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ESTABLISHED AND EMERGING USES OF PREDICTIVE SERVICES IN VICTORIA

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Cover: FBANs and users interact in the Victorian State Control Centre, January 2020. Source: Timothy Neale

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The project team acknowledges the First Nations owners of the lands where we respectively live and work. We pay respect to their Elders, lores, customs and creation spirits. We recognise that these lands have always been places of teaching, research and learning.

EXECUTIVE SUMMARY

The recent 2019-20 Black Summer bushfire season brought both sector and public attention to the important role that predictive services can play in mitigating and preventing the loss of life and assets from bushfires.

This research study focused on two key questions:

1. What are the **key features of effective relationships** between Fire Behaviour Analysts (FBANs) and their users within emergency management?
2. How might the predictive services role and predictive services outputs be **developed in the future**?

We explored these questions by conducting twenty-five (25) semi-structured interviews with key practitioners who either perform the FBAN role or use predictive services in Victoria.

Our findings are categorised into 7 topics:

1. ***Interviewee background:*** The interviewees included people who represent the following operational roles: FBAN, State Regional Commander, State Agency Commander, Level 3 Incident Controller, Level 3 Public Information Officer, Level 3 Planning Officer, Level 3 Operations Officer, and Level 3 Situation Officer.
2. ***FBAN outputs:*** We collected data from FBANs and other operations staff who occupy roles which interact with and/or use the outputs produced by FBANs from within the broad emergency and incident control arrangements provided for within the Australasian Inter-service Incident Management System.

   We found that the FBAN advice and products are used to:

   - inform operational decisions, including pre-event planning, decisions during first attack and extended attack;
   - inform the development and release of public information and warnings; and,
   - support the conduct of planned burning.

   Most interviewees agreed that the design and framing of outputs should be standardised for public dissemination, however, there was less consensus that such standardisation is required for operational purposes.
3. ***Trust in FBAN outputs:*** We found that in general:

   - there is a high level of trust in FBAN outputs amongst participants who are users of predictive services; and,
   - there are variances amongst users in terms of the level of trust they place in particular FBANs outputs and advice.

   Trust is an important factor in the high-pressure contexts of incident and land management, including both interpersonal trust and trust in particular tools and systems. We found that trust seems to depend, in part,

upon users' perceptions of a given FBAN's skills, level of experience, and knowledge of the area or context in which they are offering predictive intelligence. For FBANs, both having fireground experience and "local knowledge" and being able to convince users that one has fireground experience and "local knowledge" seem to be important factors in eliciting the trust of some users.

4. ***Timeliness of FBAN outputs:*** We explored whether FBANs produced advice and outputs in a timely manner. We found that:

    - FBAN advice and outputs were produced in a sufficiently **timely** manner for users' purposes.

    For example, a "quick and dirty" map of potential fire spread was seen to be acceptable during first attack. However, the pressure related to timeliness decreases during an extended attack and is substantially decreased during pre-event planning and planned burning, or in any instance where there is potentially more time for FBANs to converse with end-users, collect and validate intelligence and tailor the outputs to the end-users' needs.

5. ***Benefits of releasing FBAN outputs publicly:*** We explored whether participants felt predictive outputs produced by FBANs (e.g., fire spread predictions) should be released to the community (i.e., affected communities and the general public) to facilitate their decision-making and planning during periods of significantly elevated fire danger (e.g., days of "Extreme" fire danger rating). We found that:

    - with appropriate guidance and instructions, these predictive outputs **should be used** to facilitate community decision-making and planning in relation to bushfire hazards and incidents.
    - there was general support amongst both users and FBANs to release FBAN's predictive outputs publicly.
    - the benefits of releasing FBAN outputs publicly outweighed the risks.

    Participants noted that there is a moral imperative to release information to assist members of the public in their decision-making in relation to fire hazards. Further, there was a sense amongst many participants that, by releasing FBAN products publicly, emergency management organisations could support trust-building between agencies and communities and better demonstrate their transparency and accountability when working with the community to plan for and respond to bushfires.

6. ***Risks of releasing FBAN products publicly:*** We explored with the participants whether they felt that it was a risk to release FBAN outputs to the community to facilitate their decision-making and planning on days of significantly elevated fire danger. In general, participants reported that there were **low levels of risk** associated with releasing FBAN outputs to the community to facilitate community decision-making and planning.

    We found that, where there was unease amongst participants in relation to releasing FBAN outputs publicly, it was because of:

- potential political and legal risks to emergency management organisations and staff. Our analysis suggests that such legal risks are likely poorly founded.
- potential for members of the public to misinterpret these outputs, leading to risks of maladaptive behaviours. These risks, we suggest, are irreducible but can be substantially mitigated through education or explanation via social media and other channels.

7. ***The future of the FBAN role:*** We explored whether participants felt that the FBAN role will continue to be important within the broad emergency and incident control arrangements. We found that:
    - the FBAN role had **a very important role** to play in the future of planning for and responding to bushfire hazards and incidents effectively in the future; and,
    - there was agreement amongst participants that predictive services generally and the FBAN role specifically are a vital part of future emergency management arrangements in Victoria and Australia.

    With this in mind, it is important to understand that the development of predictive services must ensure that it is further integrated into emergency management arrangements outside the State Control Centre. Specifically, viewed in relation to other project findings, it is clear that for such development and integration to be effective, FBANs will be required to spend **more time interacting with users.** Such interactions may sometimes occur outside fire seasons, though it is also apparent that they also need to occur throughout the fire season, on firegrounds and in Incident Management Centres and Regional Control Centres, in order to grow FBANs' skillsets, maintain trust with users, educate users about their outputs and adapt those outputs to user needs. Various users had suggestions about how predictive services might better serve their needs, the vast majority of which related to the refinement of output types and modes of presentation to incidents and situations as they emerge.

    Following this feedback also means exploring the different ways that FBAN skillsets and competencies can be used to assist key decision-makers such as Incident Controllers and community information and warning teams which continue to be so important in terms of planning and responding to bushfires. These skillsets and competencies - at both state and regional levels - also have relevant application to conduct of planned burning, and both users and FBANs suggest that more use can be made of FBAN skillsets and competencies to assist the states land and fire management agencies in achieving fuel management goals.

