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Briefing Paper

Fire fatalities in Scotland and recommendations to help reduce them - Final Phase: Review of Fire Investigation reports

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Contents

Summary

The final phase of a two-phase research project investigating fire fatalities and serious injuries in Scotland has now been completed. During phase 1, data obtained by the Scottish Fire and Rescue Service (SFRS) using the Incident Recording Systems (IRS) permitted the identification of the key factors and common conditions under which fatalities and serious injuries were occurring that are reported in the Phase 1 Briefing Paper. This phase focussed on fire fatalities and involved a qualitative and quantitative analysis of 123 Fire Investigation reports of all accidental dwelling fires, in Scotland, during the period from April 2013 to March 2017.

A number of recommendations have resulted that are aimed at different groups including care package suppliers, manufacturers of electronic equipment, public services (NHS, carers, social workers, police, SFRS), the general public and for researchers.

This work has identified that whilst new and emerging technologies could provide supplementary protection in the future, the greater use of existing technologies could be applied immediately to offer additional protection. Existing and well-established technologies could provide more effective fire protection, that together with interventions and appropriate responses during different stages of a fire should result in further lives being saved.

Two additional areas for research are proposed that warrant further investigation. The first of these is an experimental investigation of the common electrical items involved in starting fires with attempts to replicate failure by overloading, aging etc. The second is demonstrating the effectiveness of current approved suppression strategies in two identical and standard sized rooms including furnishing, in which one is fitted with a certified watermist system and one without.

This report ends with an example concept strategy intended for Fire and Rescue Services to assist with the risk classification of vulnerable individuals and proposes solutions that would provide appropriate levels of life safety protection.

The findings detailed in this report are comprehensive and applicable to a number of different groups. The next stage will be to disseminate these findings to them and encourage the development of a broad implementation strategy.

Whilst this study focussed on data from Scotland, the findings and the resulting recommendations that have been proposed would be expected to be valid in other areas e.g. England, Wales, Northern Ireland, assuming that they are relevant and applicable. If so, the user would need to apply due diligence to ensure that the recommendations were appropriate and perform a suitable risk assessment.

Abbreviations and glossary of terms

The abbreviations list and glossary are compiled from terms used in this publication. The descriptions in the glossary are not intended to be comprehensive, but to help the reader understand the meaning of terms as they are used in this Briefing Paper.

Abbreviations

ADF = Accidental Dwelling Fires

ARC = Alarm Receiving Centre

CO = Carbon monoxide

COHb = Carboxyhaemoglobin

CN = Cyanide

FI = Fire Investigation

HFSV = Home Fire Safety Visit

IRS = Incident Recording System

LPS = Loss Prevention Standard

RIP = Reduced Ignition Propensity

SFRS = Scottish Fire and Rescue Service

Glossary

Alarm Receiving Centre – continuously manned premises, remote from those in which the fire detection and fire alarm system is fitted, where the information concerning the state of the fire alarm system is displayed and/or recorded, so that the fire and rescue service can be summoned.

Fire Fatalities – those fire incidents attended by Fire and Rescue Services that resulted in a fatality due to the fire or products of the fire.

Fire Investigation (FI) report - a report produced by a Fire Investigator summarising the events surrounding a fire and involving a fatality.

HFSV - a visit to people homes performed by the SFRS during which they assess fire safety, wellbeing and lifestyle issues that might impact on personal safety.

Incident Recording System – a digital tool used by fire and rescue service personnel to record the details of all incidents attended.

LPS 1655 Watermist system – an approved local application watermist system used as Personal Protection Systems in residential and domestic occupancies within buildings.

RIP cigarettes - Reduced ignition propensity (RIP) cigarettes have been designed to self-extinguish, after a period of time, if air is not drawn through them.

Introduction

The first phase of research analysed data obtained by the Scottish Fire and Rescue Service (SFRS) using the Incident Recording Systems (IRS) [1] and permitted the identification of the key factors and common conditions under which fatalities were occurring. This permitted a profile of a person involved in a typical fire to be formed along with identification of the associated demographic profile and common background conditions as reported in the Phase 1 Briefing Paper [2]. Additionally, 14 recommendations were proposed that, using existing and proposed new technologies as well as different approaches, may lead to a reduction in future fire fatalities.

This final phase of research work examined further, using the Fire Investigation (FI) reports generated for all fatalities, the circumstances surrounding the fire and detailed information on the fatality in domestic dwellings in Scotland, during the period from April 2013 to March 2017.

The IRS recording platform does not have capacity to record all the evidence gathered at a fire scene, such as alcohol dependency and other potential contributory factors. The process undertaken by specialist Fire Investigation teams is far more comprehensive in terms of referring to available evidence and taking opinions of qualified professionals. In this respect the data used in this study is more accurate and where there may be contradictions with the Phase 1 report, the findings stated here supersede those.

SFRS supplied 123 FI reports from accidental dwelling fire (ADF) incidents that were all examined. The responses to 36 questions and additionally eleven of the fourteen recommendations made previously during this study were considered during the review of each report. A qualitative and quantitative analysis of all available data was performed by the stakeholder group (comprising the Fire Industry Association, Scottish Government, SFRS and BRE Global).

The qualitative analysis involved reviewing each FI report in its entirety, focussing on what interventions may prevent similar fatalities in the future. For the quantitative analysis, the data from all FI reports were collectively reviewed to address questions posed by the stakeholder group.

Other areas were also investigated including the claims of an officer of one Fire and Rescue Service that hundreds of fire deaths in England may have occurred because of the use of emollient products [3]. These products, used by people with dry skin, contain paraffin and it was claimed that fabrics, clothing etc. were becoming flammable as a result. As the review of FI reports would reveal any cases in which emollient creams were used, BRE Global were requested to note reports in which the use of these had been documented in Scotland. This together with the confirmed causes of death, blood alcohol levels, alcohol combined with smoking or cooking, fires involving smoking materials and main findings from the toxicology data are also reported.

By performing the analysis in this way, as much valuable data as possible was extracted from each report leading to a number of recommendations. The report ends with a proposed example concept strategy for Fire and Rescue Services worldwide, to provide effective fire safety for vulnerable people at different levels of risk.

Figure 1: An example of the aftermath, following a fire, that Fire Investigators face

Methodology

Review of key questions

At the commencement of this work the stakeholder group had agreed the key questions to be investigated that would inform and identify the circumstances around fire fatalities and serious injuries. A significant proportion of these were addressed during the Phase 1 review and the outstanding questions are detailed, under five main sections, in Table 1. The ID numbers shown are referenced throughout this paper.

Section	ID	Question
General conditions	1_1	Were working smoke alarms present?
	1_2	Were there any issues which prevented people escaping? If so, what?
	1_3	Were any accelerants present? Skin creams, oxygen etc. If so, what?
	1_4	Were doors left open that supported the fire development?
People	2_1	Was the individual/s known to external agencies?
	2_2	Was the individual under the effects of drugs, alcohol or medication?
	2_3	Did the person live alone?
Fire Progress	3_1	Did smoke alarms operate during fire?
	3_2	If not, why not?
	3_3	Did the fire spread beyond the room of origin?
	3_4	If a flat, did it spread beyond the flat of origin?
	3_5	What item first ignited?
	3_6	How long did it take to discover the fire?
Effects of Fire	4_1	How many fatalities outside the room of origin?
	4_2	How many fatalities inside room of origin?
	4_3	How many fatalities were directly involved in the fire?
	4_4	Fire service attendance time and related fatalities?
	4_5	How many people were rescued in the flat of origin?
	4_6	How many people were rescued beyond the flat of origin?
Prediction	5_1	Would sprinklers present have made any difference?
	5_2	Why would sprinklers present have made the difference?
	5_3	Would severe injuries have been fatalities were it not for SFRS intervention?
	5_4	Would earlier warning have been provided with smoke/heat alarms?

