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Report

Bowtie Analysis – Fire in HRRB

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EXECUTIVE SUMMARY AND CONCLUSIONS

This report presents the results of a bowtie workshop considering the scenario of 'Fire in a Higher Risk Residential Building (HRRB)' and involving members of the Engineering Council's Competence Steering Group, Building a Safer Future, Working Group 1: Engineers.

The full range of potential causes and ultimate consequences of fire were considered, and it was assumed that the HRRB in question was occupied, however the resulting bowtie would also be applicable during earlier stages of a building project.

The workshop output is presented in the form of a detailed bowtie diagram, illustrating the full range of causes of a fire in an HRRB, the potential consequences and the existing and potentially desirable prevention and mitigation measures. All the prevention and mitigation barriers claimed on the bowtie are also presented in tabular form, sorted by responsible party or barrier owner.

It is concluded that bowtie analysis is a practical technique which generates output that provides an easily understood overview, and may therefore be a viable approach to assessing the significant risks associated with HRRBs as part of a safety case framework.

The bowtie diagram provides a template and reference point for fire risk management that can evolve with the lifecycle of the building, allowing knowledge and information to be transferred as the building transitions from early through detailed design, to construction and commissioning, and into occupancy.

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DISTRIBUTION

Ms K Turff	Engineering Council, London, UK
Mr G Adams	Engineering Council, London, UK
File	Risktec Solutions Limited, Warrington, United Kingdom

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ABBREVIATIONS

Abbreviation	Description	Abbreviation	Description
ALARP	As Low As Reasonably Practicable	BSRIA	Building Services Research and Information Association
HRRB	Higher Risk Residential Building	IET	Institution of Engineering and Technology
IMechE	Institution of Mechanical Engineers	IRG	Industry Response Group
IStructE	Institution of Structural Engineers	MHCLG	Ministry of Housing, Communities and Local Government
MOC	Management of Change	NFCC	National Fire Chiefs Council
QRA	Quantitative Risk Assessment	WG1	Working Group 1
WG5	Working Group 5		

1 INTRODUCTION

1.1 Background

Multi-occupancy higher risk residential buildings (HRRBs) have the potential for significant consequences, with a large number of people concentrated in a small space exposed to foreseeable events such as fire. In her independent review of UK building regulations and fire safety following the Grenfell Tower fire (Ref. 1), Dame Judith Hackitt identifies deep flaws in the current system and proposes that the key principle of risk ownership and management needs to be applied alongside a simpler, outcomes-based regulatory framework.

In September 2018, Sheryl Hurst from Risktec Solutions Ltd. (Risktec) was invited to give a presentation to the Engineering Council's Competence Steering Group, Building a Safer Future, Working Group 1: Engineers, about how a goal setting, safety case approach to risk management might be applied to HRRBs.

The presentation discussed:

- what a safety case is;
- what a safety case might look like;
- the process of creating and maintaining a safety case;
- the key safety case objective of demonstrating that risks are reduced to As Low As Reasonably Practicable (ALARP) levels; and
- two different examples of detailed risk assessment, namely Quantitative Risk Assessment (QRA) and bowtie analysis, that might be applied to significant hazards.

As a result of the presentation and discussion, it was agreed that bowtie analysis may be a practical, pragmatic way of implementing a safety case framework for HRRBs. Risktec was therefore asked to facilitate and record a bowtie workshop considering the scenario of 'fire in a HRRB' and involving members of the steering group. This report presents the results of that workshop.

1.2 Objectives

The objectives of the workshop and resulting bowtie analysis were to:

- Collect together, into one overarching document, the disparate measures which prevent or mitigate a fire and are put in place or influenced by design and engineering teams, developers, building owners, building management companies, building occupants, local authorities, emergency services, etc.
- Guard against loss of knowledge, or failure to communicate information, as a building transitions from early through detailed design, to construction and commissioning, and into occupancy.
- Avoid an impenetrable safety case document containing a large amount of technical language and numerical analysis that may not be accommodated easily within the industry.
- Instead produce a bowtie diagram that is understood easily, that spans disciplines, transcends obstacles and can evolve with the lifecycle of the building.
- Provide an opportunity for representatives from a range of engineering institutions to work collaboratively together towards a common goal.

The workshop output will be shared with the members of Working Group 1 and its Industry Response Group (IRG), together with the working group's conclusions on the practicality of the approach and the value gained by conducting bowtie analysis for HRRBs.

2 BOWTIE ANALYSIS METHDOLOGY

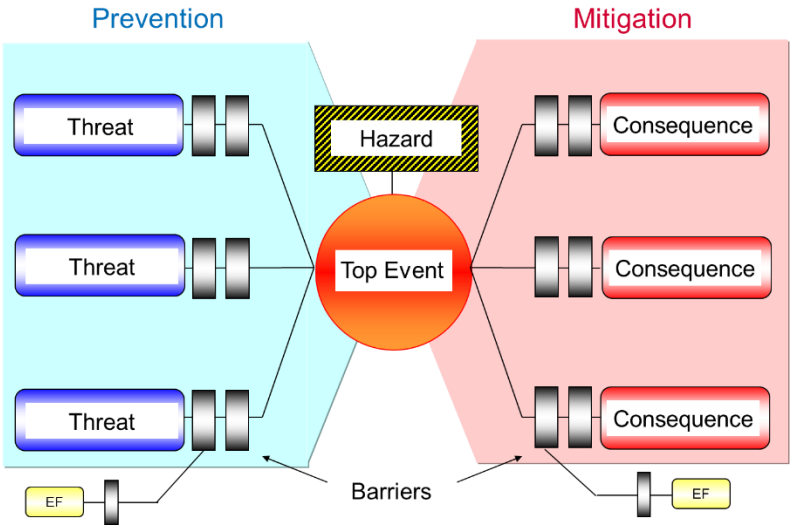
2.1 The Bowtie Diagram

Bowtie analysis (Figure 1) is based on the principle that hazards have the potential to cause harm and if control is lost, an unwanted event will occur (shown at the centre of the bowtie). The analysis involves identifying the causes of the unwanted event (shown as 'threats' on the left side of the bowtie) and the potential consequences (shown on the right) which could result if the unwanted event is allowed to develop unchecked.