Based on these findings, we make 4 recommendations, detailed as follows:

Recommendation 1: that emergency management agencies explore which FBAN outputs could be released to the community to support their planning and decision-making during bushfire season.

Recommendation 2: that emergency management agencies explore how FBANs and predictive service outputs can be utilised to better support other relevant functions such as the conduct of planned burning and public information.

Recommendation 3: that emergency management agencies explore the ongoing training and development needs of FBANs.

Recommendation 4: that emergency management agencies work with FBANs to develop continuous learning processes which can be used to improve predictive services after bushfire and planned burning seasons.

In terms of utilisation, our recommendations will require an implementation strategy which needs to be mindful of the requirements to continue to plan for and respond to ongoing incidents that require predictive services. Accordingly, we propose a staged approach to utilisation that is channelled through the Bushfire and Natural Hazards CRC Black Summer research group.

Finally, we have confidence that these findings and recommendations are relevant to many other jurisdictions in Australia, including Western Australia, Tasmania, South Australia, Australian Capital Territory, Queensland, and New South Wales, given their similarity in bushfire hazards, incident management systems, and the role and scope of predictive services.

END-USER STATEMENT

Dr Sarah Harris, *Country Fire Authority, VIC*

Darcy Prior, *Department of Environment, Land, Water & Planning, VIC*

We acknowledge the importance of the findings of this research project and recommend that they are used to further continue the development of Fire Behaviour Analysts and the role that they play in planning for and responding to bushfires. This research provides us with useful evidence to inform key directions land and fire management agencies will take in addressing policy questions and community needs. It also aligns with themes and recommendations that were highlighted in the recent Inspector-General for Emergency Management inquiry and the Royal Commission into National Natural Disaster Arrangements.

There were some interesting findings in this research that we will explore further, such as:

1. The value of trust between FBANs and Predictive Services end-users. This may mean that we need to change the way Predictive Services currently operates and we will need to explore options and actions to ensure we can build trust with end-users.
2. That, for many users, timeliness is much more important than accuracy in the prediction. In many cases, a conversation may be more important than producing a map.
3. The importance of aligning messaging and working together between Predictive Services and staff engaged in public information and warnings. The outputs that public information and warning staff produce should be based on the advice that Predictive Services gives.

These findings will be explored further by the Victorian Predictive Service team to ensure we utilise this research to produce better outcomes for the end-users and ultimately the community safety.

READER'S GUIDE TO REPORT

This report presents the findings of a research project which relates to the future of predictive services in Victoria. Our report is divided into four sections.

- **Section 1: Context (pages 10 to 11)**

  This section provides the project context and reflects on the important and ever-increasing role that FBANs play in planning for and responding to bushfires in Victoria.

- **Section 2: Research approach (page 12)**

  This section provides an overview of our research approach. We engaged participants through semi-structured interviews from across a range of different roles in Victorian emergency management to capture their perceptions about the ways in which FBANs work within emergency management arrangements. We also explored the different ways that FBAN outputs are used within Victorian emergency management arrangements.

- **Section 3: Findings (pages 13 to 24)**

  This section presents the findings in detail from our study. A summary of the findings can be found in the Executive Summary of this report.

- **Section 4: Recommendations (pages 25 to 28)**

  This section presents the four recommendations from our study. A summary of the recommendations can be found in the Executive Summary of this report.

SECTION 1: CONTEXT

With bushfire seasons beginning earlier and lasting longer in Australia, the Fire Behaviour Analyst (FBAN) role is an important function within emergency management arrangements insofar as their analysis sits at the core of matters related to predictive services within operational firefighting.

In general terms, the past 15 years has seen an increased demand for predictive services (PS) capability across Australian fire and land management agencies. This project is seeking to learn from recent FBAN experiences of significant bushfire events so that training and development initiatives can be enhanced and that they are supported to fulfil the duties of their role into the future. The FBAN role and their intelligence outputs are now considered to be significant and important within bushfire management operations. Moreover, PS have repeatedly been analysed by successive bushfire inquiries, mentioned in the news media (see Neale and May 2018, 2020), and most recently been featured prominently in operational response to the 2019-2020 Black Summer bushfire season in Victoria, New South Wales, ACT and elsewhere. Previous reviews of the PS capability in Victoria (e.g., Risk Frontiers 2017) have suggested that users would like both greater interaction with FBANs and more self-servicing, both more automated outputs and more bespoke outputs, and both more standardisation and more variety. Meanwhile, previous reviews of the FBAN role in Victoria (e.g., Tolhurst 2018) have suggested that the role has experienced "scope creep" and that FBANs both want and need more structure in their duties and role.

With this in mind, the evolution and development of PS means that there is a limited understanding of many aspects of the discipline, including user values and perceptions as well as FBAN decision-making processes. Accordingly, this study proposes to explore the following questions surrounding the current situation surrounding the FBAN role and its future within emergency management arrangements:

- **Current state:** What constitutes timely and useful predictive intelligence for users? What are the factors that lead to users trusting or distrusting an FBAN and/or their predictions? How do FBANs and users each understand the meaning of key predictive outputs (e.g., Potential Impact Zone)?
- **Future development:** What is the most appropriate path forward to develop PS into the future? How should the FBAN role develop and be resourced? How can key predictive outputs be leveraged for a range of users - including the public - whilst also being brokered into PS as part of planning for and responding to bushfires?

THE RESEARCH QUESTIONS

We asked participants semi structured interviews which directly related to:

- ***Interviewee Background***

  This section of the interview schedule focused on gaining under understanding of the expertise, experience, and current role of the interviewee.

- ***FBAN outputs***

  This section of the interview focused on the previous experience of the interviewees either in the FBAN role or interacting with FBANs and using FBAN outputs to inform their decisions.

- ***Trust in FBAN outputs***

  This section of the interview focused on the level of trust interviewees had in FBAN advice and outputs.

- ***Timeliness of FBAN outputs***

  This section focused on user perceptions and needs regarding the timeliness of FBAN advice and outputs.

- ***Benefits of releasing FBAN outputs publicly***

  This section of the interview focused on the perceived benefits of releasing FBAN outputs such as "red maps" to the public.

