DECISION PROBLEM STRUCTURING METHOD FOR THE SPECIFICATION AND SELECTION OF ACTIVE FIRE PROTECTION SYSTEMS

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ABSTRACT

The UK along with the EU has witnessed a recent proliferation of designs for potential active fire suppression systems for the mitigation of fire risks in buildings and equipment; from five in 1986 (BSI, 1986) to eleven in 2011 (BSI, 2011a). However, each technology remains limited to the protection of certain types of application only, rather than offering a solution to guard against all possible hazards. This trend occurs at the same time as a transition from *prescriptive* to *performance based* standards and against the backdrop of the current *non-prescriptive* regulatory frameworks including the Building Regulations (HMSO, 2010), The Regulatory (fire) Reform Order (HMSO, 2005) and associated guidance (Approved Documents, standards, codes of practice and guides). Hazards can be difficult to assess and describe and the inequality or absence of satisfactory methods is notable in many recently published guidance documents.

Active fire protection systems are installed to meet legislative requirements (to protect life), and / or when identified as appropriate by a cost-benefit analysis (e.g. to achieve risk reduction for business resilience purposes or to historic assets). There are many guidance documents available to assist users and designers in choosing and specifying appropriate active fire protection. These documents vary in age, relevance, scope, quality, impartiality and suitability.

The Fire Protection Association (FPA) and several leading insurers who participate in its risk management work, have identified the requirement for assistance with the decision making process of analysing fire hazards and matching them to appropriate candidate systems, in order to make informed and impartial recommendations. This has led to the undertaking of a four year research project aimed at developing a decision problem structuring method and a software tool (Expert System), for the specification and selection of Active Fire Protection Systems. The research aim is to develop a tool that will assist users in making an informed selection of a system that is likely to best suit their needs and thereby contribute to overall improvements in fire safety and outcomes. This paper presents a summary of the work to date, focusing on the demand for the work, development of the methodology and practical application of the emerging Expert System.

KEYWORDS: Expert, Fire, Selection, Suppression, System

INTRODUCTION

Background

There are a variety of sources that report the financial and societal cost of fire within the UK. The Association of British Insurers (ABI) in its' paper "Tackling Fire: A Call for Action" (ABI, 2009) estimates the insured cost of fire is £1.3bn. It also reports that 443 deaths and 13,200 casualties were caused by fire in 2007. The UK Government in its' report "The Economic Cost of Fire: Estimates for 2004" (Office of the Deputy Prime Minister, 2006) reports a projected figure of £7.03bn for the cost of fire for the year 2004. The consequence and cost of fire remains significant.

To appreciate the research problem, it is necessary to develop an understanding of two concepts: *Fire safety provisions* and *fire engineering*. These concepts form the core challenge for anyone who seeks to make improvements to fire safety of an object or building. In the context of this paper *fire safety provisions* are defined to mean anything that is done (materially or procedurally) to reduce the likelihood of or consequences from a fire. The Institution of Fire Engineers make the following definition "Fire Engineering is the application of scientific and engineering principles, rules [Codes], and expert judgement, based on an understanding of the phenomena and effects of fire and of the reaction and behaviour of people to fire, to protect people, property and the environment from the destructive effects of fire" (Institution of Fire Engineers, 2011). The majority of built or manufactured objects and buildings have *fire safety provisions* incorporated within them; Fire guards to protect from open household fires, over-current fuses protecting electrical appliances, use of non-combustible materials, thermal cut-out devices, gas safety shut-off valves, compartmentation in buildings, manual first aid (such as fire extinguishers, fire blankets, hose reels), fire service intervention, active fire protection systems (such as fixed local systems, fixed building systems). These few examples vary in scale, complexity and approach. This project focuses on the challenge of selecting appropriate Active Fire Protection Systems.

Active Fire Protection Systems

Active fire protection systems (or *suppression* or *extinguishing* systems) are systems which use "the application of agents to control, suppress, and/or extinguish fires" (DiNenno, 2002, p. 3-143). So much the better if this is done in a fashion commensurate with the mitigating need and protection objective. In order to achieve this, they must be selected, specified, installed and functioning correctly in order to provide maximum efficacy, should they be required. Suitability of the selection and design of the system for the application is critical. Points to address include: compatibility of extinguishing media with the construction and contents of the hazard (e.g. water in high voltage electrical installations can be problematic, gas in insufficiently sealed enclosures will be ineffective, etc.) Installation and maintenance are also critical; poor standards often adversely impact upon the reliability of the system and probability of success against the design objectives.

Other fire safety provisions such as passive fire protection, smoke control systems, fire detection and alarm systems may also have an impact upon performance of active systems (and vice versa). For example, the effect of interactions on smoke venting systems and sprinkler systems has been extensively studied with the objective of optimising complex

building (e.g. shopping centre) tenability to occupants (public and Fire and Rescue Service personnel) during a fire and evacuation (Morgan et al., 1999). It is also proven that gaseous systems must be able to hold extinguishing agent at the requisite concentration for a specified period; this necessitates a controlled relationship between enclosure integrity, quantity and release rate of media. Active fire protection systems are part of a range of tools available to those seeking to manage risk from fire. Because of their additional cost and complexity they tend to be incorporated in to more complex designs or higher risk/consequence scenarios.

