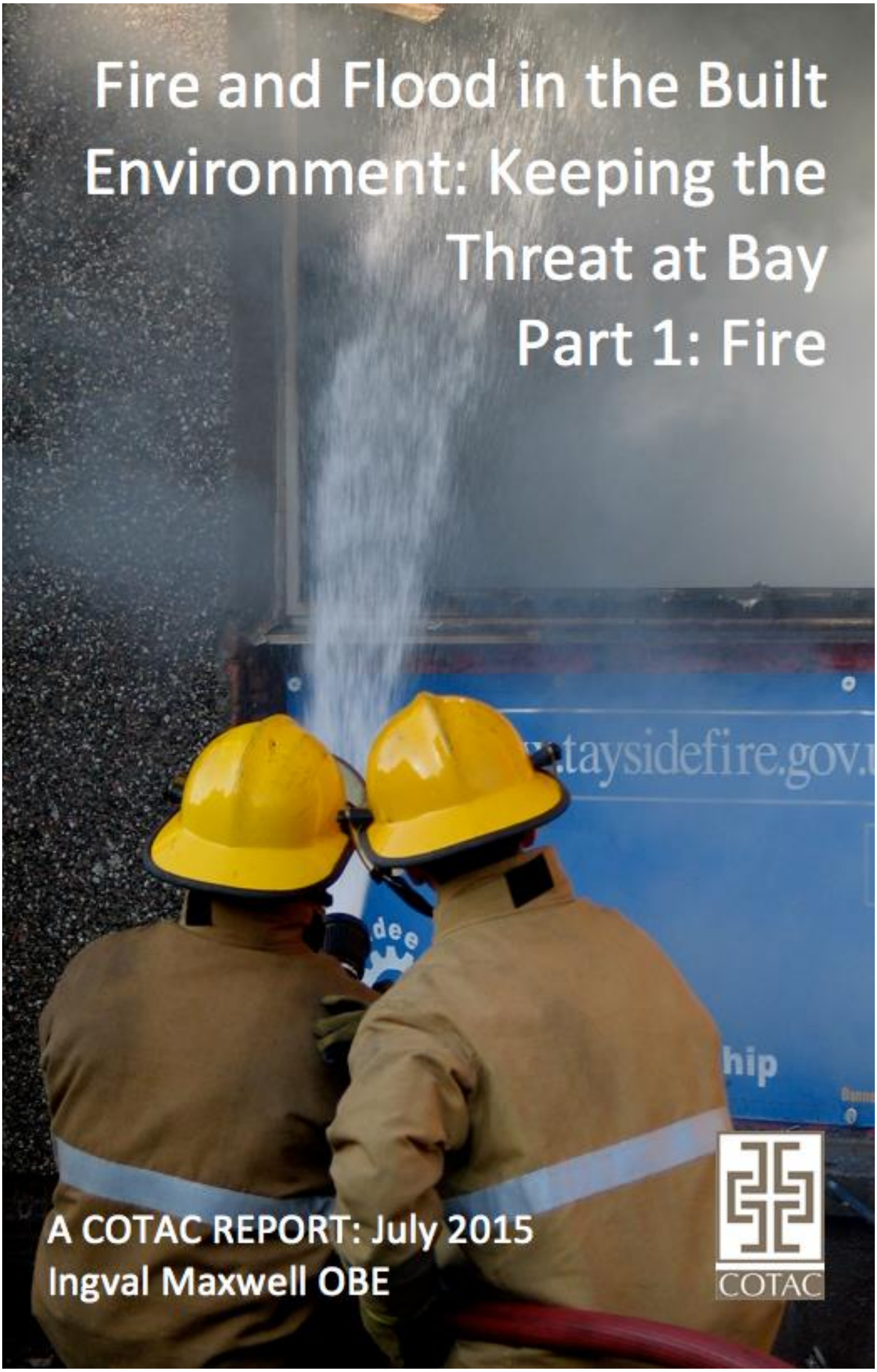

Fire and Flood in the Built Environment: Keeping the Threat at Bay
Part 1: Fire

A COTAC REPORT: July 2015

Ingval Maxwell OBE

Fire and Flood in the Built Environment: Keeping the Threat at Bay

Part 1: Fire

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COTAC, the 'Council on Training in Architectural Conservation'

COTAC, now the 'Council on Training in Architectural Conservation', originated in 1959 as the 'Conference on Training in Architectural Conservation' in response to the need for training resources for practitioners so they could properly specify and oversee work involved in repairing and conserving historic buildings and churches.

Since its inception COTAC has successfully, persistently and influentially worked to lift standards, develop training qualifications and build networks across the UK's conservation, repair and maintenance (CRM) sector, presently (2014) estimated at 42% of all construction industry activities. This has involved working partnership with national agencies, professional and standard setting bodies, educational establishments and training interests.

Acknowledgements
On 20 November 2014 COTAC's Annual Conference entitled *"Fire and Flood in the Built Environment: Keeping the Threat at Bay"* was held in The Gallery at Alan Baxter and Associates, 75 Cowcross Street, London. This Report builds upon the information and advice that was freely offered by the speakers during the Conference programme. It aims to relate the presentations, and discussion outcomes, to emerging thoughts on the impact of fire when creating a Building Information Modelling for Conservation (BIM4C) initiative by identifying what issues need to be considered in a Historic Building Information Modelling (HBIM) environment.

Thanks are due to the following speakers for the information, which underpins this report, that was offered through their various presentations:

Ingval Maxwell, COST Action C17 Chair:
COST ACTION C17: Fire Loss to Historic Buildings

Johanna Berntsson-Arje, Head of Heritage, NW Area FSR, London Fire Brigade:
Fire Safety in Heritage Buildings: Providing guidance within the context of the built heritage

David Mitchell and Chris McGregor, Historic Scotland:
The Glasgow School of Art Fire: Lessons learnt

Toby McCorry, Chartered Fire Engineer, TOGA Fire:
Building Regulations: Sympathetic Interventions in the Care of Heritage Buildings

Stewart Kidd, BAFSA:
Selection of Fire Suppression Systems for Cultural Resources

Thanks are also due to Alan Baxter Associates for providing the venue, the Conference Sponsors: Historic Scotland; British Automatic Fire Sprinkler Association; Institute of Historic Building Conservation; Henley Business School, University of Reading; Building Crafts College; and to Graham Lee and Sophie Harman of COTAC, upon whose copious conference notes, this report is also founded.