Table 1: Key questions remaining following the Phase 1 review

Of the fourteen recommendations, resulting from the Phase 1 review, eleven were examined further (see Table 2) as recommendations 3, 6 and 11 related to monitoring cold temperatures, code of practice for watermist systems and online material for IRS database were not relevant and were therefore excluded.

ID	Would this recommendation have been effective had it been present?
6_1	1 providing warnings from alarms to a mobile phone;
6_2	2 increasing the sensitivity of smoke alarms at night;
6_4	4 high-risk domestic premises to be linked to an ARC;
6_5	5 extension of the LPS 1655 watermist for personal protection system;
6_7	7 using video analytics technology to monitor and provide warning
6_8	8 research into the underlying causes of electrical fires
6_9	9 the development of an Electrical Appliance Current Monitoring Device
6_10	10 manufacturers of white goods to develop preventative measures in devices
6_12	12 detection in utility space
6_13	13 smoke alarm in loft space
6_14	14 a government campaign in winter "look out for neighbours"

Table 2: The recommendations to be reviewed

Following the completion of the Phase 1 review, eleven additional questions were proposed by the stakeholder group to gather further information. These provided more detailed information than those recorded using the IRS database as reported in the Phase 1 Briefing Paper. Whilst data addressing the questions was collated and reviewed by the stakeholder group only two questions 7_2 "What was the attendance time from ignition?" and 7_8 "What was the level of disability of the fatality?" are explored further.

Review of Fire Investigation reports

Each SFRS report is typically between 1,500 and 7,000 words and consists of the following information:

- Summary page
  - Report of fire: location, occupier, time of call etc.;
  - Other services attended e.g. police, forensic scientist, ambulance;
  - Report details i.e. reporting officer, service times and contact details.
- FI Report - Narrative
  - Sequence of events (synopsis of what happened);
  - Description of premises;
  - Description of damage;
  - Development of fire;
  - Fatality details (Name, sex, age, date and cause of fatality). Sometimes includes the relevant sections from the toxicology report and where relevant states any medication present as well as the alcohol, carboxyhaemoglobin (COHb) and cyanide (CN) level present in blood.
  - Observations- summary of key hazards and risks e.g. hoarding, overloaded extension cables, smoker's materials, alcohol bottles, evidence of previous near misses (e.g. burns in carpet) presence/ status of smoke detection;
  - Extract of witness statements (neighbours, SFRS personnel etc.);
  - Other relevant information (background information about fatality such as declined a Home Fire Safety Visit (HFSV), known to external agencies, any dependencies, etc.);
  - Conclusion- reviewing all potential causes and discounting each one, using evidence previously presented, until one is considered to be either most likely or known to be the cause.
- Appendix
  - Plan layout of premises- typically including the location of ignition and where the fatality was found;
  - Photographs of premises from the front and photographs (following the fire) supporting the main narrative of the report.

At the request of SFRS one FI report was requested to be excluded and additionally two FI reports were not available. The remaining 123 FI reports were individually examined during which it became evident that some of those reported were actually a fatality and a fire and not a fire fatality.

A fatality and a fire is when the fatality is not as a direct result of the fire. A commonly observed example of this would be one in which a person has started some cooking, gone off to do something and subsequently had a major heart attack. The smoke/fire from the cooking would eventually attract attention (trigger the smoke alarms). The forensic scientist's report would confirm that the fatality was due to another cause and not the fire e.g. there would be no COHb present in blood or soot on the lungs. It total, twelve reports fell under this category and were excluded from further analysis.

Figure 2: Observations of key hazards, such as hoarding, are recorded in FI reports

A qualitative and quantitative analysis of the data was performed on the remaining 111 fatal fire investigation reports. For the qualitative review each report was assessed in its entirety, summarising in a few words what happened and identifying what interventions, in the future, may prevent similar events. It targeted the recommendations towards a number of key groups. The quantitative analysis reviewed all the reports collectively to address the questions in Table 1.

Toxicology review

As detailed in the previous section, toxicology reports found a number of chemicals were often present in fire fatalities preserved in the blood. These include Carboxyhaemoglobin, Cyanide and alcohol. This section details the expected effects on human beings of the key chemical compounds.

Carboxyhaemoglobin

The information in this section has been obtained from "Causes and clinical significance of increased carboxyhaemoglobin" [4]. Carbon monoxide (CO) is a ubiquitous product of incomplete combustion of hydrocarbons. Common sources of CO in cases of poisoning include house fire, motor-vehicle exhaust and faulty domestic heating systems. The toxicity of CO is due in part to the effect that haemoglobin binding of CO has on the oxygen-carrying capacity of blood. Affinity of haemoglobin for CO is 200-250 times greater than that for oxygen.

CO displaces oxygen from haemoglobin and thus COHb effectively reduces the oxygen-carrying capacity in a dose-dependent manner. Organs like the brain and heart, whose normal oxygen consumption is by comparison with other organs relatively high, are particularly sensitive to the relative anoxia induced by increased COHb. The symptoms presented with the concentration of COHb in the blood are shown in Table 3.

COHb in blood (%)	Symptoms
10	No appreciable effect except shortness of breath on vigorous exertion, possible tightness across forehead
20	Shortness of breath on moderate exertion, occasional headache
30	Headache, easily fatigued, judgement disturbed, dizziness, dimness of vision
40-50	Headache, confusion, fainting, collapse
60-70	Unconsciousness, convulsions, respiratory failure, death if exposure continues
80	Immediately fatal

Table 3: Blood COHb Concentration and Associated Symptoms

Cyanide

Natural and synthetic materials found abundantly throughout the home can produce cyanide when they burn resulting in cyanide gas that can easily be inhaled by anyone in the vicinity. The information in this section has been obtained from the LabMed article "Poisoning with Cyanide" [5].

Cyanide is a rapid-acting poison with a steep dose-response curve. Death can occur within minutes following cyanide exposure. Signs and symptoms of poisoning can vary, depending on the chemical form (i.e., solid, liquid, or gas), route, dose, and speed of intake, as well as patient-specific factors, such as age, gender, overall health, stress level, and weight. The brain is the organ most sensitive to the toxic effects of cyanide, and, thus, impairment of the central nervous system dominates the initial clinical picture.

Blood cyanide testing is performed for confirmatory or forensic purposes only. A blood concentration up to 0.1 mg/L is considered normal, a cyanide blood concentration greater than 0.2 mg/L is in the toxic threshold, whereas fatal levels usually exceed 1 mg/L.

Alcohol

The information in Table 4 was obtained from the Exeter Clinical Laboratory which provides service to more than 300 GP practices, independent healthcare providers and community hospitals (NHS). From the article on Blood Sciences Test [6] the information below has been reproduced.

Ethyl alcohol is a central nervous system depressant and an anaesthetic. Alcohol ingestion may cause loss of judgment, incoordination, and disorientation and higher doses may induce stupor possibly followed by coma and death.