System Selection Challenges
The UK and EU has witnessed a recent proliferation of different types and designs of potential active fire suppression systems for the mitigation of fire risks in buildings and equipment. This has coincided with a move from prescriptive to performance based standards for example; the BS 5588 series (BSI, 1990) was replaced by BS 9999 (BSI, 2008a) . It also forms the backdrop of the current 'non-prescriptive' regulatory frameworks; including the Building Regulations (HMSO, 2010) and associated guidance such as the Fire Safety Approved Document B (DCLG, 2007), the Regulatory Reform (Fire safety) Order (HMSO, 2005) and by extension BS 9999 (BSI, 2008a) and other standards and guides. At the same time, the number of candidate active fire protection solutions has significantly increased, for example in British Standards' "Guide for the selection of installed systems and other fire equipment" (BSI, 1986) there were five fixed suppression system design standards referenced whilst in the 2011 edition of the guide (BSI, 2011a) there are eleven, yet each technology remains limited to the protection of certain types of hazard only.

Increasingly UK insurers and the Fire Protection Association (FPA) are confronted with fire losses that are greatly exacerbated by the misspecification of extinguishing technology to the hazard and the poor implementation of appropriately selected extinguishing technologies. Hazards can be difficult to assess and describe as attested to by the complexity of the storage risk hazard evaluation method in LPC Sprinkler Rules (FPA, 2010) and the notable absence of equivalent methods from other system standards.

Field experience, supported by the BRE Globals guide titled "Sprinkler installation standards and rules" (BRE Global, 2009) indicates that active fire protection systems are installed mostly; to meet legislative requirements, or to achieve risk reduction for business resilience purposes. To aid users of suppression technologies there are many standards, guides and documents intended to assist in choosing and specifying appropriate active fire protection. These documents vary in age, relevance, scope, quality and suitability. Typically they are commissions by various parties: national or international standards bodies, such as the International Standards Organisation (ISO), the European Committee for Standardization (CEN), national standards setting bodies, or trade associations. Alternatively they may be product of certification bodies, such as the BRE Global, the Loss Prevention and Certification Board (LPCB), the FM Global or commercial organisations such as risk sharing user groups or system suppliers. All are authored by committees, groups or individuals with varying levels of independence.

Aside from the system design and installation standards identified in section "Knowledge Management" which are discrete to their technology of application; there is little useful material published offering guidance upon the selection of competing active fire protection systems. Two notable publication are the BSIs "Guide for selection of installed systems and other fire equipment" (BSI, 2011a)and PD 7974-4 (BSI, 2003a). However these documents are of limited use as they offer no quantitative information relating to system performance

and little in the way of guidance upon suitability or otherwise for any given application. In the absence of this information, it remains unclear to the user whether different systems offer the same level of reliability and performance or not.

There is limited comparative performance or reliability data on such systems. The most comprehensive studies conducted to-date has been undertaken by the American organisation the National Fire Protection Association (NFPA). Their work (Hall, 2008, Hall, 2010) is mostly limited to studies on Sprinkler Systems and to a much lesser extent Gaseous Systems. In addition to this limited scope there is another problem with the dataset; due to the jurisdiction of interest to the NFPA, the systems they have studied would have tended to have been design and built to the installation standard NFPA13 (NFPA, 2010, NFPA, 1996) or the version appropriate to the year of installation. There are many other studies published that focus on very specific aspects of system performance such as the "Halon Alternatives" report (The Loss Prevention Council, 1996). With the phase out of Halon gaseous extinguishing agents, this work sought to compare the fire fighting efficacy of a number of alternative gaseous extinguishing agents.

Until recently, the scarcity of this type of information was not a significant problem as there was little competition between the fewer technology types (the suitability of each was generally easily discernable). However as noted above, since then other technologies have emerged where there is considerable overlap between claims made about application suitability, without the support of mature and comprehensive national standards. For example DD 8489 series (BSI, 2011b) exists without any companion 'component' standards, thus the specification, quality and reliability of such system components is not assured to the same extent as it is in the case of Gaseous Systems to BS EN 15004 (BSI, 2008b) (utilising components to the BS EN 12094 series (BSI, 2003b)), Sprinkler systems to BS EN 12845 (BSI, 2009a) (utilising components to the BS EN 12259 series (BSI, 1999)), foam systems to BS EN 13565-2 (BSI, 2009b) and components to BS EN 13565-1(BSI, 2003c), etc.

There are various sources of evidence in relation to fire and consequence, with varying degrees of applicability to the Europe and particularly the UK. These include:

- UK Government and Fire and Rescue Service Statistics (DCLG, 2011)
- US (NFPA) data (Hall, 2008, Hall, 2010)
- FPA Large Loss Database (FPA, 2011)
- World fire statistics, The Geneva Association (Woodrow, 2011)
- Legal case rulings (various, details follow)

In the UK the government collates statistics. Summaries of this dataset are periodically reported in the "Fire statistics monitor" series (DCLG, 2011). This dataset is not reported in sufficient detail to allow any observations about Active Fire Protection Systems reliability or performance to be made.