Background

A Recent History of Fire Safety and Consequential Costs

The modern history of Fire Safety is founded in incidents which took place in the Empire Palace Theatre, Edinburgh (1911); the Grand Assembly Rooms, Leeds (1923); Drumcollagher, Co Limerick (1926); the Glen Cinema, Paisley (1929); and in Coventry (1931), following which The Home Office published its *"Manual of Safety Requirements in Theatres and Other Places of Public Entertainment"* in 1934. The Manual noted that its recommendations were based on experiences of disasters at home and abroad, and those in Edinburgh, Leeds and Coventry were included as examples of safe escape occurring. In Edinburgh, although ten performers and stage staff died as a result of the fire, the entire audience of c3,000 apparently cleared the building in less than 2.5 minutes - while the band played the National Anthem! The inevitable, and totally understandable, resulting emphasis in the 1934 Manual is on life safety.

Subsequent developments in legislation similarly follow suit, despite an increasing understanding and awareness of the financial value of the buildings and sites that were being destroyed and lost due to the effects of fire.

There are no collated statistics on the total cost of fire in Europe, but in the US in 2008, the total cost (defined as a combination of losses caused by fire and money spent on fire prevention, protection and mitigation) was estimated at $ 362 billion, or roughly 2.5% of US GDP.
http://www.firesafeeurope.eu/fire-safety/cost-of-fire
Accessed 13 February 2015

In 2003, the Office of the Deputy Prime Minister reported that the total cost of fire in England and Wales *'was estimated at £7.7bn, equivalent to approximately 0.9% of the gross value added of the economy'.* This total includes the cost of fire losses; the costs of the fire and rescue services, and 'costs in anticipation', undertaken to provide buildings with fire resistance, and fire safety equipment and systems.
http://webarchive.nationalarchives.gov.uk/20120919132719/www.communities.gov.uk/documents/corporate/pdf/145111.pdf
Accessed 13 February 2015

Published annually by the Department for Communities and Local Government, the *'Fires Statistic Monitor: England'* provides an analysis of fire and rescue incidents, and fire casualty data for each financial year. Although accompanied by 30 reference data tables, none of these reveal the degree of fire loss to the built heritage. A similar situation exists in the related statistics for Scotland, Wales and Northern Ireland.

Consequently, despite the plethora of information that is available, it is impossible to accurately quantify what the UK's built heritage loss to the effects of fire actually is.
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/325696/Fire_Statistics_Monitor_April_2013_to_March_2014_final__3_.pdf

http://www.scotland.gov.uk/Topics/Statistics/Browse/Crime-Justice/PubFires

http://wales.gov.uk/topics/statistics/headlines/fire2012/
Accessed 13 February 2015

Development of Fire Safety Legislation

More detail on the historical developments of fire safety legislation can be found on-line at:
FireNet: History of Fire Safety Legislation and Other Interesting Dates
http://www.fire.org.uk/history-of-fire-safety.html
Accessed 15 January 2015
http://www.firesafe.org.uk/history-of-fire-safety-legislation/
Accessed 13 February 2015

COST Action C17 Built Heritage: Fire Loss to Historic Buildings

Any authentic historic structure, or fabric, lost to the effects of fire is irreplaceable. Yet the large number of high profile international heritage fire losses that have occurred over the last 35 years alone only tells part of the story. The finite nature of each country's stock means that any loss to fire of fabric or content has a significant and relentlessly cumulative cultural impact.

The wider picture is still far from clear, and the lack of a centralised reporting system for culturally significant losses means that statistics on the true impact of fire on the built heritage is generally unknown, but considered significant.

Following a series of international conferences that promoted the need for a concerted research approach aimed at addressing the significant levels of loss to the effects of fire, a Memorandum of Understanding (MoU) was reached with the direct participation of 22 European countries, with corresponding interests from Russia, USA, Canada and the Baltic States.

Ultimately designated as *"COST Action C17 Built Heritage: Fire Loss to Historic Buildings"*, a four-year EC Co-operation in Science and Technology programme was formally inaugurated in Brussels in December 2002. It delivered its final outcomes, in the form of 13 detailed reports, in 2008.

The agreed MoU described the intention of the programme, how it would involve the collaboration and integration of a variety of related projects, and partnership interests. It identified four work-packages, the themes of which were to be dealt with by interlinked groups of relevant experts involving:

- Working Group 1: Data, loss statistics and evaluating risks.
- Working Group 2: Available and developing technology.
- Working Group 3: Cultural and financial value.
- Working Group 4: Property management strategies.

COST Action C17 had as its central objective the definition, at a European level, of the degree of loss to the built heritage through the effects of fire, and the promotion of remedial actions and recommendations to combat these using minimal invasive techniques. The Action also aimed to address a lack of statistical information, and appreciation of what ameliorating measures were required and available. It sought to provide good practice guidance on how to sensitively retrofit modern-day fire protection equipment into historic fabric, and to develop related management expertise in dealing with the issues in historic premises.

During the Action a particular note was kept of the 94 significant international fire losses that where reported in the press (25 in 2003, 16 in 2004, 36 in 2005, and 17 up to August 2006). However, these numbers greatly underplayed the overall levels of loss, as more detailed statistics for the UK (compiled from press clippings and analysis) were to subsequently reveal.

Overall, almost 400 separate incidents involving fires to historic buildings were recorded in the Action's database between January 2002 and June 2006.

But, with subsequent work directly involving feedback from the Fire and Rescue Services in Scotland, emerging statistics would also appear to illustrate a significant degree of under-recording. Specifically, in the two-year period 2007 – 2009, some 900 fire incidents in all categories of Scottish listed buildings were recorded (excluding the large Strathclyde Region, that includes the City of Glasgow) – approximately 1% of the total number per annum!

The inevitable conclusion is that fire loss to the built heritage is a considerable negating factor regarding its significance, authenticity and continuing wellbeing. It followed that serious offsetting remedial considerations were required to be taken into account in the compilation of relevant data.

University of Lyon Library 1999: Post-fire interior

Heritage Fire Loss Chronology (Selected list)

From 1984 a significant chronological selection of national and international heritage fire losses might include:

- 1984 South Transept York Minster, England
- 1984 16th C Broomfield House, England
- 1984 Wakefield Covered Bridge, Québec
- 1986 Hampton Court Palace, England
- 1989 Uppark House, England

- 1992 Proveantgarden, Copenhagen, Denmark
- 1992 Odd Fellow Palace, Copenhagen, Denmark
- 1992 Christianborg Palace Church, Copenhagen, Denmark
- 1992 Windsor Castle, England
- 1992 Redoutensal, Hofburg Palace, Vienna, Austria
- 1993 Pont de la Chapelle, Lucerne, Switzerland
- 1992-93 40 Norwegian Stave Kirks (due to arson)
- 1996 La Fineca, Venice
- 1999 University of Lyon Library