Blood Alcohol Concentration (mg/dL)	Clinical Signs & Symptoms
<80	UK legal drink-driving limit
50-100	Decreased reaction time, diminished judgement, fine motor incoordination
100-200	Blurred vision, aggression, disorientation, confusion, ataxia, vasodilation, stupor, vomiting, sweating
200-450	Marked incoordination, coma, hypothermia, hypoglycaemia and potential convulsions
>450	Respiratory depression, hypotension, loss of protective airway reflexes (risk of aspiration), Potentially fatal.

Table 4: Blood Alcohol Concentration Associated Clinical Signs & Symptoms

Ethyl alcohol is absorbed rapidly (into the blood) in the proximal small intestine, usually within 30 to 90 minutes after ingestion. Blood alcohol levels vary depending on the amount consumed, the time elapsed since consumption, metabolic rate, and body weight. Ethanol clearance is nonlinear at concentrations above 20 mg/dL and changes with alcohol concentration. Generally, ethanol metabolism occurs at a rate of 10 to 30 mg/dL per hour. The average elimination rate is 12+/- 4 mg/dL per hour for non-drinkers, 15+/-4 mg/dL per hour for social drinkers, and 30+/-9 mg/dL per hour for alcoholic persons.

Findings and recommendations

Recommendations resulting from qualitative review

The Fire Investigation (FI) reports were reviewed in detail and any directly applicable recommendations were proposed that, if adopted, would be expected to lead to a reduction in fire fatalities. These are presented below and are targeted at specific groups namely, care package suppliers, manufacturers, public services (NHS, carers/social workers, police, SFRS Fire Investigators, SFRS personnel), the public and research bodies.

Public services (SFRS):

- during a Home Fire Safety Visit (HFSV) if smoke alarms are already present and locations likely to produce false alarms then consider re-locating them to a more appropriate location;
- there were lots of cases of people refusing HFSVs and SFRS have no powers of entry for domestic premises. Some promotional material produced by SFRS (e.g. video interviews) and circulated on social networks, newspapers, magazines etc., explaining the benefits of HFSVs, may encourage such people to have a HFSV;
- when performing a HFSV of a domestic dwelling, SFRS should give advice on the benefits of smoke detection in caravan properties as well as domestic property and consider fitting smoke alarms in occupier's caravans at the home address;
- to perform HFSV and install smoke alarms in all caravans in caravan parks;
- produce leaflets promoting the likely consequences of not having a HFSV when there is a fire and leaflets for general fire safety;
- to reinforce the message to get out and stay out during a fire;
- to discuss escape plans, conduct fire drills and discuss good practice (such as not using high wattage bulbs in low wattage lamps) with occupants and perhaps neighbours;
- there have been cases when issues with keys have caused delays such as neighbours that have not had keys to enter the property when the smoke alarm sounded and when neighbours have had keys but the door is dead-locked or another key is present on the inside of the door. These types of issues could be highlighted during a HFSV;
- to encourage care providers/partners, family and friends to discourage hoarding and arrange a HFSV where excessive hoarding is observed;
- to consider the option of linking the alarm systems of vulnerable people directly with an Alarm Receiving Centre (ARC) when they decline a HFSV of if they are high risk or remote;
- vulnerable people identified as high risk or living in premises that are remote, could be informed of the benefits of having a remote monitoring system in place.

Public services (SFRS – Fire Investigators):

- to check and record how many smoke alarms were present, whether they were/are working as well as its status following the fire;
- comment on ambient ventilation conditions at the time of fire;
- if a smoke alarm is suspected to be faulty then to record the manufacturer/model;

Figure 3: SFRS performing a HFSV (photo courtesy of SFRS)

- if an electrical appliance is suspected to be faulty then to record the manufacturer/model;
- to always state in detail the position of every door contributing to the fire's development;
- to report the manufacturer/models of smoke alarms that operated;
- when suspected faulty electrical items are suspected of causing fires then details of this information should be shared with SFRS and manufacturers;
- all witnesses should be asked, as standard, if a smoke alarm was heard to be sounding.

Care package suppliers:

- install smoke alarms in bedrooms/living rooms particularly when smoke seals are fitted around a bedroom door.

Manufacturers:

- to make a safe electronic cigarette lighter for those with poor co-ordination;
- of electric fires to ensure that guards are fitted with security screws reducing the likelihood of removal;
- of smoke alarms to provide fire alarm warning (vibrate and flashing) by linking to smartphones, for those that are deaf or hard of hearing.

Public services (NHS):

- when an elderly person living alone is sent home following a hospital visit, NHS should notify SFRS to perform a HFSV;
- to inform SFRS to perform a HFSV once an "at-risk person" is identified;
- when arranging for oxygen to be present in someone's home, they should request SFRS to perform an urgent HFSV.

Public services (Carers/Social workers/Police):

- to inform SFRS to perform a HFSV once an "at-risk person" is identified or if there is evidence of a previous "near-miss".

Public:

- investigate when the smoke alarms of neighbours operate, especially at night (where safe to do so after alerting SFRS);
- check the electrical items on the specific circuit when it trips prior to resetting. If in doubt, call an electrician;
- frequently check the status of smoke alarms in homes of elderly or vulnerable relatives/friends;
- if you have a fire, no matter how small, get everyone out, stay out and call the SFRS;
- if you observe "near misses" in the homes of elderly or vulnerable relatives/friends (such as cigarette scorch marks on clothing, carpets etc.) then request SFRS to perform HFSV;
- encourage vulnerable people not to reject a HFSV;
- in the event of a smoke alarm going off at a neighbour's do not call others, but call SFRS directly;
- be aware of the danger of persons hoarding both to the occupants and fire fighters;
- be aware of the dangers of highly flammable products such aerosols and alcohol wipes/gels;
- when visiting elderly or vulnerable relatives/friends look out for hazards, ensure safe escape routes;
- ensure vulnerable people have rehearsed what to do in the event of a power-cut- there is a risk that they might light a candle and inadvertently start a fire;
- purchase and locate torches so that they can be easily accessed during a power cut;
- never put wet timber onto open fires;
- perform hot works in suitable locations and not in the home;
- refill gas lighters in open areas and do not test immediately;
- relatives/friends or vulnerable people could buy safe candle holders as a gift;
- discourage elderly or vulnerable relatives/friends from smoking in bed or late at night on the sofa;
- discourage elderly or vulnerable relatives/friends to smoke or cook when tired or under the influence of alcohol;
- fit smoke alarms in bedrooms/living rooms of elderly or vulnerable relatives/friends that smoke;
- when installing smoke alarms test them upon installation and test them periodically thereafter.

Research bodies:

- investigate alternate remote fire alarm signalling systems or review existing telecare systems for improvements;
- perform research into electrical fires from the following (numbers in brackets indicate how many of the 111 cases for which particular electrical items were identified as being the most likely cause):
  - batteries, chargers and vaporiser power cells (1);
  - electric blanket (2);
  - electric convector heater (1);
  - electric fan heater (1);
  - electric wheelchair (1);
  - electrical halogen heaters (2);
  - failure mechanism of overloading lamps (1);
  - fridge freezers (1).
- perform research to identify the safe distance of different materials (e.g. carpets, clothes, upholstery) from:
  - electric 2-bar heaters (2);
  - electric heaters (2).
- identify optimum positioning of smoke alarms to reduce false alarms yet provide early warning of fire in the types of living spaces that have been observed during this study.