For each threat, there may be one or more prevention barriers which either prevent the threat from occurring at all, reduce the likelihood of its occurrence, or prevent it from resulting in the unwanted event. Similarly, between the unwanted event in the centre of the bowtie and each of the ultimate consequences, there will be one or more mitigation barriers which either prevent the consequence from occurring at all, or reduce its likelihood or severity.

The analysis also identifies mechanisms (known as 'escalation factors') by which the prevention or mitigation barriers may be undermined and made ineffective, and the safeguards which, in turn, manage these escalation factors.

Figure 1: Bowtie Diagram



The bowtie diagram therefore provides a snapshot of how a particular hazardous event is prevented and mitigated in a logical, structured fashion, and displaying this overview on a single diagram promotes discussion which makes it easy to identify gaps and weaknesses, e.g. a lack of barriers or a particularly significant threat or consequence.

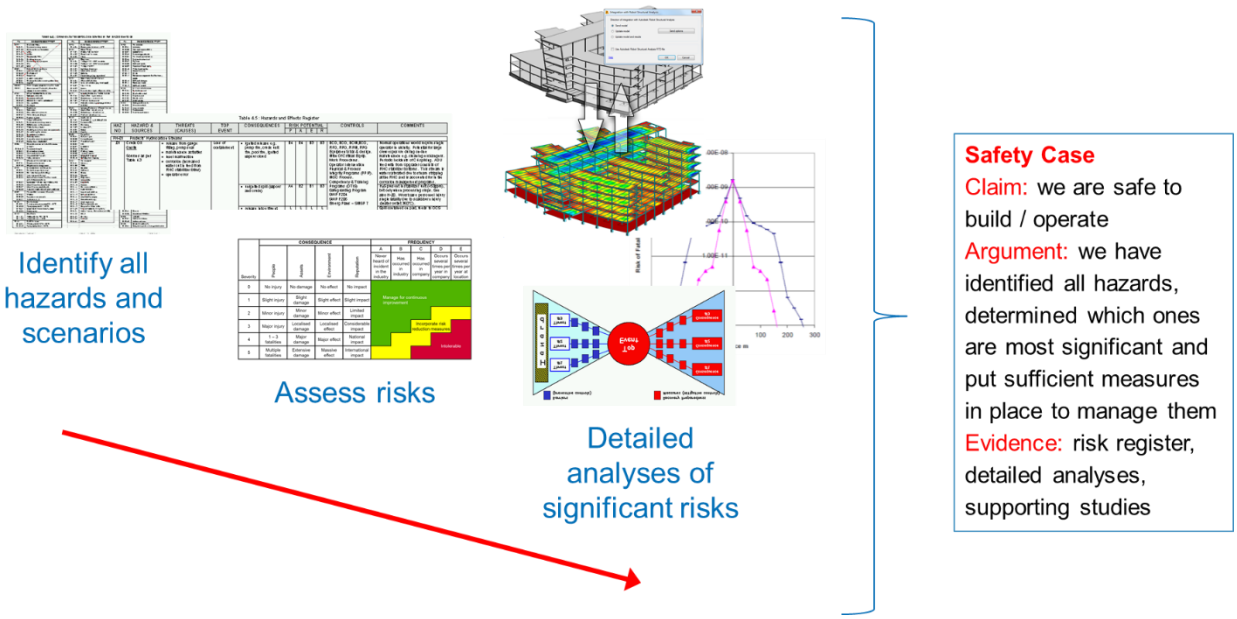
2.2 Bowties in the Context of a Safety Case

A safety case needs to demonstrate that all hazards have been identified, their risks assessed and controls put in place to manage those risks. Usually this would be in the form of some sort of hazard inventory or risk register (Figure 2), with a risk matrix used to score the risks and therefore rank the hazards. More resources would, naturally, be directed at analysing and demonstrating control of the hazards which contribute most to the overall risk. This analysis may take the form of QRA, structural analysis, bowtie analysis, etc. So, in the context of a safety case, bowties tend to be developed for the most significant hazards/risks to document, systematically and in detail, the range of prevention/mitigation measures in place to manage those most significant scenarios, and to identify weaknesses/gaps that need to be addressed.

There is a limit to the amount of detailed information that can be included on the bowtie without compromising its use as a communication tool and a means of understanding, on a single diagram, how the hazard is managed. The bowtie will, therefore, through links to supporting critical documents, processes and responsibilities (see Section 3.3), serve as a 'headline' document showing the complete range of causes

and barriers, and providing signposts to evidence (e.g. detailed structural analysis, etc.) to support the claimed effectiveness of each individual barrier.

Figure 2: Bowties and Safety Cases



3 WORKSHOP DETAILS

3.1 Workshop Timing and Participants

The workshop was conducted on Monday 29th October at the Engineering Council's offices in London. Participants are summarised in Table 1 below.