- ***Risks of releasing FBAN outputs publicly***

  This section of the interview focused on the perceived risks of releasing FBAN outputs such as "red maps" to the public.

- ***Future of predictive services***

  This section focused on any unmet needs or desires for the FBAN role as well as future predictive service outputs.

SECTION 2: RESEARCH APPROACH

Our research approach has been developed in collaboration with a project advisory committee of FBANs employed by key emergency management agencies in Victoria (e.g., Department of Environment, Land, Water and Planning (DELWP), Parks Victoria (PV), Forest Fire Management Victoria (FFM), and Country Fire Authority (CFA)).

Our research approach is qualitative and interpretive. Semi-structured interviews were the primary source of data collection based on a list of questions related to our proposal which has been informed by Victorian emergency management organisations and the Bushfire & Natural Hazards Cooperative Research Centre (CRC). Semi-structured interviews enabled us to explore the ways in which FBANs apply their knowledge and expertise while capturing their feedback on matters related to the ways in which their services and outputs are used in emergency management arrangements.

Our data was analysed using NVivo (a qualitative data analysis software package). Each participant was de-identified and assigned a code that identifies their formal role but does not reveal their identity.

RESEARCH DESIGN

We engaged in purposeful sampling insofar as we sought to engage participants in our study that work in a role where they are planning for and responding to bushfire (and other incidents). This meant that we were able to access participants who currently work as FBANs as well as those who regularly use the outputs which they produce. Moreover, 3 of the 4 members of the research team have either worked or are currently working for an emergency management organisation and are currently working or have worked in an emergency management coordination role which also played a role in deciding who to interview for this project. Essentially the research team with the guidance of a project advisory committee of FBANs decided on the final list of participants.

DATA COLLECTION AND ANALYSIS

We conducted 25 interviews during April and May 2021, and the background of participants is listed in the following section. Interviews were conducted through Zoom or Microsoft Teams lasting between 30 and 90 minutes. Each interview was recorded and professionally transcribed verbatim resulting in 272 pages of text.

SECTION 3: FINDINGS

In this section we present the findings from our analysis.

3.1 INTERVIEWEE BACKGROUND

The FBAN role and outputs have greatly evolved since the early 2000s so much so that the role plays an important role in modelling fire behaviour and predicting its pathway in the landscape. The competencies and skillsets which comprise the FBAN role are used to produce maps which are used to assist key decision-makers within incident control and community information and warning teams which sit at the core of planning and operational responses to bushfires. Since 2007, FBANs have been formally trained to operate with the emergency management arrangements and deliver a range of predictive service outputs with a focus on safeguarded life and assets which could be in harm's way as a result of bushfire or planned burn ignitions. For more on the background of the role and its integration into incident management in Victoria and other Australian jurisdictions see:

- Slijepcevic, A, K Tolhurst, and L Fogarty. 2008. "Fire behaviour analyst roles and responsibilities in bushfire management: How to make the best use of these skills." Proceedings of AFAC Conference 2008, Adelaide.
- Neale, Timothy, and Daniel May. 2018. "Bushfire simulators and analysis in Australia: insights into an emerging sociotechnical practice." *Environmental Hazards* 17 (3): 200-218.

This subsection focuses on the experience of the 25 interviewees in the bushfire management sector as well as the level of formalised training that interviewees have in the FBAN role (Table 1).

We interviewed 4 FBANs (4 males) who had <10 years (n=1), >10 years (n=1), or >20 years (n=2) experience in the role. We also interviewed 21 operational end-users of predictive service outputs (6 females and 15 males).

Role	Number of interviewees
State Regional Commander (SRC)	1
State Agency Commander (SAC)	3
Level 3 Incident Controller (IC)	5
Level 3 Public Information Officer (PIO)	4
Level 3 Planner Officer (PO)	5
Level 3 Operations Officer (Op)	3
Level 3 Situation Officer (SO)	1
Fire Behaviour Analyst (FBAN)	4

	Total: 25

TABLE 1: INTERVIEW PARTICIPANTS

Of the operational users of predictive service outputs who specified the number of years' experience in the bushfire management sector (n=19), 8 stated having > 30 years' experience, 4 had > 20 years' experience, and 6 had > 10 years' experience. 7 interviewees (1=FBAN, 6=other roles) mentioned having on-ground firefighting experience. In addition to the 5 FBANs, 5 operational staff mentioned having completed the FBAN training. They either undertook this training as part of their progress through the EM sector (PIO-2, Op-1, PO-1, PO-2) or to understand more about the role to be able to better utilise it to inform their own role (PO-3, IC-5). Two predictive service users started but did not complete the training. The reasons given was that the criteria were "too exhaustive" to get signed off and therefore, not worth pursuing (SAC-2) and that it was not necessary for the individual's role but rather an opportunity to gain a better understanding of the FBAN role and its limitations (IC-5).

3.2 FBAN OUTPUTS

This subsection highlights the main uses for the predictive service role and outputs as identified by the interviewees.

In general, predictive service users were positive about the FBAN role and the current outputs available (SAC-1, SAC-2 IC-3, IC-1, PIO-4, PO-3, IC-2). Interviewees highlighted that the outputs are comprehended and utilised best when there is the opportunity for interactive conversations with FBANs (PIO-3, SRC-1, IC-3, Op-1, PIO-4, FBAN-4, FBAN-2). Some interviews specifically referred to the fact that direct experience with outputs during an incident builds trust and understanding of the FBAN role, the outputs, and their reliability (PO-2, IC-1).

In regards to the different uses of the FBAN role and predictive service outputs, we found that FBAN outputs play a role in five key decisions, before and during an incident as well as in policy and planning decisions:

1. **Pre-event planning:** informing operational decisions prior to first attack, for example prior to or at the beginning of a period of elevated fire risk. This can often take the form of "heat maps" of high-risk areas and hypothetical scenarios to inform decisions about the positioning of patrolling effort or suppression resources.

   The pre-fire visual that the FBAN role and outputs provide during the planning phase of a fire season was seen by some to have value (PO-3, Op-2). However, it was also acknowledged that weather and the fire danger index (FDI) are more useful than predictive outputs (i.e., 5-hectare intensity mapping) in informing such decisions (PO-1).