- 2001 Morgan Academy, Dundee
- 2001 Soda Rada Church, Sweden
- 2002 Trondheim + Cowgate Edinburgh City blocks
- 2003 Baroque Luneville Chateau, north-east France
- 2003 Mount Stromlo Observatory, Canberra, Australia
- 2003 17th C Glienicke Jagschloss Hunting Lodge, Berlin
- 2003 Pratapur Temple, Swyambhunath Buddhist shrine, Kathmandu
- 2004 Wardington Manor, England
- 2004 Anna Amalia Library, Weimar, Germany
- 2004 Central Manezh Exhibition, Red Square, Moscow
- 2004 Chilandari Serbian Monastery, Mt Athos

- 2005 1,300 year-old Naksan-sa Buddhist Temple, Yangyang, South Korea
- 2005 1916 Schloss Hotel Kruen, Bavaria
- 2005 Peterhof Summer Palace, St Petersburg
- 2006 Bishops Palace, Tenerife
- 2006 Trinity cathedral, St Petersburg
- 2006 Hapsburg Reinertonishof farm, Schonwald, Germany
- 2006 13th C Provoo Cathedral, Finland
- 2006 4 buildings in Flims Old town, Graubunden, Switzerland
- 2007 Penhallow Hotel, Newquay, England
- 2007 19th C Eastern Market, Capital Hill, Washington DC
- 2007 1867 Hudson State Hospital, New York

- 2008 Military Armoury, Quebec
- 2008 Salma College, St Thomas, Ontario
- 2008 Texas Governor’s Mansion, USA
- 2008 Grange Hotel, East Parade, Rhyl
- 2008 Late mediaeval Garrick's Villa, Hampton, London
- 2009 19^{th} C Bath Street Mill, Derby
- 2009 1840 St John’s Church, Edinburgh

- 2010 Stationer's Hall, London
- 2010 100 year old Stephen Court, Kolkata
- 2010 17^{th} C 5 Higher street, Dartmouth
- 2011 London + Croydon Centre (due to riots)
- 2011 Blair Castle, Perthshire
- 2011 Hazelbank Terrace, Edinburgh
- 2011 Monastery Complex, Goldendale, USA
- 2012 El Passo City Block, USA
- 2012 Chilford Hall 18th C barn, Cambridgeshire
- 2013 15^{th} C City Hall La Rochelle, France
- 2013 17^{th} C Hotel Lambert, Paris (former home of Voltaire)
- 2013 Southwark Museum and library
- 2013 16^{th} C Lithang Monastery, Tibet
- 2013 Art Deco Dobbins Store, Oldham street, Manchester
- 2014 Aldiss Store, Fakenham
- 2014 Sleaford Maltings (Largest 'at risk' building in England)
- 2014 16^{th} C Coldham Hall, Suffolk
- 2014 Historic 1511 E Superior St, Duluth, USA
- 2014 Northfield Manor House, Birmingham
- 2014 Glasgow School of Art
- 2014 Serta Larung Monastery, Tibet

- 2015 14^{th} C Samagaon Monastery, Nepal
- 2015 Albert Square, Manchester
- 2015 Old Royal Station, Ballater, Scotland
- 2015 Battersea Arts Centre, London
- 2015 16^{th} C Novodevichy Monastery, Kremlin, Moscow
- 2015 Clandon Park, Surrey
- 2015 1876 Capel Aberfan, Merthyr Tydfil, Wales
- 2015 19th C All Saints Church, Fleet, Hampshire
- 2015 1889 Basilica of Saint Donatien, Nante, France

For a more comprehensive list of a wider variety of fire losses, covering the period from antiquity to the present day, see:
http://en.wikipedia.org/wiki/List_of_fires#2001.E2.80.93present_2

Specifically, the Action reported on the growing need to better understand the:

- Vulnerability of historic buildings to fire
- Risk assessment methodologies
- Protection of fabric and content
- Prevention of fire and fire spread
- Detection and suppression requirements
- Training and management of staff
- Insurance considerations

A number of key conclusions were also determined by the Action, and are repeated here given their relevance to current concerns, and the impact that they could have in a developing HBIM scenario. Particularly:

- *Historic buildings are of considerably economic value, especially to the tourist industry and for their impact on the attractiveness of a community and its area.*
- *Fire has always been a threat to cultural historic valuable buildings and surroundings*
- *Most property owners believe that as long as they comply with current legislation, their buildings will be sufficiently protected*
- *Historic buildings are also often built from easily-ignited materials and can be located in isolated places, too far from a fire station to allow the fire brigade sufficient time to arrive to extinguish a fire before it has created some (often considerable) degree of loss*
- *The investment in full fire protection requires that all involved really understand what constitutes historic value, and how this relates the specific buildings, its contents, and to other buildings.*
- *Considerations, such as the significance of the historic building to the people and surrounding community, must be taken into account.*
- *Against these important aspects, a curious fact remains that the regulations on how to deal with historic buildings, and most preservation programmes, frequently do not contain any special requirements for fire safety. Nor is there any standard to determine appropriate levels of insurance cover.*
- *In the area of historically valuable buildings and their contents, there is virtually no clear understanding of the extent of various types of damage, or their causes and effects.*

With regard to fire fighting operations, it considered that:

- *The more fire-fighters know about a building when called out to a fire, the greater the chances of that building being saved. It is, therefore, important to provide the fire brigade with relevant information on the values involved, and on the practical aspects of fire-fighting.*
- *A written action plan made available for every such building would greatly assist. It should include information on where keys can be found, how best to move around within the building, what special circumstances may affect the efforts etc. The action plan must be known and fully understood by all individuals who may be affected by it.*

It also noted that Management has a major role to play in fighting fire threats, particularly as:

- *It is easy to place too much trust in technical measures. Organisational safety must always take priority. The staff's ability to take the right action at the right time is vital. For this reason, the staff should undergo continuous training. The property owner as well as the tenant should have an appropriate policy to deliver this in place*
- *Protective equipment for preserving residual values and for preventing joists from collapsing should be provided, and lists of experts, who can be called in to ensure that the saved objects are handled correctly, should be available.*
- *Records should be kept of every building to ensure that any damaged parts can be properly restored or that, failing restoration, details of a lost building can be preserved for posterity.*

The use of available technology and the development of new technology can assist:

- *Using current technology it is possible to confine the fire until the fire brigade reaches the site and fire-fighting operations begin.*
- *The installation of fire alarms is predominantly there for life safety, and should be regarded as a minimum level of fire protection.*
- *Simple measures such as the installation of isolating firewalls, particularly in attic spaces, and the replacement of out-dated electrical installations in poor condition such as dangerous or dangerously-located sockets and switches, should be carried out to a much greater extent than at present.*

It also promoted the need for building owners to interface to a greater degree with Insurance Companies as:

- *All too often the insurance companies are unaware that a historically valuable building is involved.*
- *It is the policyholder who is responsible for ensuring that the policy covers the cost of restoration.*
- *The full extent of the physical loss by fire to Europe's built heritage is unknown.*

COST Action C17: Fire Loss to Historic Buildings

For additional information on the outcomes and achievements of the Action, its Final Evaluation Report, dated 13 December 2016, is available at:
http://w3.cost.eu/fileadmin/domain_files/TUD/Action_C17/final_report/final_report-C17.pdf

Copies of the 2-volume COST Action C17 Final Research Report are available through:
http://conservation.historic-scotland.gov.uk/publication-detail.htm?pubid=7250

Copies of the 4-volume COST Action C17 Conference Proceedings are available through:
http://conservation.historic-scotland.gov.uk/publication-detail.htm?pubid=7184
Accessed 13 February 2015

Consequently, when combined with more recent developments such as those addressed during the 2014 COTAC Conference, many of COST Action C17's findings have a direct relevance in emerging thinking on how HBIM might be advanced to incorporate appropriate data and some solutions to the problems.