Figure 4: Example of a fire due to an electrical cause (photo courtesy of SFRS)

Quantitative review of Fire Investigation reports

The questions detailed in the Methodology section were reviewed and the key findings are shown below. As with the qualitative, section recommendations have been made and are targeted at specific groups in the same way.

Q1_1 Were working smoke alarms present?

In 53% of cases smoke alarms were present, the remaining percentage being split equally between "No" and "Unknown". This suggests that despite the measures to increase the use of smoke alarms in homes the actual percentage of working smoke alarms, especially in fatal fires, appears to be unacceptably low.

Q1_2 Were there any issues which prevented people escaping?

In 93% of cases it was "No" and for the remaining 7% it was "Unknown".

Q1_3 What accelerants were present?

In 12% of cases accelerants were present, the majority of which were butane and aerosol canisters.

Q1_4 Were doors left open that supported the fire development?

Door/s that had been left open supported the development of fires in 60% of all cases.

Q2_1 Was the individual/s known to external agencies?

In 33% of cases the person was known to agencies other than the SFRS; had these agencies communicated with the SFRS, then a HFSV may have been performed and appropriate measures to safeguard may have been in place.

Q2_2 Was the individual under the effects of drugs, alcohol or medication?

In 48% of cases people were under the influence of substances during the fire that may have led to impairment or they may have had reduced alertness.

Q2_3 Did the person live alone?

In 80% of cases the person lived alone, 19% did not and for 1% of cases this was unknown.

Q3_1 Did smoke alarms operate during fire?

Smoke alarms operated, did not operate and it is not known whether they operated for 40%, 32% and 28% of cases respectively.

It was evident that smoke alarms were present for 59 cases and operated in 46 of those meaning that on thirteen occasions the working smoke alarms present were not heard to be operating during the fire. A logical way to improve likelihood of detection would be to have more working smoke alarms present in the first instance.

Q3_2 If not, why not?

The reasons for the thirteen working smoke alarms not operating are shown in Table 5.

Reason for smoke alarm not operating	Cases
Not heard sounding and destroyed during fire	4
Did not operate during fire, not tested during FI	3
Did not operate during fire, sounded when tested	1
Next to bed (not on ceiling), sounded when tested	1
On television, sounded when tested	1
Door shut	1
Battery removed	1
Battery depleted	1
Total	**13**

Table 5: The reasons for the 13 smoke alarms not operating

On four occasions it was not possible to identify why the smoke alarm did not operate during the fire and these were destroyed in the fire, so it was not possible to know if the alarm was working. Of the four alarms that did not operate during the fire only one was tested and it operated but it is not known why it did not operate during the fire.

On two cases working smoke alarms were reported to be present but not installed on the ceiling; being on a TV in one case and next to the bed in the other case.

In the case when the door was shut, the greater use of smoke alarms throughout the dwelling would be more likely to pick up a fire.

The case of the battery removed together with the battery depleted highlights that these could have been picked up during regular testing by others. Both these cases support the recommendation of friends and family of the vulnerable person taking the responsibility to periodically test and check the status of the smoke alarms.

Q3_3 & Q3_4 Did the fire spread beyond the room/flat of origin?

In 43% of cases the fire did spread beyond the room of origin and in 1% of cases beyond the flat of origin.

Q3_5 What item first ignited?

The item that first ignited is shown in Figure 5 and indicates that a high percentage of those directly involve bedding, furniture and clothes. A recommendation is made for friends/relatives to look out for dangers when visiting vulnerable people.

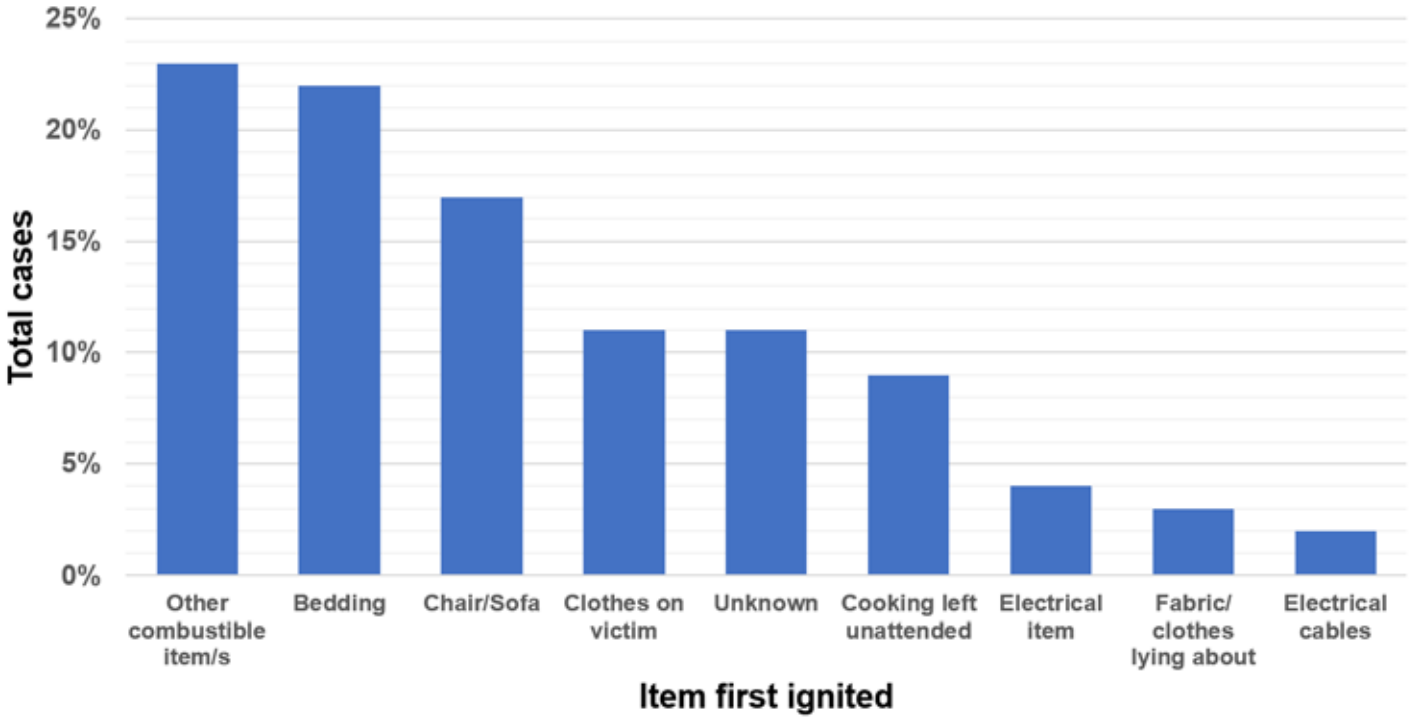

Figure 5: The items first ignited and associated percentage of cases

Q3_6 How long did it take to discover the fire?

The responses to this question are likely to be inaccurate as, in the majority of cases, in the Fire Investigation Reports this was not stated and estimations have subjectively been made on the limited information presented. In 49% of cases the estimated times to discover the fire was greater than 15 minutes and in 35% the time was unknown.

Q4_1, Q4_2, Q4_3, Q4_5 and Q4_6

The responses to five key questions are presented in Table 6.