In the US, a significant Fire Protection system reliability study by National Fire Protection Association (NFPA) (Hall, 2010) was found only to contain reliability and effectiveness estimates on sprinkler systems and chemical systems. It reports that the available data set for other types of system is too small to support estimates of reliability and effectiveness. This appears consistent with prevalence and numbers of system types installed in the field. In his 2008 summary, Hall on behalf of NFPA presents the following reliability figures (Hall, 2008); all sprinkler systems 90%, broken-down in to two system types; wet-pipe (most common) sprinklers 91 % reliable and dry-pipe (less common) sprinklers 83 %. The main

reason for sprinkler systems not operating were found to be as a result of the water supply being turned off prior to the fire starting (typically due to maintenance or inspection). Other reasons found included lack of maintenance, incorrect intervention measures at the time of the fire or inappropriate system for the type of fire. For comparison, figures are given for dry powder and CO2 systems of 49% and 90% respectively. These figures as reported by Hall in 2008 are based upon 2002 to 2004 US fire department statistics. As noted previously, no such equivalent dataset exists which is directly relevant to the UK experience.

There have been a number of legal cases where Active Fire Protection presence or absence has been subject to legal scrutiny:

- Lord Justices Stuart-Smith Potter Judge in *DEC v HANTS CC* (1997)
- Mr Justice Cresswell in *Gan Insurance v Tai Ping Insurance* EWHC 1210 (1998)
- Lord Justices Chadwick Clarke and Sir Glidewell in *Pride Valley Foods v Independent Insurance* QBENF 1701 (1999)
- His Honour Judge Peter Coulson QC *LMS International v Styrene Packaging and Insulation* EWHC 2065 (2005)
- Lord Justices Brooke Thomas and Jacob *ID & Ors v The Home Office* EWCA Civ 38 (2005)
- Mr. Justice Akenhead in *Fosse Motors v Conde Nast & Ors* EWHC 2037 (2008)
- Mr Justice Patten in *Ansari v New India Assurance Ltd* EWHC 243 (2008)

And one other identified where lack of efficacy due to poor design or specification has been subject to legal scrutiny:

- The Honourable Mr. Justice Coulson in *Cadbury v ADT* (2011)

All these cases have in common that the recorded judgements make comment on the adverse impact the omission or non-operation of protection had on events and/or critical of the selections of active fire protection technology that were made.

PROTOTYPE SYSTEM DEVELOPMENT PROGRESS

Knowledge Management

Expert Systems, with their ability to store and reference *knowledge* and act in a fashion akin to that of an expert advisor, were identified as the system type most suitable for this project. Work by Giarratano (1998), Wilson and Welsh (1986) reports that (at that time), many fortune 500 companies were seeking ways to exploit the capability of expert systems. Giarratano goes on to state that this is because they believe "there is substantial commercial value in using machines to emulate portions of human behaviour". Expert systems arise as the result of efforts to automate decision making processes. In order to achieve this, the nature of the data and processes involved must be represented in computer software (Alty and Coombs, 1984). The following (Figure 1) shows the main elements and interaction of a typical expert system. It has been developed by combining figures from Nilsson (1998, p. 281) and Giarratano (1998, p. 3). The key elements of the expert system identified in Figure 1 are described as follows:

- Knowledge base – The part of the system that contains the expert's knowledge. Composed of domain facts and heuristics based upon experience. (Medsker and Liebowitz, 1993, p. 71).
- Inference engine – Processing part of the system that combines knowledge with data.
- Explanation facility – explains the reasoning of the system to the user (Giarratano, 1998, p. 23).
- User interface – the interface with which the user can interact with the expert system. (Medsker and Liebowitz, 1993, p. 70)

Knowledge representation and processing. Knowledge can be encapsulated in a number of ways. It can be encapsulated in *rules* and *objects*. A common type of rule is an IF…THEN rule (Alty and Coombs, 1984, p. 19-21, Giarratano, 1998, p. 5). For example "IF the light is red THEN stop" (Giarratano, 1998, p. 6).

Sources of Knowledge

The literature review identified many sources of knowledge upon which to base the development of a knowledge management system for assisting in the selection of active fire protection systems. Figure 2 provides a basic illustration of the selection problem and sources of knowledge. The selection task begins with a fire hazard 'Problem' (which may or may not have been properly identified). Usually some further work is then undertaken to further describe and understand the hazard, drawing to varying degrees upon recorded and unrecorded knowledge. The process then evolves to the protection specification giving rise to the ultimate solution. Recorded knowledge is typically gleaned from sources such as those identified in Table 1 and other published guides and documents. Unrecorded knowledge is that which tends to be unpublished or more difficult to access, for example the knowledge of experts or knowledge enshrined in 'custom and practice'.