Building Regulations and Fire Risk Assessments
As previously indicated, the application of Building Regulations only relate to life safety, whilst the protection of building and contents is not considered. An appropriate HBIM approach needs to take this conundrum into account, as its adoption will inevitably face the challenge of marrying a sympathetic intervention philosophy with the regulatory requirements. Here, the consequences could be seriously detrimental if the integration is not dealt with properly.

In addition, given the need to anticipate future possibilities and risks, carrying out Fire Risk Assessments (FRA) could well lead to the results being more onerous than the application of the Regulations.

Caution is therefore required to ensuring that any appointed fire engineer has a relevant knowledge of how to apply conservation ethics and philosophy whilst undertaking risk assessments.

Fantof Stavekirk, Sogn, Norway 1992: Photo Riksantikvaren

City Hall, La Rochelle 2013: Photo The History Blog + Eastbourne Pier 2014

Advice and Support from the Fire and Rescue Services

With regard to preparing fire safety audits achieved through integrated risk management planning and considerations in historic premises, the Department of Culture Media and Sport's document *"Protection of Heritage Buildings and Structures"*, published in 2008, offers relevant advice that many Fire and Rescue Services now follow. Conservation informed support could therefore be obtained from Inspecting Officers in the Services through a two-way process of exchanging information.

Integrated risk management planning guidance for fire and rescue authorities: protection of heritage buildings and structures: DCMS Aug 2008 ISBN 9781409804017

This document is intended to guide fire and rescue authorities in the preparation of an integrated risk management planning (IRMP) strategy for heritage protection. The purpose is to assist fire and rescue authorities in understanding the scope of heritage considerations in the IRMP process to undertake risk analysis, develop response and prevention strategies, develop delivery mechanisms and to monitor and review and evaluate such activity.

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/7639/940468.pdf
Accessed 14 January 2015

With regards to emergency pre-planning events (including fire and flood) station personnel can carry out familiarisation visits in order to be aware of specific risks they could face in the event of an incident. They can also carry out joint exercises with occupiers to test salvage/damage control plans, and the robustness of any joint working intentions. The aim is to provide advice and best practice to ensure any subsequent incident runs as smoothly as possible. Emerging relevant HBIM data could include:

- Guidance with regards to common fire safety features in historic buildings;
- Best practice for fire safety management;
- Information about how to tackle common passive fire safety issues;
- A focus on compartmentation;
- Recommendations for how to plan and organise salvage and damage control; and,
- How to work with the fire and rescue services both before and during an incident.

Traditional buildings can be particularly vulnerable to fire and common risks include:

- Building and maintenance works - hot work, and loss of separation
- Electrical faults - age of wiring and overloaded circuits
- Sparks from open fires and stoves
- Defectives flues, cracked chimney and service ducts
- Redundant service ducts and hidden voids

Risks can be exacerbated when the location is being used to accommodate temporary functions and events. This heightens concerns in respect to life safety, as increased numbers will be generally unfamiliar with their surroundings, thereby endorsing the need for greater co-operation and coordination between all concerned.

Additional advice might also be available. For example, London Fire Brigades' Guidance Note on heritage premises (due to be published in 2015) will aim to give fire safety managers a steer on how to address the specific risks presented in historic buildings, and buildings with valuable collections. Its intention will be to address the lack of fire resistance without losing too much historic fabric.

But, underpinning the Fire Service approach is the need to fully understand the performance and susceptibility of traditional building materials, particularly timber structures and finishings incorporated in the construction. Such a need highlights the benefit of having essential HBIM detailed and accurate survey data, and its effective analysis, readily to hand.

Fire Safety Engineering Guidance in the Context of Built Heritage

With British Standard Published Document 7974: 2001 providing guidance, Fire Safety Engineering is a performance-based approach that takes a holistic and systematic methodology to the fire safety problems in new and existing buildings.

But, there is a need to be wary of FRA's that are simply a 'tick-box exercise' resulting in recommending prescriptive arrangements that could also be significantly damaging through not considering conservation needs. As such, prescriptive guidance generally recommends the fire-resisting performance of structure and compartmentation for specific periods in accordance with British Standard tests. However, these tests are not representative of “real” fire conditions, let alone those likely to be found in existing historic structures.

BS PD 7974: 2001
Application of fire safety engineering principles to the design of buildings. Code of practice

This document, in four parts, provides a framework for an engineering approach to the achievement of fire safety in buildings by giving recommendations and guidance on the application of scientific and engineering principles to the protection of people, property and the environment from fire. It also provides a framework for developing a rational methodology for the design of buildings.

The use of this standard will facilitate the practice of fire safety engineering and in particular it will:
a) Provide the designer with a disciplined approach to fire safety design;
b) Allow the safety levels for alternative designs to be compared;
c) Provide a basis for selection of appropriate fire protection systems;
d) Provide opportunities for innovative design;
e) Provide information on the management of fire safety for a building

http://shop.bsigroup.com/ProductDetail/?pid=000000000030028692
Accessed 15 January 2015

Consequently, the approach could be better informed if HBIM detailed survey data is readily available so that such a professional might also provide relevant and sensitive practical HBIM data on a variety of historic building issues, including:

- Fire and smoke spread analysis
- Proving existing means of escape or fire service access arrangements are adequate
- Minimising additional provisions
- Proving large spaces or compartments do not require splitting to meet compartmentation or external fire spread requirements.
- Means of escape analysis
- Structural fire protection analysis
- Fire safety detection and suppression systems
- Applying common sense.

With adequate survey information, providing and applying thoughtful and pragmatic fire safety design advice, supported by performance based engineering, can play a key part in achieving an appropriately robust level of life safety whilst preserving the buildings’ fabric, character and integrity.

In historic buildings, although compartmental integrity is rare, the ill-considered introduction of segregation can create unwanted consequences for the buildings’ internal microclimate. But, improve levels of protection can be achieved through effective compartmentation, detection, smoke control, ventilation and automatic suppression.