   IC-3: *"I've got my preferences as an Incident Controller of what I like to see, and what I like to see in those maps of "give me the absolute worst thing that can happen here today." That means ramp up the weather, within, you know a rough sort of guide, that means showing me where [fires] might go... We're already getting those products, but I've got to ask for them, they're not automatically generated".*

2. **First attack:** providing a visual representation or scenarios of where a fire might spread to in the moments after an incident has been reported for resource allocation and public information.

   Interviewees largely agreed that automated outputs (e.g., PHOENIX RapidFire predictions) and interactions with FBANs are useful during the first attack. These outputs are viewed as an indication of how a fire might move in the landscape (PO-2, IC-1, PIO-3), and are generally "put to the side" as most fires are suppressed during first attack (PO-1). At this stage, it is useful to have the maximum potential but to ensure that it is time stamped and short-term (i.e., prediction for the next hour) to communicate the timeliness of the product to the user (PIO-3, Op-1).

   PO-1: "*When you have an incident start at first attack it is good to have some feel for how an incident is going to go, or its potential. ... automatic predictions for example get done on wherever ignition gets put into the system, ... it's convenient maybe for sending resources to or just getting the incident on the map so people are aware of it*".

3. **Extended attack:** providing a visual representation or scenarios where a fire might spread as intelligence becomes available resource allocation and public information.

   The outputs were seen as being more useful during extended attack (i.e., level 2 and 3 fires) as more information that can be fed into the maps becomes available (PO-1). Although having access to maximum potential for forest fires was seen to be important (SRC-1, PIO-3), many interviewees expressed a desire for scenarios in addition to the "worst case" prediction (IC-4, PO-3, SAC-1, PIO-4, PIO-2).

   PO-3: "*... one of the products that we also use which is usually done more localised is running what if scenarios. So, with a campaign fire on the ground, we might know that we're having particular difficulty in a particular area or there's no control line there. What happens if it gets away in this spot? You can sort of customise it from there. The FBANs can go away and run a specific report. If it gets away in this area this is what you're looking at*".

4. **Public Information:** Some of the interviewees suggested that FBAN outputs are more useful for public information than decisions related to the organisation of crews and resources (IC-5, Op-1).

   FBAN-1: *"I've probably found more applicability inside community engagement and warnings and advice than with operations. I think with operations, there can be, I think there's a lot of areas it could be applied but I don't think it is as often. And in terms of why not, which is the ultimate question, I don't know, it's a good, I don't think I have a good answer to why it's not"*

   It was suggested by some interviewees that public information should be based on FBAN predictions (SAC-1, Op-1). Public Information Officers (PIO) confirmed that decisions about the placement of the warning polygons on the maps released to the public on the *VicEmergency* app are informed by predictive service outputs, but due to the fact that oftentimes

these outputs reflect the "worst case" scenario, there is a need to refine this information to meet the needs of communities (PIO-2, PIO-3). The use of scenarios was seen to be useful for public information (PIO-3). It was stated that public information should be simple so as to not "paralyse" the public (PIO-2). Closer interactions between FBANs and PIOs could improve timing of initial public information (IC-2).

5. **Planned burning:** providing scenarios to inform policy and planning related to fuel management and where and when it should take place:

   SAC-2: *"Well, the other thing that I use FBAN for significantly is planned burning and to me there's a real crucial bit of information and it's sometimes a bit hit and miss from some of the briefings that we get. I'd really like to see FBANs be able to do that future planning to give us the windows and when the windows are likely to open up for various fuel types. I find the briefings on a daily basis are pretty much oh yeah, here's okay to burn here. But what would be really handy from our perspective for planning burning a week out is to be able to say oh well there's fuel types likely to come online in a couple of days or maybe next week, this fuel type is relatively dry at the moment and won't be online. To me it's probably that input into helping from a planning perspective into the planned burn operations".*

   PIO-3: *"I always ask for a prediction of what the fire might do that we light in the planned burn space, not just to find out what the coverage might end up looking like but what would happen if we had an escape, where the contingency areas might be that would feel the pressure so we can resource it adequately... So, I always ask for FBAN input into planned burn scenarios too"*

   Some interviewees explained their preference for automated outputs such as gridded weather (IC-2, PO-1), but "*from time to time we do use like FBAN type analysis to try to work out what our rates of spread, and what a flame height's gonna be, and intensities and that sort of thing to help guide managing certain burns, so that we do them in a thought-out way*" (PO-1).

   One interviewee suggested that the current use of daily planned burning briefings should be reduced to once a week and that these briefings should present a strategic approach to fuel availability and burn windows: "*I'd really like to see FBANs be able to do that future planning to give us the windows and when the windows are likely to open up for various fuel types*" (SAC-2).

3.2.1 Standardisation of outputs

Standardisation of predictive services outputs is a contentious issue. Currently the scope and format of outputs that FBANs produce vary depending on the FBAN who produces them (SRC-1, Op-1, FBAN-3, FBAN-4) or depending on the needs of the end-user (PIO-3). It was suggested by some participants that the outputs are partially the result of the needs of different users and subjective judgements about intractable uncertainties and therefore require a level of creativity (FBAN-3, SO-1, PO-3).

Some interviewees felt that standardisation of outputs would increase general user confidence in the outputs (SRC-1, PIO-3, PO-1). Interviewee preference towards standardisation depended on use and timeliness. For example, some interviewees made a distinction between the need for standardised outputs for public-facing maps but pointed out that this is less of an issue for maps developed for operational use (FBAN-4, SO-1, PO-3).

Also, there was less concern around standardisation for first attack and extended attack because it was seen to be more important that the intelligence was shared in a timely manner (SRC-1, PIO-3, PO-3). As more than one FBAN stated: "*no one reads reports*" (FBAN-3, FBAN-2). However, interviewees also expressed the desire for maps to be timestamped (PIO-3) and that the intelligence and assumptions that went into the maps (i.e., confidence in ignition location - PO-1) are communicated (on the map or verbally) so that decision-makers can confidently validate and judge the relevance of the product (SO-1, IC-5, PO-1, Op-1, PIO-3).