In order to develop the tool it was necessary to capture relevant knowledge from both recorded and unrecorded sources.
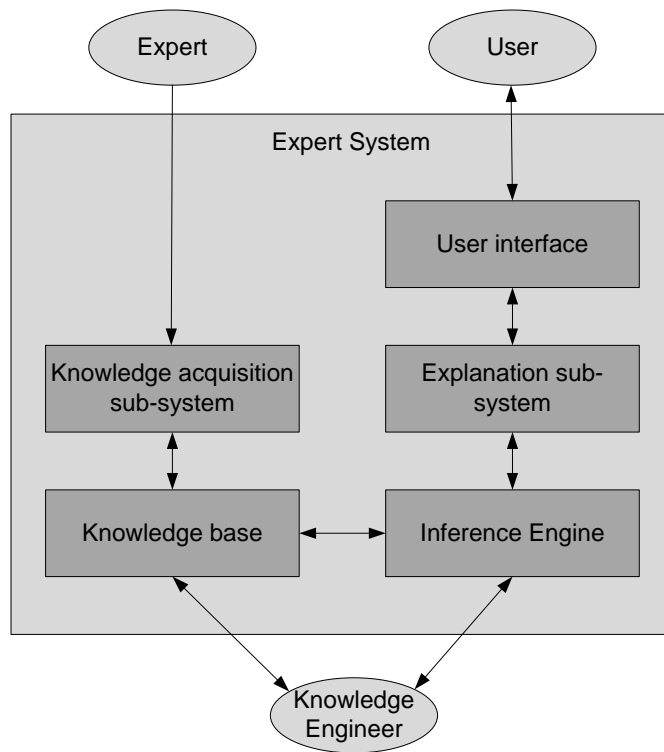
Figure 1 - the main elements and interaction of a typical expert system
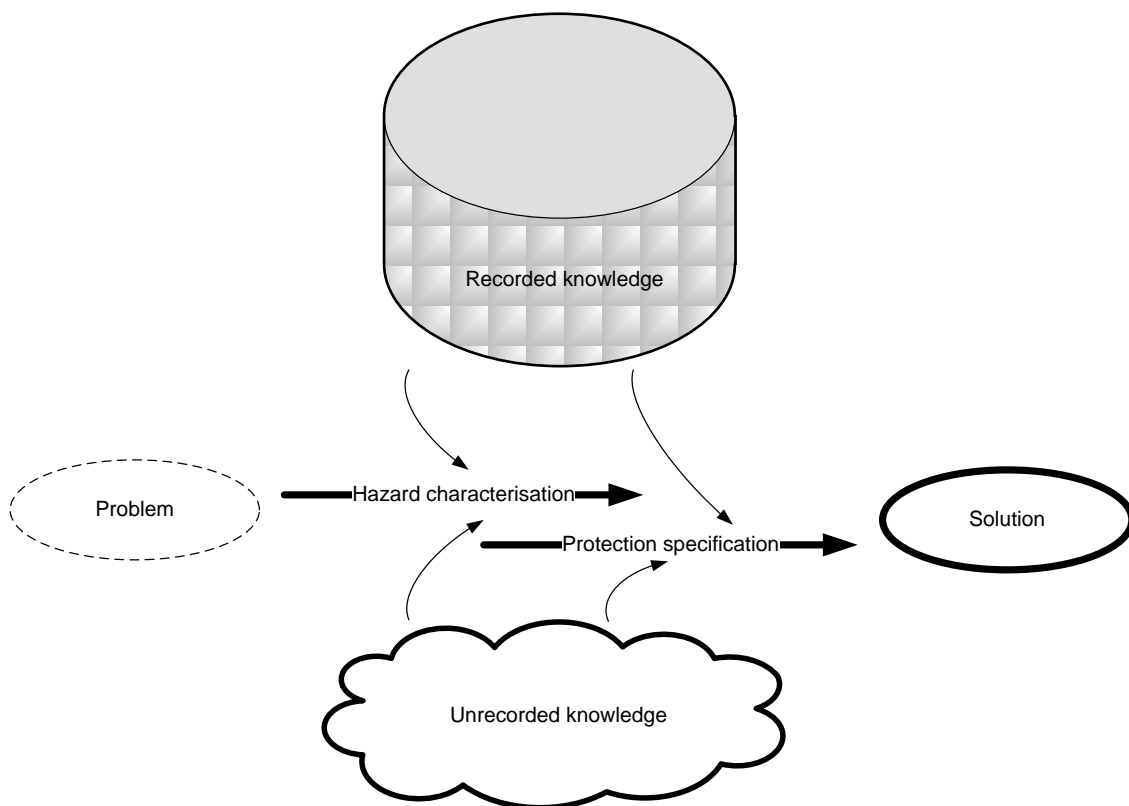
Figure 2 - The selection problem

Several Guidance Documents (Design Standards, Codes of Practice, Guides and other Documents) were identified during the literature review. One of which was BS 5306-0 "Fire protection installations and equipment on premises: Guide for selection of installed systems and other fire equipment" (BSI, 2011a), this, supplemented by sector knowledge of the research engineer confirms the identity of all notable and the most common active protection approaches found in UK. The active fire protection approaches are presented in Table 1 divided by suppression media and then further sub-divided by protection technology description. The third column provides the reference to the de facto standard, specification or document for the UK jurisdiction.

