuation decision (albeit only when the two regions' date were merged) but was not a significant predictor. Its weaker effect may be due to the fact that, as discussed earlier, perceptions of risk may not be well-formed unless vulnerabilities are communicated and/or reinforced more directly. The sight of neighbours leaving (*social cues from an unofficial source*) being significantly associated with evacuation may have been one form of communicating vulnerability to residents (see also McCaffrey et al., 2013, who reported that such social cues may be important for early evacuation). However, a more impactful communication was the subsequent issue of an official *order to evacuate*. The additional findings that the evacuation decision at this stage was significantly predicted by feeling rather *helpless* and not perceiving a little *risk of losing utilities* may be interrelated to the order. That is, being commanded to leave means the decision has been taken out of one's hands, hence the feeling of helplessness. Likewise, if officials are in the area telling people to leave then it likely suggests that utilities such as a water or power supply are not about to be imminently lost or else their operations would be in danger also.

The last significant predictor of the evacuation decision was *grouping behaviour*. This remained significant in the final regression model. Being oriented to first join up with other household members reduced the likelihood of evacuation, suggesting such action delayed individuals to the extent where it was then too late to leave. This again impresses the importance of minimising evacuation delays. Authorities do already warn against grouping behaviour. However, the provision of information could perhaps be improved upon. The findings on the first information (warning) content showed that the practice of giving advice on ASET is scarce. In fact, such content was only reported by participants in AUS and not at all in SoFR. If it was made clearer that time was short, then individuals might understand that trying to join up with others would not be feasible in the time available. However, some PWM (i.e. at INFOCA; anon. personal communication, October 18, 2018) have emphasized their reluctance to introducing advice on timing due to the possibility of the area-to-be-evacuated becoming untenable much sooner than forecasted and, if fatalities were to be incurred, that would be their direct responsibility. For this reason, running multiple evacuation simulations would enhance the capacity of PWM to anticipate movement within the community, the time such movement might take, and therefore what advice could feasibly be given to people. Alternatively, the outcomes of such simulations could perhaps be released to the public in some form to help illustrate the risk posed by grouping behaviour; this might help encourage planning, in advance of wildfires, to meet up elsewhere (e.g. at designated shelters). Such planning would also help increase awareness of shelters and how to reach them.

Evacuation destination and ingress attempt

The choice of *evacuation destination* was most often another town/village, but this was dependent on the *fire's proximity*. Therefore, PWM should be aware firstly that individuals may be inclined to travel further than perhaps anticipated to reach a place of safety, which has implications for traffic management (e.g. congestion on roads going out of town, positioning of roadblocks). Secondly, if fire prevents such travel, the choice of shelter may be ad hoc rather than the official shelter. Indeed, the choice of another building such as a hall or church – the type of structure commonly designated by officials as shelters – was surprisingly infrequent, both by AE and H participants, in SoFR and in AUS.

PWM can expect individuals to travel *by car* to their *evacuation destination*, again meaning that a focus on traffic management is required. It may assist PWM to gain data from road authorities on traffic volume during regular busy times (e.g. peak commuter hours, the start and end of public holiday weekends), which could be used in simulations to ascertain both the capacity of the roads and where bottlenecks are likely to occur or have the most negative impact. This could also be used to test for any challenges to emergency service vehicle ingress.

The findings showed that residents may *attempt ingress* themselves, either during evacuation or after having reached their destination but before such travel has been announced as safe. While this was highlighted as a problem in the interviews with PWM, the survey results suggest the number of people attempting to return to their residences may be greater than expected. This again has implications for traffic management and may be difficult to tackle if resources are necessarily deployed elsewhere. It may also be difficult to tackle given that evacuation by car offers individuals a great deal of independence of movement (if the road infrastructure and environmental conditions allow). The regression tests failed to find an acceptable model for predicting ingress attempts. However, the descriptive results showed that such travel may be motivated by a perception that the threat has passed and a desire to check on loved ones/property in the hazard zone. It is not possible to verify if the threat had indeed passed before ingress was attempted. However, the absence of any official safety announcement would suggest otherwise. Moreover, a number of participants reported travelling through smoke and suffering impaired visibility during evacuation, so they would have been aware that the fire was in somewhat close proximity. The second motivation suggests that authorities need to work on building trust with their communities, assuring them that the emergency services are best trained to protect property and informing them of other ways in which they can contact loved ones from whom they are currently separated (e.g. as discussed, plan to meet instead at shelters, or utilise ‘single-click’ apps that have been developed for use in emergencies to allow people to notify others that they are safe and well).

Future decision

Contrary to the hypothesis, female *gender* and *deciding to evacuate in the future* were significantly associated; in contrast to the results for intention and evacuation decision, here gender was a significant factor in both study regions. It is difficult to infer why gender matters more in what people do in the future. However, the additional findings that a future decision to evacuate was significantly associated with *injuries* (psychological as well as physical) being experienced, and that injuries were reported more by females, indicates that this group of individuals may be more sensitive to the experience of a wildfire and may seek in future to either (1) avoid seeing the hazard and the destruction it causes, first-hand, or (2) gain access to professional aid much sooner. These findings also call for more focus on post-wildfire care, particularly with regards to mental health and emotional well-being.

The finding of a significant association between an external *LoC* and a future decision to evacuate likely reflects the point discussed earlier about event feedback shifting individuals towards believing that external forces play a big role in wildfire outcomes. However, it also means that those choosing to stay-in-place in future have a particularly great belief in their own capabilities, possibly fostered through good mental and physical preparation.

The main determinant of the future decision, however, was the *evacuation decision* in the described wildfire. As hypothesized, past behaviour was associated with future behaviour, which means that it is not experience of a wildfire per se that is influential here but rather the individual's part in one. While other research (Oulette & Wood, 1998) has suggested that intentions rather than past behaviour may be better predictors of future behaviour in events that are occasional as opposed to regular occurrences, this study has shown that intentions are strongly linked to ultimate decisions. Hence, past behaviour may have greater impact here. However, if this behavioural loop is so strong, it could lead to inflexible thinking, which could prove disastrous at some point given the dynamic nature and increasing severity of wildfires.

7.4.3 Emotion and perceived risk

Reflecting the dynamic nature of wildfires, *emotion* and *risk perception* were examined *across different event stages*. Replicating and extending the findings of Knuth et al. (2014a) and Grimm et al. (2012), who studied other kinds of disaster, emotion and perceived risk were found to vary across wildfire stages. In addition, they were found to vary across hypothetical wildfire scenarios that differed in terms of the type of cues present and at their height. However, there were even more nuances. It was not just the level of emotional arousal or perceived risk that varied, but also the type of emotion and risk, according to the study region (SoFR/AUS), the survey sample (AE/H), and the protective action decision (evacuated/stayed-in-place). This highlights the complexity of such internal states and appears to confirm why emotion is absent from human behaviour models such as the PADM (Lindell & Perry, 2012). Nevertheless, some trends emerged. For example: feeling fearful is most likely upon the receipt of first cues and exposure to environmental cues that have escalated to their peak; individuals in AUS are more likely to feel helpless; AE participants are more likely to perceive risks related to their residence and job while H participants are more likely to perceive risks related to injury; making a decision appears to evoke greater optimism in those who evacuate and reduce alertness in those who stay-in-place. This underlines that reports of 'panic' by the media, and by PWM, are not only grossly simplistic but also misleading, as individuals are clearly responding to their specific circumstances in ways that are natural and rational (e.g. why would individuals not feel fear upon recognising a serious change in their environment? Why would individuals not be concerned about the potential loss of their homes or lives?).

It appeared that some *decisions about evacuating/staying-in-place* left negative emotional memories (see Slovic et al., 2004), ones that may influence *future decisions.* Individuals who would not evacuate again in the future felt significantly more *annoyed* after making their ultimate decision – indicating that the evacuation process involved some frustrations – while those who would not stay again felt significantly more *energetic*, *helpless* and *fearful* – indicating that they perhaps attempted to defend their property but realised the fire was possibly beyond what they could tackle. However, the results were particular to each study region; SoFR for the former and AUS for the latter. This could indicate a lack of capacity and/or preparedness, not only on the part of the individuals but possibly also on the part of the authorities, to support the decisions made, given their policies/stated preferences. In terms of *risk perception*, the focus of concern in both regions was on the *disruption to jobs* and its connection to *staying-in-place in the future*. If no such risk was perceived, individuals were less inclined to staying in future (in SoFR), while if this risk was perceived, individuals were more inclined to staying in future (AUS), suggesting evacuation may be considered wise in some cases but also a costly inconvenience that individuals would rather avoid if possible. Similar concerns were also indicated in the 2009 bushfire survivors' statements (VBRC, 2009). These findings emphasise that emotion plays a part in behavioural responses, acting along with cognitions (Salzman & Fusi, 2010), and a better understanding of how decisions may be associated with variables such as certain feelings and risk perceptions could better support PWM in their own wildfire response (i.e. in predicting the behaviour of individuals and managing that accordingly).

Despite no *gender* differences in pre-event risk perception, the analysis of peri-event *risk perception*, and *emotion*, revealed some consistent patterns of gender differences: i.e. females felt significantly greater negative emotion (e.g. feelings of fear) and perceived a significantly greater risk of direct harm than males. This likely ties in with the results on injuries discussed previously. Given the greater inclination of females to evacuate, it also is consistent with studies on emotion and action that show that feelings such as anger motivate attack whereas fear motivates withdrawal (i.e. fight or flight) (Prati et al., 2012). Thus, it can be suggested that there is more substance to gender and risk perception than previously thought, in this study and in other disaster research (Grimm et al., 2012).

The *PCA* sought to condense the feelings and concerns of individuals for the purpose of further analysis and reveal broader (human) patterns of *emotion and risk* responses to wildfires. The results showed that the components constituting emotion differed from those reported in a study on earthquakes (Lindell et al., 2016), and normally comprised a *negative state* plus a second state that represented either a more *positive active attitude* (H participants) or a *vigilant state* (AE participants). There were also normally two risk components, one representing *disruption* and another representing either *injury* (SoFR-AE/H) or *personal life impact* (AUS-AE/H). The fact that these components differed across study regions, survey samples, and occasionally event stages, indicates that it is hard to summarise emotion and risk responses into broad terms. This was foreshadowed by the preceding analysis on *emotion* and *perceived risk*, highlighting the complexities of such responses. It also loses some of the detail that perhaps better explains not only these responses but associated actions.

7.4.4 Evacuation delay time

For building evacuations, *delay* (*mobilisation*) *time* data may be more easily collected given that the first cue is typically an alarm sounding and the timing of this event is likely to be recorded by a security company or emergency service, or researcher if an experiment. Also, onsite CCTV or fire wardens can be utilised to identify when all occupants have commenced evacuation and, furthermore, when all have exited the building. For wildfire evacuations, the range of cues and occupied locations, not to mention evacuation destinations, are far wider, and thus timings are harder to obtain. The data that this study did manage to collect on mobilisation time therefore provided a starting point and had some correspondence with what could be extracted from the 2009 bushfires' dataset (BCRC, 2009). The *BI time* data corresponded more with hypothetically-prescribed data from PWM and a study on another kind of disaster than with the data from real wildfires, suggesting shorter evacuation delays than the mobilisation time distributions. However, it is possible that mobilisation time data was obtained more from participants who received early advance warnings (e.g. high fire danger day) because it was easier for them to verify the timings of the warnings while BI time data included answers from more participants who received other types of first cues (e.g. the sight of smoke) that were more personally significant. So, the BI time data is likely to be meaningful. Therefore, this study has contributed to expanding the available database of delay times for wildfire evacuation research.

The *BI* results also show what constitutes the *evacuation delay time*, which is useful for policy makers and PWM in cases where practice is based on the anticipation of and preparation for rapid evacuation. One previous study, by Kang et al. (2007) on hurricane evacuations, used a similar methodology, albeit did not capture actions or times to the level of precision done here (e.g. participants were asked to estimate the duration of each activity, e.g. 'pack travel items', using 15-minute time intervals). The findings based on the full list of activities included in the current study's survey demonstrated that a wide range of discrete actions are performed prior to commencing evacuation, ones that are rational and largely advisable given the situation being faced. When the actions were combined into categories, the results revealed that *gathering belongings* consumes a large proportion of time in both study regions. Emergency kits/'go bags' are already available commercially and designed to facilitate rapid evacuation. However, it may be difficult to encourage uptake of these products given they are rather expensive in their basic form (e.g. start around £70), more so if individuals opt for customisation, and some of the contents will need replacing if not used within a few months, incurring more expense. Therefore, educational systems should be put in place by authorities that help people to think through effective ways of packing their own belongings. Time in both regions was also committed to seeking information. Thus, authorities should work to provide not only more information in their pre- and peri-event warnings but also more specific information about what to expect and how to respond in a wildfire to help reduce *delay times*. Again, this information should be made available across a wide range of sources.

An intuitive finding was that the *more actions performed* in itineraries, the longer the *BI time*. Indeed, the number of actions was a significant predictor of BI time. In SoFR, females performed significantly more actions than males, although managed to do so without increasing the overall BI time significantly in comparison to males. Nevertheless, evacuation delay could be greater if people reside in a family house as this *property type* was significantly related to longer BI times, while *larger households* were significantly related to more actions being performed. *Being older* was not significantly associated with BI times. Although the elderly might be less likely to perform their own itineraries, this did not distort the results, since age was also not associated with the number of actions, nor were *medical conditions* (either the participant's own or that of someone else in their household) associated with BI time. Contrary to the hypothesis, having *fire safety knowledge* was significantly associated with longer BI times. In fact, this was the only pre-event variable that significantly predicted *BI time*. It could be argued that those who have been trained or work professionally in fire-related areas are more aware of the challenges that can be faced during evacuation, and how long recovery can take, and therefore ensured they packed sufficient items to meet their needs, lengthening their delay. However, *fire safety knowledge* was not significantly associated with performing more actions. Therefore, it is perhaps more likely that such individuals performed a single additional/alternative action related to tackling burning embers or even flames prior to evacuating; firefighting was not explicitly included in the list of activities provided. If so, the fact that this increased their BI time by more than an hour shows there would be resource and health implications (e.g. water required, energy expended, length of exposure to heat and smoke, etc.).

Despite being provided with *ASET-related information*, the *BI times* of H participants in both regions sometimes exceeded the stated safe window for evacuation. It could be argued that, in real life, the presence of environmental cues, particularly those indicating the fire was getting closer, would likely supersede advice about time and curtail the evacuation delay. However, data from AUS-AE participants suggested otherwise: those who received *environmental cues* at first, and those who knew the *fire reached their residential area*, had significantly longer BI times than those in a similar situation is SoFR. This indicates that, even when there is physical proof of the fire being in close *proximity*, some individuals will still delay evacuation. Such behaviour is likely to be due in part to having an *intention to stay-in-place* or *wait-and-see* (later overturned when it became clear evacuation was necessary); intention was a significant predictor of BI time. Curiously, though, delays were always longer in AUS, where evacuation is encouraged, rather than in SoFR, where the policy is to stay-in-place. It is possible that the SoFR policy has more than one effect on communities. While it might make many individuals more inclined to stay, it might also mean those inclined to evacuate are less prepared for such action and thus not aware of all the things they need to do in preparation for leaving, resulting in fewer actions being performed and, consequently, shorter BI times. Moreover, the SoFR policy stresses staying to shelter, not to fight the fire. This ties in with the point above about firefighting, which may have been more common in AUS. In total, these findings emphasise the need to better understand evacuation delay times, and to investigate them along with the safety culture, the policies and practices, in the region being studied.

Chapter summary

Regression analysis was used to predict human behavioural responses to wildfires. Binary logistic regression was used to predict decision-making and simple / multiple linear regression tests were carried out to understand what influences evacuation delay time. The outputs presented in this chapter are those that resulted from the larger samples created through merged AE data, and occasionally merged H data. The independent variables found to be significant predictors tended to overlap with those found to be significantly associated with other variables in Chapter 6. However, in that chapter, regional differences were observed at times, with some variables only being significant in SoFR and not AUS, or vice versa, and this should be kept in mind. For decision-making, it was not possible from the variables studied here to construct an acceptable regression model for choosing to attempt ingress. However, acceptable models with significant predictors for having a plan, immediate response, intention, evacuation decision, evacuation destination, and future decision were uncovered. This was done by dividing the predictor variables into groups reflecting different event stages and looking at these during their relevant stages. For evacuation delay (BI) time, certain context and behaviour-related variables, such as fire safety profession, intention, and number of actions in itineraries, showed to be important influential factors.

To demonstrate the functionality and potential uses of human behaviour data in evacuation modelling, an illustrative model for the key outcome, evacuation decision, was proposed. This model combined and tested pre- and peri-event predictors from the previous regression models, and then the results were turned into the graphical form of a decision tree, with corresponding probabilities of deciding to evacuate included. It was acknowledged that the variables involved in the proposed model may need altering or replacing depending on the study region and the capabilities of the evacuation simulation tool (i.e. the presence of smoke could trigger wildfire awareness and thus decision-making but the representation of such environmental conditions might not be possible in some simulation tools designed for modelling evacuation).

Finally, triangulation of qualitative and quantitative results was made to provide a full interpretation of the data in the context of both study areas. Such analysis provided insight and advice for policy makers and practitioners. It also offered an illustration of the benefits collecting varied data.

CONCLUSION

Chapter 8

This chapter summarises the research findings and outlines the main contributions to knowledge about human behaviour in wildfires and evacuation. It then raises points about potential implications for stakeholders, such as researchers, policy makers, end users in wildfire management organisations, and even the public. Following that, it present reflections on the CIBER-t framework, before ending this thesis with directions for further research.

8.1 Summary of research findings

The aim of this thesis was to expand current understanding of human behaviour in wildfires and evacuation in order to improve safety in WUI communities. Also, it aimed to bring Europe into the focus of research attention, alongside more well-studied regions such as Australia, due to this part of the world being neglected to date. Two research questions were set out: (1) what motivates people to evacuate or stay-in-place, and (2) how long does it take people to start evacuating in a wildfire? To answer these questions, four research objectives were defined to address current limitations of wildfire research. These objectives and the main research outcomes are outlined in Fig. 8-1.

Objectives	Outcomes
• Building a framework that defines the aspects of individual and group behaviour influencing decision making in a wildfire	• Built a holistic and flexible CIBER-t framework that encompasses factors influencing human behaviour in wildfires
• Exploring the significance of key pre- and peri-event factors influencing behaviour in a wildfire	• Various pre- and peri-event factors were tested; significant ones were identified and contextualised
• Defining and quantifying behavioural itineraries in evacuation	• The main activities and the time taken for such activities were identified and compared across samples
• Exploring the effects of pre- and peri-event factors on evacuation delay time.	• The effects of various pre- and peri-event factors were explored; significant ones were identified and contextualised

Fig. 8-1 Research objectives and main outcomes.

Firstly, to answer ***(1) what motivates people to evacuate or stay-in-place:*** A holistic CIBER-t framework was first built to help collect and organise swathes of human behaviour data from different domains and sources related to wildfires and other disasters, through the identification of grand themes and lesser themes. These sources included information already in the public domain, plus semi-structured interviews conducted with PWM in one European region, Corsica (the South of France), and in Victoria (Australia). A residents' survey (one for individuals with recent actual experience of a wildfire and one for individuals lacking such experience but also living in an at-risk area) were designed with the help of the framework and administered in both the South of France and Australia. Data were subsequently analysed. The main findings include the following:

- Various factors are significantly associated with the decision to evacuate versus stay-in-place, although a smaller number are significant predictors.
- These predictors may exist prior to the wildfire (having dependents in the household, having less wildfire experience), or may come into play upon the receipt of the first cues to the fire (forming an intention to evacuate, not attempting to first join up with others), or may even come into play upon the receipt of new cues (receiving an official order to evacuate, not perceiving a slight risk of losing utilities at the residence, feeling some level of helplessness).
- When tested altogether, the most important predictors of the evacuation decision are the factors impacting at the time of receiving the first cues.

Several novelties have emerged from this study:

- The significant predictors of the evacuation decision are related to each of the grand themes of the CIBER-t framework: i.e. context, information, behaviour, emotion, risk, and time. This reveals a wider range of influences than previously highlighted in research on more frequently studied disasters (e.g. hurricanes) or more frequently studied wildfire-prone regions (e.g. Australia).
- The evacuation decision does not take place in a vacuum but rather in a decision-making sequence spanning before (e.g. planning), during (e.g. forming an initial intention), and after the wildfire (e.g. deciding on what protective action to take in future). Several factors may have greater relevance at one or more of these other stages of the sequence. This could help explain differences in findings across studies.
- This was not only the first study of wildfire-related human behaviour in a European region but also the first study designed to directly compare such behaviour across more than one world region. It revealed that several variables significantly associated with the evacuation decision, and other responses in the decision-making sequence, were more

prominent in the South of France (e.g. gender's association with intention and the evacuation decision), while others were seen to be more relevant in Australia (e.g. community-related variables' association to pre-event risk and planning, LoC's association with future decision). Similarly, emotion and risk-related responses were characterised differently in the two regions.

- Rates of deciding to evacuate also differed across regions. By conducting qualitative interviews with PWM to supplement the quantitative data from the residents' survey, this study was able to reveal the influence of each region's respective safety culture, expressed through policies and practices, and help explain this behaviour.

To answer ***(2) how long does it take people to start evacuating:*** Quantitative analysis of behavioural itineraries was required. A method of collecting data on the actions performed by individuals prior to evacuating, and the time committed to these actions, was adapted and designed in a way that could be used both for actual wildfire experiences and hypothetical wildfire scenarios. This method was also designed to address the lack of available time estimations needed to calculate evacuation delay times in the more traditional way (i.e. time when the individual received the first cues to the fire, time when the individual commenced evacuation). The main findings include the following:

- Behavioural itineraries constitute a wide range of discrete actions.
- These actions can be summarised into five categories: seeking information, gathering belongings, protecting property, protecting life/health, and other miscellaneous activities.
- A relatively large proportion of time is commonly spent on gathering belongings.
- The overall time to perform behavioural itineraries (BI time), and therefore the evacuation delay, may be longer than anticipated or stated as safe by PWM.
- BI time is significantly associated with and predicted by a small number of variables.
- As with the evacuation decision, significant predictors of BI time may exist prior to the wildfire (having fire safety knowledge gained through training or professional experience) or may come into play during the wildfire (forming an intention to evacuate, performing a greater number of actions).
- Cumulative BI time distributions may be shorter than cumulative (mobilisation) time distributions calculated via more traditional methods but may still be meaningful and more readily available.

Several novelties arose from this analysis on time:

- Although few, the significant predictors of BI time are related to three of the grand themes of the CIBER-t framework: i.e. context, behaviour, and time.
- The data on behavioural itinerary actions demonstrate that, contrary to reports in the media and from PWM, behaviour contributing to evacuation delays should not be categorised as irrational, lacking in focus to the task at hand (i.e. responding to a wildfire), or overly focused (tunnel vision).
- This was, again, the first study of wildfire-related evacuation delay time in a European region as well as the first study designed to directly compare delay time across more than one world region. It revealed that some variables significantly associated with BI time were more prominent in the South of France, and others in Australia.
- BI time, on the whole, also differed across regions, being longer in Australia. Again, the inclusion of qualitative interviews with PWM, defining each region's policy and practice, was able to help provide an explanation for this outcome.