The Selection of Fire Suppression Systems

In the protection of heritage the full armoury of fire safety management should be adopted. This will include fire risk assessment; detection; suppression; compartmentation; staff training; mitigation; audit, and review. Compared to modern structures, the risks and differences associated with heritage buildings should be obvious, but are frequently not.

Many heritage properties can also remain unoccupied for long periods, and are frequently located where water supply and difficult access problems exist. But, the age, function and style of the building can help determine its type of construction and, in consequence, the inherent fire risk where it could spread more easily.

Against these issues a careful consideration of appropriate detection and suppression systems would be appropriate. Useful technical information is found in *Historic Scotland: Guide for Practitioner's No 7*: *Fire Safety Management in Traditional Buildings*. Published in 2010, this two-part Guide has formal guidance document status in support of the Scottish Building Regulations under the Building (Scotland) Act 2003. Part 1 deals with principles and practice, whilst Part 2 provides extensive information on the use of automatic fire suppression systems, and makes it clear that they are major assets in adaptive reconstruction.
http://conservation.historic-scotland.gov.uk/publication-detail.htm?pubid=7370

In addition, the American National Fire Protection Association's *NFPA 909:2013 Code for the Protection of Cultural Resource Properties – Museums, Libraries, and Places of Worship* also describes principles and practices for the protection for cultural resource properties, their contents, and collections, against conditions or situations with the potential to cause damage or loss. Coverage includes provisions for fire prevention; emergency operations; fire safety management; security; emergency preparedness; and inspection, testing, and maintenance of protection systems. Criteria are also provided for new construction, addition, alteration, renovation, and modification projects, along with more specifics addressing places of worship and museums, libraries, and their collections.
http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=909

The Associations' *NFPA 914: 2015 Code for Fire Protection of Historic Structures* is also helpful in its coverage of construction, operational, and occupancy features, while safeguarding the elements, spaces, and attributes that make them historically or architecturally significant. It also establishes criteria to permits prompt escape by occupants and provides for operational continuity. Whilst the NFPA is US-based, the Committee responsible for NFPA 909 and 914 includes a number of respected European experts.
http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=914

In summary, whilst the aim of 'fire risk assessment' is principally to identify people at risk, including fire fighters; to eliminate and/or mitigate hazards where possible; and to effect control by identifying appropriate measures, adding the need to be 'conservation aware' would greatly increase its relevance in built heritage matters.

With the intention of avoiding and preventing fires, the risk of financial loss should be transferred where feasible, whilst inevitably accepting residual risk. The consequences of this approach for the built heritage need to be acknowledged in a carefully assessed HBIM data base adoption of the various guidance documents.

In holistically considering the aesthetic and cultural value of the built heritage and its contents, there is also a need to consider the potential physical and chemical impact of fire fighting activities. In this process, deliberations must also consider the impact of fire, heat, smoke and water discharge on the historic fabric and contents during an incident, and how to deal with damage limitation and salvage concerns thereafter.

With consequential work required on properties that are on the Statutory Lists, Listed Building Consent will invariably be required, (Scheduled Monument Consent in the case of Scheduled Ancient Monuments) and whilst alternative approaches should be considered all 'improvements' in or to such structures should (after Maxwell, 1998) be:

- Minimally invasive
- Reversible
- Essential

- Sensitive
- Appropriate
- Compliant

When there is a consequential proposed change of use, it will be essential to identify those at risk whilst also considering and managing likely ignition sources, fuel loadings, staff intervention and fire fighting capabilities. There is also the possibility of external influences coming to bear, such as the limited supply of fire fighting water in rural areas, contractors' hot working, and arson.

A basic consideration is who, and what, can respond to any alarm emanating from a rural area, and what will the response level and timing be? Within an HBIM environment these issues also need to be considered and analysed as part of the risk assessment process.

This degree of consideration could point to a consequential need to consider installing a suppression system, and this raises the prospect of having to decide what is the most appropriate for the emerging circumstances.

Automatic Suppression
Installing automatic suppression systems in heritage properties frequently requires HBIM needs to consider the consequences of remote locations; poor access; sensitive and quality interiors; restricted fire and rescue service response; poor site utilities and services, and their legislative status.

In doing so, a high level of coordination between owner, consultant and installer is essential where Standards may have to be used as a guide rather than a rulebook. Joint commissioning and handover with the appropriate fire and rescue service is also essential.

In the process, a variety of automatic fire suppression systems are available for consideration, including:

- Gas systems:
    - Inert gases
    - Halocarbon gases
    - New generation gases
- Powder systems
- Air inerting/oxygen reduction
- Water based systems:
    - Sprinklers
    - Water mist
    - Foam

For an independent view of the pros and cons of various suppression systems refer to BS 5306 Part 0: 2011.

BS 5306-0:2011 Fire protection installations and equipment on premises. Guide for selection of installed systems and other fire equipment

This part of BS 5306 gives guidance on the selection, use and application of automatic water sprinkler, water spray, watermist, gaseous, foam and powder fire-fighting systems and hypoxic air fire-prevention systems. It also gives guidance on installed equipment for fire and rescue service use, and on the application of portable fire extinguishers. It complements the more detailed information given in the specialized parts of this standard and other relevant standards.

http://shop.bsigroup.com/ProductDetail/?pid=000000000030182749
Accessed 15 January 2015

Gas Systems
Gas systems may offer apparent benefits in reducing the impact of fire fighting agents on some historic fabric and contents, as Heptafluoropropane, also called HFC-227, HFC-227ea (ISO name), or Apaflurane (INN), is a colourless, odourless gaseous halocarbon commonly used as a gaseous suppression agent.

But, there is a need to consider the impact of halocarbon agents that can generate hydrogen fluoride when discharged into a fire as HFC-227ea (FM-200). With its higher design concentrations, its use may be inappropriate for normally occupied compartments.

Gases for Fire Suppression

Inert Gas Name:	Trade Names:	Chemical Composition:
IG-01	Argotec®, Argonfire®	Argon 100%
IG-55	Argonite®	Argon 50%, Nitrogen 50%
IG-541	Inergen® (*NB: Patent expired)	Argon 40%, Nitrogen 52% CO_2 8%

Chemical Gas Name:	Trade Names:	Chemical Composition:
HFC-227ea	FM-200®, FE-227, Solkflam 227, MH-227, Tornado	C_3HF_7
HFC-236a	FE-36®	$C_3H_2F_6$
FK-5-1-12	NOVEC 1230®	$C_6F_{12}O$

Newer agents such as Novec 1230 (FK- 5-12) are considered promising (although still generating some fluorides) as design concentrations are stated to be much lower than HFC-

227ea or HFC-125 (FE-25). But, in some Nordic countries, there is a current debate to suggest that some HCFC's could be subject to a ban in future.

Inert gas systems, especially IG-541 where suitable, may offer some advantages over the HCFC's as they will not react with fabric or contents. However, they may require significant storage space, and could create floor-loading and spatial demands in some historic properties.