One interviewee highlighted the issue of a lack of leadership on standardisation (FBAN-3). According to this interviewee, much effort has already been spent on identifying user needs and developing and trailing different options, but where standardisation has fallen short is having support and endorsement from someone with a leadership position.

3.2.2 Presenting probability

Currently, FBAN advice and outputs are not produced using standardised words of estimative probability (WEPs) or explicit levels of confidence. So, for example, a common word used in both advice and outputs is to describe predictions as showing "potential," which is a general term covering almost all probabilities. Participants had a variety of suggestions regarding how probability might be represented to users including greater use of some probabilistic terms already in informal use - such as "low and high risk" (PO-3) and "worry zones" (FBAN-1) - or introducing percentages of certainty (SAC-1) or confidence, potentially presented in a similar way to the confidence bar used by BOM (SO-1). Isochrones showing the time of a fire's predicted progression (i.e., where the fire will be in 3, 6, or 12 hours) was also seen as a vital attribute to be maintained (PO-3, PIO-2). Interviewees also discussed linking the outputs to the colours used in the Fire Danger Rating system (PIO-3) and providing links to the *VicEmergency* App by using the same iconography (PIO-4).

3.3 TRUST IN FBAN OUTPUTS

We found that in general there is a good level of trust in FBAN outputs amongst participants who are users of predictive services. However, there are variances amongst users in terms of the level of trust they place in particular FBANs. This level of trust seems to depend, in part, upon three interrelated factors:

a) users' perceptions of a specific FBAN's level of experience and knowledge of the area or context in which they are offering predictive intelligence;

b) users' confidence in their own knowledge and experience of the area or context in which the prediction is being made; and/or,

c) users' perceptions of the comparative superiority of their knowledge and experience as against that of the specific FBAN they are receiving outputs and/or advice from.

POI-1: "*If there is a local person in the team or in the ICC that has better knowledge you sort of run it under their noses to let them know, to get a better feel of them. 'What, is this right, does this look right?'*"

PO-1: "*If it's a local FBAN and someone you know has really great local knowledge on that stuff you might trust it a lot more too. There's a level of trying to ground truth data and what we're seeing and whether it matches up to what people expect if they know that landscape.*"

Op-1: "*I've tended to find that predictions are more accurate the more local knowledge that an FBAN has… Probably local knowledge, of both that area of the state and the fuel types, probably their operational firefighting experience, can probably influence that level of trust, and probably their past experience with wildfires as well*".

Op-3: FBANs "*sort of come in from sideways sometimes… [it's] not a job for a first year PFF, it needs somebody who understand their fuels quite well... And there's that school of thought that says, oh, you know, you don't need to have good fire knowledge to be in incident control, you just need to know how to manage people. And I say that's bloody bullshit.*"

For FBANs, both having fireground experience and "local knowledge" and being able to convince users that one has fireground experience and "local knowledge" seem to be important factors in eliciting some users' trust.

3.4 TIMELINESS OF FBAN OUTPUTS

We found that in general that there was some difference across and between participants in terms of timeliness surrounding the production of FBAN outputs insofar as it is difficult for almost all participants to delineate a set of criteria for when an output is or is not considered "timely". It would seem, on the basis of our data, that users know a timely output when they see it. "But *the quicker you get it the better*" (Op-3). This is important because it allows for conversations amongst officers within Incident Control Centres to predict the path of the fire and evaluate the risk to lives and assets as soon as possible by asking each other key questions:

SAC-3: "… *what's at risk here? Is this fire going to impact on, you know, houses? Is it going to go into the bush and then push out at some stage into the future?" So that early advice recognising that things are going to change and do change, sort of with the weather and topography and things like that, is particularly useful. So having that early prediction that stamp that comes out after two or five minutes, whatever it is, is particularly - because you can actually apply a risk lens to what that fire's actually going to do and where it's going and what's in its path.*"

Nonetheless, several interviewees mentioned the importance of having "rough and ready" or "quick and dirty" outputs, which could be produced in just a few minutes, in the first 20-30 minutes after a fire is reported (Op-1, PIO-3, FBAN-1, SO-

1, PO-1). While it was understood that these outputs were based on limited and preliminary information, having such a product in hand gave users a basis for making quick decisions. Several interviewees identified "rough and ready" outputs with hand-drawn maps on paper or a whiteboard as useful (FBAN-1, SO-1, PO-2, IC-1) and distinguished them from computer-generated outputs. While both are based on models, hand-drawn maps may be perceived as based more on personal experience and local knowledge than algorithms.

PO-2: "*[w]hether the [initial] prediction is produced by Phoenix RapidFire or whether it's produced by an FBAN, in some respects, it's still all just a model tool. Phoenix is based on experience to create the algorithms. A hand drawn prediction, if you like, has a different set of experiences and values sitting behind it*". To this user, a "quick and dirty" hand-drawn prediction was better for communicating the uncertainty of the underpinning analysis.

Interviewees were all too aware that fire will often escalate in a manner which is rapid as well as unpredictable which means that timeframes for prediction become compressed:

OP-1: "*So if you've got a rapidly escalating incident, it's getting a lot larger, it's threatening communities, the time frame that you need to get a prediction back in is obviously far shorter, because any delays can be the difference between a decision that may affect protection of community and obviously ultimately maybe loss of life. So, in those rapidly escalating situations you probably need a rough and ready prediction within 15, you know, 15 minutes to an hour of being instigated to prepare it.*"

Interviewees stressed that discussions around timeliness need to recognise that bushfires (and other incidents) are fast moving as well as dynamic circumstances which are continually changing. This means that priorities must change too:

IC-4: "*… when you're in a dynamic situation of new fire starts, and you've got changing community or changing priorities really with new fire starts, the initial system that generates the predictive fire spread is okay… it tends to be a little, be misleading…*"

Delivering timely products remains an ongoing challenge for FBANs. Developing predictive products takes time this is rarely a luxury afforded to officers who must plan for and respond to escalating incidents:

FBAN-3: "*All predictions take time, they're very complicated factors we're dealing with here, very complex situations, multiple dimensions. You know, the old saying is if you think it's hard to predict the weather, try fire behaviour prediction because that's taking weather and fire and the interactions of all of that with fuels, weather, topography. It's much harder. So yeah, it's really important we do get information to the right people in a timely manner. It's critical if it's going to be useful.*"

3.5 BENEFITS OF RELEASING FBAN OUTPUTS PUBLICLY

This subsection relates to users' views of the realised and potential benefits of releasing predictive services outputs, such as fire spread prediction maps, to audiences outside the emergency management sector including members of

the general public. Overall, users were interested in sharing information that they believe will drive sound decision-making by members of the public. As such, they wanted that information to:

a) boost public trust in firefighting authorities and their advice;

b) encourage readiness, both in the earlier stages of an unfolding incident, and also seasonally, in advance of any particular incident; and,

c) give the public the tools to interpret information and act on it wisely, particularly by acting earlier in an unfolding incident.