8.2 Contributions to existing knowledge

To the best of this author's knowledge, no study to the extent of this thesis has previously been conducted on human behaviour in wildfires and related-evacuations. This study has expanded the current knowledge-base in several ways:

- It has gathered empirical evidence of the factors that motivate the decision to evacuate in response to wildfires. This empirical evidence shows how external forces (which may have previously been observed, albeit not for each individual) and internal forces (which have previously been assumed, sometimes incorrectly, if at all) affect a sequence of behavioural responses, amidst which is the evacuation decision. Preceding this decision are pre-event risk perception, planning, the immediate response to fire cues, and initial intentions; following it are the evacuation destination choice and ingress attempt, and the future decision.
- This study has also quantified and contextualised evacuation delay times in wildfires, as well as gathered an inventory of actions performed prior to evacuation, which help show where most time is spent and therefore lost.
- It has constructed a new research tool, a framework called CIBER-t. This has been demonstrated to effectively sort large volumes of diverse data on human behaviour, for wildfires but also adaptable to other disasters, thereby facilitating comparisons. It can also facilitate the design of study materials.

- Through the regression and illustrative models, this study has proposed a means of marrying social science and mathematical approaches, to the benefit of non-academics as well as academics.
- A comparison between a never-before-studied region, the South of France, and a more frequently studied region, Australia, was a first. It showed which behaviours may be more generalised and which may be more region-specific.

8.3 Implications for stakeholders

PWM – those involved in making policy but particularly those interacting directly with the public, either via issuing advice/orders or via managing the execution of evacuations – can benefit from the information about what people do and when during wildfires but also the motivations for such human behaviour during evacuations. By understanding the range of behaviours, the goals behind these, other influencing factors, and the stage of the event where such factors are most dominant, PWM can be better prepared and tailor their own response accordingly. For instance, they can learn whether certain interventions might be effective (e.g. by comparing the influence of social versus environmental cues on responses), who to target them at (e.g. by comparing groups based on factors such as individuals' gender, whether households have dependents, whether communities have experienced fires before, and so forth), when best to intervene (prior to a wildfire, or at different stages during a wildfire), and the channels through which interventions might be most effectively communicated (e.g. via formal safety training, via owners of guest residences or hosts of community meetings, via television, etc.). Additionally, the findings on internal states such as emotions and risk perceptions can help PWM recognise that certain behaviours frequently labelled as 'panic' are in fact natural responses to specific circumstances and serve a purpose. This may result in a reduction of the use of such an unhelpful term and begin investigations into the ways in which people's feelings (e.g. helplessness) can be supported both during events and post-event. Furthermore, this study showed that official policies and practice can be influential, helping form a safety culture, which in turn forms patterns of behaviour in communities. This should encourage PWM to design clear informed messages, and to work to ensure that any competing conflicting messages are eliminated or their impact minimised. However, PWM should also make sure that the message conveys that there is no single solution to wildfires and that people are equally prepared to implement different types of protective action.

The study findings also have the potential of benefiting the general public residing (permanently or temporarily) in areas that are at-risk from wildfires. Being better informed about the emotion and risk responses frequently accompanying actions in wildfires could lead to better self-awareness, as ‘panic’ is also a term used by the public in their own accounts to researchers and the media. Understanding what actions need to be done to prepare for evacuation, and what is feasible or not within given ‘safe windows’ of time, can help with planning. Indeed, the findings will hopefully demonstrate the benefits of planning in general. The behavioural itinerary questions could become a tool for PWM to administer in their communities, or could even be self-administered by the public, to test current levels of preparedness, and to reveal where preparedness is lacking (i.e. within certain sections of communities or households, and also in relation to certain categories of action). Following such revelations, planning can be implemented and the tool can be re-administered to monitor for changes. The information from the residents’ survey can be further used to understand training needs of communities, as individuals who chose first to wait-and-see, both in actual wildfires and in the hypothetical scenarios, should particularly be targeted for behavioural change given this response’s contribution to evacuation delay. Training could focus on improving appraisal of cues (e.g. what they represent, what the associated risks are, and what action would be most appropriate in the given circumstances). Furthermore, the finding on fire safety knowledge and evacuation delay (i.e. how much time putting such knowledge into practice may cost individuals and leave them exposed to harmful environmental conditions) could also raise awareness within the public about the practicalities and advisability of such behaviour.

Finally, researchers and evacuation modellers can benefit from the CIBER-t framework. For instance, the name provides a handy acronym to remind which elements to search for when reviewing literature, research materials, or models. In particular, it can help remind researchers/modellers of elements that might be missing from the aforementioned sources and therefore address such omissions through the collection of new data or through assumptions grounded in theory and previous research findings. The framework can also help reduce large amounts of information into manageable categories and facilitate comparisons despite the information coming from different domains or being presented in different formats (e.g. text versus videos and other images). The regression and illustrative models can help social science results be implemented into evacuation modelling tools and thus advance the development of such tools by enhancing their ability to simulate and predict human behaviour. In addition, this study provides a dataset related to decision-making, evacuation delay time, and various attributes associated with and influencing these outcomes, all of which can be used to set up and test various evacuation scenarios. These scenarios can be used for learning how to improve public safety. Such work consequently has the potential to increase the worth and marketability of evacuation modelling tools to a range of end users.

8.4 Assessing the CIBER-t framework

The theory-based approach to this research – considering the sociology of everyday life, and in particular the practices of everyday life – has helped to re-evaluate the importance of micro-processes in at-risk communities. Thus, the study of human behaviour in wildfires and evacuations was fragmented into themes, all the while keeping the regional and WUI setting in focus, as well as allowing qualitative accounts to elucidate the quantitative outcomes of the data analyses. This thesis has contributed empirically to an influential, but largely qualitative, body of literature that has shown the importance of everyday life, and considered wildfires within that.

Some of the CIBER-t themes that were identified during a review of the literature and qualitative analysis were not represented in the residents' survey as that would have required an even longer questionnaire. Moreover, some themes showed less importance than expected. Nevertheless, the grand themes or main elements of CIBER-t – context, information, behaviour, emotion, risk, and time – were able to successfully organise a large amount of information on wildfires gathered from the literature, the public domain, and interviews with PWM, and helped with the design of the residents' survey.

Based on the survey results, the final regression model for predicting the decision to evacuate showed that peri-event variables related to the grand theme of behaviour were most dominant. Thus, it remains of primary importance to ask "what do people do during a wildfire?" However, five other variables were identified as being significant predictors of the evacuation decision in earlier rounds of regression analysis. Two of these were pre-event variables related to context, highlighting the need to understand vulnerabilities associated with individuals' households and broader home environment. The remaining three were peri-event variables related to information, emotion and risk, demonstrating that while it is of worth to look at external forces (e.g. authorities ordering residents to evacuate), internal forces (feelings, cognitions) should not be overlooked. The fact that the predictors were relevant to different stages of a wildfire (before and at different moments during) highlighted the importance of time also.

For predicting evacuation delay (BI) time, the regression analysis demonstrated the importance of three CIBER-t themes: behaviour, context and time. Two peri-event variables again showed that what people do during the wildfire is highly important. The third significant predictor, a pre-event variable, revealed that being trained in fire safety could foster resilience (i.e. being better prepared for what is ahead) and/or vulnerability (i.e. by putting one's self in harm's way when a fire occurs).

Returning to the variables predicting the evacuation decision, some comparisons with Huang et al.'s (2015) meta-analysis on hurricanes can be made. Unfortunately, there were no behaviour-related variables included in the meta-analysis. However, that study did include some other relevant variables. The equivalent variables related to context (children at home, previous hurricane experience) and information (reliance on authorities) were not significant predictors of the evacuation decision in hurricanes. In contrast, the equivalent risk-related variable (expected service disruption) was a significant predictor. Emotion was again conspicuous by its absence, while the only time-related variable (expected rapid onset) was not a measure of evacuation delay, nor a significant predictor of the evacuation decision. This indicates that the grand themes of the CIBER-t framework are applicable to disasters in general but, conversely, they demonstrate that existing research on human behaviour in other disasters may be too limited in scope and the findings not wholly generalisable to wildfires.

Some recent work has been done by others to predict the evacuation decision in wildfires, and the relative speed of commencing evacuation, although only in AUS (Strahan, Whittaker, & Handmer, 2018a). This research took a different approach, identifying 'archetypes' following qualitative analysis of interviews with residents. Some of the variables used to characterise these archetypes are the same or similar to the significant predictors in this study. They are related to context (dependents, bushfire experience, fire safety knowledge), information (advice from the emergency services), and behaviour ([pre-event] intention), and there is some overlap in Strahan et al.'s predictions and those of this study. For example, the 'worried waverer' – characterised as lacking bushfire experience but having an intention to evacuate and fire safety knowledge – was expected to delay evacuation, possibly until the last minute, while the 'considered evacuator' – characterised as lacking bushfire experience and fire safety knowledge, having an intention to evacuate, and being responsive to information/advice from the emergency services – was expected to evacuate early. However, although the authors make a statement acknowledging that emotion, risk perceptions, and external circumstances may change and trigger evacuation, they nonetheless fail to represent dynamic aspects such as emotional states, (peri-event) perceived risk, or event stages, in their archetypes. There is therefore the potential for this work on archetypes to be misinterpreted as implying that behaviour is fixed prior to the event, which could lead PWM to underestimate the flexibility required in planning their own response. It is also difficult to see how Strahan et al.'s qualitative findings could be incorporated into evacuation models. Several attributes could be applied to agents prior to running the simulations (as with the pre-event predictors identified in this study). Yet, how would scenarios be set up to simulate behavioural responses to progressively worsening environmental conditions rather than the presence/absence of social cues? When exactly would evacuation be triggered? Similarly, how soon is "early" evacuation? CIBER-t offers a simple and effective reminder to researchers of the range of important elements regarding human behaviour in wildfire and evacuations, and this framework could help reduce the omission of elements from conceptual or mathematical models in the future.

8.5 Directions for further research

1. Additional cases.

Regional differences observed in human behaviour in wildfires have revealed that official policy and practices, and safety culture, matter on various levels from planning through to evacuation decisions and delay time. Therefore, in pursuit of building a truly 'universal' model of human behaviour, more data collection is needed in other European and world regions. Such work can be facilitated through the existing network of PWM that has been built, and continues being built, through international projects supported by the EU Horizon 2020 programme and its successors. For example, as part of this thesis, utilising GEO-SAFE project links, additional work was undertaken to translate the residents' survey and interview questions for PWM into Spanish, and additional evacuation data sources were located (e.g. Spanish Civil Protection Authorities [GREA], Australian Country Fire Authority [CFA]). These sources hold data which can inform of a wildfire incident's start time, when an evacuation order was issued and where, as well as provide an official count of evacuees. Although these records do not take into account people who left voluntarily, before being asked to evacuate by authorities, such alternative, real-event-based data sources should be sought whenever possible. The information on these wildfire evacuations can potentially be coupled with the available databases on the fire properties and behaviour during these events.

2. Improved methodology and analysis.

For the data analysis, additional statistical methods should be investigated, such as the use of Bayesian statistics, which would validate the results for the human behaviour models. The survey data on responses to the hypothetical scenarios hold more potential for inferential statistical analysis on decision-making than there has been the time and scope to reveal in this study. This data could be explored further to gain a deeper understanding of the effects of the manipulation of the type of cues and their escalation. For example, the effects of smoke and different visibility on decision-making should be explored better through the use of visual aids, and across the different stages of wildfire. This would improve the understanding of when the decision to travel through smoke can be made and when it is considered too late to travel, and would subsequently support modelling the untenability of the roads as the fire hazard advances. Additionally, the list of behavioural itinerary actions in the residents' survey could be expanded to include firefighting activities, and real data on this could be compared against the already-collected responses from the hypothetical scenario that included firefighting as an option at one point.

3. Expanding studied populations.

More effort should be put into targeting temporary residents as well as residents of settlements that fall through the gaps of official fire risk prevention strategies, such as informal settlements and harder-to-reach residences in wildfire-prone areas. The transient nature of the former and the social plus geographical isolation of the latter present challenges. Language barriers would also likely be an issue. Work would first have to focus on establishing local contacts (e.g. guest residence owners, the settlements' own authority figures) and building trust with them to gain their collaboration in accessing and communicating with residents. Once such networks have been created, research efforts could include the development and testing of signage (e.g. to signal the presence/availability of evacuation routes), the observation of planned evacuation drills, and the running of controlled experiments.

Additionally, more focus should be put on the evacuation decision and behavioural itinerary needs of individuals with reduced mobility, as well as other health issues. Although medical conditions were rarely observed to be a factor arising from the residents' survey data, the interviews with PWM highlighted that individuals with impairments may either be evacuated early or kept at their residence by authorities/emergency services. As such, the individuals themselves may have less say in what protective action they ultimately take (something they may not be aware of) and authorities may be less informed as to the individuals' needs.

4. Real-time data collection.

The residents' survey is currently designed for being administered prior to a wildfire or after one is over. Some of the survey, particularly the section on the behavioural itinerary, could be completed during a wildfire (i.e. once at the evacuation destination). Timing information in particular would likely be more available, accurate and precise if prompted for closer to the event. The survey would necessarily require modification and shortening. The current findings and the CIBER-t framework could be used to identify the most relevant aspects and amend and reduce questions accordingly, in a way that still allows meaningful comparison with previous datasets and other studies' findings. Also, while the survey has already been designed for use on mobile devices, newer app technology could be consulted to enhance user-friendliness and uptake.

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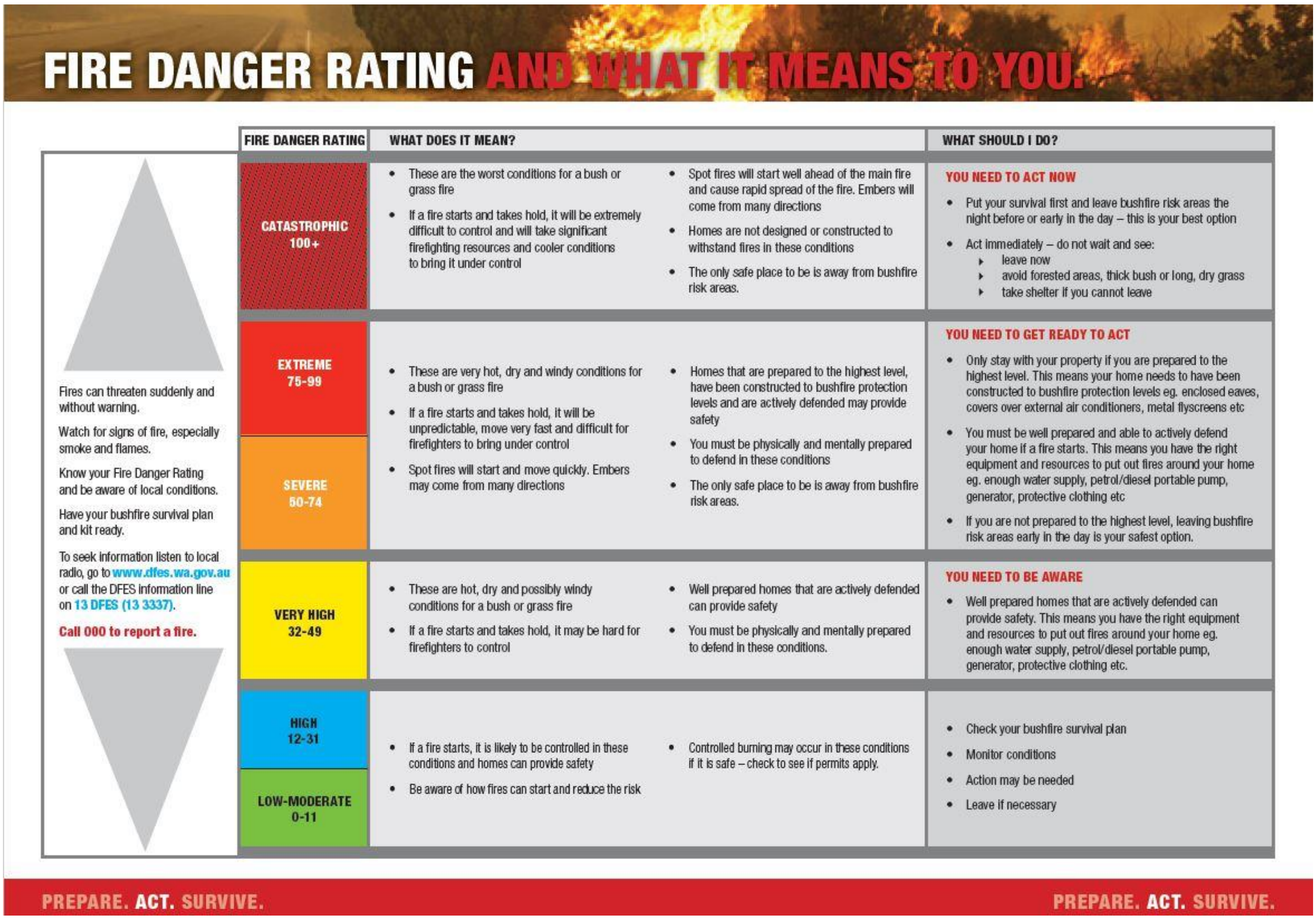
APPENDICES

Appendix A – Fire Safety leaflets and public domain video analysis



FIRE DANGER RATING AND WHAT IT MEANS TO YOU.

FIRE DANGER RATING	WHAT DOES IT MEAN?		WHAT SHOULD I DO?
CATASTROPHIC 100+	• These are the worst conditions for a bush or grass fire • If a fire starts and takes hold, it will be extremely difficult to control and will take significant firefighting resources and cooler conditions to bring it under control	• Spot fires will start well ahead of the main fire and cause rapid spread of the fire. Embers will come from many directions • Homes are not designed or constructed to withstand fires in these conditions • The only safe place to be is away from bushfire risk areas.	**YOU NEED TO ACT NOW** • Put your survival first and leave bushfire risk areas the night before or early in the day – this is your best option • Act immediately – do not wait and see: ▸ leave now ▸ avoid forested areas, thick bush or long, dry grass ▸ take shelter if you cannot leave
EXTREME 75-99 SEVERE 50-74	• These are very hot, dry and windy conditions for a bush or grass fire • If a fire starts and takes hold, it will be unpredictable, move very fast and difficult for firefighters to bring under control • Spot fires will start and move quickly. Embers may come from many directions	• Homes that are prepared to the highest level, have been constructed to bushfire protection levels and are actively defended may provide safety • You must be physically and mentally prepared to defend in these conditions • The only safe place to be is away from bushfire risk areas.	**YOU NEED TO GET READY TO ACT** • Only stay with your property if you are prepared to the highest level. This means your home needs to have been constructed to bushfire protection levels eg. enclosed eaves, covers over external air conditioners, metal flyscreens etc • You must be well prepared and able to actively defend your home if a fire starts. This means you have the right equipment and resources to put out fires around your home eg. enough water supply, petrol/diesel portable pump, generator, protective clothing etc • If you are not prepared to the highest level, leaving bushfire risk areas early in the day is your safest option.
VERY HIGH 32-49	• These are hot, dry and possibly windy conditions for a bush or grass fire • If a fire starts and takes hold, it may be hard for firefighters to control	• Well prepared homes that are actively defended can provide safety • You must be physically and mentally prepared to defend in these conditions.	**YOU NEED TO BE AWARE** • Well prepared homes that are actively defended can provide safety. This means you have the right equipment and resources to put out fires around your home eg. enough water supply, petrol/diesel portable pump, generator, protective clothing etc.
HIGH 12-31 LOW-MODERATE 0-11	• If a fire starts, it is likely to be controlled in these conditions and homes can provide safety • Be aware of how fires can start and reduce the risk	• Controlled burning may occur in these conditions if it is safe – check to see if permits apply.	• Check your bushfire survival plan • Monitor conditions • Action may be needed • Leave if necessary

Fires can threaten suddenly and without warning.

Watch for signs of fire, especially smoke and flames.

Know your Fire Danger Rating and be aware of local conditions.

Have your bushfire survival plan and kit ready.

To seek information listen to local radio, go to www.dfes.wa.gov.au or call the DFES information line on 13 DFES (13 3337).

Call 000 to report a fire.

PREPARE. ACT. SURVIVE.

PREPARE. ACT. SURVIVE.

Fig. A 1 Victoria, Australia. Fire danger rating and what it means to you.

Fig. A 2 Spain, Andalucía. Self-protection plans for residential urban environments (1/2).

Fig. A 3 Spain, Andalucía. Self-protection plans for residential urban environments (2/2).

Fig. A 4 Corsica: public information on what to do in the case of a wildfire.

Fig. A 5 Corsica: what to do in the case of a wildfire, information on social media (Twitter).

Table A-1 Human behaviour in response to smoke and fire – public video analysis.

Behaviour, Location	**Visual evidence**
Sheltering on the beach **Corsica**	 **Snippet 1 https://www.youtube.com/watch?v=ssLhPMHqLNk**

Watching smoke/ fire **Corsica**	**Snippet 2 https://www.youtube.com/watch?v=ssLhPMHqLNk**
Corsica	**Snippet 3 https://www.youtube.com/watch?v=ssLhPMHqLNk**
Corsica	**Snippet 4 https://www.youtube.com/watch?v=eBqstMd3sUA**

Fighting fire locally with unsuitable clothing. **Melbourne, Australia**	 **Snippet 5** Seven News Melbourne - 2014 Victorian Bushfires- Evening News Updates [9.02.14].
Regardless of the left side of the bridge nearly covered in smoke people walked both ways **Mexico City**	 **Snippet 6 https://www.youtube.com/watch?v=WNC9Mp9u8Bc**
When there was nobody left on the bridge, people still stood at the closer end of it **Mexico City**	 **Snippet 7 https://www.youtube.com/watch?v=WNC9Mp9u8Bc**

Not driving through an area with dubious safety; captured while standing on the road. **Corsica**	 **Snippet 8 https://www.youtube.com/watch?v=FjTAqgcIe2o**
Driver slowed down and stopped not advancing into smoke; a few moments later, other cars kept advancing and so did the driver **Mexico City**	 **Snippet 9 https://www.youtube.com/watch?v=QVR0pRxTutI**
A bus driver can be seen to advance into the smoke **Mexico City**	 **Snippet 10 https://www.youtube.com/watch?v=QVR0pRxTutI**

The motorcycle driver is indicating to go backwards and is driving against the flow **Mexico City**	 **Snippet 11 https://www.youtube.com/watch?v=wVTqvRq6c1I**
The driver hesitates before entering the smoke **Mexico City**	 **Snippet 12 https://www.youtube.com/watch?v=wVTqvRq6c1I**
Cars reversing from smoke **Mexico City**	 **Snippet 13 https://www.youtube.com/watch?v=wVTqvRq6c1I**

Person walking in smoke at a normal walking pace, for about 50-100 metres **Mexico City**	 **Snippet 14 https://www.youtube.com/watch?v=wVTqvRq6c1I**
Two passenger busses emerge from the smoke **Mexico City**	 **Snippet 15 https://www.youtube.com/watch?v=wVTqvRq6c1I**
Using a bicycle and riding towards the smoke area **Corsica**	 **Snippet 16 https://www.youtube.com/watch?v=GcEVKxbfUmk**

Proximity of the fire and smoke to homes **Corsica**	 **Snippet 17 https://www.youtube.com/watch?v=ssLhPMHqLNk**
Mexico City	 **Snippet 18 https://www.youtube.com/watch?v=WWJA13geO_4**
Filming in smoke, but for a brief time – choosing not to stay in smoke **Corsica**	 **Snippet 19 https://www.youtube.com/watch?v=ssLhPMHqLNk**

<table>
<tr><td>Mexico City</td><td>

Snippet 20 https://www.youtube.com/watch?v=CLzdi_-FiW8</td></tr>
<tr><td>Capturing the remains of cars
Corsica</td><td>

Snippet 21 https://www.youtube.com/watch?v=ssLhPMHqLNk</td></tr>
<tr><td>Flames engulfing the neighbouring property.
Sydney, Australia</td><td>

Snippet 22 https://www.youtube.com/watch?v=T1KThW3tgg0</td></tr>
</table>

Appendix B – Interview guide for PWM

- What are your main tasks, roles and responsibilities? Are you involved in evacuations of residents in bushfire emergencies?
- Can you tell your **observations** of inappropriate response to bushfires by individuals in the community you work?
- Could you tell what would be the **appropriate behaviours** for what you have just mentioned?
- Have you observed any particular **behaviours in children** that you found either inappropriate or appropriate when it comes to emergency response?
- What are the **actions of individuals** that make your response difficult or complicates it?
- What are the specific **characteristics of the population** where you work in terms of their resilience and risk culture?
- Do you feel that there is enough understanding among people in the community you work on what to do in the case of a bushfire?
- What do you think determines the **response times** (time it takes to understand that there is a risk and decide on how to respond to that risk) of people to bushfire? (e.g. visibility of the hazard, feeling of heat or smoke effects, availability of good escape routes, closeness to refuge locations, alerts and warnings, experience with past fires, prior intentions to stay or leave, self-sufficiency)
- Do you use any **simulation model** to predict fire behaviour and evacuation model to predict human behaviour?
- Which **warning and guidance systems** are the most efficient for an evacuation due to wildfire? (phone calls, SMS, tv broadcast, social media, sirens, signage, flashing lights, door-to-door knocking).
- **Constructing a warning message** – the warning message described in the handbook seems to outline all necessary parts of the message that would leave as little doubt about the importance of the message and what to do following it that it would be hard to believe people fail to react. Would you say people still fail to react? And why?