Question	Number of people or fatalities		
	0	1	2
Q4.1 How many fatalities outside the room of origin?	76%	22%	2%
Q4.2 How many fatalities inside room of origin?	24%	74%	2%
Q4.3 How many fatalities were directly involved in the fire?	71%	29%	0%
Q4.5 How many people were rescued in the room/flat of origin?	93.5%	4.5%	2%
Q4.6 How many people were rescued beyond the flat of origin?	100%	0%	0%

Table 6: Responses to 5 questions on people

These demonstrate that:

- 76% of fatalities occur inside the room of origin;
- in terms of people rescued in the room/flat of origin the majority (93.5%) were deceased when they were removed and for the remaining 6.5%, they died later from their injuries.

Q5_1 and Q5_2 Would sprinklers present have made any difference? If so, why?

It was identified that in 70% of cases, sprinklers, if present, would be expected to have activated and in 23% of would not have operated due to lack of heat (smouldering fires). For the remaining it could not be determined or was not applicable (e.g. caravan). Note that the responses to these are based on the limited content in the reports and does incorporate some level of subjective judgement.

It is difficult to know exactly how the fire progressed, when/if the sprinkler would have operated, the level of toxic gases present when/if the sprinkler would operate and whether it would have provided sufficient protection to save the person's life. That said, it is presumed that it would have been sited appropriately and been effective in reducing the spread of the fire.

Q5_3 Would severe injuries have been fatalities were it not for SFRS intervention?

This question would look at the cases of serious injuries in more detail to identify what factors prevented the serious injury from becoming a

fatality. This data, in a workable form, is not available so is not pursued further but a recommendation for SFRS is made to generate detailed reports from incidents leading to serious injury.

Q5_4 Would earlier warning have been provided with smoke/ heat alarms?

Whilst in many cases fire alarms were present in the premises, it was identified that additional smoke and/or heat alarms present may have provided warning sooner, potentially preventing a fatality. Table 7 shows if additional alarms would be expected to make a difference and if so, the proposed location of where the alarms should have been fitted.

Would earlier warning have been provided with smoke/heat alarms?	Cases (%)
Yes, smoke alarm in lounge	32%
Yes, smoke alarm in bedroom	23% *
Unlikely	16%
Yes, heat alarm in kitchen	12%
Unknown	10%
No	5%
Yes, smoke alarm in room where casualty found	2%
Yes, smoke alarm in circulation space	1%
Heat alarm in kitchen and smoke alarm in lounge	1%

Table 7: Types of alarms and location that would have provided earlier warning

** Note that in two cases the fire started outside the bedroom (with occupant in the bedroom) so interconnected smoke alarms may have provided earlier warning. In one case the fire started in the bedroom but the occupant, in the kitchen, was unable to escape, as the fire was discovered too late.*

If working smoke alarms had been present in lounges, bedrooms and circulation spaces as well as heat alarms in the kitchen, then these may have provided earlier warning for 69% (in bold) of all cases in which fatalities were observed. It is likely this would have resulted in earlier warning to occupants, provided opportunity to alert others and summoned SFRS assistance in a shorter timescale. A percentage of these would be expected to result in non-fatal injury, rather than death, or perhaps even no injury at all. Additionally, the interlinking of smoke and heat alarms throughout premises would be expected to provide more effective audible warning to occupants and neighbours in the event of a fire. This demonstrates that as well as exploring new technologies (as done in Phase 1) there is much that can be done simply by using existing technologies more effectively.

Q7_2 What was the attendance time from ignition?

The response to this question is effectively the sum of the recorded fire service attendance time and the estimated time of ignition to first call to SFRS. In 84% of cases SFRS attend fifteen minutes after ignition; this is simply too late to expect SFRS to save lives in most dwelling fires. This delay is most often due to the fire been discovered late and/or delays to SFRS being notified.

Q7_8 What was the level of disability of the fatality?

From a review of the 2015 records from Statista [7] approximately 53% of all disabilities in the UK are mobility related and 22% of people in Scotland are reported to have disabilities. This would suggest that around 11.7% of people in Scotland suffer from a mobility related disability. During this study, the percentage of cases in which mobility

Figure 6: Using existing technologies and maintaining them will save lives

issues were noted is 28% which is significantly greater than the 11.7% national estimate. These figures suggest that individuals with mobility issues are at higher risk of fatality in a fire and as such consideration of enhanced protection measures could be beneficial.

Quantitative review of other related data

Other areas warranting further investigation were identified and are explored further in this section. These relate to:

- Summary of causes of death;
- The contribution emollient creams may have played in any fatalities;
- The blood alcohol levels present in fatalities;
- The cases in which alcohol was combined with smoking or cooking;
- The fires involving smoking materials;
- Toxicology data.

Summary of causes of death

From the Phase 1 IRS review the cause of death and associated figures were 46% from toxic gases, 12% from burns, 15% toxic gases and burns and 21% were reported unknown at the time. Figure 7 summarises, as a percentage of all cases, the cause of death resulting from the review of all FI reports. Those that were reported under "toxic gases and burns" and under "unknown" have been confirmed and this has resulted in an increase in the percentage of deaths caused by "toxic gases" and "burns".

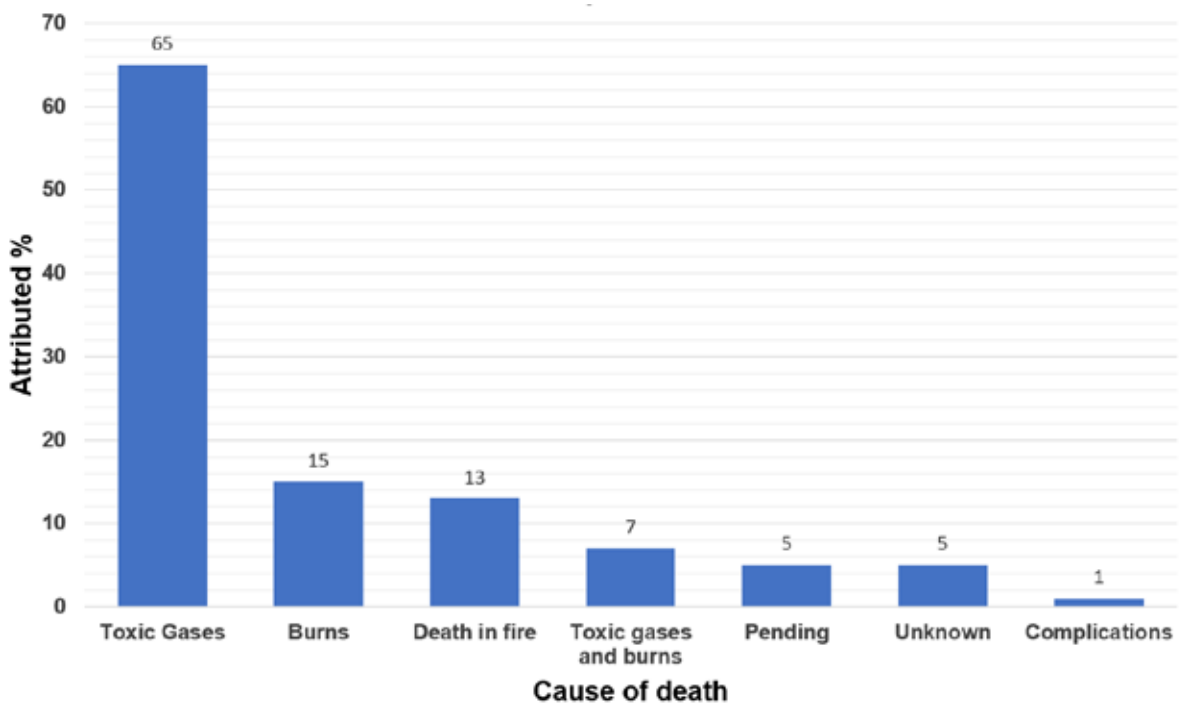

Figure 7: Cause of death as confirmed in FI reports

Toxic gases are directly attributed to 65% of fatalities and potentially a further 7% more that fall under "toxic gases and burns". Burns, in comparison, are attributed for less than a quarter of those under toxic gases.