In many cases, users framed the benefits of publicly releasing predictive services outputs as straightforwardly "the right thing to do" (PIO-3) in terms of emergency managers' duty to the public. In an evacuation, one user noted, "*the decision [to evacuate or not] is theirs. So, we need to have given them all the information they need to make a rational and the right decision for themselves*" (IC-3). Interviewees were also mindful that their decision-making processes could come under scrutiny, as for example by the Victorian Bushfires Royal Commission that followed the 2009 Black Saturday fires. Sharing predictive outputs was seen by some as a way to pre-empt negative accountability for decisions that did not play out as expected or being seen to withhold information from affected communities. As one user said, "*if you can share the knowledge that you're using to make decisions… whether the decision is ultimately right or wrong, it's just being transparent about it*" (PO-1).

For some, the release of this information was seen as both serving the state control priority "to save lives" (PIO-1) and potentially useful for overcoming issues with delayed decision-making by members of the public during a bushfire. Releasing such maps, "*especially on those bigger days increases awareness to the general public*" (FBAN-2).

FBAN-2: "*It makes people focus on what's probably more important… [people] go, "Oh, this is important. I need to do something" or "I need to provide assistance" or whatever. I think it raises awareness in people to do the right thing*."

PIO-1: Awareness and action "is *the biggest problem we have… [and if] We're actually showing the flames coming at them [in a prediction]... that will get people to move, it'll save lives… if we have information that potentially is of value to the community to make a decision to actually get out of the road of the fire, do we have the moral obligation to actually use it and provide it? I'd say yes.*"

Further, as one user noted, recent bushfire events including those during the Black Summer season showed that community members were increasingly seeking information about emergency incidents online. "*I think in this day of media, [releasing predictive maps] certainly gives some truth, rather than Twitter and Facebook, about where fires are at*" (IC-2).

Several interviewees were aware of the risk that, by providing information on low-probability worst case scenarios, this could lead to warning fatigue and criticism from affected communities. As one user stated, though:

IC-1: "*I'll wear that criticism. I'll wear it because I'd rather have them alert and with a heightened awareness than not. I'd rather have that charge made*

against me, that I actually frightened someone unnecessarily, in their view, rather than have the accusation that I left them completely unprepared".

PIO-1: "I understand all the other arguments about the potential fallout from it after the fact," another stated, "but our moral obligation is to save lives".

"*You always get backlash*" (PIO-4), many noted, but it's also been "*a constant criticism of the fire agencies over the years is that they just don't give out enough information of the right kind at the right time*" (FBAN-3). In short, the benefits of releasing robust predictive maps were not seen to be outweighed by the risks of criticism. In fact, users noted, an important feature of any rollout of predictive maps would be ensuring they were consistent, clear, and well-explained (FBAN-4, PO-3, PIO-4, PIO-3), "*with enough simple caveats around it*" (PO-1). "*There needs to be that real world layman's education piece to explain these to their full potential I think*" (PIO-4) or, as another noted, "*an education campaign… so they know what to do with it*" (PIO-2).

3.6 RISKS OF RELEASING FBAN OUTPUTS PUBLICLY

This subsection relates to users' views of the realised and potential risks of releasing predictive services outputs. One risk identified by users was that the release of predictive maps could lead to issues of legal and political risk, for example through analysing predictions against subsequent operational resource allocations and, thereby, claims that such allocations were not prioritised according to predictive intelligence (Op-1). "*To get this map signed off in the real world*," another user stated (PIO-1), incident controllers would likely opt to release it but "*at a corporate, state level, they'd be going, 'We need to be certain of this. This is a legal issue, potentially.'*" Given the legal protections that emergency services have in relation to releasing information about hazards, it is more likely that the release of predictive maps comes with political risks than legal ones.[1] Politically, "*[y]ou need to use the front page of* The Herald Sun *test, and have a look at it and see, 'well, what might Andrew Bolt, or someone like this, twist this around to mean?'*" (SAC-1).

Nonetheless, there was some reluctance amongst participants about releasing predictive maps to the community for use, much of which related to the risks of members of the public misinterpreting such outputs and then taking maladaptive or unintended courses of action. Some participants expressed doubts, therefore, on providing too much spatial or temporal detail within outputs to the public.

IC-4: "*So I think it'd be very dangerous at this stage to put a product like that out without someone explaining it or the community understanding it... They have enough trouble understanding FDI, really. It's too complicated*."

PO-1: "*There's a massive challenge in explaining what it is that they're looking at. The lowest common denominator is probably pretty low. You could put as much explanatory text or caveats or whatever on the things, but people will just focus in on a line*."

[1] Legally, as Eburn and Dovers (2012) have shown, there is "no legal impediment to releasing reasonably accurate hazard information" in Australia.

IC-5: "*I think we should demonstrate it as a fuzzy line, or not a solid line and say, 'This is roughly where we think it's going to end up'*."

A spatially explicit map, representing an extreme scenario, could be read by some audiences as authoritative advice that an area will or will not be affected. As a Public Information Officer (PIO-3) said they were in favour of releasing predictions publicly, "*But wanting to do that, I guess, carefully to not cause maladaptive behaviours or panic or conversely people thinking that they won't be affected so they don't need to act. I mean it's kind of a balancing act*." This helps contextualise how, for some participants, the most significant risks of publicly releasing predictive outputs were that, in the first instance, they would not be preceded by sufficient educational or explanatory effort from agencies and, additionally, they might be used as substitutes for more dialogical modes of engagement that they consider more effective in generating shared understandings between emergency management staff and others.