- What determines **the timing of evacuation warning**? (e.g. characteristics of the transportation networks/ routes pedestrian routes networks, vulnerability of people, vulnerability of houses, fire travel time)
- How would you **persuade a family** if they wouldn't want to leave their home?
- Would they leave by themselves or in an organised manner?
- Do they take any personal belongings with them?
- After the fire, is fire service involved in post-accident care?
- As a resident in the community, how should you make decisions in an event where you have a lack of information? PADM is a theory for decision making but what is the real way of approaching this?

Who gives the final approval for evacuation operation? Who decides that in Victoria and other states?

Appendix C – Information sheet for participants

Human behaviour in urban-scale evacuations during wildfire

This research aims to explore how people behave when they receive an evacuation warning, what actions they undertake and how long it takes for them to evacuate from home to a safe place outside the wildfire danger.

You have been invited to participate in this interview because you have observed/experience with evacuations/wildfire and we believe your insight could be valuable.

What will I have to do if I take part?

If you agree to take part, you will be asked to meet with the researcher to share your evacuation/wildfire experience.

You will be asked questions that are related to the aim of this study.

You are welcome to fully express your ideas and experiences that are related to the research topic before, during and after the discussion.

When answering questions, you are expected to reflect on your personal experiences.

If you do not understand a question, feel free to ask for an explanation.

The interview is expected to last approximately 45 minutes.

Do I have to take part?

Your participation in this research is voluntary.

Please consider whether you would be comfortable revisiting your experiences. If you have any concerns, it is recommended that you speak with your GP or a counsellor.

You can withdraw from the study at any time, up until 1 January 2019, and do not have to give a reason for withdrawing.

If I agree to take part what happens to what I say?

The interview will be recorded for note-taking purposes and then the recording will be transcribed where necessary.

The researcher will store any documentation and the recording securely and these files will be shredded or deleted once the research is complete.

All the information from the discussion that you provide **will be confidential** and will be used anonymously if quoted in this research, e.g. no names or street addresses will be published in any written or spoken dissemination of the research findings.

The information will be used for research purposes only and findings will be shared with professionals working on the GEO-SAFE project (http://cordis.europa.eu/project/rcn/199945_en.html) as well as other international professionals involved in public safety.

What if I have more questions or there is a problem?

If you have any questions, you should first speak to the researcher.

You may also get in touch with the contact persons listed at the end of this document.

What do I do now?

If you agree to take part, please complete and sign the consent form.

Contact Persons

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Appendix D – AE and H surveys

Table D 1 Correspondence between CIBER-t framework and AE and H survey question topics.

Context	*Physical environmental context*	External natural and anthropic disturbances, proximity to hazard, WUI type, property type and attachment (question examples: “what was the most recent and closest fire to you that you have experienced?”, “how close did you think the forest fire was at this moment [when encountering the first fire cues]?”, “please indicate on the map the location where you were when you experienced this most recent closest forest fire”, “what was the size and type of this location?”, “what was your relationship to this location?”, “when evacuating did you experience difficulties associated with any of the following [environmental and traffic conditions]?”, “which of the following images best represent the worst level of smoke you saw while at your location/travelled through as you evacuated from your location to your destination?”)
	Social context	Household make-up, gender, closeness to and influence of neighbours/the community (question examples: “what is the size of your household at this residence?”, “do you have any dependents living with you who you would need to look after during a forest fire?”, “do you have any pets or livestock at this residence?”, “what is your gender?”, “how close (i.e. familiar, socially connected) would you say you are to your neighbours?”)
	Individual cognitive context	Preparedness, knowledge, experience, LoC (question examples: “had you prepared a forest fire plan and/or an evacuation plan?”, “is your current or a previous profession related to fire safety?”, “to what extent are you aware of the forest fire evacuation routes in your area?”, “in your lifetime, how many times have you experienced a forest fire?”, “who would you say has control over the forest fire consequences to you and your property?”)
	Individual physical context	Age, health (question examples: “what is your age?”, “do you or anyone else in your household have any of the following medical conditions?”, “did the environmental

		conditions while staying at your location during the forest fire/during the evacuation process affect you physically?")
Information	*Information source and type*	Social/environmental cues and other types of information (question examples: "If not warned in advance, what was the first cue(s) that made you realise there was a forest fire nearby?", "from what sources did you receive a new warning and perceive new cues?", "in the last 12 months, have you received any information from the following sources about preparing for forest fires?")
	Information content	Protective action, fire properties (question examples: "what was the content of the first warning you received?", "what was the content of the new warning?")
Behaviour	*Immediate response*	Active or passive reaction to the situation (question example: "what was your immediate reaction to the first cues?")
	Response intention and response execution	Initial and ultimate decisions about protective action (question examples: "which one of the following best matches your intended response to the forest fire?", "which of the following best matches your eventual response to the forest fire?", "you will now be presented with different forest fire scenarios; please state your potential actions in the given situations")
	Decision triggers	Motivations to start evacuating (question examples: "what was the main reason you evacuated at the particular moment you did?", "under what circumstances are you most likely to leave your residence during a forest fire?")
	Behavioural itinerary	Actions prior to commencing evacuation (question example: "please choose and order the following activities that best describe what you did from the moment you began wondering what to do in response to the forest fire until you physically left your location (or, if you originally chose to evacuate but eventually stayed, until you tried to leave/realised you would be staying)")
	Grouping behaviour	Joining up with others before evacuating (question example: "during your response to the forest fire, did you seek to join up with others (e.g. family members)?")
	Travel itinerary execution	Choice of evacuation destination, means of reaching destination, ingress attempt (question examples: "when

		you evacuated, where did you go?", "how did you get there?", "did you try and return to your original location before receiving official notification that it was safe to return?")
	Future decision	Decided-upon future behaviour based on the lived experience (question example: "if there was another similar forest fire in your town/village or residential area, what action would you take?")
Emotion	*Emotions at different stages*	Feelings when encountering first cues, new cues, during evacuation/staying-in-place; feelings when scenario has escalated to its peak ("please indicate the extent to which the first perceived cues made you feel the following emotions", "to what extent did the new warning make you feel the following emotions?", "how did you feel during the process of evacuation from your location to your destination?", "how did staying at your location during the forest fire make you feel?", "please indicate to what extent this scenario would make you feel the following emotions [with social cues/environmental cues/social + environmental cues having peaked]?")
Risk	*Perceived risk at different stages*	Pre-event risk; risk perceived when encountering first cues, new cues, during evacuation/staying-in-place; risk perceived when scenario has escalated to its peak (question examples: "to what extent were you concerned about a forest fire affecting you or this property?", "after perceiving the first/new cues, to what extent were you concerned that the following things might happen?", "during the process of evacuation from your location to your destination, to what extent were you concerned that the following things might happen?", "when staying at your location during the forest fire, to what extent were you concerned that the following things might happen?", "to what extent would you now be concerned that the following things might happen [with social cues/environmental cues/social + environmental cues having peaked]?")
	Event consequences	Physical and psychological damage to health/lives, property damage (question examples: "did you or any family members experience injuries [including fatal ones]

		as a result of the forest fire?", "was the residence/property from which you evacuated damaged at all during the fire?")
	Risk mitigation	Insurance, other risk mitigation activity (question examples: "is this property insured against wildfires?", "are you involved in any community action for forest fire mitigation?")
Time	*Fire arrival time*	Time until hazard arrived (question example: "when did the fire reach your location?")
	Evacuation delay time	Response time, how long it takes to perform behavioural itinerary (question examples: "when did you perceive these first cues?", "when did you leave your location?", "please indicate the time (in minutes) you think you spent on each of the activities")
	Travel time	Time to move to evacuation destination (question example: "when did you arrive at your evacuation destination?")

Both surveys are also available in separate .pdf documents.

Fire Safety
Engineering Group (F:

Fire Safety
Engineering Group (F:

Appendix E – Literature review keywords

The literature review in this thesis used an initial search based on the following keywords: *Wildfire/ Forest fire evacuation; Bushfire evacuation; Evacuation behaviour / behavior; Behaviour in fire / wildfire/ bushfire; Behaviour in evacuation; Behaviour in disaster / emergencies; Disaster related cognitive science; Decision making in evacuation; Decision making in disaster / emergencies; Gender behaviour in disaster; Urban-scale evacuation; Urban-scale disaster evacuation; Evacuation modelling / modeling; Urban-scale evacuation modelling; Urban-scale evacuation modelling in wildfire; Wildfires in Corsica; L'incendie en Corse; Feux de Forêt en Corse; Wildfires in Southern France; Bushfires in Australia; Wildland urban interface; Wildland urban intermix; Urban wildfire; Human response to disaster / evacuation.* The searches did not include professional wildfire response behaviour, e.g. firefighting by firefighters, but included wildfire disaster management more generally and its systems. Subsequently, further literature was identified through the reference section of each relevant research paper.

Appendix F – Literature review findings’ summaries

Table F 1 Factors affecting human behaviour in evacuation, Chapter 2.

Individual and social characteristics	*Effects of these characteristics on the evacuation process in ‘man-made’ disasters (Sorensen, 1991)*	***Individual and environmental characteristics***	*Variable relationship with hurricane evacuation (Huang et al., 2015); significant (S), non-significant (NS), effect size ($\bar{r}$)*	
			Actual experience	***Hypothetical***
Hazard proximity	Increases chance of hearing a warning	***Expected nearby landfall***	S, r = .13	NS, $\bar{r}$ = .00
Involvement in community		***Reliance on peers***	S, $\bar{r}$ = .09	n/a
Female gender/ living in a family home		***Female gender***	S, $\bar{r}$ = .08	NS, $\bar{r}$ = -.02
Closely-knit subculture		***Peers evacuating***	S, $\bar{r}$ = .3	n/a
Knowledge about specific disaster		***Reliance on news media***	NS, $\bar{r}$ = .04	n/a
Prior disaster experience		***Previous hurricane experience***	NS, $\bar{r}$ = .01	NS, $\bar{r}$ = -.06
Elderly age	Decreases chance of hearing a warning	***Age***	NS, $\bar{r}$ = -.02	NS, $\bar{r}$ = .00
Perceived threat	No significance for (early) mobilisation time	***Expected personal casualties***	S, $\bar{r}$ = .29	n/a
Message ‘quality’		***Official warning***	S, $\bar{r}$ = .35	S, $\bar{r}$ = .15
Larger family size		***Children at home***	NS, $\bar{r}$ = .06	n/a
Personal warnings	Decreases time for mobilisation	***Previous unnecessary evacuation***	NS, $\bar{r}$ = .01	n/a
Physiological aspects and physical impairments	Could not be assessed	***Expected flood damage***	S, $\bar{r}$ = .15	S, $\bar{r}$ = .12
Lacking place to evacuate to	Decreases chance of hearing a warning	***Expected surge damage***	S, $\bar{r}$ = .22	NS, r = .06
Family separated at time of evacuation		***Expected service disruption***	S, $\bar{r}$ = .07	n/a
Living in apartment home		***Expected storm intensity***	S, $\bar{r}$ = .08	S, $\bar{r}$ = .31
Personal warnings	Decreases time for mobilisation	***Expected wind damage***	S, $\bar{r}$ = .17	NS, $\bar{r}$ = -.01
		Household size	NS, $\bar{r}$ = -.02	NS, $\bar{r}$ = .00

Individual and social characteristics	*Effects of these characteristics on the evacuation process in 'man-made' disasters (Sorensen, 1991)*	***Individual and environmental characteristics***	*Variable relationship with hurricane evacuation (Huang et al., 2015); significant (S), non-significant (NS), effect size ($\overline{\boldsymbol{r}}$)*	
			Actual experience	***Hypothetical***
Elderly age	No significance on (early) mobilisation time	***Environmental cues***	S, $\bar{r}$ = .19	S, $\bar{r}$ = .17
		Home ownership	S, $\bar{r}$ = -.08	NS, $\bar{r}$ = .06
		Mobile home residence	S, $\bar{r}$ = .28	S, $\bar{r}$ = .15
		Reliance on authorities	NS, $\bar{r}$ = .05	n/a
		Businesses closing	S, $\bar{r}$ = .17	n/a
		Risk area residence	S, $\bar{r}$ = .20	S, $\bar{r}$ = .20
		Concerns about evacuation costs	NS, $\bar{r}$ = .07	n/a
		Concerns about looting	NS, $\bar{r}$ = -.03	n/a
		Concerns about property protection from the storm	NS, $\bar{r}$ = -.03	NS, r = -.16
		Concerns about traffic jams	NS, $\bar{r}$ = .03	NS, r = .10
		Expected rapid onset	NS, $\bar{r}$ = -.04	S, $\bar{r}$ = -.03
		Expected job disruption	NS, $\bar{r}$ = -.03	S, r = -.10

Table F 2 Factors affecting human behaviour in evacuation, Chapter 2.

Individual & social characteristics	*Effect on perceived risk in building fires (Kinateder 2016)*	***Individual and social characteristics***	*Increased/ decreased likelihood of evacuating (Drabek, 1986)*	***Individual and social characteristics***	*Effect on evacuation (Burnside et al., 2007)*	***Individual and social characteristics***	*Relationship with evacuation (McLennan et al. 2013a, 2013b; 2013c; McLennan, et al., 2012)*
Hazard proximity	Inconclusive	***Disaster proximity (less time/distance)***	Increases likelihood of evacuating	***n/a***	*n/a*	***Expected fire hazard***	Those who left reported higher fire hazard
Groups	Higher perceived risk in groups	***Close relationships to community***		***n/a***	*n/a*	***n/a***	*n/a*
Gender	Tendency toward lower perceived risk in males	***Gender***	Being male decreases likelihood	***n/a***	*n/a*	***Gender & fire plan***	No relationship between gender and readiness

Individual & social characteristics	*Effect on perceived risk in building fires (Kinateder 2016)*	***Individual and social characteristics***	*Increased/ decreased likelihood of evacuating (Drabek, 1986)*	***Individual and social characteristics***	*Effect on evacuation (Burnside et al., 2007)*	***Individual and social characteristics***	*Relationship with evacuation (McLennan et al. 2013a, 2013b; 2013c; McLennan, et al., 2012)*
	but depends on age and context		of evacuating; being female increases it				
n/a	*n/a*	***n/a***	*n/a*	***n/a***	*n/a*	***Gender & evacuation***	Higher proportion of males stayed and defended but no significance
Hazard knowledge	Increases perceived risk	***n/a***	*n/a*	***n/a***	*n/a*	***Fire knowledge***	Those who stay-in-place had better fire knowledge
Previous experience	Inconclusive	***Previous evacuation experience***	Increases likelihood of evacuating	***n/a***	*n/a*	***n/a***	*n/a*
Behavioural training	Inconclusive	***Having an evacuation plan***	Increases likelihood of evacuating	***Hurricane plan***	People with a plan will be more likely to evacuate	***Fire plan***	Those who stayed-in-place in 2009 bushfire had better long-term preparation
Property attachment	Inconclusive	***Living in the place for less than 5 years***	Increases likelihood of evacuating	***n/a***	*n/a*	***Property attachment***	Non-statistical analysis shows those who stay-in-place were more emotionally attached to home
Behaviour of others	Moderates perceived risk and protective action	***Seeing others evacuate***	Increases likelihood of evacuating	***n/a***	*n/a*	***Emotional response***	Those who stayed-in-place reported high anxiety and stress levels; nothing reported on those who evacuated
Trust in authorities	High trust - lower risk; low trust - higher risk	***Believing in weather forecasts *fire ban day etc.***	Increases likelihood of evacuating	***n/a***	*n/a*	***Reliance on oneself***	Those who stayed-in-place may have believed they were responsible for their own safety
Cognitive bias	Inconclusive	***n/a***	*n/a*	***n/a***	*n/a*	***Psychological readiness***	People who stayed-in-place ranked higher in psychological readiness,

Individual & social characteristics	*Effect on perceived risk in building fires (Kinateder 2016)*	***Individual and social characteristics***	*Increased/ decreased likelihood of evacuating (Drabek, 1986)*	***Individual and social characteristics***	*Effect on evacuation (Burnside et al., 2007)*	***Individual and social characteristics***	*Relationship with evacuation (McLennan et al. 2013a, 2013b; 2013c; McLennan, et al., 2012)*
							but the difference was non-significant
Complexity of information and clarity of information	Complexity is inconclusive but easily understood information lowers perceived risk	***Increased number of messages***	Increases likelihood of evacuating	***n/a***	*n/a*	***Radio - as information source***	Decision influence but not significant
Fire cues	Closer, more intense cues - higher risk perception	***n/a***	*n/a*	***n/a***	*n/a*	***Cues (smoke, fire, embers)***	Those who left were more likely to report an environmental trigger
Personal traits	Inconclusive	***Being religious***	Decreases likelihood of evacuating	***n/a***	*n/a*	***n/a***	*n/a*
Age		***Elderly age***	Decreases likelihood of evacuating	***n/a***	*n/a*	***n/a***	*n/a*
Credibility of information	Likely to depend on information source (individual v system)	***Evacuation advice from official source***	Increases likelihood of evacuating	***n/a***	*n/a*	***Warning type - social***	Those who left reported influence from neighbours and family members
Social roles	Inconclusive	***Young children present in the household***	Increases likelihood of evacuating	***n/a***	*n/a*	***n/a***	*n/a*
Context	*n/a*	***Family members together at the time of evacuation***	Increases likelihood of evacuating	***n/a***	*n/a*	***Destination choice***	Those who left late sheltered in their cars or open areas
Emotional states	High arousal increases perceived risk	***n/a***	*n/a*	***n/a***	*n/a*	***Recommendation/ order to evacuate***	Those who left reported influence from neighbours and family members
n/a	*n/a*	*n/a*	*n/a*	***n/a***	*n/a*	***Insurance***	Those who left were more likely to be insured and those who stayed-in-place underinsured but not significant

Individual & social characteristics	*Effect on perceived risk in building fires (Kinateder 2016)*	***Individual and social characteristics***	*Increased/ decreased likelihood of evacuating (Drabek, 1986)*	***Individual and social characteristics***	*Effect on evacuation (Burnside et al., 2007)*	***Individual and social characteristics***	*Relationship with evacuation (McLennan et al. 2013a, 2013b; 2013c; McLennan, et al., 2012)*
Medical factors/cognitive abilities	Inconclusive	***n/a***	*n/a*	***n/a***	*n/a*	***Lack of time due to lack of warnings***	Decision influence but non-significant
						Need to protect animals	

Appendix G – Chapter 5 qualitative analysis Vignettes

Vignette G 1 Human behaviour in wildfires: perspectives in the media analysed.

Context	*Smoke* – discomfort and obstruction to breathing, especially when in a rush to leave; obstruction of visibility on the road; smoke seen in all directions; as a first (environmental) cue to a wildfire; impacts the shutting down of businesses. *Fire* – a particular danger, associated with high temperatures and rapid onset/movement; element of randomness in structures catching fire is noted while multiple fires reported to be burning simultaneously and embers flying. *Other cues* – winds and lightning; noise and loss of power as a first sign to evacuate. *Physiological and cognitive effects* – sickness due to smoke inhalation; "FOR days, sleep was a dream. The heat — two consecutive days of 40C-plus temperatures — and a week of little sleep — made for an irrational mind"; “I walked around in circles [while getting ready to evacuate]”. *Traffic conditions* – few egress routes; stranded vehicles. *Emergency services* – their presence is highlighted as well as deaths, injuries and missing persons during the wildfires; specific concerns regarding the capacity to get people out before fire destroys homes.
Information	*Information content* – evacuation directions given over the radio; appeals to the community for collaboration to pick up evacuees; protective action messages; urging to leave “or you’re on your own”. *Type of information* – sirens, police driving past shouting “evacuate!” because mobile towers down, called “old school”. *Information availability* – lacking information about environmental and other cues although general situational information coming through; residents wanting to know exactly what to do and seeking information on emergency numbers; accurate fire information not transmitted even though helped by technology. *Late information* – by the time SMS received, smoke too thick to walk or drive through or flames already visible in some instances; residents caught off guard before going to sleep.

	Information source – maps; firefighters; police cars; SMS; emergency application alerts; social media; siren; neighbours knocking on doors telling others to evacuate.
Behaviour	*Shelter* – sheltering at schools, grocery stores, hikers' refuges, emergency shelters, beaches, local sports stadiums, gymnasiums, airports; community centres. *Driving behaviour* - driving with a lack of fuel; driving in traffic; speeding; driving long hours (as much as 20); driving on a "windy, dirt and gravel mountain road through a canyon"; riding motorbikes through densely-vegetated areas. *Safety-related behaviour* – suggestions by authorities to pack bags in advance in case of needing to quickly evacuate; saving own animals; assumptions about safe evacuation do not necessarily match reality: "Evacuation in general is fraught with a lot of problems, […] It kind of assumes that you're alert, able, sober, that you have a vehicle, that you have a way to get out." *Evacuation means* – on foot; in cars; picked up by authorities by plane and by boat – women and children prioritised; orderly evacuation. *Inappropriate behaviour* - ignoring evacuation orders, including anecdotal account of family with young children ignoring an order to evacuate; waiting too long to leave. *Forced to flee* – taking few belongings; people told to 'run'; abandoning cars.
Emotion	*Fear* – "I was scared. I picked up my immigration papers and moved fast". *'Panic'* – "I have things that I probably wouldn't have left in the house if I hadn't been so panicked"; "At that moment, when I realised I was alone, I panicked." *Terror* – mostly reported being felt by tourists. *Surprise* – a reaction to the velocity of the event: "shocked by the speed and ferocity of the flames"; "They burned so quickly. There was no time to notify anybody. These fires came down into neighbourhoods before anybody realized the fires were occurring in many cases." *Calmness* – composed in voice; "It was keep calm and carry on, make some tea, serve some biscuits and hope that you get some information"; "Having not sensed smoke outdoors after hearing the emergency news made her feel calmer"; "[when reading news of being in imminent danger] tension rose inside me" but "by nature, I'm not prone to panic." *Helplessness* – "people were crying, and the kids didn't understand what was going on"; "I want to cry. I'm trying not to…"; "We're going to die. I don't want my babies to die like this…"

	Alertness - "People were alert to the situation."
Risk	*Cognitive bias* – people do not believe themselves to be in danger; "On days when conditions weren't catastrophic, people were still underestimating the risk posed by fires on 'severe' or 'extreme' days"; "Never mind that the fire was 20 km away, that it wasn't a code red day, that there were at least 20 trucks attending and that the wind had dropped slightly. It was recent history — Ash Wednesday, Black Saturday — that fuelled my panic." *Death* – deaths reported and risk of death very clear when evacuating late; planning to prevent fatalities; official assessment exceeding expectations for survival; people identified to have died (50%) were between 57 and 95 years old; a person died in a car crash due to "blunt force injuries with terminal smoke inhalation and thermal injuries"; life at risk when attempting to save others: "…risked their lives in efforts to free the horses." *Property damage* – knowing that the fires will destroy property; government officials stating that they are on the lookout for looters in evacuated areas; power remains out for extended periods.
Time	*Quick turn of events* - "She said some of her neighbours were slow to realise the danger"; "People around me were saying, 'no we've got time' and I said, 'no you know when things happen, they happen really quickly' but it even really surprised me."