In addition, the compartmental integrity required to effectively retain the released concentrations of any of the firefighting gases, is rarely possible in heritage and traditionally constructed buildings.

Powder Systems

With regard to important historic interiors, the adoption of powder suppression systems needs to be given extremely cautions and careful consideration. The powder (treated sodium bicarbonate) that is used is hygroscopic and will bake on to most materials, such as stone, wood, brass, glass and fabric

St Mary and St Nicholas Church, Spalding, Lincolnshire

In 2006, the wilful discharge of a 6kg dry powder extinguisher in the medieval Spalding Parish Church of St Mary and St Nicholas resulted in clean-up costs of more than £250,000, and related litigation that ran until 2010.

The dry powder contained a number of ingredients, including mono-ammonium phosphate and ammonium sulphate, which adhered to tapestries, metalwork and masonry. This had the potential to cause considerable damage to the building fabric and contents, due to its corrosive and abrasive qualities.

All contaminated surfaces, including the organ that had to be dismantled for treatment, had to be carefully cleaned to restore their visual appearance, and to eliminate the risk of subsequent corrosion and abrasive damage.
http://www.lincoln.anglican.org/media/2067/use-of-fire-extinguishers-in-church-buildings.pdf
Accessed 15 January 2015

Air Inerting (Hypoxic) Systems

Hypoxic systems work by reducing oxygen levels within a protected area to below 16%-17%, sufficient to prevent combustion. They are superficially attractive for heritage protection but, to be effective, they rely on maintaining compartmental integrity.

In an HBIM context factors that need to be considered are the location of plant, noise, energy costs, and life safety.

Research Report 'Hypoxic Air Venting for Protection of Heritage'

Full details of Hypoxic systems can be found in the *Research Report 'Hypoxic Air Venting for Protection of Heritage'* jointly published by Riksantikvaren and Historic Scotland, in support of COST Action C17 in 2006.
http://www.cowi.no/SiteCollectionDocuments/cowi/no/menu/Rapporter/Hypoxic%20Air%20for%20Protection%20of%20Heritage%20COWI.pdf
Accessed 15 January 2015

Water Based Systems

Foam
Foam systems offer no significant benefits over water sprinkler and mist systems. They still require a water supply, pumps, and pipework and visible discharge heads. Some foam compounds are slightly acidic, and may cause environmental damage to historic interiors, and when discharged into drains or watercourses.

The European Standard, *'BS EN 13565-2:2009 Fixed firefighting systems. Foam systems. Design, construction and maintenance'* provides guidance on the design of various foam systems effective in protecting specific hazard configurations. With regard to its HBIM relevance for heritage properties, it might be noted that the Standard does not cover the need for a risk analysis by a competent person.
http://shop.bsigroup.com/ProductDetail/?pid=000000000030234306

Automatic Water Sprinkler Systems
Worldwide, the use of automatic sprinkler systems is greater than any other fixed fire protection system, with over 40 million sprinklers fitted each year. Proven in use for well over 100 years, possibly the oldest British system was fitted in 1812 at the Theatre Royal, Drury Lane. Its updated, but recognisable form, is still in use today.

From an HBIM perspective, losses from fires in sprinkler-protected buildings are estimated to be less than 1/10 of those in unprotected buildings. Collated over a 10-year period, European statistics indicate that in fully protected buildings:

- 99% of fires were controlled by sprinklers alone
- 60% of fires were controlled by the water discharged from no more than 4 sprinklers

The accidental discharge of water from sprinklers is considered at 1 in 500,000 whilst discharge due to manufacturing defects sits at 1 in 14,000,000. But, the potential for water damage in premises left empty for long periods can also be an issue. Consequently, the incorporation of water-flow alarms, connected to an Alarm Receiving Centre, is essential. Problems with freezing temperature might also emerge, particularly in un-insulated roof spaces, so the incorporation of trace heating elements, lagging and anti-freeze in the system may be required.
http://www.bafsa.org.uk/sprinkler-information/sprinkler-facts.php

Where water service mains flow, or pressure is low, space allocations for tanks and pumps will be required in many cases. Internally, pipework may have to be surface run if floorboards cannot be lifted, but existing voids should be used to aid the design and insertion of pipework etc. if these can be identified through HBIM survey techniques - ensuring effective compartmentation stopping-up as an end part of the installation.

Water Mist

Water Mist systems are similar to sprinklers in that they employ water propelled through pipes to be projected onto a fire through fixed heads. Due to the greater heat absorption capacity of very small water mist droplets, less water is employed and discharged than in a sprinkler system. But, to achieve this, mist systems have to operate at much higher pressures with:

- Sprinklers at 3 - 9 bars
- Low Pressure Mist at 12 - 20 bars
- High Pressure Mist at 200 - 225 bars

The consequential impacts between adopting water hose, sprinkler or mist delivery systems in fighting fire.

High-pressure systems are more costly, having critical requirements for pipework, water quality, and pumps to function correctly, and more mist heads are required than sprinkler heads to protect a similar sized area. On price, low-pressure mist systems can compare favourably with sprinklers.

Whilst sprinklers can be designed using established tables, the design of mist systems requires each application to be proven by reference to a test or computer simulation.

Watermist systems should be designed and installed in compliance with an appropriate standard. In the UK, this is BS DD 8458 for domestic and residential properties, or BS DD 8459 for other occupancies. (Note: both documents are presently being reviewed with the intention of making them full British Standards in 2015). CEN has published Technical Specification 14972:2014 which could also be referenced, and this may become a full standard in 2016 - at which time it would supersede any BS documents. Until the question of standards is resolved, independent guidance may be found in '*Watermist Systems: Compliance with Current Guidance'* published by the UK WaterMist Coordination Group. http://www.bafsa.org.uk/pdfs/publications/5/00000115.pdf

Pipework Choices

Installing any form of modern mechanical or electrical services within the confines of a traditionally constructed historic building is inevitably going to be challenging. The success of doing so boils down to having a full understanding of the three-dimensional structure, its hidden voids, and the resulting opportunities that can be identified. A pipe or service run connecting 'A' to 'B' might have to proceed via 'C' and 'D'.

Emphasising the need for an accurate HBIM survey and analysis to determine least damaging pipework routes, a choice of what is possible also focuses on the acceptance or otherwise of the use of:

- Black steel
- Stainless steel
- Copper
- Approved Chlorinated Polyvinyl Chloride (CPVC)

In terms of installation ease and flexibility, CPVC has the benefit of allowing smaller diameter pipes to be used with clean cutting capabilities and no hot-work jointing. But, solvent jointing is critical, requiring it to be effected by trained operatives using approved handbook guidance, such as that offered in the *Loss Prevention Standard* '*LPS 1260 Plastic pipe and fittings for Use in Automatic Sprinkler Systems'*.
http://www.bafsa.org.uk/pdfs/news/6/00000696.pdf

Water Storage Tanks

Water-based suppression systems inevitably carry the caveat that a sufficient supply and appropriate volume of water is available to charge and maintain the technique in operation. Recent case studies have indicated that adopting and constructing modular water storage tanks in available confined spaces can help overcome this challenge within historic structures. Pre-fabricated modular tanks are factory flat-packed to ensure ease of transportation and construction. There is no on-site requirement for rigging, welding, cutting, coating, working at height or scaffolding, thereby greatly reducing installation time whilst minimising exposure to occupational health and safety issues.