PIO-2: "*[Each] time we've [put out new or different warning outputs] we've had to put a really big, concerted education campaign behind it to make sure we're reaching as many people as we can, and that education campaign is going to have to go over a couple of years because we know not everyone's going to be listening. And a lot of them won't be listening until it's affecting them or it's too late and then they listen really really well.*"

SO-1: "*...it's probably an education piece and it's about change in our business, and we've got to go through a change process with the public if we're going to put out something like this - and ensure people know how to read it. Because you can't put something out and just assume people are going to know what you're talking about. It's a very simple message there, the red shows the predictive spread of fire… There's nothing [in Red Maps] about the dynamic nature of what we're dealing with. But how much can you put in there?*"

IC-1: "*So there's this risk about if we value add to the VicEmergency app it's never, in whatever format, it's never going to be able to do what a community meeting might do… If the community feels that they can get everything off that they think is relevant off the app, then we're not going to attract them into the other things that we do which are inherently more worthwhile. It's inherently more worthwhile for someone to come to a community meeting and hear from an incident control and operations officer exactly what's happening, and someone that can talk to them about their street name... VicEmergency app isn't going to do that.*"

Overall, as stated above, participants supported the public release of predictive outputs but were wary of the risks of misinterpretation which, several suggested, could be mitigated through careful design and suitable public education effort by relevant agencies.

3.7 FUTURE OF PREDICTIVE SERVICES

Preceding subsections have, to some extent, already noted several future changes that participants would like to see in predictive services, particularly relating to the development of prediction inputs (e.g., fire suppression) and outputs (e.g., planned burning, scenario planning, probabilistic forecasting).

Various users had suggestions about how predictive services might better serve their needs, the vast majority of which related to the refinement of output types and modes of presentation.

Interviewees were specifically asked if they believed that there was anything missing from the current predictive service outputs that would help to improve the outputs and better support their role as a result. Some suggestions were made, such as including the effect of suppression efforts (i.e., firefighting) in the fire predictions to enhance the accuracy of current outputs (PIO-1, FBAN-4). Also including local effects (SAC-1) and using existing data about fuel impacted areas, grazed areas, and fuel load were all identified as pathways FBANs should explore to create more accurate predictions (SAC-2, PO-1).

Importantly, the need to review and learn from the applied use of predictive outputs, including the effectiveness of predictive service outputs, was seen as an opportunity to increase user confidence in FBANs (SRC-1). However, it was also acknowledged that the evaluation of predictive service outputs is challenging.

FBAN-2: "*[I]t's really difficult to learn from this stuff if we don't actually go back and validate it because we're not quite sure what we're learning. Sure, we did a prediction, but we don't know why that prediction was accurate, what was wrong.*"

PO-3: "*...the product that I think we need to get to communicate is 'here's the fire, this area here is low risk, this area here is high risk and this area that's high risk could do this' ... Some way of heat mapping the risk of movement around the edge of the fire.*"

SAC-3: "*I actually find they're pretty good now. I mean... the information in the maps that we currently get I think are good. I've got no real major concerns with the information that the FBANs are currently providing.*"

Another user, discussed how a service they currently receive should be more formalised as part of the FBAN role, describing how on high hazard days that ask FBANs to "*do some simulations for me and I'll pick a couple of spots that might be giving me concern. So, say a fire starts here at 3 o'clock, tell me what that looks like, and they'll run those analyses for me... So, if you get an automatically generated something you've got something to reference and prepare to that was prepared earlier*" (Op-2). Other users identified how they would like to see predictive analysis used more comprehensively through fire management operations. For example, reflecting on issues with uncoordinated warning polygons in the landmark 2019-2020 bushfire season, users stated:

PIO-4: "*genuinely speaking I think that the symptom that we had of those polygons in particular was - this was absolutely the case - we did have ICCs issuing warnings without really looking at what's happening about them. It's that bird's eye view, that bird's eye coordination view, that probably lacked for a little bit.*"

IC-4: "*[We] should never see a loss of life like that again because these [predictive] outputs exist, and that's the day when you do want those raw outputs, that have got a bit of emotion in them, because you need to, that emotion needs to continue through the IMT into the community. Otherwise [the community] won't get the message in enough time.*"

SAC-3: "*Basically I would hope that what's in the Vic Emergency page would be taken from the prediction maps that are prepared by the FBANs… That was what I was sort of talking about the connection between the work the FBAN does, the incident and the public information section so that they're all working together to come up with an agreed - and the [Incident Controller] has to approve that emergency warning or whatever it is, or the advice message based on the information that they're getting from the FBANs and the intelligence unit.*"

Such comments can be read, we suggest, as votes of confidence in Victoria's predictive service capability. In parallel, FBAN participants seem to be aware that "*end-users want more consistency or predictability or reliability out of predictive services*...[but] I don't think we will get to that with current procedures, systems, processes and technology "(FBAN-4). Another FBAN explained how, in their view, "the map is not even essential" during operational response in many instances, suggesting that the most important dimension of predictive services is in fact "*that process of just talking through what was happening*" with users; or, more directly, "*the high impact is the conversations that you have*" (FBAN-2).

It would seem, on the basis of our research, that FBANs are not opposed to greater use of their services, greater connection with other roles and functions, and greater interaction with their users, but they have doubts this can be achieved with current resourcing and policies.

SECTION 4: RECOMMENDATIONS

Our findings provide the basis for four recommendations which will further support the sustaining and strengthening of predictive services in future. Our research clearly shows that FBANs not only play an important role in operational planning for and response to bushfire incidents but also that there is increasing scope for them to contribute more broadly to other emergency management activities that seek to build and enhance community safety. Specifically, our findings show that the skills and competencies of FBANs can be brought to bear on planned burning operations where mapping and predictive services have an important role to play in modelling fire behaviour in informing decision-making about the resourcing and completion of burns in the landscape. Furthermore, our findings show that there is support amongst the research participants to explore the ways in which FBAN outputs can be made available to the community in such a way that, in conjunction with other sources of emergency management information and advice, they can be used to inform decision-making. With these considerations in mind, we present our recommendations.