Vignette G 2 Human behaviour in wildfires: perspectives in the media Video material analysed. Some findings are illustrated in Appendix A.

Context	*Smoke* – reduced visibility due to smoke; at worst, only visible as far as the length of the headlights; difficulties breathing even when in a car. *Fire* – fire out of control; rapid onset; approaching property; on one or both sides of the roads when driving; people watching fire submerged in smoke either outdoors or indoors. *Heat* – feeling the heat from the fire. *Social and environmental cues* – others' encouragement to leave reinforced by the sight of fire. *Traffic conditions* - jammed both ways, before and after getting through the smoke; people divert from the road to avoid smoke if possible; road closures and re-direction.

Information	*Information type and source* – evacuation order heard on the radio. *Information content* – fire danger level high to very high. *Information availability* – updates received every hour; in many cases, however, not enough information for people to know exactly how to react. *Protective action announcement* - "emergency warning for the bushfires under catastrophic conditions: CFA advises that an extremely dangerous bushfire is burning out of control. This bushfire warning message is for the following areas: fire is travelling at south east direction and may impact [road names] within the next 2 hours. There is a risk to life and property. People in these areas are in danger. Act immediately, follow your bushfire survival plan. Do not leave or enter these areas in vehicles or on foot; it's too late and the roads will not be safe. Take shelter in a building and actively defend it. Take shelter before the fire arrives as radiant heat can kill you before flames reach you." – the length of the announcement is 1 minute 30 seconds. *Directions* – people directed by other cars, police officers.
Behaviour	*Shelter* – beach used as a shelter; many standing in the water. *Inappropriate behaviour* – taking photographs/watching fire. *Driving behaviour* – speed of the cars visible in different videos ranges from 5 mph (8km/h) to 15-20 mph (24-32km/h); others speeding as nudged by their passengers; some cars decide to pass the traffic jam using the hard (road) shoulder. *Putting out fire* – small fires as well as larger ones at the property before the fire services arrive; inappropriately dressed to fight fire. *Forced to flee* - "families fled with minutes to spare"; people report seeing blackness, dark fire right behind them. *Running* – elderly say that they could not run; people report thinking of running instead of getting in the car because the roads are jammed. *Indecision* - people hesitate when no instructions are given: "Do we stay in/do we go?" a male asks 30 seconds into the video, but receives no response from a female who is shooting the video; another 15 seconds pass in silence until the video ends.
Emotion	*Various feelings* – uneasy, nervous, stressed, surprised, calm. *Repetition* – people's commentary seems to often repeat phrases such as 'what's going on?!' or other exclamations (little narrative).

Risk	*Cognitive bias* - before official warnings are given the risk seems to be underplayed. *Uncertainty* – it is difficult for people to anticipate the conditions ahead of them on the road.
Time	*Unexpected amount of time needed* – “We thought that it will take 5 minutes to evacuate but it took 2 hours.” *Fire arrival time* – 30 minutes from spotting the fire until fire’s arrival at the property.

Vignette G 3 Corsica: media importance in safety culture. Corse-Matin wildfire reports analysed.

Context	*Safety culture* - three main messages that could be perceived from these reports were as follows: (1) focus on ***individual responsibility*** when it comes to clearing is seen to be good, instilled by legal requirements, and is needed mainly to stop the combustion of fuels and allow for easier firefighter intervention; it is highlighted that sanctions will be applied for not having cleared and also in cases where such negligence causes an accidental fire on the proprietor’s terrain. (2) public ***trust in firefighters***, most likely highlighted to have people understand the importance of cooperating when necessary (e.g. in evacuations). (3) ***climate conditions*** in Corsica resembling those in California (USA), Central Chile, South Africa, and South-West Australia, and CO_2 emissions contributing to global climate change, most likely reported to suggest that wildfires are not only a national problem but part of a bigger safety issue that is likely to grow and affect masses of people if steps are not taken to control the risks. *Traffic conditions* - traffic difficulties due to evacuation operations, as well as part of control measures during the airplane water drop (Fig. 7-1). *Physiological and cognitive effects* - smoke in the environment seems to cause ‘confusion’ and ‘disorientation’ among people.

	 De gros embouteillages se sont formés, les gendarmes ayant fermé la RN198. **Fig. 0-23**: Bottlenecks on the street, 16 August 2014, Corse-Matin
Information	*Content* – announcements for public vigilance, total fire ban, fire danger index and risk maps.

Behaviour	*Ingress attempts* - returning to pick up items in camping areas that have been affected by a wildfire (Fig. 0-24). *Motivations for decisions* – survivors' accounts state reasons for not wanting to leave homes. *Inappropriate behaviour* - displayed by tourists and locals, such as standing on the roads and taking photographs of the wildfire, as well as extinguishing fire in casual clothing (Fig. 0-25).  **Fig. 0-2**: Campsite after the forest fire, 17 August 2014, Corse-Matin

	 **Fig. 0-3**: A female in casual clothing demonstrating inappropriate behaviour when fighting fires, 12 August 2016, Corse-Matin
Emotion	*Fear* – the response to evacuation due to leaving own home in someone else's hands. *'Panic'* – the sight of fire causes 'panic'.

Vignette G 4 Victoria: survivors' statements from the 2009 Black Saturday bushfires analysed.

Context	*Smoke* - lack of visibility prevents movement: "I tried to leave their house numerous times in the darkness, even though it should have been light. The thick smoke made everything appear more like night than day. I was scared to leave their house as I was unsure where the fire front was, and half expected it to just come rolling over the hills"; not always immediately perceived: "[anon.] called me […] and asked if we had seen the smoke in the sky. I hadn't noticed it at that stage, but I looked up and sure enough, I could see a lot of smoke. Up until then I had no idea that there might be a fire nearby."

	Medical conditions - mobility issues cannot always be helped, even though authorities have a vulnerable persons register: “At about 5.00 pm, I received a telephone call from our neighbour, [anon.]. [Anon.] also has restricted mobility and I understand that he suffers badly from arthritis. […] [anon.] replied that the CFA could not help [anon.] and that it would be up to his neighbours to get him out if there were any problems”; “In our local neighbourhood there are a very high proportion of aged pensioners and disability support pensioners, many of whom have mobility issues and/or other illnesses which would have made it extremely difficult for them to cope with the fire threat.” *Community closeness* - the personal extent of closeness can vary greatly, but people with community ties may be more committed to staying-in-place and helping others: “because [anon.] was part of a local Community Fire Guard Group with [anon.] family and other neighbours, he would feel committed to going back to Callignee.”; also more likely to be better prepared: “I did not get any professional assistance in designing or building the bunker and don't have an engineering background. I designed the bunker by just speaking to friends and people in the community to find out the best way of doing things”; but social connections may also break: “We stopped attending any of the group meetings when someone else took over the group and made it some sort of a social event rather than the serious business of making decisions about fire defence. I had no problem with that, but when the group leader issued a fire tree telephone system, it looked more complicated than a wiring diagram for a space shuttle. That was when my wife and I decided to have no more interaction with the newcomers.” *Lifestyle differences* – “My wife didn't listen to the car radio or read the newspaper or listen to the news. I think a lot of people in Strathewen are like that. I listen to current affairs and have the radio on a lot”; “[anon.] also told me that while driving that she had called [anon.] and [anon.], friends of ours who live in Kinglake West and who have nine children and told them that they should evacuate and not go via Kinglake. The [anon.] did not have a television or the internet and they were completely unaware of the bushfire threat. They took [anon.] advice and drove to Puckapunyal via Yea.” *Preparedness* – statements that the wildfire was impossible to prepare for; some individuals already knew they were ill-prepared for different types of protective action: “My bushfire plan initially was just to go. I remember when I bought the house the previous owner showed me how to use the sprinkler system and I had said to him 'There's no point showing me because I won't be here'.”

	Locals v outsiders - “[anon.] and I want to say on record that we owe our survival to the CFA. We have never been members of the CFA and when we moved to Marysville, we were city people who were quite ignorant about how to fight fires.” *Safety culture* – too much information, with mixed views on what triggers evacuation, resulting in unclear interpretation of the policy; financial constraints on businesses if left unattended leading to economics being prioritised over personal safety. *Experience* - bushfire experience may act against decision-making: “Those [previous bushfire] experiences gave us the impression that we would always have time to assess a bushfire for ourselves before deciding whether to evacuate. We also expected to have an opportunity to defend our property.”
Information	*Information content* – not always sufficient: “We had heard various statements on Friday 6 February about the following day potentially being a particularly bad fire day but had not heard anyone suggest that people should consider leaving their homes in the light of these generalised expressions of foreboding.” *Information source* – official sources not always useful: “The ABC's information seems to come from Melbourne, and it is often out-of-date, irrelevant to my area or just plain wrong. I believe the best warning system in the bush is the UHF radio system that has been used by forestry workers and other community and industry groups for many years”; official sources are mainstream and some people are disengaged from such media (live off-grid); official sources not always timely: “By the time the message came on the radio we could already see the glow from the fires over the hills towards Beechworth”; official sources not always trusted: "They told me to go home and go into the house, that it would be safer there […] I actually did a U-turn and I got probably 50 metres back down the road before I thought ‘I don't want to go back to that house’. I just knew that the street was a death trap. I pulled over, [anon.] pulled over in front of me and we talked. I told him what had been said, and I said, ‘But they don't know where we live, how can they send us back to that house?’" *Way of delivering information* – suggestion that shock tactics needed: “From my experience, I think that you need to scare people to get them to listen. Even though I live with fire threat, when I was at the CFA meetings and they were talking about potential impact zone, it still didn't frighten me the way it should have”. *Type of information* – police officers’ announcements: “[the police] told me that a road block had been set up at the end of the street, […] and stated that everyone in the immediate area needed to evacuate. This was the only time I received any warning or advice

	from an official source”; people expect different types of warning: siren, face-to-face evacuation order, environmental cues; multiple types may be necessary before action triggered: “The combination of smoke, wind, and such warnings on police vehicles would have alerted us sooner. If one of us was warned earlier, we would have warned the others.” *Contrasting information* – verification attempts can increase the credibility of initial information and lead to effective decision-making but they can also mean encountering contrasting (and possibly incorrect) information: “I telephoned [anon.] next door. He said he had just come out of the shower and would be over. He didn’t come immediately so I went over and told him what my friend had said. I kept on asking him ‘Is that flames in the sky?’ By then the sky was becoming very cloudy, very smoky and you could see orange through it, and I wasn't sure if it was the sun or flames. He told me he thought it was the sun, and I accepted what he said as he is more knowledgeable about weather than I am.” *Non-verbal information* – “we were never at any stage told to leave; no one came near us. During the afternoon, I saw our neighbour named [anon.] (who worked for the DSE) drive past very quickly. I had never seen him drive so quickly. I knew that DSE were fighting fires on Kings Road. Seeing him race down the street alerted me to the fact that something was up.”
Behaviour	*Seeking information* - “On 7 February 2009, because of the weather forecasts I had heard, we had kept an eye on the internet. I also had the ABC going on the car radio all day with the windows down”; “I asked someone in the car behind me ‘Is this where we go?’ but he didn't know”; “Once [anon.] and I arrived, [anon.] and I went outside about every 20 minutes to look around for any new smoke and we took photographs on each occasion. We were glad that we did this because it assisted us to monitor the progress of the fires around us (we could see how the smoke was changing) and to respond in the most effective way.” *Waiting for information* – “My neighbour [anon.], who lived at […], had told me he would have his radio on and that he would be in touch if there was anything to worry about”. *Shelter* – sheltering in the home when it is not advised: “I used my house initially to shelter from the flames and I then escaped before my house was destroyed by the fires”; “I fled in to the house through the back door and ran down the spiral staircase and climbed into the drain under my house”; other places: “our fire plan is for [anon.] and my son [anon.] to go down to the pub on really bad days. This is where everyone else in the town goes on potential fire days. When the time comes, everyone then goes to the town’s fire refuge which is at an adit or mining tunnel”; “There were 50 to 70 local people at the oval, together with groups of CFA

	and DSE trucks. Because they were there, I felt reasonably safe on the oval because I knew they would have plenty of water and probably food and other things we would need if we were going to be stuck there for a long time"; "When we got to the golf course, the shrubs and trees were on fire but the building itself was okay." *Ingress attempts* - "Near Pakenham, we found that the Princes Highway had been blocked by police at the beginning of the Pakenham Bypass. We were very determined to get to Callignee, so we took an alternative route." *Driving behaviour* – dangerous driving: "I saw my neighbour [anon.] fly past, beeping her horn like crazy. She did not usually drive that fast"; "It was then that I witnessed cars that had collided and crashed into trees"; "He said there were burnt and smashed up cars on Gangelhoff"; "Shortly after I received my friend's phone call, I noticed people driving dangerously past my property. The cars were moving very fast and I could hear tyres screeching. People were clearly panicking, and it was scary." *Inappropriate behaviour* – sheltering in a car in a fire danger zone; not disengaging from usual activities during a high fire danger day: "I was inside reading a book with the air conditioner on. I had the radio on until lunchtime and heard reports of bushfires burning in Gippsland. After lunch, I turned the radio off so that I could read my book in peace"; fighting fire in inappropriate gear; videoing the fire instead of taking shelter. *Appropriate behaviour* – dressing properly to protect one's self from smoke and radiant heat; checking the weather forecast before going camping. *Responsibility towards others* – taking responsibility for others under one's supervision, i.e. employees, clients, transients: "I have spoken to all of our guests from that weekend since the fire and I know that they all evacuated safely and that none of them were injured"; "Our fire plan, not only in our home but also for any guests staying at our bed and breakfast […] was to evacuate in the event of fire. In every single cottage or apartment, we supplied […] a directory folder which included that fire plan and instructions on where to head to"; but such leadership cannot always be relied upon and survival may fall upon the shoulders of transients: "Our room had glass doors to the west and to the south and we could see the flames coming down the ridge. In the few minutes it took me to get dressed and take my asthma medication, the fire was halfway down the ridge, about 400 metres away, and racing towards us."

	Evacuation decision triggers – are thought of in advance but in a vague way and perhaps should be considered more deeply: “Our fire plan was always to get out and not worry about the house. The trigger for us to leave would be if there was a bushfire in the area.” *Change of plan* - “when I saw the fire front approaching I knew straight away that we would not be able to defend our property against it and that despite our fire plan, we were confronted with "Scenario Z" and needed to focus all of our attention on saving our lives”; “All of us survived the fire by fleeing although it had always been my intention to stay and defend our property.” *Behavioural itinerary* – people who leave due to a direct threat of fire may not take anything with them, barely the basics, and so if people want to save their belongings then they need to act early and swiftly.
Emotion	*Difficulty recalling emotion* – “I do not recall feeling afraid or anxious”; “I was thinking rationally about what might happen and because of that, I had absolutely no comprehension of how bad the fire might be.” *Distress* - “we decided to evacuate early as we did not have the firefighting equipment and preparations in place to enable us to stay. We found this to be a very disempowering and distressing experience”; “When [anon.] called [anon.] at home and advised her that we should activate our bushfire plan, [anon.] became very distressed. [Anon.] was not in any mental state at that stage to make the next phone call in the chain, which was how the phone tree was supposed to work.” *Shock* – “I felt energy being displaced before I saw or heard the fire. It was like a massive force that made me feel like I was no longer part of my environment.” *‘Panic’* – the word ‘panic’ was used to describe responses of other people more than one’s self and more often in situations where danger was imminent: “A large number of people had gathered at the oval and there was a lot of confusion and panic.” *Calmness* – holding one’s self together: “The main thing that I wanted to do was to keep my head and not panic – I thought that if I panicked in a major bushfire I would probably die or at least lose the house”; achieving it through acceptance: “I realised that we would do whatever we had to do to protect the kids, and we might die in the process. A great sense of calm then came over me. I remember thinking, whatever happens here, happens, and we will have to do the very best we can.”
Risk	*Cognitive bias* – tendency to normalise cues: “When we first heard the fire approaching us, we didn't know what it was. We heard this really big rumble and [anon.] said 'Oh my God, there's a thunderstorm. That's great, it will put the fire out'. We could hear the

	rumbling getting louder and feel the vibrations, but we couldn't actually see it because of the trees"; "we heard the most terrible roaring sound. [Anon.] said, 'I hope that's not the fire'. But we realised that it was." *Not taking risks* - "I implemented my fire plan by leaving Kinglake with my children in my car on Friday 6 February 2009. I made my decision to leave on Thursday and I told my daughters' teachers that I would be taking the kids out of school early the following day." *Pre-event risk* – acknowledging the risk but unable to take action: "On the southern slope up from the creek there is about 200 to 250 metres of intense bush. It's not mine and I can't clear it up. I don't know how you protect yourself from that"; "I always understood the bushfire risk in our street to be extremely high. It was surrounded by the National Park and there was only one way out of the street"; acknowledging the risk but choosing not to take action: "I was aware that my property was possibly at risk in the case of a bushfire and knew that the house could be threatened or lost. I was not going to cut down the trees to reduce the fire risk. My attitude was that what will happen, will happen"; not understanding the risk: "I did not think that I lived in a high fire risk area because I thought that I lived in the town not the country"; "In hindsight, I think we had a false sense of security about our safety, which was brought about by the fact that we had lived in Marysville for 50 years and never had any trouble."
Time	*Fire arrival time* – 15-30 minutes after notified by CFA. *Mobilisation time* – 5-10 minutes; 20-30 minutes; 1 hour.

Vignette G 5 Interviews with Corsican PWM analysed.

Context	*Experience* – lack of experience in wildfire evacuation: "people here are not used to evacuating their home" – incident commander; at the same time, when people are told to go indoors (referred to in Corsica as 'confinement'), they refuse to do this: "they think they will burn in their home" – operations/prevention officer. *Property attachment* – "Typical for Mediterranean culture is that their house is often the fruit of their work life; it is inheritance or work tool for the farmers" – incident commander.

	Attitudes of locals – general culture of contradicting authorities: “local people, everyone knows what to do, but it’s never the same thing as we say. The problem with this is that local people are very tough, stubborn, strong character, have their own idea of what to do; it’s very difficult; but they are quite sensitized towards the fire.” – incident commander. *Attitudes of tourists* – tourists often disobey or are not familiar with the local rules: “tourists when they come here, they think that Corsica is a forest, that there are no rules to follow and they are the king here” – incident commander. *Dependents* – individuals with children tend to be better decision-makers, take less risks.
Information	*Information availability* – campsite visitors who notice smoke start getting ready promptly, as they have already heard on the news or the radio, or seen in the newspapers, information about wildfires; it was noted that because of such available information people’s behaviour is changing and they are becoming more vigilant. *Information source* – official channels are TV (France 3) and radio (Bleu RCFM, 101.7); for some communes, projects involving text message notifications are being developed, and some individuals via their travel insurance can already receive SMS alerts; SDIS communicate wildfire risks and events to the prefecture and the prefecture puts up relevant information on the government website (e.g. haute-corse.gouv.fr) for the public to access; such information is regularly checked by tourist information centres, which may advise people against trekking plans in certain areas if the fire danger is high or a wildfire is present; campsites said to use megaphones to notify guests of an emergency; campers may also be influenced by other sources, e.g. observing animals fleeing can make campers uneasy about staying in the area; evacuation of residences would be carried out by face-to-face visits from a firefighter or police officer.
Behaviour	*Inappropriate behaviour of…* *Adult locals* – fight fire wearing inappropriate clothes such as t-shirts and shorts; refuse to shelter indoors when firefighters tell them to; likely to attempt to return for forgotten personal items; misjudge the vulnerability of own situation: “sometimes they call firemen to say that they are in danger, so we send the trucks but they are not in danger – they just think they are. They see and smell fire and they think they are in danger; so we use a lot of tricks to see if they are in danger or not” – operations/prevention officer; overestimate own expertise and knowledge: “Sometimes there are old firemen who think that they know better than us what we have to do” – operations/prevention officer; overreliance on electricity for wildfire response: “Some people say that it is good to have electric water

	pump but in case of fire we shut the electricity so it is better to have a manual pump. Also, portals – gates can be electric, so it is better to open them in advance" – civil security reserve chief. *Adult tourists/transients* - take photographs instead of taking care of their own safety: "you can see tourists on the road taking pictures" – incident commander; can cause problems on the roads due to a lack of familiarity with fire and routes: "We have problems with summer vacationers, because they are not used to see fire, they are not used to narrow roads" – incident commander; also enter forest areas when the official red or black fire danger notification is in place. *Children around firefighters* – "Children's behaviour is not mature, children trying to wait and see what you [the firefighter] will do, then they are at risk seeing your work, sometimes it is problematic" – incident commander; "Children are afraid of fire, and also of the firemen because, when we come, we wear uniform, helmet, mask. They sometimes hide under the bed. Often they are afraid when they are not with their parents" – operations/prevention officer.
Emotion	*Stress* – said to induce irrational and potentially hazardous behaviour: "When people are stressed, they don't realise the danger of fire; when they see fire, they become completely out of their mind and don't have fair judgement, the reaction is very irrational" – incident commander. *Fear* – "it's very dangerous because they drive fast because they are afraid" – operations/prevention officer. *'Panic'* – said to induce tunnel-vision regarding priorities (such as collecting belongings, e.g. passport, instead of escaping): "they are vulnerable to accidents, they focus on one thing and cannot listen" – incident commander.
Risk	*Risk awareness* – local population is generally thought to be sensitized towards wildfire and capable of protecting themselves from hazards due to having knowledge of typical wind direction, speed and fire behaviour, so can make more informed decisions compared to tourists/transients: "If we have a knowledge that 1-2-3 people in the village can be alone in the fire, maybe we say there is no more risks because they have the culture of wildfire, but if we have 1 or 10 people who are new inhabitants here it would be more dangerous because of them, because this behaviour, culture of risks is present in Corsica but there are a lot of people who came here 1-2 years ago and they don't have it. I think resilience went down." – civil security reserve chief. *Risk mitigation* – transients more compliant with activities such as clearing than long-term locals: "for the new habitants it is easier to make them clear the field but […] with the older habitants, it is more difficult" – mayor.