Table 1: Workshop Participants

Name	Position	Organisation
George Adams	WG1 Chair	Engineering Council
James Breach	Policy	MHCLG
Brian Cox	CBSD Member	IMechE
Emma Fairman	Committee & Project Support Executive	Engineering Council
Sheryl Hurst	Facilitator	Risktec
Christopher Jones	IET Member	IET/Preface Ltd.
Tassos Kougionis	Principal Consultant	BSRIA
Chris O'Regan	IStructE Fellow	IStructE
Adreena Parkin	WG5 Chair	NFCC
Katy Turff	WG1 Secretariat	Engineering Council

3.2 Workshop Scope

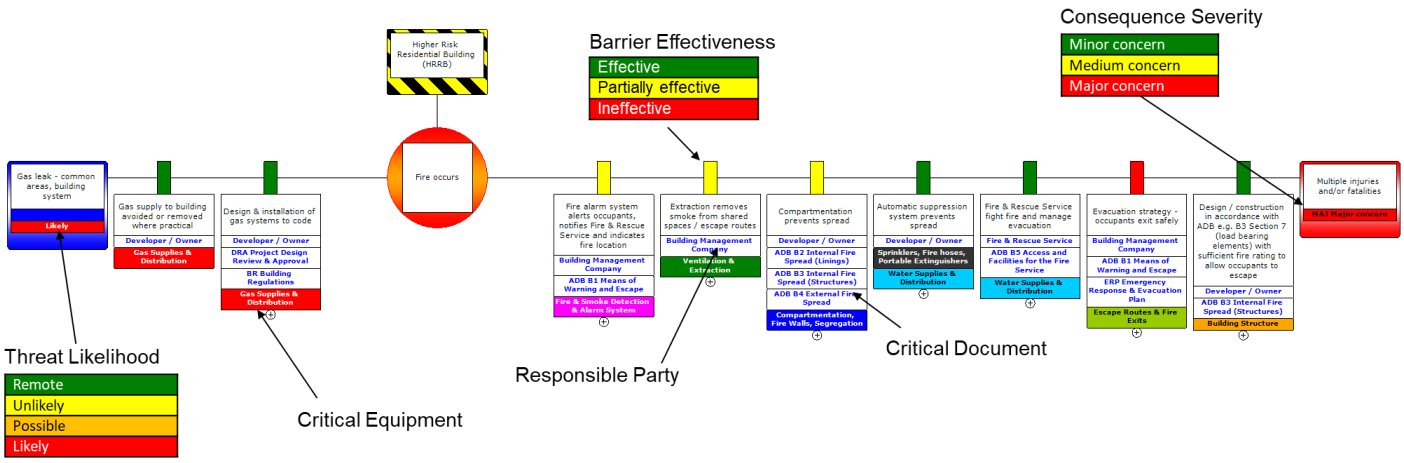
The scope of the workshop was to conduct a bowtie analysis for the significant hazard of 'fire in a HRRB'. The full range of potential causes and ultimate consequences of fire were considered.

It was assumed that the HRRB in question was existing and occupied, given that the vast majority of HRRBs that will fall under the recommended safety case approach will be in this category. However, the resulting bowtie would also be applicable during earlier stages of a building project (see Section 4.2).

3.3 Additional Information (Metadata)

Depending on the uses that the bowtie will be put to, further, more detailed information can be overlaid onto the bowtie diagram to support the analysis. Figure 3 shows the additional information that was solicited during the bowtie workshop.

Figure 3: Bowtie Additional Information



Each threat (cause) was labelled with a relative likelihood to show those threats which are more or less likely to occur. Note that the likelihood is the inherent likelihood of the *threat occurring*, and not the likelihood of

the threat *resulting* in a building fire (which would also require all the preventive barriers to fail). This inherent threat likelihood therefore gives an indication of how important the preventive barriers are for each threat; the more likely a threat is to occur, the more reliance is placed on the barriers to prevent that threat from leading to a fire.

Critical equipment is highlighted to indicate which prevention or mitigation barriers rely on systems or components of the building (Table 2).

Table 2: Critical Equipment

Critical Equipment
Building Security Systems
Building Structure
Compartmentation, Fire Walls, Segregation
Escape Routes & Fire Exits
Fire & Smoke Detection & Alarm System
Gas Supplies & Distribution
Lightning Protection
Power Supplies & Distribution Systems
Safety Signage
Sprinklers, Fire hoses, Portable Extinguishers
Ventilation & Extraction
Water Supplies & Distribution
Wet/Dry Risers, Fire Fighting Lift

Identifying critical items of equipment allows for owners (e.g. Project or Management Company) to identify standards of performance that have to be achieved by these items. Such standards may include functionality, reliability and survivability targets. By defining the standards based on hazard scenarios, and by having in place measures to assure that the standards of performance are achieved operationally, assurance is given that risks are being effectively managed throughout the HRRB's lifetime.

Critical documents (Table 3) are referenced where they provide relevant information about the barrier (although note that compliance with a referenced document may not be mandatory in all cases, provided equivalent measures are taken).

Table 3: Critical Documents

Code	Description
Approved Document	
ADA	Approved Document A
ADB B1	Approved Document B Part 1 - Means of Warning and Escape
ADB B2	Approved Document B Part 2 - Internal Fire Spread (Linings)
ADB B3	Approved Document B Part 3 - Internal Fire Spread (Structures)
ADB B4	Approved Document B Part 4 - External Fire Spread
ADB B5	Approved Document B Part 5 - Access and Facilities for the Fire Service
ADK	Approved Document K
ADM	Approved Document M
Regulations / Regulatory Documents	
FSO	Regulatory Reform (Fire Safety Order) / Fire Risk Assessment

Code	Description
ESR	Electrical Supply Regulations
BR	Building Regulations
CDM	CDM Regulations 2015 / O&M Manual
TS	Technical Submissions
Developer / Project Documents	
DRA	Project Design Review & Approval
PC	Procurement Controls
PMOC	Project's Management of Change Process
Building Management Company Documents	
MCMOC	Management Company's MOC Process
ERP	Emergency Response & Evacuation Plan
FRA	Fire Risk Assessment
IR	Inspection Records

The expected effectiveness of each prevention or mitigation barrier is indicated by the coloured vertical bar as shown in Figure 3. Barriers may be only partially effective or ineffective if they are unlikely to be present or, even if present, they may not prevent the threat leading to the fire, or may not prevent the ultimate consequence from arising from the fire.