RECOMMENDATION 1

That emergency management agencies explore which FBAN outputs could be released to the community to support their planning and decision-making during bushfire season

- We explored whether participants believed whether there was value in releasing FBAN outputs (i.e., fire spread predictions, "red maps) to the community. Various predictive services outputs were released to the public during the 2019-2020 season in other jurisdictions and there are indications that many jurisdictions, including Victoria, will pursue this in future bushfire seasons. Participants in this study saw clear value in making outputs such as predictive fire spread and potential impact zone maps publicly available, framing them as another way in which emergency management organisations can work with communities to safeguard against loss of life and assets. However, some participants stressed that there was a need for further exploratory work to develop processes that ensured FBAN outputs were approved and released in an appropriate manner and that relevant communities were educated about the appropriate interpretation and use of these outputs.
- Interviewees wanted that information to:
    1. encourage readiness, both in the earlier stages of an unfolding incident, and also seasonally, in advance of any particular incident;
    2. give the public the tools to interpret information and act on it wisely, particularly by acting earlier in an unfolding incident; and,
    3. boost public trust in firefighting authorities and their advice.
- The CRC Black Summer research group could usefully be extended to assist emergency management agencies in the selection and design of

FBAN outputs for a public audience, particularly by assessing the needs and preferences of both agency practitioners and target audiences. This is likely work that would benefit from significant cross-jurisdictional collaboration given that these issues are being encountered in other jurisdictions.

RECOMMENDATION 2

That emergency management agencies explore how FBANs and predictive service outputs can be utilised to better support other relevant functions such as the conduct of planned burning and public information

- The forms of fire behaviour analysis used by FBANs in predictive services have clear relevance for a range of different activities beyond operational planning and response to bushfire incidents. Participants noted that planned burning operations offer a significant opportunity to utilise FBAN skills and predictive service outputs which could be used to predict the rate of fire spread and flame height of planned and scheduled burns. Furthermore, participants have noted that there is further scope for FBANs to offer capacity and capability for long term prediction related to planned burning which would assist burn incident controllers and operations personnel with burning different fuel types within different windows of opportunity. Participants also noted that there is currently limited use of predictive services advice and outputs in the development of public warnings and information and that the latter would benefit significantly from greater integration of such advice and outputs. With this in mind we propose piloting these initiatives in a way that seeks to progress them into practice.
- The CRC Black Summer research group could usefully be extended to assist emergency management agencies in assessing the opportunities and challenges for enhancing the engagement of Predictive Services in other relevant functions, as such enhancements could have significant institutional and resourcing implications.

RECOMMENDATION 3

That emergency management agencies explore the ongoing training and development needs of FBANs

- The recent 2019-20 Black Summer bushfire season brought both sector and public attention to the important role that predictive services can play in mitigating and preventing the loss of life and assets from bushfires. With this in mind, it is important to continue to ensure that training and development initiatives continue to evolve and even be expanded. It is clearly vital that less experienced FBANs undertake training to understand the key competencies of the role but are also mentored by their experienced counterparts to ensure that they are given opportunities to hone their skills during different types and levels of bushfire incidents. Further, our research suggests that fire behaviour training, knowledge of

fuels and fireground experience are all important to creating and sustaining user trust in FBANs and, therefore, that agencies should ensure FBAN development supports the acquisition and maintenance of these skills and experiences. We propose training and development which requires:

1. FBANs with more than 5 years' experience to be identified as formal mentors to newly appointed FBANs;
2. FBANs develop a statewide perspective which requires them to work to across regions and districts during bushfire season; and,
3. FBANs to develop standardised working procedures and practices across regions and districts.

- The CRC Black Summer research group could usefully be extended to assist emergency management agencies in this matter, given that the training and development needs identified will require an iterative program design and the strong connections that have now been established between researchers and the FBAN community in Victoria and elsewhere can support such a design process.

RECOMMENDATION 4

That emergency management agencies work with FBANs to develop continuous learning processes which can be used to improve predictive servcies after bushfire and planned burning seasonsbv

- The skillsets of FBANs continue to develop every season, yet participants noted that there is scope for FBANs to become better still at learning from their experiences and applying their competencies. Accordingly, we propose that a process of continuous improvement is developed which encourages FBANs to periodically debrief as a group and with key users so that lessons learned can be carried forward into future practice. This is important because it will help identify the training and development needs of FBANs while also bringing attention both within the cohort and amongst users to the ways that their skills can be applied in other a range of emergency management planning and response activities. We propose a learning approach that requires:

1. *End of shift review:* this will enable predictive services personnel to develop routines whereby continuous improvement is part of everybody on shift.
2. *End of incident review:* this will enable predictive services personnel to reflect on key learnings from specific incidents that can be used to further refine practices which need to be changed during a bushfire season.
3. *End of season review:* this will enable predictive services personnel to conduct a whole-of-season review and identify areas of practice for change and improvement into the future.

- The CRC Black Summer research group could usefully be extended to assist emergency management agencies in this matter, as currently they do not have a formal process for the kinds of review program recommended above. Such a review program should be informed by programs elsewhere that seek to both ensure that knowledge is shared and that practitioners are supported. Researchers can assist in the design and testing of such a review program.

UTILISATION OUTPUTS

Our recommendations will require an implementation strategy which needs to be mindful of the requirements to continue to plan for and respond to ongoing incidents that require predictive services. Accordingly, we propose a staged approach to utilisation that is channelled through the Bushfire and Natural Hazards CRC Black Summer research group in the following ways:

1. The project chief investigators present the key findings and recommendations to CFA and DELWP as the basis for developing an implementation strategy.
2. The project chief investigators work with CFA and DELWP to identify priority recommendations for implementation in the short, moderate, and longer terms.
3. The project chief investigators in collaboration with CFA and DELWP identify the resource requirements to implement the recommendations.
4. The project chief investigators in collaboration with CFA and DELWP develop a research agenda which seeks to develop empirical insights from ongoing research with a dedicated focus on predictive services generally and more specifically on the FBAN role.

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