Time	*Assumed RSET/ASET* – confinement preferred over evacuation (if suitable structure is available), therefore**,** time references were indefinite – anything from 1 to 3 hours before the fire arrival. *Door-knock time* – "we [the firefighters] will stay 5-10 minutes with them [households] to explain that they need to leave". *Travel time* - SDIS led and completed an evacuation of around 190 cars from a forested recreational area along 6.10 km of road in nearly 4 hours.

Vignette G 6 Interviews with Victorian PWM analysed.

Context	*Culture* - reactions to fires expected to be more human than cultural, whereas uptake of information before fires is seen as more culturally-influenced; changes in safety culture: "Now we're educating our communities to be more resilient and take responsibility; in a community meeting I would now say 'what you are doing about fire?'" – police sergeant; "we're better at educating people to understand the ramifications in relation to not having a good plan. It's no good from making the plan today when the fire's on your tail chasing you because you'll make bad decisions" – police sergeant; instilling safety culture at an early age: "if we want a more disaster resilient Australia we need to start with children and make sure that they are provided with the programme that is age-appropriate education throughout their school years around natural hazard, risk and what actions can be taken" – community safety director. *Property attachment* - residence status and evacuation compliance are not seen to be related. *Community type* - two types of community distinguished, integrated and dysfunctional, and it is challenging to plan for both; also people who live off-grid (the homeless as well as people who are voluntarily living disconnected from the world) whose responses may therefore be difficult to predict; another type is individuals with summer properties, who are again challenging: "We can organise a street talk to show the potential risks and drop pamphlets advertising it – no one turns up. No one. Not one. And that's in one particular area, it's a very well-to-do area, high value properties; over a number of years we tried to educate those people and offer different styles of engagement, but no one turned up. It's extraordinary." – police sergeant.

Information	*Warning messages* - constructing a warning message is currently a work in progress and it is recognised as an area where improvement is needed; the warning message is expected to prompt people to seek further information: "if we're sending out an evacuation notice, we also have the SEWS (sigma emergency warning system) so the siren would go, so emergency warning siren would play, so people are supposed to be attuned and once they've heard that siren going they need to stop, listen, and take note of the message and then seek more information." – community programmes' coordinator. *Information source* – one message multiple channels; technology used but is criticised for not working properly, i.e. not smart enough to inform people who are at-risk, thus causing confusion and the message loses credibility. *Communication barriers* – foreigners lack information in their own language: "we had non-Australians if you like. That enormous language barrier was a real challenge for us to communicate; we should have had translators; have the documentations translated so it was readable and even the road signs with message board on them, use symbols not words, so that everyone can understand them." – police sergeant. *Reliance on authorities* - people rely on the emergency services to inform them when to leave but services want people to be more independent in making this decision: "people think 'they'll tell me when it's time to go, if there's a fire in the area'. So, on a hot day, they'll pull the curtains, turn the AC on, and watch cricket. They'll think, 'oh, they'll tell me on the phone, they'll ring when it's time to leave'. To that point people are now reliant on us…" – police sergeant.
Behaviour	*Appropriate behaviours* – do what you are told, but also wear the right clothing and be prepared, since it is believed that people need a plan to be able to evacuate successfully. *Inappropriate behaviours* – speeding on the roads, e.g. from 60-80 km/h to 100 km/h; forcing way back through roadblocks: "so trying to force your way through a roadblock is where we've got a lot of confrontation; they don't understand we're trying to minimise their risk, all they're interested in is getting back to their property" – emergency management coordinator; tourists also make ingress attempts: "we had a lot of people in a caravan park in Wye River who evacuated, who got Christmas presents hidden in their caravan, people wanted to get back to their caravan, pick up their surf-boards, and there was frustration around 'I just want to go there and get my kids' presents'" – police officer; waiting-and-seeing resulting in late evacuation: "there's people who when they get a warning they're going to leave straight away, that's a good thing, then there are those who just

	want to wait and see; that's typically where you're going to see deaths; or evacuation, they're the ones that jump in the car at the last minute, get on the roads and the roads are clogged up" – emergency management coordinator; waiting-and-seeing is likely to do with evacuation being part of the policy but not yet fully adopted by people as practice; individuals take too many belongings with them to shelters, including animals that are hard to cater for: "One of the issues is that people would rock up with their cockatoos and llamas, they arrive with as much as they can carry in the trailer and it can get very congested." – police sergeant. *Behavioural itineraries* - depending on how much time there is until the fire's arrival, people will take more/less of their belongings. *Shelter* - shelters are chosen by people but not always approved by the authorities: "[my mother] has her neighbourhood safer place at the bottom in the big shopping centre, big open car park, but […] refuses to go there because she says she'll go halfway down the hill and there will be a traffic jam with everyone with their lamas and trailers and she'll get stuck. So […] she goes now to a golf club, which isn't a designated place; but that's one of the things we're finding here in Australia is that people are going to places that historically they've gone to" – police sergeant; shelter-in-place is re-considered as a large-scale operation due to logistics but may be the preferred option for some vulnerable groups: "what we consider now is putting fire trucks at nursing homes because we've learned that the shock…and where do you move them, particularly the high care and the elderly; so we try now to help them shelter-in-place." – police sergeant. *Evacuation* - there is not necessarily a direct relationship between fire danger day ratings and evacuation in practice: "some of our stats show we had fires escape on a day of very high than extreme" – community programmes' coordinator; the only other precautionary action that can be taken in terms of self-evacuation is deciding to leave by a certain time on a certain fire danger day; historical pre-disposition against evacuation: "We're getting better. There has been historically people who say 'yes, thanks, don't want to leave'" – police sergeant; evacuation when businesses are at-risk is seen as potentially problematic: "majority of people heeded the warning when we put on them and they did evacuate; big decision to do the evacuation because there was some risk, in particular in relation to Christmas day and then boxing day the next day, it is the biggest trading days of the year for them down there" – police sergeant.

Risk	*Credible risk* - repeated evacuation warnings lower credibility and perception of actual risk: "…when you have a long period of no catastrophic events, people become quite complacent, and they don't realise the actual danger that they could be facing, because the warning's been issued 10-20 times and nothing's happened, or they've been told to evacuate 15 times before and the fires didn't come through here, so, unfortunately that complacency is a big risk and something which has been actively managed" – emergency management coordinator. *Risk awareness* – "We also have a tree change […] where people who were city dwellers move for the change of lifestyle into a rural environment or down at the seaside, and don't actually understand the potential risk of fires, or may not go through the fire preparations beforehand" – emergency management coordinator; "country people are used to the risk, they understand it a lot better, so they're more likely in such cases to respond and evacuate" – police sergeant. *Risk mitigation* – lacking due to an appreciation of nature's aesthetics but not its risks: "a community member who's a long-term resident, when I visited his house a couple of times, […] show me photos of what Moggs Creek used to be like. So, pre-Ash Wednesday, and none of the vegetation that's there now was there back then. And he talks to me about how a lot of holiday home owners want to live in the bush, and they want the beautiful vistas of the great ocean road […] with the trees and so forth, but that's not actually the indigenous landscape for this area, it's been introduced over time" – community safety manager.
Time	*Warning time* - evacuation warning time varied a lot from 1 to 72 hours. *Response times* - highly dependent on circumstances and each interviewee had their own experience, meaning timing precision may be difficult to achieve; people under the influence of alcohol will have a longer response time. *Door-knock time* – limited time spent at each residence, decided on a case-by-case basis, but not believed to compromise the evacuation operation on the whole. *Mobilisation time* – with police officers knocking at each door, evacuation of homes was completed in 2 hours.

Appendix H – Chapter 6 results' summaries

Table H 1 Test results for relationships between variables and pre-event risk perception.

PRE-EVENT RISK									
	SoFR			**AUS**			**Merged**		
Gender (AE)	Male	Female	*Test results*	Male	Female	*Test results*	Male	Female	*Test results*
Median (IQR)	2 (1-3)	2 (1-3)	*p = .410, r = -.08*	2 (2-3)	3 (2-3)	*p = .216, r = -.12*	2 (2-3)	2 (2-3)	*p = .088, r = 11*
Gender (H)									
Median (IQR)	1 (1-2)	1 (0-2)	*p = .276, r = -.09*	1 (0-1)	1 (0-2)	*p = .110, r = -.14*	1 (0-2)	1 (0-2)	*p = .720, r = -.02*
Dependents (AE)	Yes	No	*Test results*	Yes	No	*Test results*	Yes	No	*Test results*
Median (IQR)	2 (2-3)	2 (1-3)	*p = .060, r = .18*	3 (2-3)	2 (2-3)	*p = .125, r = .15*	3 (2-3)	2 (2-3)	***p = .019, r = .16***
Dependents (H)									
Median (IQR)	1 (1-2)	1 (0-2)	*p = .227, r = .10*	1 (0-2)	1 (0-2)	*p = .394, r = .08*	1 (1-2)	1 (0-2)	*p = .162, r = .08*
Info: Community meetings (AE)									
Median (IQR)	3 (1-3)	2 (1-3)	*p = .356, r = .09*	3 (2-3)	2 (2-3)	*p = .85, r = .16*	3 (2-3)	2 (2-3)	***p = 002, r = .21***
Info: Community meetings (H)									
Median (IQR)	2.5 (2-3)	1 (0-2)	*p = .113, r = .01*	2 (2-3)	1 (0-1)	***p < .001, r = .33***	2 (2-3)	1 (0-1)	***p < .001, r = 21***
Mitigation involvement (AE)									
Median (IQR)	2 (1-3)	2 (1-3)	*p = .735, r = .04*	3 (2-3)	2 (2-3)	*p = .092, r = .19*	3 (2-3)	2 (1-3)	***p = .014, r = .21***
Mitigation involvement (H)									
Median (IQR)	2 (.5-2)	1 (1-2)	*p = .413, r = .08*	2 (2-3)	1 (0-1)	***p < .001, r = .45***	2 (2-3)	1 (0-2)	***p < .001, r = .26***
Family house (AE)									
Median (IQR)	2 (1.25-3)	2 (1-2)	***p = .032, r = .20***	3 (2-3)	2 (2-3)	*p = .606, r = .05*	2 (2-3)	2 (1-3)	*p = .190, r = .05*
Family house (H)									
Median (IQR)	2 (1-2)	1 (0-1)	***p < .001, r = .38***	1 (0-2)	0 (0-1)	***p = .003, r = .27***	1 (1-2)	1 (0-1)	***p < .001, r = .27***
Medical conditions (AE)									
Median (IQR)	3 (2-3)	2 (1-3)	***p =.030, r = .21***	3 (2-3)	3 (2-3)	*p = .580, r = .05*	3 (2-3)	2 (2-3)	***p = .037, r = .14***
Medical conditions (H)									
Median (IQR)	2 (1-2)	1 (0-2)	*p = .308, r = .08*	1 (.5-1)	1 (0-2)	*p = .870, r = .01*	1 (1-2)	1 (0-2)	*p = .747, r = .02*
Insurance (AE)	Yes	No/DK	*Test results*	Yes	No/DK	*Test results*	Yes	No/DK	*Test results*
Median (IQR)	3 (2-3)	2 (1-3)	***p = .007, r = .26***	3 (2-3)	3 (2-3)	*p = .216, r = -.12*	3 (2-3)	2 (1-3)	***p < .001, r = .24***
Insurance (H)									
Median (IQR)	1 (1-2)	1 (0-2)	*p = .205, r = .10*	2(1-2.5)	0 (0-1)	***p < .001, r = .60***	2 (1-2)	1 (0-1)	***p < .001, r = .36***

NOTE: DK = don't know; significant results are highlighted in orange font.

Table H 2 Test results for relationships between variables and planning.

PLANNING												
	SoFR				AUS				Merged			
	NP	Plan	KWTD	*Test results*	NP	Plan	KWTD	*Test results*	NP	Plan	KWTD	*Test results*
Age (AE)												
Mean	41.01*	50.37*^	41.71^	**$p = .042, eta^2 = .04$**	47.11*	51.14*	43.11	**$p = .021, eta^2 = .06$**	42.27*	50.99*^	42.20^	**$p < .001, eta^2 = .08$**
SD	14.87	11.63	14.89		11.19	13.39	13.68		14.35	13.00	14.41	
Age (H)												
Mean	43.00	43.00	43.91	$p = .933, eta^2 = .001$	40.72*	49.28*	46.05	**$p = .001, eta^2 = .10$**	42.26*	47.24*	44.62	**$p = .021, eta^2 = .02$**
SD	12.80	15.26	15.49		11.47	12.90	11.45		12.39	13.92	12.22	
Gender (AE)												
Male	49%	15%	36%	$p = .854, \varphi_c = .05$	10%	63%	27%	$p = .379, \varphi_c = .13$	33%	34%	33%	$p = .691, \varphi_c = .05$
Female	52%	12%	36%		19%	61%	20%		35%	37%	28%	
Gender (H)												
Male	61%	14%	26%	$p = .476, \varphi_c = .09$	51%	26%	23%	$p = .132, \varphi_c = .17$	33%	34%	33%	$p = .691, \varphi_c = .05$
Female	69%	12%	19%		44%	42%	14%		35%	37%	28%	
Info source: Radio (AE)												
No	50%	14%	36%	$p = 1.00, \varphi_c = .01$	27%	54%*	20%	**$p = .006, \varphi_c = .29$**	42%*	28%^	30%	**$p = .001, \varphi_c = .23$**
Yes	51%	14%	35%		6%	69%*	25%		23%*	48%^	29%	
Info source: Radio (H)												
No	71%*	10%^	19%	**$p = .010, \varphi_c = .22$**	57%*	30%^	13%	**$p = .001, \varphi_c = .25$**	66%*	17%^	17%	**$p < .001, \varphi_c = .25$**
Yes	49%*	21%^	29%		32%*	47%^	21%		41%*	34%^	25%	
Info source: Government's website (AE)												
No	52%	13%	35%	$p = .739, \varphi_c = .07$	21%*	54%^	25%	**$p = .045, \varphi_c = .22$**	41%*	28%^	31%	**$p < .001, \varphi_c = .29$**
Yes	42%	16%	42%		8%*	74%^	19%		17%*	58%^	25%	
Info source: Government's website (H)												
No	64%	13%	22%	$p = .928, \varphi_c = .02$	58%*	28%^	14%	**$p < .001, \varphi_c = .37$**	62%*	18%^	20%	**$p < .001, \varphi_c = .27$**
Yes	62%	13%	25%		19%*	58%^	23%		31%*	46%^	24%	
Info source: Community Meetings (AE)												
No	54%*	13%	33%^	**$p = .014, \varphi_c = .23$**	20%	50%*	30%^	**$p = .003, \varphi_c = .30$**	42%*	26%^	32%	**$p < .001, \varphi_c = 39$**
Yes	10%*	20%	70%^		8%	80%*	12%^		8%*	70%^	22%	
Info source: Community Meetings (H)												
No	65%	13%	22%	$p = .067, \varphi_c = .19$	52%*	30%^	18%	**$p < .001, \varphi_c = .38$**	60%*	20%^	20%	**$p < .001, \varphi_c = .32$**
Yes	0%	0%	100%		6%*	83%^	11%		5%*	75%^	20%	
Info source: Workplace (AE)												
No	56%*	13%	31%^	**$p = .003, \varphi_c = .27$**	15%	66%	19^	$p = .412, \varphi_c = .12$	39%*	35%	26%^	**$p = .004, \varphi_c = .20$**
Yes	17%*	17%	67%^		15%	55%	30%		16%*	41%	43%^	

PLANNING												
	SoFR				AUS				Merged			
	NP	Plan	KWTD	*Test results*	NP	Plan	KWTD	*Test results*	NP	Plan	KWTD	*Test results*
Info source: Workplace (H)												
No	66%*	11%^	23%	**$p = .002$, $\varphi_c = .28$**	50%*	32%^	18%	**$p = .011$, $\varphi_c = .26$**	60%*	19%^	21%	**$p < .001$, $\varphi_c = .29$**
Yes	33%*	50%^	17%		21%*	68%^	11%		26%*	61%^	13%	
Info source: Internet (AE)												
No	57%*	9%^	34%	**$p = .004$, $\varphi_c = .28$**	21%	59%	20%	$p = .178$, $\varphi_c = .17$	44%*	27%^	29%	**$p < .001$, $\varphi_c = .30$**
Yes	31%*	28%^	42%		10%	65%	25%		17%*	52%^	31%	
Info source: Internet (H)												
No	67%	12%	21%	$p = .589$, $\varphi_c = .08$	49%	29%*	23%^	**$p = .009$, $\varphi_c = .26$**	60%	19%*	22%	**$p = .020$, $\varphi_c = .15$**
Yes	59%	16%	25%		40%	52%*	8%^		50%	32%*	17%	
Info source: None (AE)												
No	43%	17%	39%	$p = .051$, $\varphi_c = .20$	14%	64%	23%	$p = .069$, $\varphi_c = .22$	27%*	43%^	30%	**$p < .001$, $\varphi_c = .34$**
Yes	63%	7%	30%		15%	62%	23%		62%*	10%^	28%	
Info source: None (H)												
No	53%*	17%^	29%$^+$	**$p < .001$, $\varphi_c = .30$**	40%*	41%^	19%	**$p = .001$, $\varphi_c = .32$**	47%*	29%^	24%$^+$	**$p < .001$, $\varphi_c = .34$**
Yes	84%*	6%^	10%$^+$		93%*	7%^	0%		85%*	6%^	9%$^+$	
Info source: TV (AE)												
No	53%	12%	35%	$p = .524$, $\varphi_c = .09$	18%	64%	18%	$p = .616$, $\varphi_c = .09$	43%*	27%^	30 %	**$p = .002$, $\varphi_c = .21$**
Yes	45%	18%	36%		14%	61%	25%		25%*	46%^	29%	
Info source: TV (H)												
No	74%*	8%^	18%	**$p = .003$, $\varphi_c = .25$**	48%	37%	15%	$p = .838$, $\varphi_c = .05$	66%*	17%^	17%	**$p = .002$, $\varphi_c = .19$**
Yes	51%*	21%^	28%		44%	38%	18%		47%*	30%^	23%	
Info source: Social Media (AE)												
No	54%	14%	32%	$p = .313$, $\varphi_c = .13$	18%	60%	22%	$p = .676$, $\varphi_c = .08$	40%*	32%	28%	**$p = .036$, $\varphi_c = .16$**
Yes	40%	13%	45%		12%	65%	23%		24%*	43%	33%	
Info source: Social Media (H)												
No	66%	13%	21%	$p = .562$, $\varphi_c = .08$	54%*	30%^	16%	**$p = .035$, $\varphi_c = .22$**	62%*	19%^	19%	**$p = .018$, $\varphi_c = .16$**
Yes	59%	13%	28%		33%*	49%^	18%		46%*	31%^	23%	
Info source: Newspaper (AE)												
No	53%	13%	34%	$p = .542$, $\varphi_c = .09$	*17%*	*58%*	*25%*	$p = .469$, $\varphi_c = .12$	38%*	32%^	30%	**$p = .034$, $\varphi_c = .16$**
Yes	42%	16%	42%		12%	70%	18%		24%*	47%^	28%	
Info source: Newspaper (H)												
No	70%*	12%	18%^	**$p = .004$, $\varphi_c = .24$**	50%	32%*	18%	**$p = .048$, $\varphi_c = .22$**	62%*	20%^	18%	**$p = .002$, $\varphi_c = .20$**
Yes	45%*	17%	38%^		31%	56%*	13%		39%*	33%^	28%	

PLANNING												
	SoFR				**AUS**				**Merged**			
	NP	Plan	KWTD	*Test results*	NP	Plan	KWTD	*Test results*	NP	Plan	KWTD	*Test results*
Insurance (AE)												
No/DK	65%*	7%^	28%$^{+}$	**$p = .002, \varphi_c = .32$**	29%	36%*	36%	**$p = .029, \varphi_c = .24$**	59%*	12%^	29%	**$p < .001, \varphi_c = .46$**
Yes	33%*	21%^	46%$^{+}$		13%	70%*	17%		19%*	54%^	27%	
Insurance (H)												
No/DK	76%	8%	16%	$p = .112, \varphi_c = .17$	72%*	18%^	10%	**$p < .001, \varphi_c = .60$**	73%*	14%^	13%$^{+}$	**$p < .001, \varphi_c = .31$**
Yes	59%	12%	29%		12%*	65%^	23%		43%*	30%^	27%$^{+}$	
Experience (AE)												
Once	58%	10%	32%	$p = .571, \varphi_c = .09$	21%	51%	28%	$p = .132, \varphi_c = .18$	38%	33%	*29%*	$p = .712, \varphi_c = .05$
> once	48%	15%	37%		12%	69%	20%		33%	37%	30%	
Experience (H)												
Never	68%*	13%	19%*	**$p = .026, \varphi_c = .17$**	54%*	32%	14%	**$p = .001, \varphi_c = .24$**	62%*	21%	17%*	**$p < .001, \varphi_c = .19$**
Once	63%	15%	22%		29%	57%	14%		51%^	29%	20%^	
> once	36%*	14%	50%*		6%*	56%	38%		34%*^	32%	45%*^	
Community closeness (AE)												
Low	64%	8%	28%	$p = .300, \varphi_c = .19$	27%*	46%^	27%	**$p = .027, \varphi_c = .31$**	47%*	26%^	*28%*	**$p = .004, \varphi_c = .28$**
High	44%	12%	44%		9%*	76%^	15%		23%*	52%^	26%	
Community closeness (H)												
Low	70%	14%	16%	$p = .270, \varphi_c = .15$	57%*	28%^	15%	**$p = .019, \varphi_c = .28$**	63%*	21%	16%	**$p = .035, \varphi_c = .18$**
High	57%	14%	29%		30%*	51%^	19%		45%*	30%	25%	
Mitigation involvement (AE)												
No	55%	8%	37%	$p = .352, \varphi_c = .16$	20%	55%	25%	$p = .072, \varphi_c = .27$	39%*	29%^	32%	**$p < .001, \varphi_c = .36$**
Yes	40%	20%	40%		9%	80%	11%		16%*	67%^	18%	
Mitigation involvement (H)												
No	65%*	14%	21%^	**$p = .009, \varphi_c = .29$**	47%*	35%^	18%	**$p = .024, \varphi_c = .27$**	57%*	24%^	19%	**$p = .001, \varphi_c = .25$**
Yes	22%*	11%	67%^		14%*	71% ^	14%		17%*	48%^	35%	
Pets (AE)												
No	60%	8%	32%	$p = .308, \varphi_c = .15$	18%	53%	29%	$p = .688, \varphi_c = .09$	48%*	20%^	31%	**$p = .001, \varphi_c = .24$**
Yes	46%	16%	37%		15%	65%	20%		28%*	45%^	27%	
Pets (H)												
No	69%	9%	22%	$p = .579, \varphi_c = .09$	79%*	14%^	7%	**$p < .001, \varphi_c = .49$**	72%*	11%^	17%	**$p < .001, \varphi_c = .31$**
Yes	60%	12%	27%		27%*	52%^	21%		43%*	34%^	24%	
Family house (AE)												
No	67%	4%	30%	$p = .135, \varphi_c = .20$	36%	36%	27%	$p = .051, \varphi_c = .21$	58%*	13%^	29%	
Yes	47%	17%	37%		13%	66%	21%		29%*	43%^	28%	**$p < .001, \varphi_c = .26$**

	PLANNING											
	SoFR				**AUS**				**Merged**			
	NP	Plan	KWTD	*Test results*	NP	Plan	KWTD	*Test results*	NP	Plan	KWTD	*Test results*
Family house (H)												
No	67%	15%	19%	*p = .171, φc = .15*	80%*	15%^	5%	***p = .002, φc = .32***	70%*	15%^	16%	***p = .004, φc =.20***
Yes	62%	8%	30%		38%*	44%^	18%		48%*	28%^	24%	
Property attachment (AE)												
Temp.	66%	9%	25%	*p = .095, φc = .22*	21%	50%	29%	*p = .413, φc = .15*	52%*	22%^	26	***p = .001, φc = .26***
Perm.	42%	17%	41%		12%	70%	19%		26%*	46%^	29%	
Property attachment (H)												
Temp.	82%	14%	5%	*p = .058, φc = .19*	72%*	11%^	17%	***p = .021, φc = .25***	78%*	13%^	10%	***p = .013, φc = .18***
Perm.	63%	10%	18%		40%*	44%^	16%		53%*	25%^	23%	
Pre-event risk (AE)												
Low	65%	6%	29%	*p = .163, φc = .18*	0%	50%	50%	*p = .064, φc = .22*	52%*	14%^	33%	***p =.001, φc = .25***
High	47%	15%	38%		17%	65%	19%		30%*	44%^	27%	
Pre-event risk (H)												
Low	63%	16%	21%	*p = .063, φc = .19*	62%*	22%^	16%	***p < .011, φc = .59***	63%*	19%^	19%	***p = .003, φc = .20***
High	65%	5%	31%		3%*	81%^	16%		42%*	32%^	26%	
LoC *self* (AE)												
No	49%	8%	43%	*p = .551, φc = .13*	19%	65%	15%	*p = .630, φc = .12*	38%*	29%^	33%	***p = .003, φc = .29***
Yes	57%	14%	29%		11%	68%	21%		21%*	57%^	22%	
LoC *self* (H)												
No	68%	10%	22%	*p = .407, φc = .12*	54%	29%	17%	*p = .177, φc = .18*	63%*	17%^	20%	***p = .022, φc =.19***
Yes	57%	17%	26%		37%	46%	17%		46%*	33%^	21%	

*NOTE: NP = no plan at all, KWTD = knew what to do; symbols * ^ and $^+$ indicate significant differences in a post-hoc test.*

Table H 3 Test results for relationships between variables and immediate response.