From the data it appears that the noxious chemicals released during the incipient and developing stages of the fire are likely to be incapacitating victims preventing them from escaping. If the production of toxic gases could be significantly reduced the victims would have increased chances of surviving.

Emollient creams

During this quantitative review, there was only one case in which the fire investigation report identified the presence of emollient cream. In this case, it was not considered to be a contributing factor to the fatality.

It can be concluded that the reported high numbers of fatalities that may be due to emollient creams in England (as detailed in the Introduction) were not recorded in the data set for this study. SFRS have since recognised the increased fire risk that is present when emollient products are in use and are training staff to recognise/record the use of these. SFRS are proactively raising awareness with users/consumers and the care sector. A similar study to this one, using fire investigation reports from fire incidents in England, could investigate further cases of fire fatalities known to involve emollient creams.

Blood alcohol levels

There were forty-two cases for which the recorded blood alcohol levels were measured and these are plotted in Figure 8. Note that for the following alcohol concentrations the associated symptoms are generally present: 50-100mg/dL decreased reaction time, 100-200 mg/dL blurred vision, 200-450 mg/dL marked incoordination, >450 mg/dL potentially fatal.

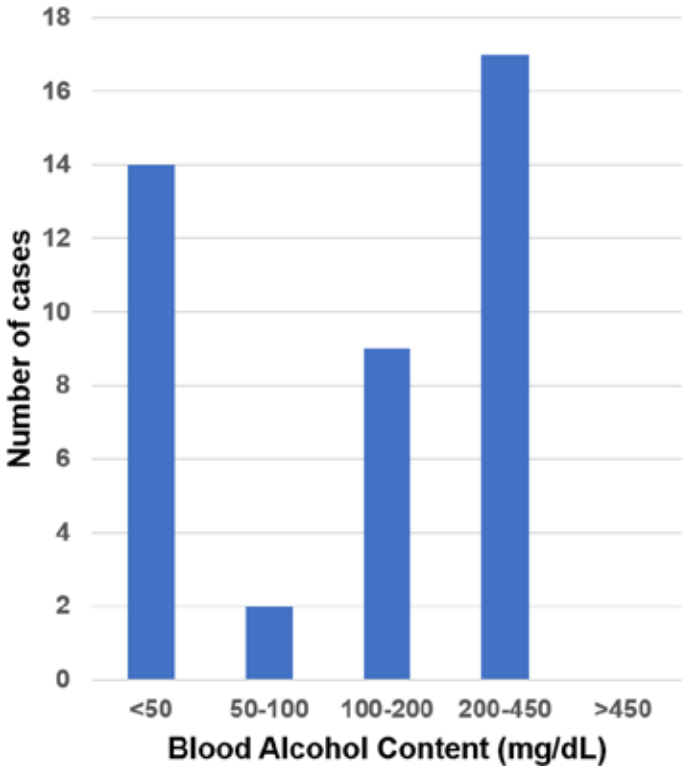

Figure 8: The blood alcohol content of fatalities for which alcohol was measured

There were seventeen cases in which the blood alcohol content was at a very high level approaching potentially fatal levels. The twenty-eight cases greater than 50mg/dL, after which there is a decreased reaction time, may have been a contributory factor leading to the fatality. Clearly those with elevated levels of alcohol should be considered to be individuals at an increased risk in the case of a fire.

Alcohol combined with smoking or cooking

When the cases in which alcohol was present (or suspected to be present) are combined with other variables, such as smoking, cooking and other factors, then these account for 17%, 6% and 15% of all fire fatalities, respectively. All these cases demonstrate that the consumption of alcohol and the subsequent loss of concentration/ consciousness increases the chances of relatively minor incidents leading to more serious outcomes.

Causes of fires involving smoking materials

It was reported in the Phase 1 Briefing Paper that, in 44% of cases, the cause of fire was smoking related; the majority of these were probably caused by cigarettes and some by other materials related to the act of smoking. In these cases, many fire safety provisions would be expected to be in place, such as the Furniture and Furnishings (Fire Safety) Regulations 1988 (as amended), reduced ignition propensity (RIP) cigarettes and use of flame retardants. This does raise the question of how fires involving cigarettes are leading to ignition and fire growth and further research work is recommended to investigate this.

Toxicology data

If toxic chemicals were preserved in the blood of fire fatalities, these were measured and stated in the toxicology report. A summary of the overall observations is presented below.

- There were 69 cases for which carboxyhaemoglobin was recorded in the blood and these varied from 0-78% COHb with a peak in the 50-59% range.

Figure 9: Accumulation of fire fatality risk factors: alcohol, smoking and sleeping

- Cyanide was recorded in 8 cases and for all of these, carboxyhaemoglobin was also present. The levels of CN were between 0.75-32.4 μg/ml with 5 cases above the threshold considered to the fatal.

Quantitative review of previous recommendations

Of the fourteen recommendations put forward previously, only eleven were examined during this review. Of these recommendations, 10 (development of preventative measures in white goods) could not be made for certain and recommendation 13 (the use of a smoke alarm in the loft) would not apply for the 111 cases examined. The responses for the remaining nine recommendations are made in Table 8:

Proposed recommendation	Yes	No	Unknown	N/A	Maybe
1 providing warnings from alarms to a mobile phone;	82%	15%	3%	0%	0%
2 increasing the sensitivity of smoke alarms at night;	21%	76%	3%	0%	0%
4 high-risk domestic premises to be linked to an ARC;	78%	19%	2%	1%	0%
5 extension of the LPS 1655 watermist system;	90%	5%	4%	1%	0%
7 using video analytics technology to provide warning	82%	14%	3%	1%	0%
8 research into the underlying causes of electrical fires	1%	1%	0%	98%	0%
9 the development of an Electrical Monitoring Device	2%	0%	0%	98%	0%
12 detection in utility space/vestibule	1%	0%	0%	99%	0%
14 a government campaign to "look out for neighbours"	17%	69%	9%	0%	5%

Table 8: Likelihood of proposed recommendations resulting in a positive outcome

This data demonstrates that:

- Providing warning to a locally linked mobile phone to a neighbour or other "sentinel" (as explored during Phase 1) would be expected to lead to a quicker intervention and likely more positive outcome for a proportion of the 82% of cases. Of course, this presumes that in all cases the warning was received and acted upon immediately.
- Increasing the sensitivity of smoke alarms at night would have resulted in an earlier warning on 21% of occasions that combined with recommendation 1 would be expected to increase the likelihood of earlier intervention.
- There were occasions during which local residents either tried to tackle the fire or neighbours, upon hearing a sounding smoke alarm, called up relatives. These (and other) responses inevitably lead to a delay in SFRS being notified. The use of an ARC would serve to reduce the reporting time and thereby reduce the "SFRS attendance from ignition" time which would increase the chances of earlier intervention.
- The early activation (due to the use of optical smoke alarms) of an approved LPS 1655 watermist suppression system [8] during the incipient stage of a fire was expected to be effective in 90% of all cases (see Figure 10). As well as taking out the energy of the fire, covering combustible materials in a layer of water the additional benefit of earlier activation would be a significant reduction in the production of toxic gases. The latter were considered to be the cause of at least 65% of the fatalities. The effectiveness of the watermist system to both contain the fire and reduce the build-up of toxic gases could be demonstrated experimentally. This could be achieved by having two identical full-size furnished rooms and fitting one room with an LPS 1655 approved watermist system and other with no system. By measuring the heat and toxic gases build-up during the tests and comparing these, the contribution of the watermist system could be demonstrated. This is proposed to be an area warranting further research.
- Whilst the use of video analytic technology may have provided warning of a fire during the early stages, the effectiveness of this very much depends on interventions in place and presumes that SFRS would be notified directly.
- The two recommendations around electrical fires/monitoring account for a very small percentage of fires in which fatalities were observed ≤ 2%. However further work is recommended to address the high number of electrical fires that have been reported previously and with a number of high-profile cases of fires started by electrical appliances.
- There was one case of a fire from a vestibule directly leading to a fatality. The victim, whilst elderly was not under the influence of drugs or alcohol so may have been warned earlier and escaped had a working smoke alarm been present.
- Like the recommendation for video analytics, the one for a government campaign to look out for neighbours relies on neighbours immediately hearing the smoke alarm on activation and reporting the fire immediately in which case a maximum of 17% may have been saved through the earlier intervention of SFRS.

Recommendations resulting from quantitative review

In the summary below are additional recommendations resulting from the quantitative review and are presented for SFRS, Scottish Government, the public and research bodies.

Figure 10: An LPS 1655 approved system (photo courtesy of Surefire Services) - see www.redbooklive.com for listings of all approved companies

Public services (SFRS):

- To perform more HFSV, especially of vulnerable people, and install smoke alarms.
- Scoring system of risk may capture vulnerable people to identify the level of risk and identify appropriate fire safety measures.
- Consider interventions to provide more protection to those individuals living further away from an SFRS station.
- To consider collecting data and producing more detailed reports of those cases that fall under "Serious Injuries" when completed in the IRS.
- Inter-linking smoke and heat alarms to provide effective warning throughout the premises.
- Consider benefits of enhanced protection for mobility impaired persons at higher risk from fire.
- To develop a risk scoring system, taking into account many factors such as impairment, to enable the identification of the most vulnerable individuals and suitable fire protection measures.
- Inform hoarders of the associated fire risks to occupier and SFRS personnel in the event of a fire.

Scottish Government

- To re-introduce campaigns to increase awareness about working smoke alarms particularly in the light of forthcoming legislation.

- To bolster existing campaigns and develop innovative new campaigns that increase awareness of the dangers, to vulnerable people of smoking or cooking, when under the influence of alcohol.
- To consider the relative benefits of sprinkler systems with other approved suppression systems such as LPS1655 watermist for personal protection.

Public

- Discourage relatives/friends, particularly if vulnerable, to smoke or cook when under the influence of alcohol, or when tired.
- Close doors at night.
- Be aware that those that live alone or vulnerable people (either living alone or together) are at greater risk- think of relatives and neighbours that you may be able to help.
- If you visit a vulnerable person look out for heat sources that are close to combustible items. Inform the owner of the possible dangers and create some space between heat sources and combustible items.
- Remind elderly friends and relatives that in the case of a fire to leave the premises immediately.

Research bodies

- Research to understand the mechanism that leads to fires from RIP cigarettes that may be preventable with appropriate interventions. This research may incorporate a literature review of the development of RIP cigarettes and review any independent evidence to support their enhanced performance over non-RIP cigarettes.
- To quantify the capabilities of approved watermist systems to both contain the fire and reduce the build-up of toxic gases in full-scale demonstration fires.

Figure 11: Closing doors at night delays fire spread and contains smoke

Figure 12: Research work to identify the mechanism of cigarette fires is recommended

Collaborative approach to fire safety of vulnerable individuals

The significant number of recommendations reveal that there are lots of approaches that can be taken to help make vulnerable people safer. If all groups identified take on board the recommendations and contribute towards the fire safety of vulnerable individuals in domestic dwellings, then more can be done and is likely to lead to lives being saved.

In order to bring some level of context and clarity for the reader the key recommendations are extracted from the previous section and ordered in Figure 13 in terms of what can be done in preparation for a fire and how the proposed interventions would help during a fire event.