Each barrier was assigned an owner to indicate who would be likely to have overall responsibility for ensuring that the barrier is in place and maintained in an effective state. As discussed in Section 4.2, for a building project at the design stage, responsibility for most barriers will rest with the developer and/or project design team, but as the building progresses towards occupation responsibility for some barriers will be transferred to the building management company. The bowtie presented in this report reflects this latter situation, i.e. an existing, occupied building.

The additional information shown was based on group consensus during the workshop; depending on the circumstances for a specific project or building, the effectiveness ratings, critical equipment, critical documents and responsibilities may differ from those shown in this report.

4 WORKSHOP RESULTS

The workshop output is recorded as a detailed bowtie diagram, with supporting information, illustrating the causes of a fire in an HRRB, the potential consequences and the existing and potentially desirable prevention and mitigation measures. The complete bowtie is presented, branch by branch, in Appendix A. Appendix B presents a list of all the prevention and mitigation barriers claimed on the bowtie, sorted by responsible party or barrier owner.

All threat and consequence branches (except one, see below) have a range of barriers, spanning design and occupation/operational risk control measures, with critical equipment and supporting documents highlighted and barrier owners assigned. Some barriers are legal requirements, or are established good practice and would be expected for a HRRB, and are indicated as such by having a relatively high effectiveness rating (i.e. they are likely to be present and effective or at least partially effective). Other barriers may be desirable or 'nice to have' but are less common and tend to be assigned a low effectiveness rating. When the bowtie is applied to actual buildings (see Section 4.1), these less effective, nice to have barriers could be the focus for discussions around what further steps are required to reduce risks to ALARP levels.

One consequence branch (social/psychological impact of a building fire) was not developed during the workshop; this scenario is believed to be being addressed by an alternative working group and so has been referred back to the IRG.

4.1 Use of the Bowtie Analysis Results

Ultimately the future use of the bowtie presented here is to be decided by the working group/IRG; the workshop was intended as a test case to trial the methodology but also to generate a bowtie diagram that might be used as a template or checklist for specific building projects or existing HRRBs when assessing their management of fire risk.

For example, the bowtie in Appendix A may be used as an audit checklist for an existing HRRB or new HRRB project, to verify that the full range of fire prevention and mitigation measures as depicted in the diagram are either in place or planned to be in place. The bowtie could also be used to question if there are any building-specific escalation factors present that would weaken the effectiveness of the barriers and hence require to be mitigated against by design or operational measures.

The bowtie diagram can be customised to reflect the audit findings, amending the barrier effectiveness and including additional barriers where extra steps have been/are being taken. Recommendations may be made where barriers are found to be ineffective or missing. The bowtie in Appendix A presents the working group's expectations and, therefore, where barriers do not exist for an actual HRRB or project it would be good practice to investigate whether the barrier, or its equivalent, could be introduced. In this way, the bowtie presented in this report is a template illustrating expected fire risk management measures.

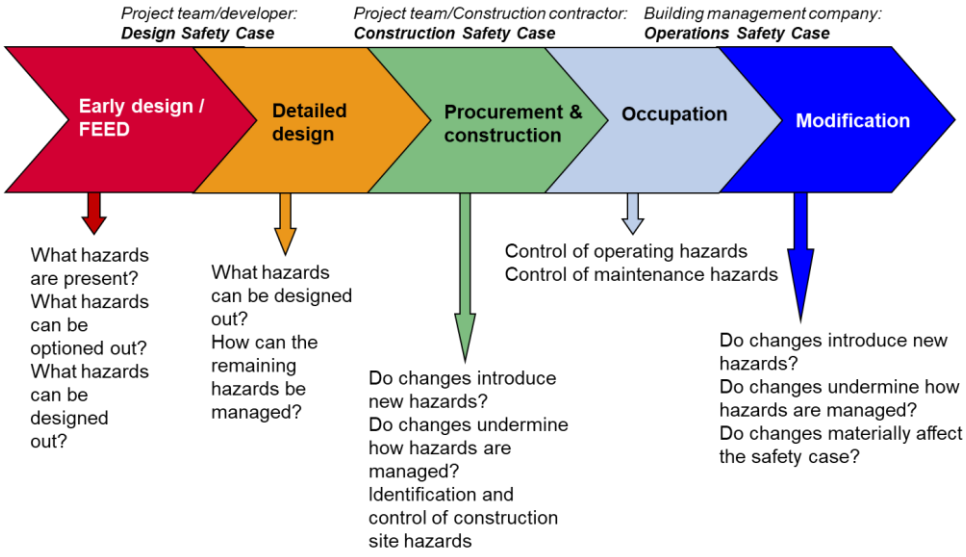
The list of barriers in Appendix B can also be used as a checklist, focussing in this case on the prevention and mitigation measures that are the responsibility of a single party. For example, the building management company could use the list to confirm the presence and quality of its barriers and supporting documentation as part of the building fire risk assessment required under the Regulatory Reform (Fire Safety) Order 2005.