	IMMEDIATE RESPONSE								
	SoFR-AE			**AUS-AE**			**Merged**		
Visibility	Passive	Active	*Test results*	Passive	Active	*Test results*	Passive	Active	*Test results*
Median (IQR)	1 (1-2)	2 (1-3)	*p = .077, r = .23*	2 (1-3)	2 (1-3)	*p = .340, r = .11*	1 (1-2)	2 (1-3)	***p = .032, r = .18***
Plan									
NP	29%	71%	*p =.359, φ_c = .18*	50%*^	50%*^	***p =.006, φ_c = .35***	35%*	66%*	***p = .004, φ_c = .25***
Plan	10%	90%		13%*	88%*		12%*	88%*	
KWTD	17%	83%		11%^	89%^		15%	85%	
Gender									
Male	32%	68%	*p = .062, φ_c = .20*	12%	88%	*p = .284, φ_c = .11*	22%	78%	*p = .514, φ_c = .05*
Female	15%	85%		21%	79%		18.3%	82%	

*NOTE: NP = no plan at all, KWTD = knew what to do; significant results are highlighted in orange font; symbols * and ^ indicate significant differences in a post-hoc test.*

Table H 4 Test results for relationships between variables and intention.

INTENTION												
	SoFR-AE				AUS-AE				Merged			
	Wait	Stay	Evacuate	*Test results*	Wait	Stay	Evacuate	*Test results*	Wait	Stay	Evacuate	*Test results*
Age												
Mean	40.78	46.24	45.64	$p = .376, eta^{2} = .03$	50.17	53.89*	44.58*	**$p = .022, eta^{2} = .08$**	44.25*	51.38*	44.91	**$p = .022, eta^{2} = .05$**
SD	15.93	16.17	13.82		13.13	13.10	13.96		15.54	14.47	13.61	
Gender												
Male	54%	39%*	7%^	**$p = .015, \varphi_c = .34$**	24%	49%	27%	$p = .293, \varphi_c = .17$	38%	44%*	18%^	**$p = .014, \varphi_c = .23$**
Female	59%	14%*	27%^		29%	32%	39%		42%	24%*	34%^	
Experience												
Once	67%	6%	28%	$p = .089, \varphi_c = .26$	34%	18%*	47%^	**$p = .003, \varphi_c = .36$**	45%	14%*	41%^	**$p = .001, \varphi_c = .30$**
> once	54%	30%	17%		21%	54%*	25%^		38%	42%*	21%^	
Plan (formal or informal)												
No	61%	19%*	20%	**$p = .026, \varphi_c = .33$**	57%*	23%^	20%$^{+}$	**$p < .001, \varphi_c = .48$**	60%*	20%^	20%$^{+}$	**$p = .001, \varphi_c = .47$**
Yes	25%	63%*	13%		12%*	47%^	42%$^{+}$		13%*	49%^	38%$^{+}$	
Community closeness												
Low	60%	12%	28%	$p = .275, \varphi_c = .21$	41%	46%	14%*	**$p = .047, \varphi_c = .28$**	51%	28%	21%	$p = .078, \varphi_c = .19$
High	50%	29%	21%		20%	40%	40%*		32%	36%	33%	
Property attachment												
Temporary	74%	16%	11%	$p = .307, \varphi_c = .21$	50%*	8%^	42%	**$p = .037, \varphi_c = .28$**	65%*	13%^	23%	**$p = .004, \varphi_c = .28$**
Permanent	51%	29%	20%		21%*	43%^	36%		33%*	37%^	30%	
Fire safety knowledge												
No	57%	16%*	28%	**$p = .010, \varphi_c = .40$**	24%	41%	36%	$p = .518, \varphi_c = .13$	39%	29%	32%	$p = .088, \varphi_c = .19$
Yes	38%	63%*	0%		33%	44%	22%		35%	50%	15%	
LoC *Self*												
No	60%	17%	23%	$p = .357, \varphi_c = .20$	39%	23%	39%	$p = .053, \varphi_c = .27$	52%*	19%^	29%	**$p = .001, \varphi_c = .33$**
Yes	43%	36%	21%		21%	51%	28%		25%*	48%^	27%	
Pets												
No	68%	19%	13%	$p = .255, \varphi_c = .20$	40%	20%	40%	$p = .232, \varphi_c = .18$	59%*	20%^	22%	**$p = .009, \varphi_c = .24$**
Yes	49%	27%	24%		24%	43%	33%		33%*	37%^	30%	
Insurance												
No/DK	57%	23%	21%	$p = .953, \varphi_c = .04$	50%	20%	30%	$p = .202, \varphi_c = .20$	56%*	22%	22%	**$p = .020, \varphi_c = .22$**
Yes	57%	25%	18%		24%	41%	36%		33%*	37%	34%	
Visibility												
Median	1	3	2	$p = .131, eta^{2} = .07$	2	3	2	**$p = .013, eta^{2} = .11$**	2	3	2	**$p = .001, eta^{2} = .10$**
(IQR)	(1-2)	(1-3)	(1-3)		(1-3)	(2-3)*	(1-3)*		(1-2)*	(2-3)*	(1-3)	
Environmental cues												
No	64%	14%	21%	$p = .616, \varphi_c = .12$	24%	39%	37%	$p = .491, \varphi_c = .13$	31%*	35%	34%	**$p = .043, \varphi_c = .20$**

INTENTION												
	SoFR-AE				AUS-AE				Merged			
	Wait	Stay	Evacuate	*Test results*	Wait	Stay	Evacuate	*Test results*	Wait	Stay	Evacuate	*Test results*
Yes	54%	27%	20%		37%	37%	26%		49%*	29%	21%	
First cue(s): Saw Smoke												
No	53%	40%	7%	*p = .203, φ_c = .24*	25%	63%	13%	*p = .136, φ_c = .46*	44%	48%*	9%	***p = .032, φ_c = .29***
Yes	56%	21%	23%		46%	18%	36%		54%	20%*	26%	
Advance wildfire warning												
No	55%	26%	19%	*p = .657, φ_c = .11*	37%	37%	26%	*p = .490, φ_c = .13*	51%*	29%	21%	***p = .027, φ_c = .21***
Yes	64%	14%	21%		24%	39%	37%		31%*	35%	34%	
Recommendation to evacuate												
No	62%	15%	23%	*p = .741, φ_c = .21*	27%	43%	30%*	***p =.006, φ_c = .38***	33%	38%	29%*	***p = .014, φ_c = .32***
Yes	100%	0%	0%		0%	13%	88%*		11%	11%	78%*	
Order to evacuate												
No	62%	15%	23%	*p = .741 φ_c = .21*	22%	41%	38%	*p =.055, φ_c = .30*	28%*	37%	35%	***p =.026, φ_c = .29***
Yes	100%	0%	0%		100%	0%	0%		100%*	0%	0%	
Pre-event risk												
Median (IQR)	2 (1-3)	2 (2-3)	2.5 (1-3)	*p = .508, eta^2=.02*	2 (2-3)	3 (2-3)	3 (2-3)	*p = .645, eta^2=.01*	2 (1-3)*^	2 (2-3)*	3 (2-3)^	***p = .031, eta^2=.04***

*NOTE: DK = don't know; significant results are highlighted in orange font; symbols * ^ and $^+$ indicate significant differences in a post-hoc test*

Table H 5 Test results for relationships between variables and evacuation decision.

EVACUATION DECISION									
	SoFR-AE			**AUS-AE**			**Merged**		
	Stay	Evacuate	*Test results*	Stay	Evacuate	*Test results*	Stay	Evacuate	*Test results*
Gender									
Male	82%	18%	**$p = .041, \varphi_c = .24$**	58%	42%	$p = .180, \varphi_c = .14$	69%	31%	**$p = .019, \varphi_c = .19$**
Female	59%	41%		43%	57%		50%	50%	
Dependents									
No	80%	21%	**$p = .041, \varphi_c = .27$**	54%	46%	$p = .263, \varphi_c = .12$	65%	36%	**$p = .034, \varphi_c = .17$**
Yes	55%	46%		42%	58%		48%	52%	
Children									
No	75%	26%	$p = .110, \varphi_c = .19$	$54\%_a$	46%	$p = .152, \varphi_c = .15$	63%	37%	**$p = .043, \varphi_c = .17$**
Yes	56%	44%		$38\%_a$	62%		46%	54%	
Pets									
No	77%	23%	$p = .138, \varphi_c = .18$	53%	47%	$p = .706, \varphi_c = .04$	70%	30%	**$p = .049, \varphi_c = .16$**
Yes	61%	39%		48%	52%		53%	47%	
Grouping behaviour									
No	20%	80%	**$p = .008, \varphi_c = .63$**	45%	55%	$p = .130, \varphi_c = .28$	39%	62%	**$p = .002, \varphi_c = .41$**
Yes	83%	17%		78%	22%		81%	19%	
Experience									
Once	61%	39%	$p = .466, \varphi_c = .09$	37%	63%	$p = .051, \varphi_c = .21$	45%	55%	**$p = .020, \varphi_c = .19$**
> once	70%	30%		58%	42%		64%	36%	
Pre-event risk									
Median (IQR)	2(1-3)	2(2-3)	$p = .076, r = .21$	2(2-3)	3(2-3)	$p = .337, r = .10$	2(1.5-3)	3(2-3)	**$p = .013, r = .19$**
LoC ***Self***									
No	71%	29%	$p = .100, \varphi_c = .02$	52%	48%	$p = .200, \varphi_c = .14$	61%	39%	$p = .525, \varphi_c = .05$
Yes	67%	33%		68%	32%		68%	32%	
Community closeness									
Low	64%	36%	$p = .432, \varphi_c = .10$	64%	36%	$p = .384, \varphi_c = .10$	64%	36%	$p = .719, \varphi_c = .03$
High	74%	27%		53%	47%		61%	39%	
Fire safety knowledge									
No	67%	33%	$p = .234, \varphi_c = .16$	54%	46%	$p = .607, \varphi_c = .06$	60%	40%	$p = .384, \varphi_c = .08$
Yes	88%	13%		61%	39%		69%	31%	
Property attachment									
Temporary	79%	21%	$p = .253, \varphi_c = .14$	25%	75%	$p = .109, \varphi_c = .18$	58%	42%	$p = .810, \varphi_c = .02$
Permanent	64%	36%		50%	50%		56%	44%	
Plan									
NP	71%	29%	$p = .243, \varphi_c = .20$	36%	64%	$p = .558, \varphi_c = .11$	62%	39%	$p = .760, \varphi_c = .06$
Plan	88%	13%		52%	48%		56%	44%	

EVACUATION DECISION									
	SoFR-AE			AUS-AE			Merged		
	Stay	Evacuate	*Test results*	Stay	Evacuate	*Test results*	Stay	Evacuate	*Test results*
KWTD	58%	42%		50%	50%		55%	45%	
Insurance									
No/DK	71%	30%	$p = .584$, $\varphi_c = .06$	50%	50%	$p = .876$, $\varphi_c = .02$	67%	33%	$p = .076$, $\varphi_c = .14$
Yes	64%	36%		47%	53%		52%	48%	
Household size									
Median (IQR)	3(2-4.5)	3(2-5)	$p = .610$, $r = -.06$	3(2-4)	3(2-4)	$p = .851$, $r = -.02$	3(2-4)	3(2-4)	$p = .457$, $r = -.06$
Age									
Mean (SD)	43 (15.63)	42 (15.57)	$p = .707$, $eta^2 = .002$	53.11 (14.40)	47.37 (13.04)	$p = .105$, $eta^2 = .03$	47.57 (15.59)	45.58 (14.05)	$p = .404$, $eta^2 = .004$
First cues									
Social/unofficial	38%*	62%*		36%	64%		37%*	63%*	
Official/fire service	100%*	0%*	**$p = .034$, $\varphi_c = .30$**	55%	45%	$p = .340$, $\varphi_c = .16$	60%	40%	**$p = .034$, $\varphi_c = .21$**
Environmental	70%	30%		47%	53%		64%*	36%*	
New cues									
Social/unofficial	50%	50%		42%	58%		44%	56%	
Official/fire service	50%	50%	$p = .266$, $\varphi_c = .23$	50%	50%	$p = .959$, $\varphi_c = .06$	50%	50%	$p = .440$, $\varphi_c = .14$
Environmental	81%	19%		43%	57%		64%	36%	
Mixture	61%	39%		44%	56%		52%	48%	
New warning content									
Fire properties	81%	19%		50%	50%		60%	40%	
Protective action	0%	100%	**$p = .025$, $\varphi_c = .50$**	60%	40%	$p = .817$, $\varphi_c = .09$	50%	50%	$p = .214$, $\varphi_c = .17$
Both	36%	64%		44%	56%		42%	58%	
New warning content: evacuation order/recommendation									
No	79%	21%	**$p = .010$, $\varphi_c = .54$**	54%	46%	**$p = .025$, $\varphi_c = .24$**	57%	43%	**$p = .007$, $\varphi_c = .25$**
Yes	22%	78%		21%	79%		22%	78%	
Intention									
Wait-and-see	81%*	20%*		50%*	50%*		69%*	31%*	
Stay-in-place	88%^	12%^	**$p < .001$, $\varphi_c = .65$**	83%*	17%*	**$p < .001$, $\varphi_c = .63$**	85%^	15%^	**$p < .001$, $\varphi_c = .62$**
Evacuate	7%*^	93%*^		10%*	90%*		9%*^	91%*^	
Visibility									
Median (IQR)	1.5(1-3)	1.5(1-3)	$p = .596$, $r = -.08$	2(2-3)	3(1-3)	**$p = .006$, $r = -.31$**	2(1-3)	2(1-3)	$p = .184$, $r = -.11$
Fire proximity									
Median (IQR)	1(1-2)	1(1-2)	$p = .471$, $r = -.09$	1(1-2)	1(1-2)	**$p = .041$, $r = -.21$**	1(1-2)	1(1-2)	$p = .264$, $r = -.09$

*NOTE: NP = no plan, KWTD = knew what to do; DK = don't know; significant results are highlighted in orange font; symbols * ^ and ⁺ indicate significant differences in a post-hoc test.*

Table H 6 Summary of different H scenario responses.

Responses	Hypothetical Scenarios					
	Social Cues		Environmental Cues		Social + Environmental Cues	
	SoFR	AUS	SoFR	AUS	SoFR	AUS
Most common first response	Seek Info (61%)	Seek Info (66%)	Seek Info (65%)	Seek Info (76%)	Seek Info (54%)	Seek Info (56%)
Other first responses ranked	2. Wait (24%) 3. Evacuate (12%) 4. Shelter (2%)	2. Evacuate (18%) 3. Wait (16%) 4. Shelter (0%)	2. Wait (15%) 3. Evacuate (13%) 4. Shelter (7%)	2. Shelter (12%) 3. Evacuate (10%) 4. Wait (2%)	2. Evacuate (22%) 3. Wait (20%) 4. Shelter (4%)	2. Evacuate (40%) 3. Wait (2%) 4. Shelter (2%)
Trend if *Evacuate* most common first response	Majority remain *Evacuate* from start (A) onwards	Majority remain *Evacuate* from start (A) onwards	Majority remain *Evacuate* from start (A) onwards [except (C), Call FFs]	Majority remain *Evacuate* from start (A) onwards	Majority remain *Evacuate* from start (A) onwards	Majority remain *Evacuate* from start (A) onwards
Otherwise, when does most common response switch to become *Evacuate*	*Seek Info:* from (D) onwards *Wait:* from (E) onwards *Shelter:* Never	*Seek Info:* from (D) onwards *Wait:* from (E) onwards *Shelter:* N/A	*Seek Info:* at end (D) *Wait:* at (B) onwards [except (C), Call FFs] *Shelter:* Never	*Seek Info:* from (B) onwards *Wait:* Never *Shelter:* at (C) then Shelter onwards	*Seek Info:* from (B) onwards [except (D), Shelter] *Wait:* from (B) onwards *Shelter:* Never	*Seek Info:* from (B) onwards *Wait:* from (C) onwards *Shelter:* At (B) onwards then Shelter (D) onwards

Note: I. Social Cues scenario stages: (A) = Media warning, fire approaching; (B) = (A) plus warning gives estimated time of fire's arrival; (C) = (B) plus neighbours leaving; (D) = (B) plus family urge participant to leave; (E) = (B) plus officially ordered to evacuate; (F) = (E) plus door knock from firefighters; II. Environmental Cues scenario stages: (A) = See smoke plumes in distance; (B) = See embers land nearby; (C) = See vegetation around residence catch fire; (D) = See smoke, embers and flames nearby plus feel physiological effects of fire; III. Social + Environmental Cues scenario stages: (A) = Social Cues (A) plus Environmental Cues (A); (B) = Social Cues (A) plus Environmental Cues (B); (C) = Social Cues (A) plus Environmental Cues (C); (D) = Social Cues (A) plus Environmental Cues (D); (E) = (D) plus officially ordered to evacuate; N.B. As Environmental Cues stage (C) involved an active fire at the residence, at a stage prior to being physically affected by it, participants were offered two additional response options here – try to tackle the fire personally or call firefighters (FFs) to do that.

Table H 7 Test results for relationships between variables and evacuation destination.

	EVACUATION DESTINATION									
	SoFR					AUS				
Route knowledge (AE)	Res. nearby	Church hall	Another town		Test results	Res. nearby	Church Hall	Another town		Test results
Median (IQR)	0 (0-1.5)	n/a	3 (1-3)		*p = .077, eta^2=.37*	3 (2.5-3)	3 (2-3)	3 (2-3)		*p = .782, eta^2 = .02*
Route knowledge (H)	DK	Res. nearby	Church Hall	Another town	Test results	DK	Res. nearby	Church Hall	Another town	Test results
Median (IQR)	1* (0-1)	1.5 (1-2)	2.5* (1-3)	1 (0-2)	***p =.008, eta^2= .14***	0* (0-.5)	0 (0-1)	n/a	2* (1-3)	***p < .001, eta^2 = .25***
Fire prox. (AE)	Res. nearby	Church Hall	Another town		Test results	Res. nearby	Church Hall	Another town		Test results
Median (IQR)	1.5 (1-2)	n/a	1 (1-2)		*p = .804, eta^2=.04*	2 (1.5-2)	1 (1-1.5)	1 (1-2)		*p = .188, eta^2 = .10*

*NOTE: Res. = residence; DK = don't know; significant results are highlighted in orange font; symbol * indicates significant difference in a post-hoc test.*

Table H 8 Test results for relationships between variables and future decision.

	FUTURE DECISION								
	SoFR-AE			AUS-AE			Merged		
Gender	Stay	Evacuate	*Test results*	Stay	Evacuate	*Test results*	Stay	Evacuate	*Test results*
Male	89%	11%	***p = .003, φ_c = .48***	60%	40%	***p = .048, φ_c = .26***	72%	28%	***p = .001, φ_c = .34***
Female	43%	57%		34%	66%		38%	63%	
LoC *Self*									
No	65%	35%	*p =.100, φ_c = .07*	35%	65%	***p = .004, φ_c = .37***	48%	52%	***p = .049, φ_c = .20***
Yes	50%	50%		79%	21%		75%	25%	
Past action									
Stay	81%	13%	***p =.004, φ_c = .49***	71%	29%	***p < .001, φ_c = .49***	76%	24%	***p < .001, φ_c = .51***
Evacuate	31%	69%		22%	78%		24%	76%	
Injuries									
No	75%	25%	***p =.033, φ_c = .36***	50%	50%	*p = .271, φ_c = .14*	60%	40%	***p = .022, φ_c = .23***
Yes	36%	64%		35%	65%		36%	64%	

NOTE: significant results are highlighted in orange font

Table H 9 Test results for relationship between variable and injury.

INJURY									
	SoFR-AE			AUS-AE			Merged		
Gender	No	Yes	*Test results*	No	Yes	*Test results*	No	Yes	*Test results*
Male	92%	8%	***p = .004,***	87%	13%	***p = .002,***	89%	11%	***p < .001,***
Female	58%	42%	φ_c **=.37**	52%	48%	φ_c **= .35**	55%	45%	φ_c **= .36**

Table H 10 Emotion/risk: Scenarios 1 (social), 2 (environmental) and 3 (social + environmental).