Protection systems by Extinguishing Media	Protection technology description	Standard, Specification or Document (s)
Water	Industrial and commercial sprinkler systems	BS EN 12845 (BSI, 2009a)
	Industrial and commercial sprinkler systems	LPC Rules (FPA, 2010)
	Domestic and residential sprinkler systems	BS 9251 (BSI, 2005)
	Water spray systems and deluge systems	DD CEN/TS 14816 (BSI, 2008c)
	Domestic and residential watermist systems	DD 8458 (BSI, 2010)
	Commercial and industrial watermist systems	DD 8489 series (BSI, 2011b)
Gaseous	Inert gas and halocarbon agent systems	BS EN 15004 (BSI, 2008b)
	Carbon dioxide systems	BS 5306‑4 (BSI, 2001a)
	Halon. Obsolescent for use in the built environment as outlawed by the Montreal Protocol (United Nations Environment Programme, 2000) and The Environmental Protection (Controls on Ozone‑Depleting Substances) Regulations 2002 (U. K. Parliment, 2002) on the grounds of being an Ozone depleting substance.	
Other Chemical	Foam systems (Low, Medium and High expansion systems)	BS EN 13565-2 (BSI, 2009b)
	Powder systems	BS EN 12416-1 (BSI, 2001b)
	Aerosol systems	CEN/TR 15276-2 (BSI, 2009c)
Hypoxic Fire Prevention	Oxygen displacing systems	PAS 95 (BSI, 2011c)

Table 1 – Active fire protection approaches

In the process of developing the first prototype module of the selection tool, limited to one *end user purpose group* (this term is defined in section "system application by 'end user purpose groups'") it became evident that there were many key parameters, limitations or other information essential to the process not recorded in the cited documents. For example:

- Good quality hazard classification (required by all approaches) was only present in BS EN 12845 (BSI, 2009a) and the LPC Rules (FPA, 2010)
- Although widely known, there was a lack of any clear written exclusion of storage from Light Hazard (LH) hazard group in both BS EN 12845 (BSI, 2009a) and the LPC Rules (FPA, 2010)
- Outdated requirements for sprinkler protection design details to suit modern HHS storage configurations in both BS EN 12845 (BSI, 2009a) and the LPC Rules (FPA, 2010).

The first point determines that for all practical purposes of developing this module the rules of the expert system ought to lead only to these documents (BS EN 12845 (BSI, 2009a) and the LPC Rules (FPA, 2010)) as they are the only ones judged capable of adequate assessing the hazard for this module. The second point is remedied for the purposes of the development

of this module by simply including this *custom and practice* knowledge in the expert system (much of the knowledge required to overcome these design challenges is known only to experts and not documented in primary UK documents and guides. This type of knowledge is of the type referred to as *custom and practice*). The solution to the third is more complex. In recent years there have been a number of developments which have fundamentally altered the nature of this type of hazard, including:

- Automation of storage systems / stock control / stock picking systems
- Changes to products stored in warehouses (More plastic in goods and packaging and handling equipment ('totes'))
- Anticipated changes to value density of stored goods (i.e. proliferation of small high value consumer goods).

The work of Factory Mutual Insurance Company in the U.S. is perhaps the most advanced as documented in their datasheet "Property Loss Prevention Data Sheets 8-9: Storage of class 1, 2, 3, 4 and plastic commodities" (Factory Mutual Insurance Company, 2011). Much of the practice identified in this document has become adopted by more advanced users on a custom and practice basis (in that it is not formally specified by any of the documentation applicable to the UK or Europe). To formally capture such knowledge a working group was convened with the objective of overseeing the researching and authoring of standard technical requirements to address these issues for the UK. The working group was composed of several insurance risk management professionals and representation from the fire protection design and installation industry. The output of the group is to be published in draft form to allow for peer review by other insurance risk surveyors the fire protection industry and the public. When completed and consensus ("general agreement, characterized by the absence of sustained opposition to substantial issues by any important part of the concerned interests and by a process that involves seeking to take into account the views of all parties concerned and to reconcile any conflicting arguments" (BSI, 2011d, p. 4)) is achieved, the new requirements would become part of the next edition of the LPC Rules.