The key issue however depends upon having a detailed HBIM 3D survey of the property within which locational space and volume possibilities can be pre-determined before designing and ordering.

16thC masonry vault with 6m3 modular Water Storage tank offering 30 minutes water mist system coverage. Photo Stewart Kidd

Fire Incident-related HBIM Documentation

The fire prevention section of any HBIM documentation ought to describe in detail the building and its system and appliances; its usage; the organisational structure that is in place; together with logged details of any physical alterations that have occurred since the document was originally produced. It should be compiled and maintained by in-house personnel who are well versed in the building and its function.

Fire Safety Handbook

All larger premises or sites should develop and maintain a Fire Safety Handbook as part of HBIM data system. This should set out the fire prevention strategy, detail action plans in case of fire, and be used as a basis for staff training. Information on all fire safety systems and components should be detailed to include floor plans showing locations of fire extinguishers; hose reels; hydrant points; gas, water and electric shut-off points; wiring diagrams; equipment specification sheets, and replacement part lists.

The handbook should also incorporate the operational, service and maintenance instructions for fire protection systems and equipment, together with details of any modifications or upgrades undertaken. Whenever adjustments or improvements are made to structural fire safety, or when new equipment is introduced, the handbook should be revised and kept up to date. A copy of the fire safety policy document and all fire risk assessments should be incorporated, and a record of 'near misses' will also be of value.

Fire Safety Log Book

Integrating with the HBIM data, a Fire Safety Log Book should be maintained for all historic buildings as a separate day-to-day working document. It should contain a note of all fire-related events and compliment the reference document role of the Fire Safety Handbook. The Fire Safety Log Book should continuously record information such as:

- Fire training sessions undertaken or delivered - including the event duration, content and names of those who attended.
- Fire drills undertaken - including the time, duration and names of those who participated. The record should include a comments column for noting any particular problems and other relevant observations. If a problem or difficulty has been encountered, details of the remedy should also be included.
- Inspections or visits by the insurance company, fire brigade or other competent persons, including brief details of any observations made.
- Full details of all fire equipment and fire system maintenance, including emergency lighting. It is suggested that this information is recorded even where there are separate maintenance logs for such equipment.
- Details of any fire incidents, false alarms or other matters of relevance together with responses or remedial actions.

In current litigious times, the value of comprehensive records cannot be over-emphasised. Information in the Fire Safety Log Book may be critical in, for example, convincing a court that everything 'reasonable' has been done to manage fire - or to persuade an insurer that policy conditions have been met. This means that where locations keep the information electronically, care should be taken to ensure that adequate backup arrangements are in effect. Where paper records are kept, consideration should be given to storing them in a fire resistant unit or safe, with updated duplicate material held off site.

Salvage Plans

As part of the fire safety documentation it is recommend that all historic buildings with valuable collections should also have adequate salvage, recovery and protection provisions in place. As part of an HBIM data approach, Salvage Plan could include the following:

- Details of the salvage incident commander and any deputies;
- Contact lists for relevant persons in case of an incident;
- Details of salvage team training;
- Site and building plans;
- Salvage priorities (snatch list);
- Salvage and item removal logging procedures:
- Emergency fire aid conservation; and
- Safe storage of items after they have been moved from the affected building
- Post incident survey arrangements.

The Plans should be clear and easy to understand, with drawn or photographic details of the building, identified historically important parts requiring damage control, and where artefacts are held. For ease of interpretation in an emergency situation, simplified single line drawings, rather than complicated architectural plans, are preferred as they are clearer to understand in stressful situations.

Salvage plans, and relevant HBIM data, should indicate how it is intended to work with the Fire Service, and be securely stored in a location that can be readily accessed by attending crews. Through a pre-determined agreement, it may be possible for similar nearby organisations to join forces and resources in sharing salvage teams, conservation specialists, equipment and storage facilities in the event of an incident.

During an incident, the Incident Commander will decide on relevant operational tactics, and quickly develop an approach for dealing with the incident. If a pre-existing relationship has been established before an incident, a more effective response will emerge. Through visiting and familiarisation with the circumstances, it will potentially avoid un-necessary delays on arriving at an actual incident. Collaborative exercises will also help identify issues, such as potential hazards to fire fighters, limited water supplies, and access problems.

Salvage Equipment

Within HBIM, the extent and amount of salvage equipment that should be held on the database will be dependent on the building size, and the scale of what might potentially need to be removed. Along with the Salvage plan in a locked, but accessible, secure location, the following basic salvage equipment might be held:

- Personal Protective Equipment
- Power packs
- Plastic foil
- Plastic tarpaulins
- Nail gun
- Hammer and nails
- Silver duct tape
- Transportation boxes
- Large plastic bags – preferable extra strong
- Small plastic bags
- Bubble wrap on a roll and bags
- Box tape on a holder
- Knives
- Plastic foil (for books)
- Dry gel
- Tools to remove paintings

Additional equipment and materials may have to be secured from equipment supply merchants or building supply companies. Therefore, a Company Source Inventory might be incorporated in the Plan where other materials and needs can be quickly obtained:

- Wet/dry vacuum cleaners
- Fans

- Dehumidifiers
- Lighting
- Freezers
- Building materials

Learning from the Glasgow School of Art (2014) and Other Post Disaster Recovery Experiences

The extensively damaging fire in May 2014 that devastated the West Wing of the internationally re-known Glasgow School of Art by Charles Rennie Mackintosh took an understanding of the Basic Salvage equipment considerations to a new level. In the prevailing circumstances, where the Student's annual work was being set up for assessment, this had to be devised and acted upon as the later stages of the incident unfolded. This required the initiation, development and implementation of an immediate salvage strategy set against a highly charged scenario of political, press and operational needs.

Significant lessons were learnt from the approach, and through other fire salvage incidents experienced during the COST Action C17 programme, such as the 2004 Anna Amalia Library fire in Weimar, Germany. These have a distinct bearing on what considerations should be incorporated in developing HBIM data for disaster awareness and mitigation plans.