4.2 Application of the Bowtie Through the Building Lifecycle

The bowtie generated in the workshop assumed an existing, occupied building. However, the same bowtie would be applicable to a new building project. In that case, the emphasis would be on design barriers and responsibilities of the developer, project team, etc. rather than operational barriers and the responsibilities of the future building management company and building occupants. The developer/project team could use the diagram in Appendix A and/or the list of barriers in Appendix B to confirm that all fire-related barriers have been considered as early as possible during the design.

At the early stage of a project (Figure 4), there is much more potential to eliminate or 'design out' hazards so a bowtie developed during early design may identify significant, effective barriers which greatly improve the inherent safety of the building. Conversely, once a building becomes occupied, the scope for risk reduction relies more heavily on operational, procedural controls and there is limited potential to change the design. A bowtie analysis conducted for the first time on an existing, aged building, may determine that some of the design stage barriers are either absent or ineffective, and alternative measures may be required to reduce the risk.

Figure 4: Building Lifecycle



As a building ages, there may be progressive degradation of barriers. This is illustrated on the bowtie in Appendix A by the use of escalation factors to highlight how uncontrolled modifications could undermine design barriers such as compartmentation; this specific escalation factor arises many times across the bowtie. Applying the bowtie to an existing building should therefore alert those responsible for managing and maintaining the building to the importance of having processes in place to properly plan and manage modifications.

Revisiting the bowtie analysis periodically through the lifecycle of a building will help to ward off progressive degradation; conducting a health check of bowtie barriers should provide an early warning of problems and allow for remedial action to be taken.

5 CONCLUSIONS

A bowtie analysis workshop was conducted by the Engineering Council's Competence Steering Group, Building a Safer Future, Working Group 1: Engineers on 29th October 2018, to assess the causes, consequences, prevention and mitigation of fire in a typical, existing, occupied HRRB.

The workshop output is presented in the form of a detailed bowtie diagram. A full range of barriers has been identified for all threat and consequence branches (except social/psychological impact of a building fire, which is the remit of a different working group). All barriers have critical equipment and supporting documents highlighted and barrier owners assigned. A table listing all the prevention and mitigation measures, sorted by responsible party, is also provided.

It is important that the designers, project team and management company recognise where their highest exposures lie. For the current bowtie diagram it is noted that a frequently occurring threat for fire within an apartment (arising from human action) also has the fewest and least effective barriers in place. Also, unusually in comparison to major hazard industries where bowties have been used traditionally, the threat branches overall each have a relatively low number of barriers and this places a greater reliance on the mitigation (right side) barriers rather than preventive measures.

It is therefore concluded that the objectives of the workshop have been met, specifically:

- the various measures which prevent or mitigate fire in an HRRB have been collected together, into one overarching bowtie diagram;
- the bowtie provides a template and reference point for fire risk management that can evolve with the lifecycle of the building, allowing knowledge and information to be transferred as the building transitions from early through detailed design, to construction and commissioning, and into occupancy;
- the bowtie diagram and tabulated supporting information is easily understood and may discourage development of a large, impenetrable safety case document;
- representatives from a range of engineering institutions participated in the workshop and contributed to the final bowtie diagram.

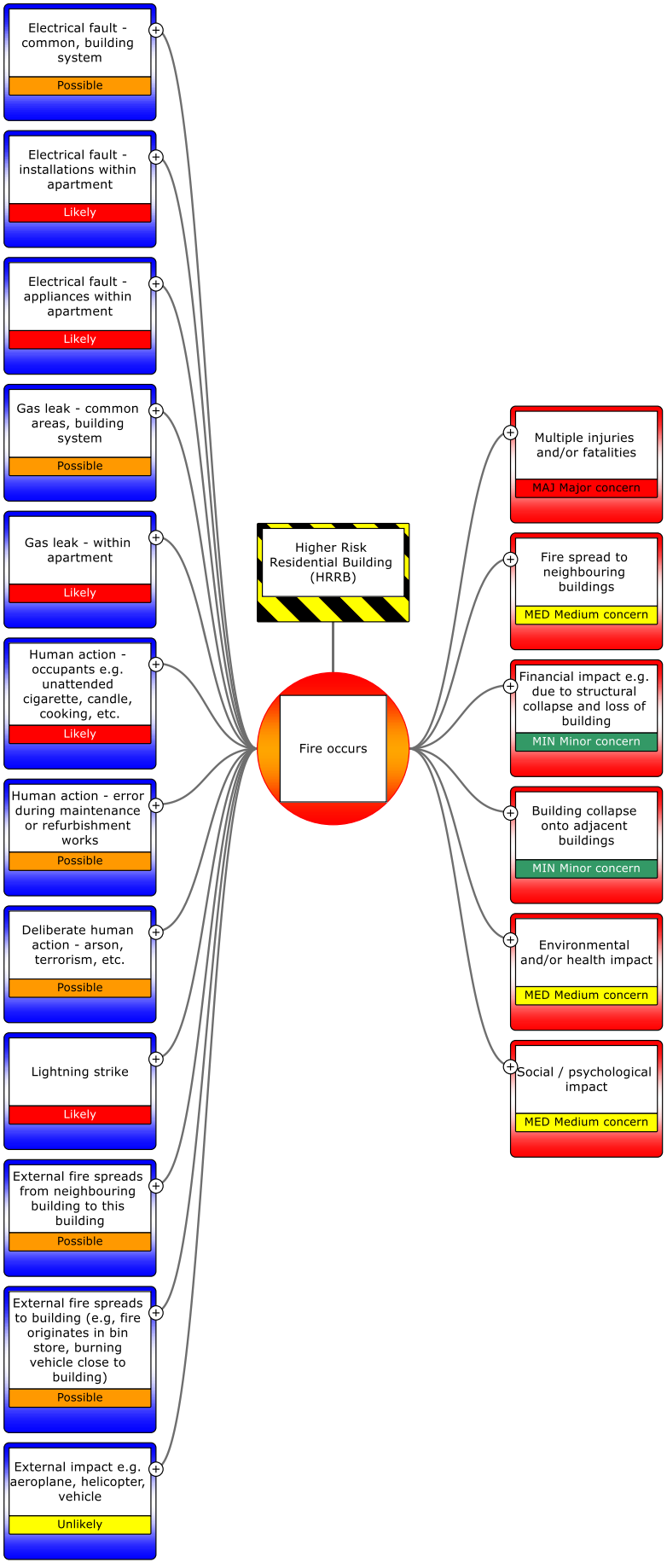
Ultimately the future use of the bowtie will be decided by the working group/IRG, however suggestions include:

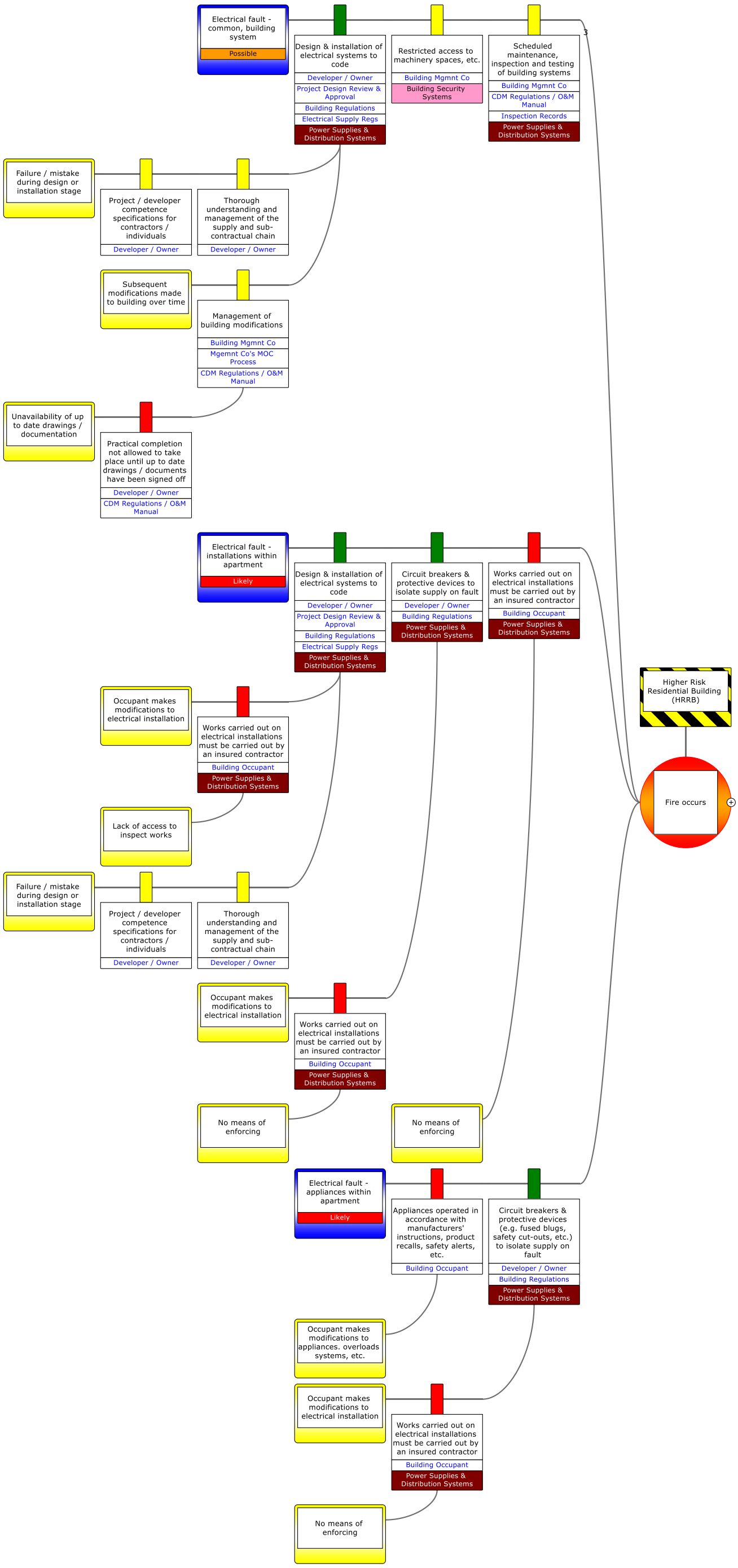
- as a template of expectations / good practice, for individual projects or existing buildings to use as a starting point, to develop their own bowtie analysis of their fire risk management provision;
- as an audit checklist for verifying arrangements comply with expectations and raising recommendations where expectations are not met;
- to highlight the importance of management of changes and modifications which may otherwise undermine the effectiveness of fire prevention or mitigation barriers;
- to conduct a periodic health check through the lifecycle of a building to avoid progressive degradation, provide an early warning of potential problems and allow for remedial action to be taken.