The Prototype Expert System
Having identified all protection technologies currently available and suitable to the project requirements, it was necessary to conduct a systematic review of the intended scope of application of each of the candidate technologies against subdivisions of application. By considering system application by 'end user purpose groups' it was possible to modularise development of the Expert System. 'Application' headings and subdivisions (as shown in Figure 3) are based upon Department for Communities and Local Governments (DCLG) Incident Recording System (IRS). This naming convention is used elsewhere ("The Building Regulations 2010" (HMSO, 2010) and associated guidance "The building regulations 2010 fire safety approved document B" (DCLG, 2007), BB 100 (Department for Education, 2007), LPC Sprinkler Rules (FPA, 2010), BS 5306-0 (BSI, 2011a), BS 9999 (BSI, 2008a)). It is intended that (where possible) using such common vocabulary will assist in the development and maintenance of the system as well as assisting the user to understand the system.
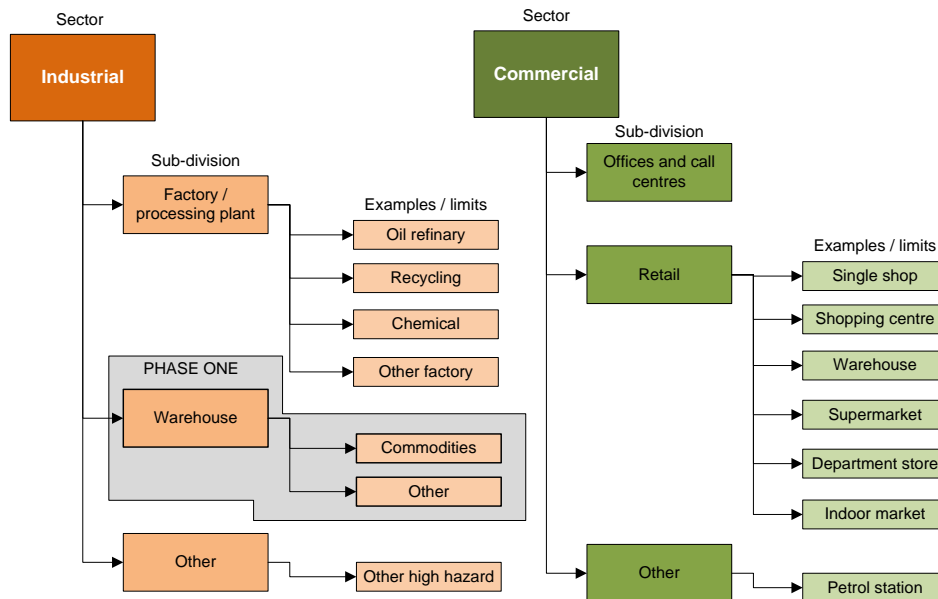
Figure 3 - Building purpose groups by Sector and Sub-division (note Sectors "Residential" and "Other" are intentionally omitted from this figure as not relevant at this stage)

Work completed so far, focusing on developing one module of the Expert System for Warehouse (as identified in Figure 3 as the region labelled "PHASE ONE") fire protection has shown it is necessary to develop a more fully formed definition to properly describe and identify this type of risk. Notable further distinctions of interest to fire protection include: Type of goods stored, fire risk posed by goods and storage configuration, geometry of storage, automation features within the risk, etc. This further level of definition has been accomplished by reviewing available standards (as summarised in Table 1) and adopting elements from the most useful hazard classification system(s) within these documents for use in the Expert System. In the process of doing so, it was noted that the only documents that deal with hazard classification with any level of rigor were BS EN 12845 (BSI, 2009a) and the LPC Rules (FPA, 2010).

Knowledge extraction from the identified Guidance Documents - Review of scopes

For a type of protection technology and associated Guidance Documents to be considered suitable for this application (Warehouse protection), they must:

- reasonably be expected to be able to suppress (or extinguish) fires in this class of hazard
- be compatible with the typical uses of such buildings;
  - Containing stored goods in various complex geometric configurations
  - Occupied by humans
  - Large volumes with potentially frequently used large openings
- have either a proven history of being appropriate and successfully used in such circumstances, or for novel protection approaches, be supported by sufficiently robust and appropriate evidence of performance in equivalent circumstances.

These terms of reference give rise to three initial broad assessment criteria:

1. Is the technology intended to be used in this application?
2. Is the extinguishing media compatible with the application?
3. Is their sufficient experience or evidence of technology used in this application?

Undertaking a systematic review against these criteria eliminated all candidate protection approaches for this type of end user purpose group except BS EN 12845 (BSI, 2009a) and the LPC Rules (FPA, 2010). It should be noted that certain types of Gaseous protection systems might be considered in very exceptional circumstances. It also gives rise to some of the 'rules' which can subsequently be used in this module of the Expert System.

Development of the prototype Expert System
With understanding of the information that must be elicited from the user to match against system suitability as determined by the knowledge elicitation phase, it is possible to assemble the 'questions' in to a flow chart (Figure 4) and then input this information in to a proprietary Expert System development environment.
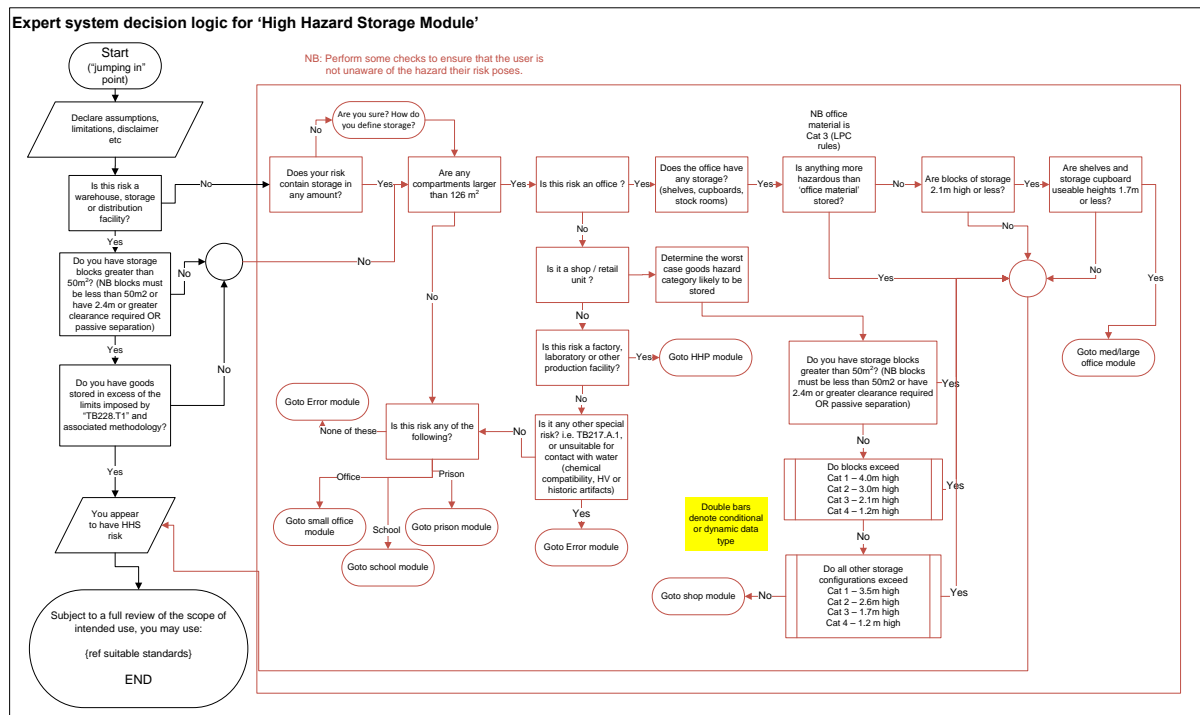