Variable	Region	Scenario	Mdn (IQR)	*p*	*r*
Optimistic	SoFR-H	1	1 [0-2]		
		2	0 [0-2]	all > .117	all < -.12
		3	1 [0-1.5]		
	AUS-H	1	1 [0-2]		
		2	0 [0-1]	all > .093	all < -.15
		3	0 [0-1]		
Relaxed	SoFR-H	1	0 [0-1]		
		2	0 [0-1]	all > .210	all < -.11
		3	0 [0-1]		
	AUS-H	1	0 [0-1]		
		2	0 [0-1]	all > .126	all < -.15
		3	0 [0-0]		
Energetic	SoFR-H	1	2 [1.75-3]		
		2	2 [2-3]*	**.048**	-.20
		3	2 [1-2.5]*		
	AUS-H	1	2 [2-3]		
		2	2 [0.25-3]	all > .070	all < -.21
		3	2 [2-3]		
Helpless	SoFR-H	1	1 [0-2]		
		2	1 [0.25-2]	all > .281	all < -.10
		3	1 [0-2]		
	AUS-H	1	1 [1-2]*	**.035**	-.24
		2	2 [1-2]*		
		3	2 [1-2]		
Annoyed	SoFR-H	1	1 [0-2]		
		2	1 [0-2]	all > .398	all < -.08
		3	1 [0-2]		
	AUS-H	1	1 [0-2]		
		2	1 [0-2]	all > .060	all < -.19
		3	0 [0-2]		
Active	SoFR-H	1	3 [2-3]		
		2	3 [3-3]	all > .485	all < -.07
		3	3 [3-3]		
	AUS-H	1	3 [2-3]		
		2	3 [2-3]	all > .293	all < -.11
		3	3 [2.5-3]		
Nervous	SoFR-H	1	2 [1-3]*	**.025**	-.23
		2	2 [2-3]*		
		3	2 [1-3]		
	AUS-H	1	2 [2-3]*		
		2	2 [2-3]	**.043**	-.23
		3	3 [2-3]*		
Fearful	SoFR-H	1	1 [1-2]*	**<.001**	-.40
		2	2 [2-3]*		
		3	2 [1-3]		
	AUS-H	1	2 [2-2]*^	**.010**	-.30
		2	3 [2-3]*		
		3	2 [2-3]^	**.014**	-.28
Alert	SoFR-H	1	3 [2-3]*	**.041**	-.21
		2	3 [3-3]*		
		3	3 [2-3]		
	AUS-H	1	3 [3-3]		
		2	3 [3-3]	all > .104	all < -.16
		3	3 [3-3]		
Personal injury	SoFR-H	1	1 [1-2]*^	**<.001**	-.39
		2	2 [1-3]*		
		3	2 [1-2.5]^	**<.001**	-.40
	AUS-H	1	2 [1-2]*^	**<.001**	-.43

Variable	Region	Scenario	Mdn (IQR)	*p*	*r*
		2	3 [2-3]*		
		3	2 [2-3]^	<.001	-.44
Loss of utilities	SoFR-H	1	1 [0.75-2]	all > .795	all < -.03
		2	1 [1-2]		
		3	1 [0-2]		
	AUS-H	1	2 [2-3]	all > .346	all < -.10
		2	2.5 [2-3]		
		3	2 [1-3]		
Residence damage	SoFR-H	1	2 [1-3]	all > .209	all < -.11
		2	2 [2-3]		
		3	2 [2-3]		
	AUS-H	1	3 [2-3]	all > .896	all < -.02
		2	3 [2-3]		
		3	3 [2-3]		
Family/ friends injury	SoFR-H	1	2 [2-3]*	.041	-.21
		2	3 [2-3]*		
		3	3 [2-3]		
	AUS-H	1	2 [2-3]*^	.008	-.31
		2	3 [2-3]*		
		3	3 [2.25-3]^	.001	-.38
Job compromised	SoFR-H	1	1 [0-1.25]	all > .605	all < -.05
		2	1 [0-2]		
		3	1 [0-2]		
	AUS-H	1	0 [0-2]	all > .226	all < -.12
		2	1 [0-1]		
		3	0 [0-2]		

Table H 11 Emotion/risk across stages for whole AE sample, evacuees and non-evacuees.

	SoFR-AE	Evacuees	Non-evacuees	AUS-AE	Evacuees	Non-evacuees
p						
Optimistic	.008	.031	.138	<.001	<.001	.094
Mdn [IQR]						
FC	1 [0-2]	1 [0-1.5]	1 [0-2]	1 [0-2]	1 [0-2]	1 [0-2]
NC	1 [0-1.5]*	0 [0-1]*	1 [0-2]	1 [0-1]*	1 [0-1]*	1 [0-2]
DM	1 [0-2]*	1 [0-2]*	1 [.5-2]	2 [0-2]*	2 [0-2]*	1 [0-2]
Relaxed	.023	.191	.949	.156	.028	.620
FC	1 [0-2]	0 [0-1]	1 [0-2]	1 [0-1]	0 [0-1.5]*	1 [0-1]
NC	1 [0-1.75]	0 [0-1]	1 [0-2]	0 [0-1]	0 [0-1]*	0 [0-2]
DM	1 [0-1]	0 [0-1]	1 [0-2]	0 [0-1]	0 [0-1.5]	0 0-2]
Energetic	.354	.727	.486	.371	.662	.486
FC	2 [1-2]	2 [1-2]	2 [1-2]	2 [1-2]	2 [0.5-2]	2 [1-2]
NC	2 [1-2]	2 [1-3]	2 [1-2]	2 [1-2]	2 [1-2]	2 [1-2]
DM	2 [1-2]	2 [1-2]	2 [1-2]	2 [1-2]	2 [0.5-2]	2 [1-3]
Helpless	.116	.846	.051	.011	.023	.114
FC	1 [.25-2]	2 [1-2]	1 [0-2]	0 [0-2]*	1 [0-2]*	0 [0-1]
NC	1 [0-2]	2 [0-2]	1 [0-2]	1 [0-2]*	2 [1-2]*	0 [0-2]
DM	1 [0-2]	2 [0-2]	1 [0-1]	1 [0-2]	1 [0-3]	0 [0-2]
Annoyed	.074	.039	.447	.278	.677	.082
FC	2 [0-2]	2 [.5-2]	2 [0-3]	0 [0-1]	0 [0-.15]	0 [0-1]
NC	2 [.25-2.75]	2 [0-2]	2 [1-3]	0 [0-1]	0 [0-1]	0 [0-1]
DM	2 [0-2]	2 [0-2]	2 [1-2]	0 [0-1]	0 [0-2]	0 [0-1]
Active	.893	.165	.587	.129	.163	.012
FC	3 [2-3]	3 [3-3]	3 [2-3]	3 [2.5-3]	3 [2-3]	0 [0-0]
NC	3 [2-3]	3 [3-3]	3 [2-3]	3 [3-3]	3 [2.5-3]	0 [0-0]
DM	3 [2-3]	3 [2-3]	3 [2-3]	3 [3-3]	3 [2-3]	0 [0-0]
Nervous	.726	.882	.602	.299	.047	.694
FC	2 [1-2]	2 [1-2]	2 [0-2]	2 [1-3]	2 [1-3]	2 [1-3]
NC	1 [1-2]	2 [1-2]	1 [0-2]	2 [1-3]	2 [1.5-3]	2 [1-2]

	SoFR-AE	Evacuees	Non-evacuees	AUS-AE	Evacuees	Non-evacuees
DM	1.5 [1-2]	2 [1-2]	1 [1-2]	2 [1-3]	2 [1-3]	2 [1-3]
Fearful	.006	.125	.039	.087	.026	.861
FC	2 [1-2]*	2 [1-2]	2 [1-2]	2 [1-2]	2 [1-3]*	2 [1-2]
NC	2 [0-2]	2 [1-2]	1.5 [0-2]	2 [1-3]	2 [1-3]*^	2 [0-3]
DM	1 [0-2]*	1 [0-2]	1 [0-2]	2 [0-3]	2 [1-3]^	2 [0-3]
Alert	.008	.135	.030	.759	.472	.692
FC	2 [2-2]	2 [2-3]	2 [2-2]	3 [3-3]	3 [2-3]	3 [3-3]
NC	2 [2-2]*	2 [2-3]	2 [2-2]	3 [3-3]	3 [3-3]	3 [3-3]
DM	2 [1-2]*	2 [2-3]	2 [1-2]	3 [3-3]	3 [3-3]	3 [3-3]
Personal injury	.666	.565	.717	.091	.175	.051
FC	0 [0-1]	1 [0-1]	0 [0-1]	0 [0-1]	0 [0-1]	1 [0-1]
NC	0 [0-1]	1 [1-1]	0 [0-1]	1 [0-1.5]	1 [0-2]	1 [0-1]
DM	0 [0-1]	1 [0-1]	0 [0-1]	1 [0-2]	0 [0-2]	1 [0-2]
Loss of utilities	.884	.607	.689	.378	.039	.090
FC	1 [0-2]	1 [0-2]	1 [0-2]	2 [1-3]	2 [1-3]	2 [1-3]
NC	1 [0-2]	1 [0-2]	1 [0-2]	2 [1-3]	3 [2-3]	2 [1-2]
DM	1 [0-2]	1 [0-2]	1 [0-2]	2 [1-3]	2 [0.5-3]	2 [1-3]
Family injury	.629	.717	.537	.519	.486	1.000
FC	1.5 [0-2]	2 [1-2]	1 [0-2]	2 [1-2]	2 [1-2.5]	1 [1-2]
NC	1.5 [0-2]	2 [1-2]	1 [0-2]	2 [0.5-3]	2 [1-3]	2 [0-2]
DM	1.5 [0-2]	2 [1-2]	1 [0-2]	2 [0.5-3]	2 [0.5-3]	1 [0-3]
Residence damage	.169	.230	.089	.001	.016	.070
FC	1 [1-2]	2 [1-3]	1 [1-2]	2 [1-2]*	2 [1-3]*	2 [1-2]
NC	1.5 [0-2]	2 [2-3]	1 [0-2]	2 [2-3]*	2 [2-3]*	2 [2-3]
DM	1 [0-2]	2 [1-3]	1 [0-2]	2 [1.5-3]	2 [2-3]	2 [1-3]
Job disruption	.956	1.000	1.000	.622	.032	.465
FC	0 [0-2]	0 [0-2]	0 [0-2]	0 [0-0]	0 [0-0]	0 [0-0]
NC	0 [0-2]	0 [0-2]	0 [0-2]	0 [0-0]	0 [0-.5]	0 [0-0]
DM	0 [0-1]	0 [0-2]	0 [0-1]	0 [0-0]	0 [0-0]	0 [0-0]

NOTE: FC = First cues; NC = New Cues; DM = Decision-making

Table H 12 Emotion/risk: relationship with past and future decisions of AE participants.

	Evacuees			Non-evacuees		
	Would evacuate again	**Would not evacuate again**	*p*	**Would stay again**	**Would not stay again**	*p*
Optimistic						
Mdn [IQR] SoFR DM	0 [0-2]	1 [0-1.5]	.811	1 [0-2]	1 [0-2]	.184
AUS DM	1 [0-1]	1 [0-2]	.376	1 [0.25-2]	1 [0-2]	.192
Relaxed						
SoFR DM	0 [0-1]	1 [0-1]	.531	2 [0-2]	0.5 [0-1.25]	.057
AUS DM	0 [0-1]	1 [0-2]	.730	1 [0-2]	0 [0-1]	.237
Energetic						
SoFR DM	2 [1.5-2.5]	2 [0.5-2.5]	.400	2 [2-2]	2 [1-2]	.133
AUS DM	2 [1-2]	2 [0-2]	.140	2 [0-2]	2 [1.5-3]	.008
Helpless						
SoFR DM	2 [0-2]	2 [1-2]	.104	1 [0-1]	2 [1-2.25]	.107
AUS DM	1 [0-2]	1 [0-2]	.419	0 [0-0.75]	0 [0-2]	.020
Annoyed						

	Evacuees			Non-evacuees		
	Would evacuate again	**Would not evacuate again**	*p*	**Would stay again**	**Would not stay again**	*p*
SoFR DM	1 [0-2]	2 [2-2.5]	**.038**	2 [0-2]	2 [1-3]	.881
AUS DM	0 [0-1]	1 [0-2]	.316	0 [0-1]	0 [0-1]	.845
Active						
SoFR DM	3 [2.5-3]	3 [2.5-3]	.577	3 [1-3]	2.5 [2-3]	.225
AUS DM	3 [3-3]	2 [1.5-3]	.151	3 [2.25-3]	3 [2.5-3]	.899
Nervous						
SoFR DM	2 [1-2.5]	2 [1-2]	.227	0 [0-2]	2 [1-3]	.090
AUS DM	2 [1.5-3]	2 [1-2.5]	.818	2 [0-2]	2 [2-3]	.062
Fearful						
SoFR DM	2 [1-2]	2 [1-2]	.575	0 [0-1]	2 [1.75-3]	.173
AUS DM	2 [1-2.5]	1 [1-2]	.465	1 [0-2]	2 [1-3]	**.022**
Alert						
SoFR DM	2 [2-3]	2 [2-2]	.337	2 [2-2]	2 [2-3]	.780
AUS DM	3 [2-3]	3 [2-3]	.298	3 [3-3]	3 [2.5-3]	.277
Personal injury						
SoFR DM	1 [0-1.5]	1 [0-2]	.371	0 [0-1]	1 [0-1.25]	.882
AUS DM	0 [0-1]	0 [0-1]	.701	0 [0-1]	1 [0-2]	.520
Loss of utilities						
SoFR DM	0 [0-2]	0 [1-2]	.811	1 [1-2]	1 [0-2.25]	.192
AUS DM	2 [1-3]	1 [0-2.5]	.163	1 [0-2.75]	2 [0.5-3]	.663
Family injury						
SoFR DM	2 [1-2]	2 [1-2]	.669	1 [0-2]	1.5 [1-2]	.197
AUS DM	2 [1-3]	2 [0.5-2.5]	.759	1 [0.25-2]	2 [1-3]	.091
Residence damage						
SoFR DM	2 [1.5-2.5]	2 [0.5-2.5]	.963	1 [0-2]	1 [0-2.25]	.900
AUS DM	2 [1-3]	1 [0-2]	.788	1 [0-2]	2 [1-3]	.305
Job disruption						
SoFR DM	0 [0-1.5]	0 [0-1.5]	.614	0 [0-2]	0 [0-0]	**.010**
AUS DM	0 [0-0]	0 [0-1]	**.037**	0 [0-1]	0 [0-0.5]	.676

Table H 13 Emotion/risk: males versus females in H samples.

Variable	Region	Gender	Mdn (IQR)	*p*	*r*
Optimistic	SoFR-H	Male	1 [0-2]	**.019**	-.20
		Female	0 [0-1]		
	AUS-H	Male	1 [0-1]	.978	.00
		Female	1 [0-1]		
Relaxed	SoFR-H	Male	1 [0-1]	**<.001**	-.23
		Female	0 [0-0]		
	AUS-H	Male	0 [0-1]	**.019**	-.22
		Female	0 [0-0]		
Energetic	SoFR-H	Male	2 [2-3]	.075	-.15
		Female	2 [1-3]		
	AUS-H	Male	2 [1-3]	.415	-.08
		Female	2 [2-3]		
Helpless	SoFR-H	Male	1 [0-2]	**.022**	-.19
		Female	2 [1-2]		
	AUS-H	Male	1 [1-2]	.214	-.12
		Female	2 [1-2]		
Annoyed	SoFR-H	Male	1 [0-2]	.081	-.15
		Female	1 [0-2]		

Variable	Region	Gender	Mdn (IQR)	*p*	*r*
	AUS-H	Male	1 [0-2]	.566	-.05
		Female	1 [0-2]		
Active	SoFR-H	Male	3 [3-3]	.904	-.01
		Female	3 [2-3]		
	AUS-H	Male	3 [2-3]	.111	-.15
		Female	3 [2-3]		
Nervous	SoFR-H	Male	2 [1-2]	**.001**	-.28
		Female	3 [1-3]		
	AUS-H	Male	2 [2-3]	**.023**	-.21
		Female	3 [2-3]		
Fearful	SoFR-H	Male	2 [1-2]	**.016**	-.20
		Female	2 [1-3]		
	AUS-H	Male	2 [1.25-2]	**.001**	-.31
		Female	3 [2-3]		
Alert	SoFR-H	Male	3 [2-3]	.188	-.11
		Female	3 [2.5-3]		
	AUS-H	Male	3 [3-3]	.502	-.06
		Female	3 [3-3]		
Personal injury	SoFR-H	Male	2 [1-2]	.595	-.04
		Female	2 [1-2]		
	AUS-H	Male	2 [1-2]	**.010**	-.24
		Female	2 [2-3]		
Loss of utilities	SoFR-H	Male	1[0.25-2]	.404	-.07
		Female	1 [0.5-2]		
	AUS-H	Male	2 [2-3]	.801	-.02
		Female	2 [2-3]		
Residence damage	SoFR-H	Male	2[1.25-3]	**.042**	-.17
		Female	3 [2-3]		
	AUS-H	Male	3 [2-3]	.510	-.06
		Female	3 [2-3]		
Job compromised	SoFR-H	Male	1 [0-2]	.727	-.03
		Female	1 [0-2]		
	AUS-H	Male	1 [0-1]	-.361	-.03
		Female	0 [0-1.25]		
Family/ friends injury	SoFR-H	Male	3 [2-3]	.197	-.11
		Female	3 [2-3]		
	AUS-H	Male	2 [2-3]	**.040**	-.19
		Female	3 [2-3]		

Table H 14 Emotion/risk: males versus females in AE samples.

Variable	Region	Gender	Mdn (IQR)	*p*	*r*
Optimistic	SoFR-AE	Male	1 [0-2]	**.001**	-.24
		Female	1 [0-2]		
	AUS-AE	Male	1 [0-2]	.104	-.10
		Female	1 [0-2]		
Relaxed	SoFR-AE	Male	1 [0-2]	**<.001**	-.32
		Female	0 [0-1]		
	AUS-AE	Male	1 [0-2]	**<.001**	-.28
		Female	0 [0-1]		
Energetic	SoFR-AE	Male	2[1.75-2]	.238	-.08
		Female	2 [1-2]		
	AUS-AE	Male	2 [1-2]	.498	-.04
		Female	2 [0-2]		

Variable	Region	Gender	Mdn (IQR)	*p*	*r*
Helpless	SoFR-AE	Male	1 [0-2]	**.001**	-.23
		Female	2 [0-2]		
	AUS-AE	Male	0 [0-1]	**.001**	-.20
		Female	1 [0-2]		
Annoyed	SoFR-AE	Male	2 [1-3]	.747	-.02
		Female	2 [0-2]		
	AUS-AE	Male	0 [0-2]	.412	-.05
		Female	0 [0-1]		
Active	SoFR-AE	Male	2.5 [2-3]	.058	-.13
		Female	3 [2-3]		
	AUS-AE	Male	3 [2.25-3]	.766	-.02
		Female	3 [3-3]		
Nervous	SoFR-AE	Male	1 [0-2]	**<.001**	-.37
		Female	2 [1-2]		
	AUS-AE	Male	1 [0-2]	**<.001**	-.34
		Female	2 [2-3]		
Fearful	SoFR-AE	Male	0 [0-2]	**<.001**	-.31
		Female	2 [1-2]		
	AUS-AE	Male	1 [0-2]	**<.001**	-.36
		Female	2 [1-3]		
Alert	SoFR-AE	Male	2 [2-2]	**.027**	-.16
		Female	2 [2-3]		
	AUS-AE	Male	3 [2-3]	**.015**	-.15
		Female	3 [3-3]		
Personal injury	SoFR-AE	Male	0 [0-1]	.539	-.04
		Female	1 [0-1]		
	AUS-AE	Male	0 [0-1]	.244	-.07
		Female	1 [0-2]		
Loss of utilities	SoFR-AE	Male	1.5 [1-2]	**.025**	-.16
		Female	1 [0-2]]		
	AUS-AE	Male	2 [1-3]	.115	-.10
		Female	2 [1-3]		
Residence damage	SoFR-AE	Male	1 [0-2]	**.005**	-.20
		Female	2 [1-2]		
	AUS-AE	Male	2 [1-3]	**.043**	-.13
		Female	2 [1-3]		
Family/ friends injury	SoFR-AE	Male	1 [0-2]	**.005**	-.20
		Female	2 [0-2]		
	AUS-AE	Male	1 [0-2]	**.045**	-.13
		Female	2 [1-3]		
Job compromised	SoFR-AE	Male	0[0-1.25]	.298	-.07
		Female	0 [0-1]		
	AUS-AE	Male	0 [0-0]	.859	-.01
		Female	0 [0-0]		

Table H 15 Tests for gender differences regarding BI time committed to action categories.

Action category	Median BI time (IQR)			
Seeking information	**SoFR-AE**	**SoFR-H**	**AUS-AE**	**AUS-H**
Male	0 (0 – 1.00)	2.50 (0 – 11.00)	0 (0 - 0)	1.00 (0 - 7.00)
Female	1.00 (0 – 5.00)	2.50 (0 – 8.50)	0 (0 – 5.00)	3.50 (0 – 11.75)
Test results	p = .063 U = 98.500 rho = .38	p = .974 U = 1,915.000 rho = -.01	p = .175 U = 2,048.000 rho = .12	*p = .049 U = 2,381.000 rho = .17*
Gathering belongings				
Male	3.00 (0 – 10.00)	9.50 (6.00 – 13.00)	0 (0 - 0)	8.50 (0 – 13.00)
Female	2.50 (0 – 8.50)	8.00 (3.50 – 14.50)	0 (0 – 15.00)	10.50 (2.87 – 18.00)
Test results	p = 1.000 U = 67.000 rho = .01	p = .487 U = 1,783.000 rho = -.06	*p = .006 U = 2,288.000 rho = .25*	*p = .033 U = 2,424.000 rho = .18*
Protecting property				
Male	n/a	1.00 (0 – 3.75)	0 (0 - 0)	1.00 (0 – 4.00)
Female	1.00 (0 – 1.00)	1.00 (0 – 2.00)	0 (0 - 0)	1.00 (0 – 6.00)
Test results	p = .094 U = 96.000 rho = .37	p = .624 U = 1,826.500 rho = -.04	p = .648 U = 1,897.000 rho = .04	p = .399 U = 2,148.000 rho = .07
Protecting life / health				
Male	1.00 (0 – 3.50)	5.00 (2.75 – 9.50)	0 (0 - 0)	2.00 (0 – 6.50)
Female	3.50 (2.00 – 10.00)	5.00 (2.50 – 8.00)	0 (0 – 4.50)	5.25 (1.00 – 9.37)
Test results	p = .094 U = 95.500 rho = .34	p = .404 U = 1,755.500 rho = -.08	p = .078 U = 2,121.500 rho = .16	p = .018 U = 2,473.000 rho = .21
Other miscellaneous				
Male	n/a	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Female	0 (0 – 1.00)	0 (0 - 0)	0 (0 - 0)	0 (0 – 2.50)
Test results	p = .651 U = 75.000 rho = .13	p = .880 U = 7,940.000 rho = .01	p = .418 U = 1,750.500 rho = -.07	p =.144 U = 2,231.500 rho = .13

Table H 16 Tests for differences between variables and number of actions and BI time.