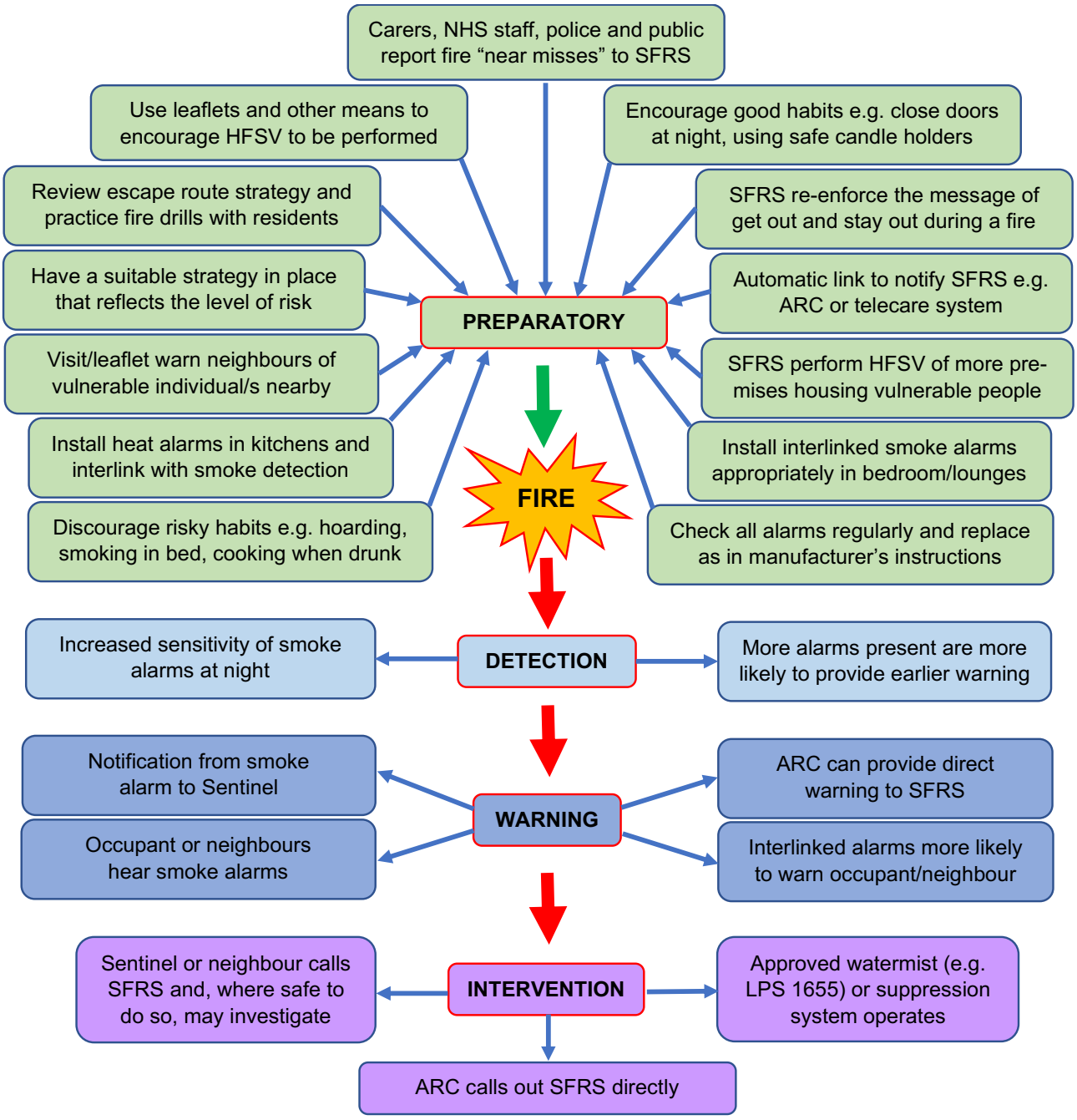

Figure 13: The preparatory steps and proposed interventions to improve fire safety

In the next section the application of the above preparatory steps and interventions are explored.

Strategy for providing fire safety

SFRS already have in place a comprehensive means of assessing individual risk and this section is intended to complement this. However, the findings from this work may well be beneficial for Fire and Rescue Services generally, some of which will potentially be attempting to protect a large number of vulnerable people requiring varying levels of protection from the risk of fire. It may be difficult for them to identify and classify those most at risk and identify appropriate measures to provide them with the most suitable protection. This section attempts to address this by proposing different factors that increase risk and applying a rating score to each of these from which a total risk score can be determined; this concept risk score is then used to propose suitable interventions.

Risk score

A concept scoring system is provided as a working example that could be shaped by and completed by an expert group. Once an appropriate set of factors are identified an overall score can be determined as shown in the example presented in Table 9. This could be used to identify the overall level of risk and propose various interventions with those most at risk having the most comprehensive strategies in place.

Factor	Gradations	Score per gradation	Max score
Smoker	Heavy smoker	20	20
	Moderate smoker	16	
	Light smoker	12	
Age	>80	15	15
	60< age <80	12	
	<60	9	
Alcohol	Heavy drinker	15	15
	Medium drinker	12	
	Occasional drinker	9	
Mobility	High dependency	10	10
	Medium dependency	8	
	Low dependency	6	
Occupancy	Occupants comprise vulnerable adult/s only	10	10
	Vulnerable adult/s alone >16 hours per day	8	
	Vulnerable adult/s alone 16-8 hours per day	6	
	Vulnerable adult/s with live-in adult	4	
Drugs/medication	Known drug user or on prescribed medication that could cause drowsiness	10	10
Hoarder	Heavy hoarder	5	5
	Hoarder	3	
Distance from nearest SFRS station	>6 miles	10	10
	4-6 miles (15 minutes)	8	
	2-4 miles (10 minutes)	6	
	0-2 miles (5 minutes)	4	
Medications	On medications that cause drowsiness	5	5
		Total Score	**100**

Table 9: Concept example of how factors/weightings could be used to identify risk of individuals

Protective interventions

Once the score of an individual is calculated a table like the concept example in Table 10 below can be used, by Fire and Rescue Services, to identify minimal interventions. All the interventions that sit under the risk classification would also be recommended. For example, someone that scores 45 would be classified as medium risk and the proposed minimal interventions would be for leaflets to be deposited in neighbour's homes, a HFSV every 2 years and for interlinked smoke and heat alarms throughout the property.

Risk Score	Proposed minimal interventions
Risk Score	Proposed minimal interventions
81-100	Approved watermist system or sprinkler system
61-80	Direct link to ARC Fire and Rescue Services visit to neighbours
41-60	Fire and Rescue Services deposit fire safety leaflets in neighbours Verified and frequently tested (during HFSV) telecare system
21-40	HFSV every 2 years during which strategy for escape during a fire is discussed
1-20	Interlinked smoke alarms in bedrooms and living spaces as well as heat alarms in kitchen

Table 10: Concept example of how risk score can be used to identify protective interventions

In this example the scores help to indicate the minimum appropriate interventions. If the professional opinion of Fire and Rescue Service personnel is that a vulnerable person requires additional interventions, then these would supersede those proposed in the table. An example might be of a vulnerable individual living in a property that is located 10 miles from the nearest Fire and Rescue Service station yet scores less than 40; according to the table it would not require a telecare system but if deemed appropriate this would be included in the overall strategy.

If, in the future, video analytic technology becomes tested and certified for providing fire protection and direct warning to Fire and Rescue Services then this (or others) could be added to this list as a protective intervention.

Figure 14: Heat alarms can detect and provide warning of fires in kitchens

Conclusions

The review of the Fire Investigation reports provided more detail and clarity than the IRS review. Of 126 FI reports produced over 4 years, 123 were provided by SFRS and reviewed. It was identified that twelve of those were cases of fatalities that were not primarily due to the fire.

For the remaining 111 reports a comprehensive qualitative and quantitative review was performed that led to a greater understanding as the causes of the fire fatalities e.g. 65% of fatalities were attributed to inhalation of toxic gases/smoke. A number of recommendations have resulted that are aimed at different groups including care package suppliers, manufacturers of electronic equipment, public services (NHS, carers, social workers, police, SFRS), the general public and for research bodies.

Whilst new and emerging technologies may provide additional protection in the future this work identified that the greater use of existing technologies could be applied immediately and would be expected to save lives. Some of these include providing inter-linked smoke alarms in bedrooms and living spaces, heat alarms in kitchens, the greater use of the certified watermist systems and greater communication of agencies, neighbours and relatives with the SFRS when an at-risk person has been identified.

The review of the effectiveness of the Phase 1 proposed recommendations demonstrates that:

- the use of a local "sentinel" may have led to a more positive outcome for a proportion of 82% of cases.
- increasing the sensitivity of smoke alarms at night would have resulted in an earlier warning on 21% of occasions
- an approved LPS 1655 watermist suppression system during the incipient stage of a fire was expected to be effective in 90% of all cases.
- up to 17% of fatalities may have been saved through the pro-active engagement of neighbours and resulting earlier intervention of SFRS.

In terms of further research work there are two key areas that warrant further investigation. The first of these is an experimental investigation of common electrical items involved in starting fires with attempts to replicate the failure by overloading, aging etc. This will lead to a greater understanding of the mechanisms that lead to failure and potentially identify effective interventions to provide protection. The second is a proposed fire test demonstration in two identical and standard sized rooms including furnishing, in which one is fitted with a certified watermist system and one without. By measuring the heat release and toxic gases emissions it will be possible to predict if and when persons present in each scenario would be expected to survive for the conditions studied.

Based on the risk factors contributing to a fatality an example strategy using a risk score is proposed, to assist Fire and Rescue Services, that can be used to identify those vulnerable individuals most in need of care and introduce measures that may save lives.

The findings detailed in this report are comprehensive and applicable to a number of different groups. The next stage will be to disseminate these findings to them and encourage the development of a broad implementation strategy.

Figure 15: Public services working more closely together can improve fire safety, as can the general public by checking on neighbours and relatives

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