Figure 4 - First presentation of all Decision Problem Structuring Information

The "Corvid" development environment by "Exsys" was used for this phase of the research project. This development environment was found to be comparatively simple to use and incorporated all features required to efficiently develop this phase of the system. Figure 5 shows a screenshot of 'variables' and a 'logic block' as input in to the development environment. Figure 6 shows the system output obtained after the 'user' has input data about a (fictitious in this case) warehouse building. In this case the output is achieved having followed the simplest path through the question set (the Expert System ensures that as the user answers questions, subsequent questions rendered redundant are not asked (unless there is a reason to do so). The simplicity of this case is in the extreme, but is used to illustrate the principles of operation of the system.
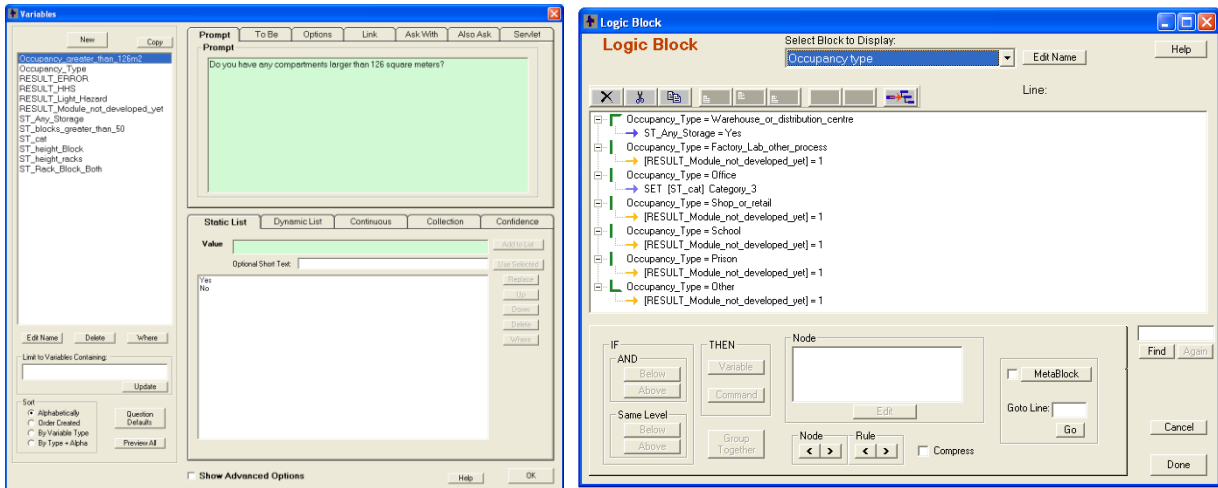
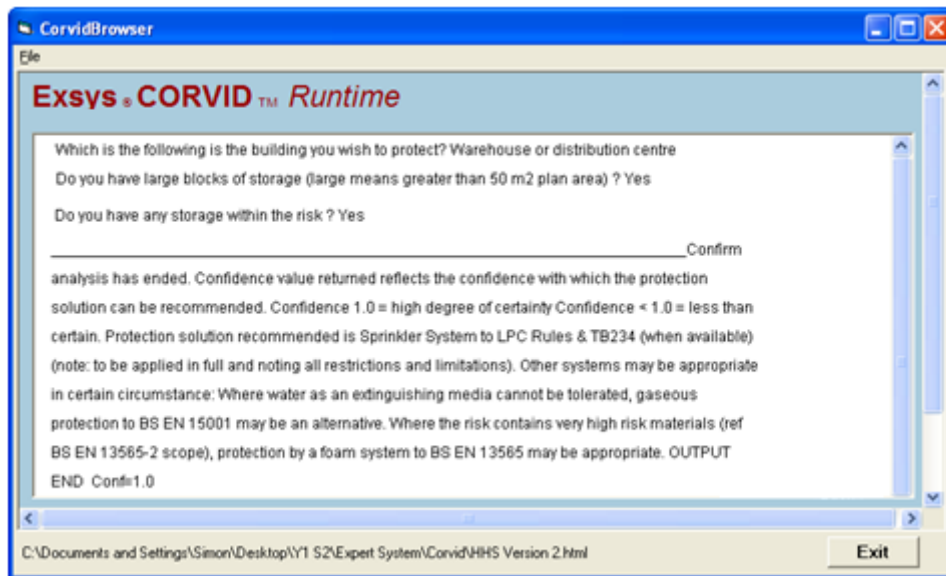**Figure 5 - screenshot of 'variables' and a 'logic block'**