6 REFERENCES

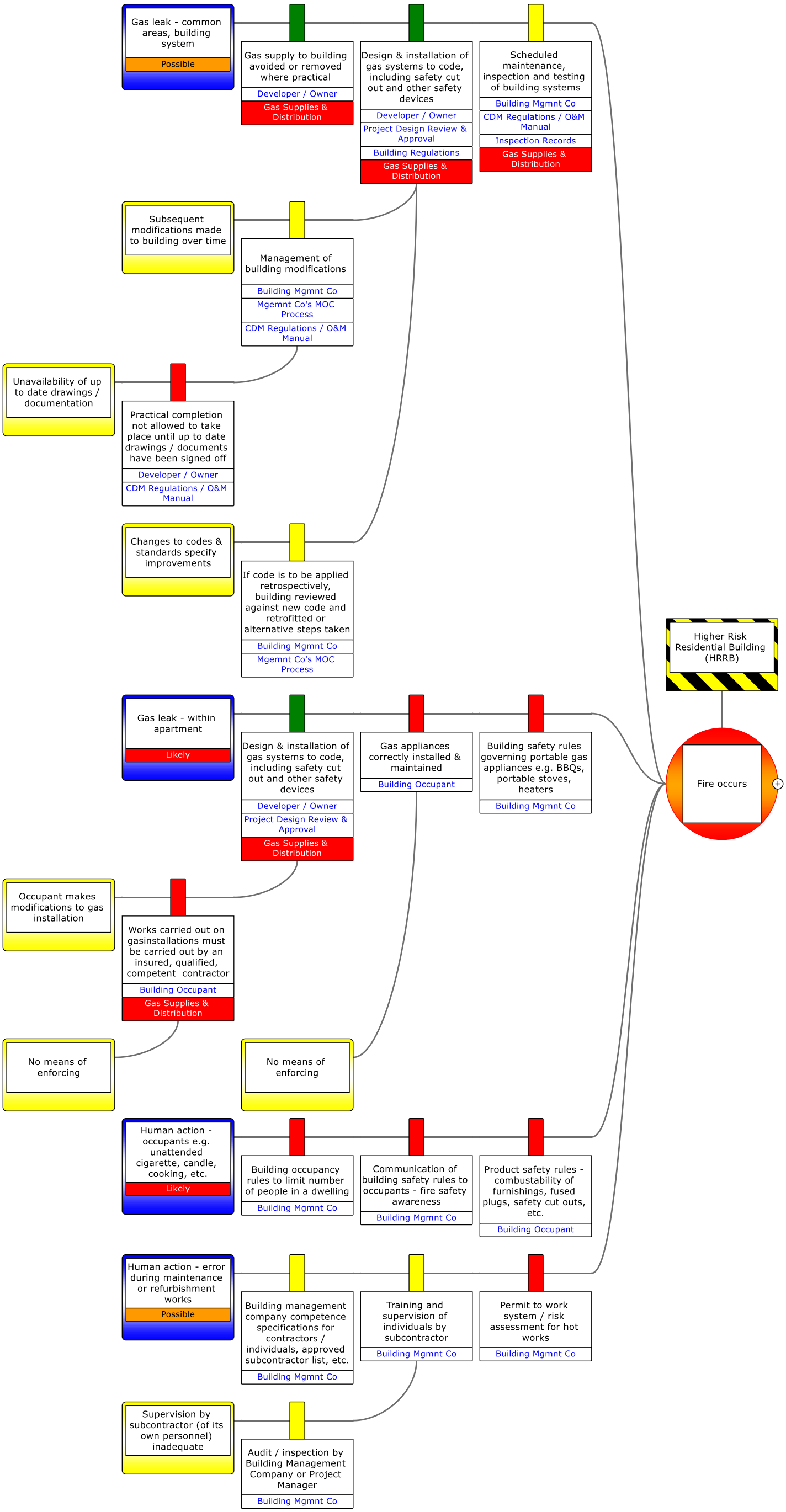
1. Building a Safer Future – Independent Review of Building Regulations and Fire Safety: Final Report, May 2018.