	Gender		Household size				Medical conditions		Dwelling type		Age	FS knowledge	
	Male	**Female**	**1**	**2-3**	**4-5**	**6+**	**Yes**	**No**	**House**	**Other**		Yes	No
Mean no. actions (SD)													
SoFR-AE	3.29 (1.70)	5.53 (2.04)	3.00 (2.00)	5.00 (2.26)	5.83 (1.72)	4.86 (2.34)	5.57 (1.62)	4.68 (2.33)	5.33 (2.03)	3.20 (2.05)		6.50 (2.12)	4.87 (2.18)
SoFR-H	9.08 (5.30)	7.85 (3.93)	7.17 (3.73)	7.97 (4.46)	10.32 (5.34)	10.50 (0.71)	8.00 (3.65)	8.48 (4.72)	8.71 (4.42)	8.16 (4.94)		7.64 (2.78)	8.61 (4.89)
AUS-AE	9.31	7.94	9.00	7.64	9.40	7.00	6.33	8.64	8.56 (5.00)	3.50		10.57	7.88

	Gender		Household size				Medical conditions		Dwelling type		Age	FS knowledge	
	Male	**Female**	**1**	**2-3**	**4-5**	**6+**	**Yes**	**No**	**House**	**Other**		Yes	No
	(7.09)	(3.95)	(7.38)	(4.38)	(5.50)	(3.46)	(2.80)	(5.22)		(2.12)		(6.75)	(4.74)
AUS-H	12.85 (6.50)	11.99 (5.62)	14.60 (7.27)	12.07 (5.70)	13.10 (6.28)	7.00 (5.66)	13.13 (6.33)	12.16 (5.83)	12.16 (5.90)	13.00 (6.00)		15.43 (6.52)	12.10 (5.86)
Test results	***p = .016, r = .47;*** *all other groups: ps > .146, rs < -.14*		***p = .008, rho = .24;*** *all other groups, ps > .309, rhos < .22*				*all ps > .298, all rs < .20*		***p = .046, r = .40;*** *all other groups: ts < -1.42, ps > .164, rs < .22*		*all ps > .311, all rs < .11*	*all ps > .174, all rs < .21*	
Median BI time (IQR)													
SoFR-AE	9.00 (4.00-12.00)	25.50 (5.50-44.00)	4.50 (2.50-8.00)	17.00 (8.50-27.63)	47.50 (10.25-59.63)	9.00 (4.00-34.50)	25.50 (9.00-41.00)	10.50 (5.00-34.50)	**22.00 (6.75-42.50)**	**5.00 (1.75-10.00)**		17.25 (9.00 – 25.50)	12.00 (5.00 – 41.00)
SoFR-H	22.00 (14.50-35.00)	22.00 (14.50-28.63)	22.00 (14.50-32.00)	21.50 (13.50-30.00)	27.00 (14.50-41.50)	22.00 (15.50-28.50)	12.50 (10.50-26.00)	22.00 (15.13-32.00)	**24.25 (15.50-36.25)**	**20.00 (12.25-29.00)**		25.50 (16.75 – 39.12)	22.00 (14.50 – 31.25)
AUS-AE	31.50 (16.00-64.25)	40.75 (21.38-97.38)	100.00 (25.75-245.00)	33.25 (17.00-70.63)	34.50 (22.50-89.50)	23.50 (13.00-49.50)	31.75 (18.50-83.00)	34.50 (18.00-75.00)	34.50 (21.00-75.00)	13.25 (3.50-23.00)		**100.00 (35.50 – 162.50)**	**32.00 (17.25 – 69.25)**
AUS-H	26.50 (14.88-55.63)	34.00 (17.00-54.38)	34.00 (18.25-43.75)	33.00 (16.00-55.50)	29.50 (20.25-58.25)	14.75 (8.50-21.00)	35.75 (18.63-53.63)	32.00 (15.50-56.00)	33.50 (18.25-55.00)	29.75 (12.50-58.75)		48.00 (28.00 – 95.00)	31.00 (15.84 – 54.12)
Test results	*all Us < 1664.00, all ps > .054, all rhos < .39*		*all ps > .128, all rhos < .16*				*all Us < 735.00, all ps > .242, all rhos < .20*		***AE: U = 88.00, p = .019, rho = .46; and H: U = 2271.50, p = .048, rho = .18;*** *all other groups: Us < 823.00, ps > .112, rhos < .26*		*all ps > .194, all rhos < -.13*	***U = 185.000, p = .012, rho = .40*** *all other groups: Us < 1,167.500, ps > .104, rhos < .17*	

Note: SoFR = South of France; AUS = Australia; AE = Actual Experience; H = Hypothetical scenario; SD = standard deviation; IQR = interquartile range; BI = behavioural itinerary

Table H 17 BI times according to fire proximity knowledge and first (environmental) cues.

	SoFR		AUS		SoFR v AUS	
Fire proximity: residential area	**Yes**	**No**	**Yes**	**No**	**AUS**	**SoFR**
Median (IQR)	8.75 (4-37-46.50)	17.25 (6-33.25)	68.50 (22-117)	31.25 (16.50-59.25)	68.50 (22-117)	8.75 (4.37-46.50)

	SoFR		AUS		SoFR v AUS	
Test results	*p = .484, r = -.14*		*p = .073, r = .27*		***p = .001, r = .63***	
First info source: environmental cues						
Median (IQR)	11.25 (5.12-26.62)	41.75 (11.12-58.12)	68.50 (23.25-136)	32.50 (18.75-68.75)	68.50 (23.25-136)	11.25 (5.12-26.62)
Test results	*p = .210, r = -.26*		*p = .255, r = .17*		***p = .004, r = .52***	

Appendix I – Chapter 7 results' summaries

Table I 1 Binary logistic regression analysis results for pre-event variables predicting *having a plan*.

Regression predicting: having a plan ***(any plan, i.e. formal plan/knew what to do vs. no plan)***	**Intercept**	**B**	**SE**	**Wald**	***p.***	**OR**	**95% C.I.for OR**		**Nagelkerke R^2**	**Correct (%)**	**Model**
							Lower	**Upper**			
Merged data – AE											
Having a plan	-4.14								.39	77	$p < .001$
Info source: community meetings (vs. any other)		1.22	0.53	5.42	**.020**	**3.40**	1.21	9.54			
Mitigation involvement (vs. no involvement)		1.48	0.46	10.10	**.001**	**4.38**	1.76	10.89			
Age		0.06	0.02	13.08	**.000**	**1.06**	1.03	1.10			
Merged data – H											
Having a plan	-1.41								.42	76	$p < .001$
Wildfire experience:											
- Once (vs. never)		-0.07	0.43	0.02	.873	0.93	0.39	2.18			
- More than once (vs. never)		1.64	0.52	9.87	**.002**	**5.17**	1.85	14.38			
Info source: none (vs. any other)		-2.53	0.46	30.59	**.000**	**0.08**	0.03	0.19			
Pets (vs. no pets)		1.15	0.30	14.60	**.000**	**3.15**	1.75	5.66			
Insurance (vs. no insurance)		1.37	0.31	20.29	**.000**	**3.95**	2.17	7.18			

NOTE: OR = odds ratio; (vs.) = reference category for categorical variables

Table I 2 Binary logistic regression analysis results for pre-event variables predicting *intention to stay-in-place, wait and evacuate.*

Regression predicting: intention ***(one intention vs. any other)***	**Intercept**	**B**	**SE**	**Wald**	***p.***	**OR**	**95% C.I.for OR**		**Nagelkerke R^2**	**Correct (%)**	**Model**
							Lower	**Upper**			
Merged data – AE											
Intention to ***wait-and-see***	2.02								.31	73	$p < .001$
Having a plan:											
- Plan (vs. NP)		-2.21	0.49	20.60	**.000**	**0.11**	0.04	0.29			
- KWTD (vs. NP)		-0.29	0.46	0.40	.523	0.74	0.30	1.84			
Intention to ***stay-in-place***	-3.18								.18	73	$p < .001$
Age		0.04	0.01	10.26	**.001**	**1.04**	1.02	1.07			
Info source: workplace (vs.any other)		1.71	0.47	13.15	**.000**	**5.53**	2.19	13.93			

NOTE: NP = No plan; KWTD = Knew what to do

Regression predicting: intention *(one intention vs. any other)*	Intercept	B	SE	Wald	*p.*	OR	95% C.I.for OR		Nagelkerke R^2	Correct (%)	Model
							Lower	Upper			

Table I 3 Binary logistic regression analysis results for pre-event variables predicting *evacuation decision.*

Regression predicting: evacuation decision *(evacuate vs. stay)*	Intercept	B	SE	Wald	*p.*	OR	95% C.I.for OR		Nagelkerke R^2	Correct (%)	Model
							Lower	Upper			
Merged data – AE											
Evacuation decision	0.71								.08	63	p = .007
Dependents (vs. no dependents)		0.68	0.33	4.31	**.038**	**1.98**	1.04	3.79			
Wildfire experience: more than once (vs. once)		-0.79	0.34	5.46	**.019**	**0.45**	0.23	0.87			

Table I 4 Binary logistic regression analysis results for peri-event variables predicting *immediate response of individuals.*

Regression predicting: immediate response *(active vs. passive)*	Intercept	B	SE	Wald	*p.*	OR	95% C.I.for OR		Nagelkerke R^2	Correct (%)	Model
							Lower	Upper			
Merged data – AE											
Immediate response	-1.09								.18	83	p < .001
Feeling alert:											
- VL (vs. NAA)		0.92	1.30	0.49	.482	2.50	0.19	32.19			
- SW (vs. NAA)		2.36	1.19	3.93	**.047**	**10.60**	1.03	109.45			
- TGE (vs. NAA)		3.39	1.21	7.81	**.005**	**29.62**	2.75	319.18			

NOTE: NAA = not at all; VL = very little; SW = somewhat; TGE = to a great extent.

Table I 5 Binary logistic regression analysis results for peri-event variables predicting *intention to wait, stay-in-place, evacuate.*

Regression predicting: intention *(one intention vs. any other)*	Intercept	B	SE	Wald	*p.*	OR	95% C.I.for OR		Nagelkerke R^2	Correct (%)	Model
							Lower	Upper			
Merged data – AE											
Intention to *wait-and-see*	0.71								.32	73	p < .001
Having a plan:											
- Plan (vs. NP)		-2.09	0.50	17.60	**.000**	**0.12**	0.05	0.33			
- KWTD (vs. NP)		-0.28	0.49	0.32	.570	0.76	0.29	1.97			
Visibility:											

Regression predicting: intention *(one intention vs. any other)*	Intercept	B	SE	Wald	*p.*	OR	95% C.I.for OR		Nagelkerke R^2	Correct (%)	Model
							Lower	Upper			
- Reduced (vs. good)		0.57	0.51	1.26	.261	1.77	0.65	4.80			
- Poor (vs. good)		-1.24	0.48	6.83	**.009**	**0.29**	0.11	0.73			
Intention to *stay-in-place*	-0.92								.22	74	p = .001
Visibility:											
- Reduced (vs. good)		0.13	0.59	0.00	.982	1.01	0.13	3.25			
- Poor (vs. good)		1.75	0.49	12.60	**<.001**	**5.78**	2.19	15.24			
Feeling Nervous:											
- VL (vs. NAA)		-0.37	0.65	0.33	.565	0.69	0.19	2.47			
- SW (vs. NAA)		-0.12	0.60	0.43	.836	0.88	0.27	2.88			
- TGE (vs. NAA)		-1.35	0.69	3.87	**.049**	**0.26**	0.07	0.99			
Intention to *evacuate*	-0.89								.13	72	p = .004
Recommendation to evacuate (vs. no recomm.)		2.15	0.84	6.54	**.011**	**8.59**	1.65	44.63			

Table I 6 Binary logistic regression analysis results for peri-event variables predicting evacuation decision after receiving first cues.

Regression predicting: evacuation decision *(evacuate vs. stay)*	Intercept	B	SE	Wald	*p.*	OR	95% C.I.for OR		Nagelkerke R^2	Correct (%)	Model
							Lower	Upper			
Merged data – AE											
Evacuation decision	0.20								.71	85	p < .001
Intention:											
- To stay-in-place (vs. to wait-and-see)		-1.57	0.92	2.91	.088	0.21	0.03	1.26			
- To evacuate (vs. to wait-and-see)		3.99	1.37	8.45	**.004**	**54.00**	3.66	795.64			
Grouping behaviour (vs. no grouping)		-2.72	1.16	5.52	**.019**	**0.07**	0.01	0.64			

Table I 7 Binary logistic regression analysis results for peri-event variables predicting *evacuation decision* after receiving new cues.

Regression predicting: evacuation decision *(evacuate vs. stay)*	Intercept	B	SE	Wald	*p.*	OR	95% C.I.for OR		Nagelkerke R^2	Correct (%)	Model
							Lower	Upper			
Merged data – AE											
Evacuation decision	-0.48								.32	73	p < .001
Order to evacuate (vs. no order)		1.79	0.70	6.44	**.011**	**5.97**	1.50	23.76			
Perceived risk: loss of utilities											

Regression predicting: evacuation decision *(evacuate vs. stay)*	Intercept	B	SE	Wald	*p.*	OR	95% C.I.for OR		Nagelkerke R^2	Correct (%)	Model
							Lower	Upper			
- VL (vs. NAA)		-1.72	0.76	5.05	**.025**	**0.18**	0.04	0.80			
- SW (vs. NAA)		-1.17	0.67	3.09	.079	0.31	0.08	1.14			
- TGE (vs. NAA)		-0.14	0.67	0.04	.837	0.87	0.24	3.22			
Feeling helpless:											
- VL (vs. NAA)		1.90	0.67	8.06	**.005**	**6.72**	1.80	25.01			
- SW (vs. NAA)		1.30	0.58	5.11	**.024**	**3.67**	1.19	11.36			
- TGE (vs. NAA)		1.46	0.80	3.35	.067	4.33	0.90	20.79			

Table I 8 Binary logistic regression analysis results for peri-event variables predicting evacuation destination.

Regression predicting: evacuation destination *(another town vs. any other shelter)*	Intercept	B	SE	Wald	*p.*	OR	95% C.I.for OR		Nagelkerke R^2	Correct (%)	Model
							Lower	Upper			
Merged data – AE											
Evacuation destination	-0.29								.17	70	p = .009
Fire proximity: not in residential area (vs. closer)		1.56	0.61	6.45	**.011**	**4.76**	1.42	15.87			
Merged data – H											
Evacuation destination	-1.34								.09	59	p < .001
Evacuation means: car (vs. other)		1.48	0.37	16.26	**.000**	**4.41**	2.14	9.06			

Table I 9 Binary logistic regression analysis results for peri-event variables predicting *ingress attempt.*

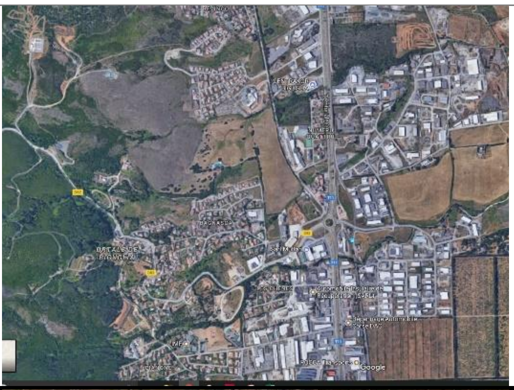
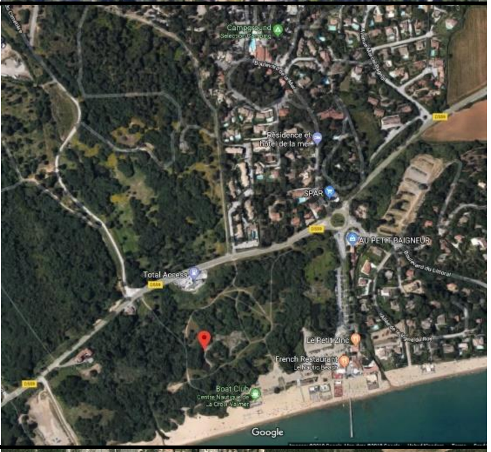
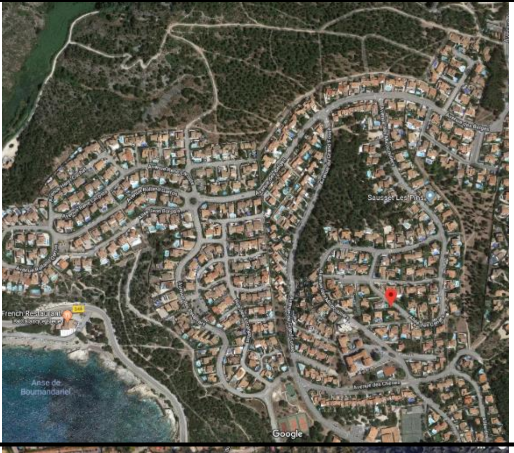
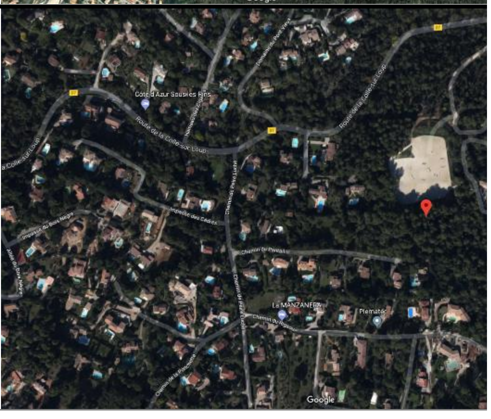
Regression predicting: Ingress attempt *(yes vs. no)*	Intercept	B	SE	Wald	*p.*	OR	95% C.I.for OR		Nagelkerke R^2	Correct (%)	Model
							Lower	Upper			
Merged data – AE											
Ingress attempt	0.18								.10	62	p = .045
Evacuation difficulties: some (vs. none)		-1.21	0.63	3.73	.053	0.29	0.90	1.02			
Merged data – H											
Ingress attempt	0.39								.01	66	p = .306
Evacuation means: car (vs. other)		0.35	0.34	1.06	.303	1.42	0.73	2.76			

Table I 10 Binary logistic regression analysis results for peri-event variables predicting *future decision.*

Regression predicting: future decision *(evacuate vs. stay)*	Intercept	B	SE	Wald	*p.*	OR	95% C.I.for OR		Nagelkerke R^2	Correct (%)	Model
							Lower	Upper			
Merged data – AE											
Future decision	-3.43								.32	76	p < .001
Evacuation decision: evacuate (vs. stay)		2.278	0.471	23.39	**.000**	**9.75**	3.87	24.53			

Appendix J – WUI research

Table J 1 Exploratory typology for WUI research.

		Interface	Intermix
RURAL	Dense		
	Scattered		
URBAN	Dense		
	Scattered		

Appendix K – Peer-reviewed publications

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Island vulnerability and resilience to wildfires: A case study of Corsica

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ABSTRACT

The number of wildfires occurring globally is exacerbated by urbanisation and changes in weather patterns. In response, researchers have conducted studies of wildfires and human behaviour in regions such as Australia and the USA. Regions in Europe have received less attention, despite facing the same issues. Even more overlooked are one particular type of territory: islands. With their climates, islands across the Mediterranean remain attractive second home and tourist destinations, resulting in urban development. Yet due to certain features (e.g. cultural, socio-political, geographical), the ways in which their people deal with wildfires may differ somewhat from that in some mainland territories. This paper explores human behaviour in wildfire emergencies in the context of island vulnerability and resilience in Europe, with the Mediterranean island of Corsica as a case study. Qualitative analysis of semi-structured interviews (n = 8) with Corsican professionals involved in wildfire management and quantitative analysis of around 100 surveys from civilians was conducted. This analysis revealed that Corsica's population approach to wildfire safety is shaped by available information as well as a strong risk culture, which stands in contrast with new/temporary residents moving into the island each summer season. The results drawn from the analysed sample suggest potential social vulnerability in wildfires when a decision to evacuate the population is taken by emergency managers as the most effective emergency response. Population behaviour were not influenced by property attachment, perceived risk, hazard knowledge, community closeness and locus of control, suggesting that island WUI resident characteristics may not be generalised from human behaviour in wildfires studies carried out in the USA or Australia.

1. Introduction

Wildfires are a recognised major risk to communities across Europe [1], especially in the Mediterranean region [2], and more research is attending to the effects of wildfires on populations' vulnerability in the wildland-urban interface (WUI) [3]. Nonetheless, less research is focused on understanding these populations' preparedness for and their lived experiences in responding to wildfire events, for example having to evacuate their homes. While current studies on human responses to wildfires are mostly focused on North American and Australian populations [4–6], studies particular to the context of European populations are rare, particularly so for the islands at-risk from wildfires [7,8].

This paper begins by reviewing the occurrence of wildfires in the islands in the Mediterranean and across Europe, as well as contextualises important features of WUI communities, recognised by wildfire research, to islands. Key elements widely reported to influence human behaviour in disasters are outlined and their importance for one European island with a WUI population, Corsica, is explored. The results highlight the differences and convergence between the findings across risk culture, wildfire management and response to a developing fire, comparing the results with those from previous studies and their implications for policy.

1.1. Island wildfires

Wildfires are a major challenge connected to urban sprawl. Growing cities force humans further into natural territories, both through the outward extension of the city limits and through generating a desire in some to permanently or temporarily escape densely built-up areas [9,10]. Growing cities also draw people in from rural communities, with forestation replacing their now abandoned farmland, resulting in wider areas covered in more combustible vegetation [9]. This movement, of city limits, of people to and from more isolated settlements, and of vegetation, results in a clash between wildland and urban areas, the

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Cross-cultural comparison of behavioural itinerary actions and times in wildfire evacuations

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ABSTRACT

Evacuation of residents during wildfire is a highly time-sensitive process. Available time may be limited. Previous research on other types of incident demonstrate that individuals delay their evacuation by first undertaking actions in response to the threat. However, currently there is little evidence of what actions individuals undertake ('behavioural itineraries'), how many, which are prioritised, and how much time is committed to them in a wildfire. Additionally, where some understanding exists concerning human behaviour in wildfire evacuations, data has mostly been acquired from Australia; European regions, which are increasingly threatened by wildfires, lack attention. This study presents the first cross-cultural investigation of its kind: survey data (N = 293) from the South of France and Australia were compared. Participants with actual experience of wildfires and those inexperienced yet residing in at-risk areas answered questions about what they did or would hypothetically do, respectively, and for how long, prior to commencing evacuation. Results revealed that, across the two regions, the discrete actions comprising behavioural itineraries were similar overall, albeit their priority sometimes differed. However, when analysed by category, the prioritisation of actions was uniform across samples. Of significance is the finding that regional differences were also observed in relation to: mean number of actions, time committed to actions and the influence of socio-demographic factors, indicating geographical and cultural determinants. Implications for future research, evacuation modelling and wildfire management, education and training are discussed.

1. Introduction

1.1. An ongoing wildfire evacuation challenge

Recent wildfires (also known as bushfires or forest fires) in Europe, Australia, and other parts of the world illustrate how rapidly growing cities and nature challenge one another, and most of all, human safety. Disasters like these claim people's lives as well as affect individuals' physical and psychological health (Jogia et al., 2014; Russel, 2017). Unfortunately, neither published fire statistics provided by European countries (Brushlinsky et al., 2019), nor Australia's official bushfire data source (Geoscience Australia, 2020), report the number of people involved in wildfire evacuations. However, some political organisations, local researchers, and the international media have followed and documented cases. For example, in 2017, around 12,000 people evacuated in an incident in France (Valabre, 2017), a country where policy typically dictates staying put inside one's home (GOUVERNEMENT.fr, 2020). In 2018, a year where large wildfires were experienced by a greater number of European countries than recorded previously (European Commission, 2018), hundreds evacuated during an incident in Greece, many heading for the sea; unfortunately, this ended in the greatest number of fatalities seen in a European wildfire (CBS News, 2018; Škrlec, 2018). In 2019, nearly 9000 people evacuated during an incident on the Spanish island Gran Canaria, while even Norway experienced a mass evacuation of 250 people (Log et al., 2020; The European Space Agency, 2019). The 2019/2020 Australian bushfire season has seen the largest bushfires ever reported in Australia. During this period, the state of Victoria for the first time ordered mandatory evacuations – previously allowing people to choose to stay or go at their own risk (Loh, 2007). In just the Mallacoota region alone, over 1000 people were evacuated in the largest sea-based evacuation in Australian history (Filkov et al., 2020). Given current projections of climate change, wildfire occurrence across the globe is likely to become more frequent (Filkov et al., 2020; IPCC, 2018) and so too may associated mass evacuations.

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