Figure 6 - screenshot of Expert System output

CONCLUSION

Summary of progress

The research and prototyping work completed to-date demonstrates the ambition to assist users of Active Fire Protection Systems by giving them and automated and independent way to check upon the suitability of a protection technology type to their particular needs will be possible.

The literature review has uncovered extensive documentation that could form the majority of the knowledge base. However, gaps in knowledge have been identified and a methodology has been developed and tested in order to fill such knowledge gaps. Methods have been derived to ensure that underpinning knowledge (both that enshrined in documents and *custom and practice* knowledge) used to form the logic of the system is peer reviewed and acceptable to the intended users of the system. To aid the development process, the task of developing the Expert System has been broken down in to modules (by hazard Purpose Group). This is to keep the work manageable and to enable development by a rapid application development

type approach; developing a module at a time, and subjecting it to each of the development cycles.

The first module of the Expert System has been developed to prototype level, which has provided invaluable knowledge acquisition and learning of how to approach the complexity of such an approach within this field. The next phase of the research project will focus on advancing the development of the tool to increase the breadth of industry participation and awareness of the tool and the process. In order to support the development of the tool, a number of future stakeholder engagement activities are planned, including workshops, correspondence and questionnaires all intended to improve understanding and targeting of the system selection tool. Key stakeholders are identified by group and sub-group below in Table 2.

Group	Sub-group
Users	Insurers
	End users
Standards setting bodies and Regulators	Department for Communities and Local Government
	Building control officers
	Fire & Rescue Services
	BSI (British Standards Institution)
	BRE (Building Research Establishment)
Trade	Fire Engineers and IFE (Institution of Fire Engineers)
	Architects
	Project managers (of 'design and build' contracts)
	BAFSA (British Automatic Fire Sprinkler Association)
	FIA (Fire Industry Association)
	RSA (Residential Sprinkler Association)
	IWMA (International Water Mist Association)

Table 2 - Key stakeholders by group and sub-group

. To assist with delivery of the remainder of the Expert System modules, a phased approach is considered appropriate. The next phase will focus on delivery of a simplified Expert System, putting to the user questions from reduced question set and handling residual uncertainty in the output reports generated, by way of general commentary and recommendations. For example such an output might only eliminate obviously unsuitable technologies and accompany any recommendations made with advice and best practice information about each technology put forward. This would continue to leave a degree of the decision making to the user. Subsequent phases would seek to reduce the amount of uncertainty passed to the user by systematically closing the knowledge gaps, achieving as far as possible the original aim of the research project.

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BSI 2001a. *BS 5306-4 Fire extinguishing installations and equipment on premises. Specification for carbon dioxide systems,* London, UK, British Standards Institute.

BSI 2001b. *BS EN 12416-2 Fixed firefighting systems. Powder systems. Design, construction and maintenance,* London, UK, British Standards Institute.

BSI 2003a. PD 7974-4 Application of fire safety engineering principles to the design of buildings. *Part 4: Detection of fire and activation of fire protection systems (Sub-system 4).* London, UK: BSI.

BSI 2003b. *BS EN 12094 - Fixed firefighting systems - Components for gas extinguishing systems (multiple parts),* London, UK, British Standards Institute.

BSI 2003c. *BS EN 13565-1 Fixed Firefighting Systems. Foam systems. Requirements and test methods for components,* London, UK, BSI.

BSI 2005. *BS 9251 Sprinkler systems for residential and domestic occupancies. Code of practice,* London, UK, British Standards Institution.

BSI 2008a. *BS 9999 Code of practice for fire safety in the design, management and use of buildings,* London, UK, BSI Group.

BSI 2008b. *BS EN 15004-1 Fixed firefighting systems. Gas extinguishing systems. Design, installation and maintenance,* London, UK, British Standards Institute.

BSI 2008c. *DD CEN/TS 14816 Fixed firefighting systems - Water Spray Systems - Design, Installation and maintenance*, BSI.

BSI 2009a. *BS EN 12845 Fixed firefighting systems — Automatic sprinkler systems — Design, installation and maintenance,* London, UK, BSI Group.

BSI 2009b. *BS EN 13565-2 Fixed Firefighting Systems. Foam systems. Design, Construction And Maintenance,* London, UK, BSI.

BSI 2009c. *PD CEN/TR 15276-2 Fixed firefighting systems — Condensed aerosol extinguishing systems Part 2: Design, installation and maintenance,* London, UK, BSI.

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