Reiterating in part, but also expanding upon what is set out above as required basic salvage equipment, effective action includes the need to determine an integrated conservation and salvage approach in:

Co-ordination:
- Explain the significance and value of the building and its contents to the Fire authorities
- Have immediate access to essential and accurate floor and layout plans
- Work with owners/occupiers to determine locational information of contents
- Establish good working relationship with the Fire and Rescue Services to enable access for salvage possibilities through use of safe working tethering lines
- Work with and manage Building Control to ensure salvage operatives safety, building stability, and to determine if partial demolition is necessary
- Note that Building Control will take control of building once the fire is extinguished
- Work with the Police to secure the incident and the removal of salvaged contents

Communication:
- Identify a specialist to deal with the media and politician, in an inevitably highly charged situation
- Identify an effective management structure to ensure efficient working arrangements and liaison needs
- Have ID packs and records available to ensure effective staff identities
- Have access to and the use of site communication radios
- Consider the possibility of the incident being a crime scene

Determination:
- Assess how long will the fire burn ‘under control’ during fire fighting
- Use thermography to determine hot-spots
- Laser scan the remnants from all accessible surrounding locations
- Use post-event laser scanning to compare with pre-event scanning to determine structural risks and stability

Reparation:
- Have details of salvage kits and equipment to hand
- Consider post fire recovery needs as a archaeological investigation
- Seek support information on important contents, furbishings and fittings
- Identify a sufficiently large nearby safe and secure salvage area storage facility
- Arrange a human chain to move materials in the salvage process
- To help identify items, salvaged material should be laid out in the same location in a disciplined similar grid formation to that as extracted
- Label identify, and sequentially store, down-taken structural components that are capable of cleaning and reuse

Salvation:
- Arrange sustenance and victualing supplies to keep the teams going
- Keep On-call emergency contacts and information data up to date
- Plan for post incident temporary roof covers and structural support
- Revisit fire prevention procedures and plans, and keep up to date

Expanding relevant information under each of the heading and sub-point should form an integral part of future HBIM data planning considerations when applied to built heritage concerns.

Conclusions

The existing built heritage is an irreplaceable asset, and a full range of appropriate HBIM fire prevention and salvage data should be incorporated in any BIM4C approach. With the aim of ensuring its future wellbeing, the seriousness and rigour by which the HBIM data should be compiled would do well to acknowledge the high levels of loss that has already occurred through the effects of fire.

BIM4C HBIM data should include a balanced approach, integrating conservation requirements with effective risk assessment analysis covering:

- Disaster preparedness information and handbook documentation
- Guidance based on a range of relevant standards and advisory publications
- Guidance determined and based on dialogue with the Fire and Rescue Services
- Guidance based on input from qualified Fire Engineers and other specialists
- Operational data on installed fire detection and suppression systems
- Appropriately detailed GIS survey information of the structure, its internal contents, and surroundings.
- An assessment of functions, access provisions, water supplies, salvage needs, and post-disaster recovery considerations
- Operational lessons learnt from previous post-fire salvage and recovery incidents

References: Standards and Guides

BS 9991:2011 Fire safety in the design, management and use of residential buildings. Code of Practice

BS 9991:2011 gives recommendations and guidance on the design, management and use of the following building types, to achieve reasonable standards of fire safety for all people in and around:

- *Dwellings (single-family dwelling houses, self-contained flats or maisonettes);*
- *Residential accommodation blocks (e.g. for students or hospital staff), with individual bedrooms and the provision of kitchen/sanitary facilities constructed within a fire compartment, accommodating not more than six persons;*
- *Sheltered housing and extra care housing.*

It is not applicable to hotels, caravans/mobile homes, hospitals, residential care/nursing homes, places of lawful detention, hostels or houses of multiple occupancy.

BS 9991:2011 is applicable to the design of new buildings, and to material alterations, extensions and material change of use of an existing building. It also provides guidance on the on-going management of fire safety in a building throughout the entire life cycle of the building, including guidance for designers to ensure that the overall design of a building assists and enhances the management of fire safety. It can be used as a tool for assessing existing buildings, although fundamental change in line with the guidelines might well be limited or not practicable.

http://shop.bsigroup.com/ProductDetail/?pid=000000000030203948

BS 9999:2008 Code of Practice for fire safety in the design, management and use of buildings

BS 9999:2008 is the fire safety code of practice for building design, management and use. The standard outlines ways to meet fire safety legislation through a more flexible approach to design. BS 9999:2008 provides a risk-based structure that takes varying human factors into account, including improving emergency exit access for disabled people. The standard can be used in and around existing buildings, at design stage for new buildings or extensions, and also applies to alterations, extensions and changes of use of an existing building. It also provides an assessment tool to ensure fire safety strategy remains robust.

BS 9999:2008 is based on government guidance and provides a best practice framework for fire safety. The standard outlines ways to test all aspects of your fire strategy, including easy access to exits, to ensure the safety of people in and around the buildings. This includes how to manage fire safety throughout the entire life cycle of the building – starting with design or re-design, to fire system assessment, and maintaining a fire detection system. BS 9999:2008 also gives guidance on training employees in fire safety, organising an efficient evacuation plan and allocating *leadership responsibilities. The recommendations and guidance given in this British Standard are intended to safeguard the lives of building occupants and fire-fighters.*

http://shop.bsigroup.com/en/ProductDetail/?pid=000000000030158436

Integrated risk management planning guidance for fire and rescue authorities: protection of heritage buildings and structures: August 2018: DCLG: ISBN 9781409804017

This document is intended to guide fire and rescue authorities in the preparation of an integrated risk management planning (IRMP) strategy for heritage protection. The purpose is to assist fire and rescue authorities in understanding the scope of heritage considerations in the IRMP process to undertake risk analysis, develop response and prevention strategies, develop delivery mechanisms and to monitor and review and evaluate such activity.

https://www.gov.uk/government/publications/integrated-risk-management-planning-guidance-for-fire-and-rescue-authorities-protection-of-heritage-buildings-and-structures

Historic Scotland: Guide for Practitioner's No 7:
Fire Safety Management in Traditional Buildings

The Guide (which has ACOP status in Scotland) makes it clear that automatic fire suppression systems are a major asset in adaptive reconstruction. Part 2 of the Guide provides extensive information on the use of fire suppression systems in older buildings
ISBN 978-1-84917-035-2

www.historic-scotland.gov.uk/v1/product_detail.htm?productid=1783

NFPA 909:2013 Code for the Protection of Cultural Resource Properties – Museums, Libraries, and Places of Worship

This code describes principles and practices of protection for cultural resource properties (such as museums, libraries, and places of worship), their contents, and collections, against conditions or physical situations with the potential to cause damage or loss. Coverage includes provisions for fire prevention; emergency operations; fire safety management; security; emergency preparedness; and inspection, testing, and maintenance of protection systems. Criteria are also provided for new construction, addition, alteration, renovation, and modification projects, along with specific rules addressing places of worship and museums, libraries, and their collections.

http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=909
Accessed 15 January 2015