Appendix A DETAILED BOWTIE DIAGRAM – FIRE IN A HRRB

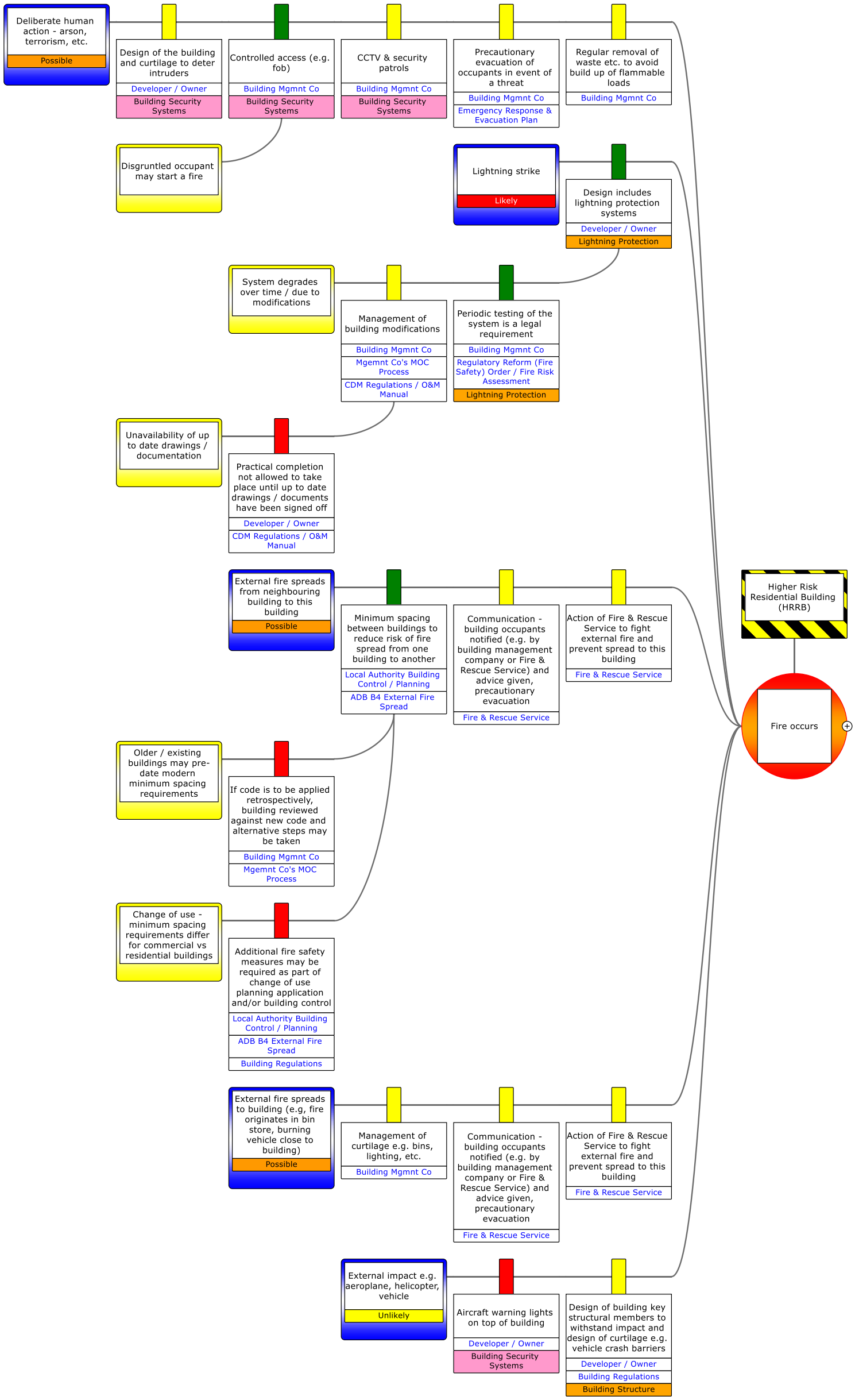




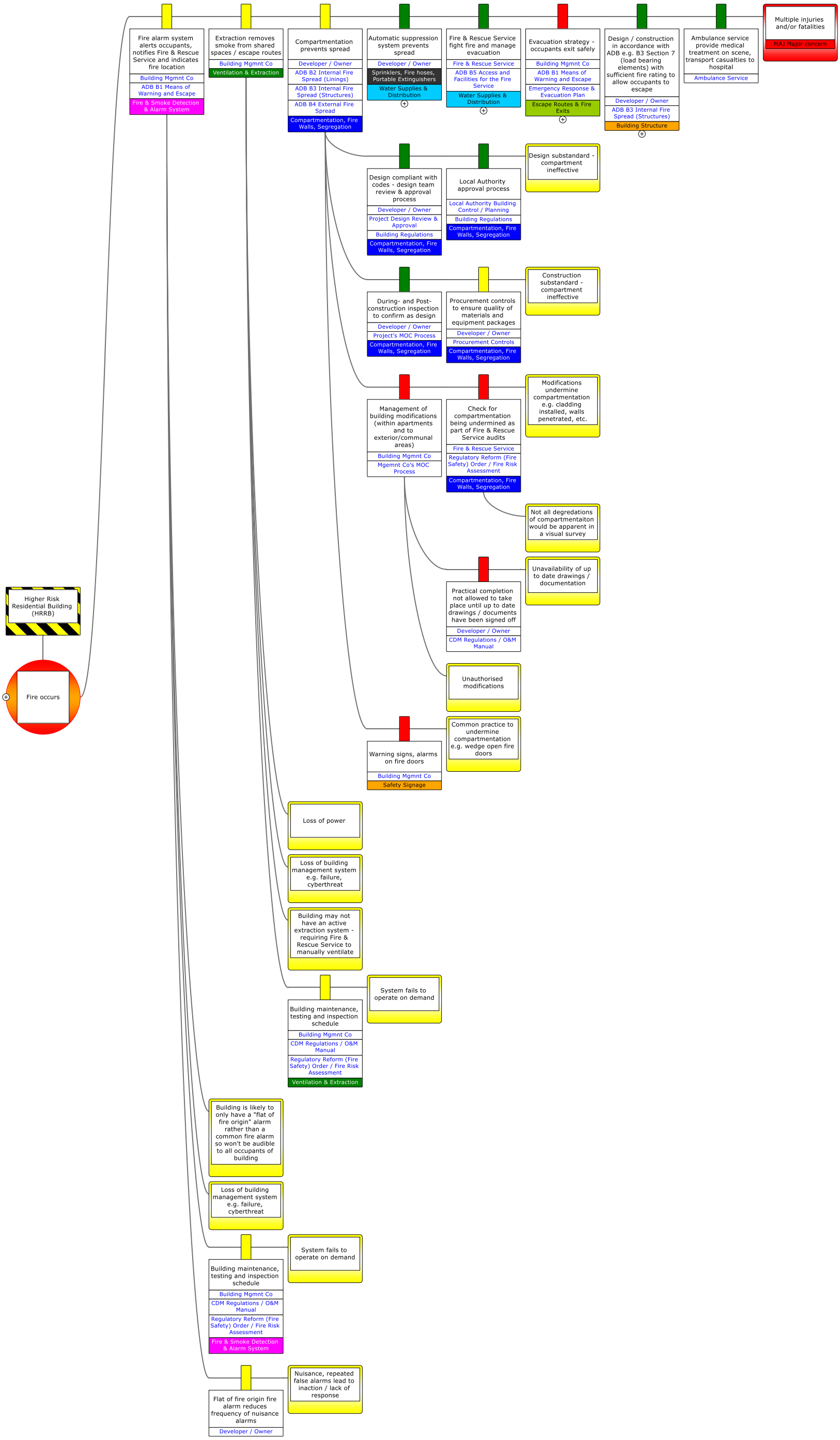
Threat Branches 1, 2 and 3 all barriers fully expanded



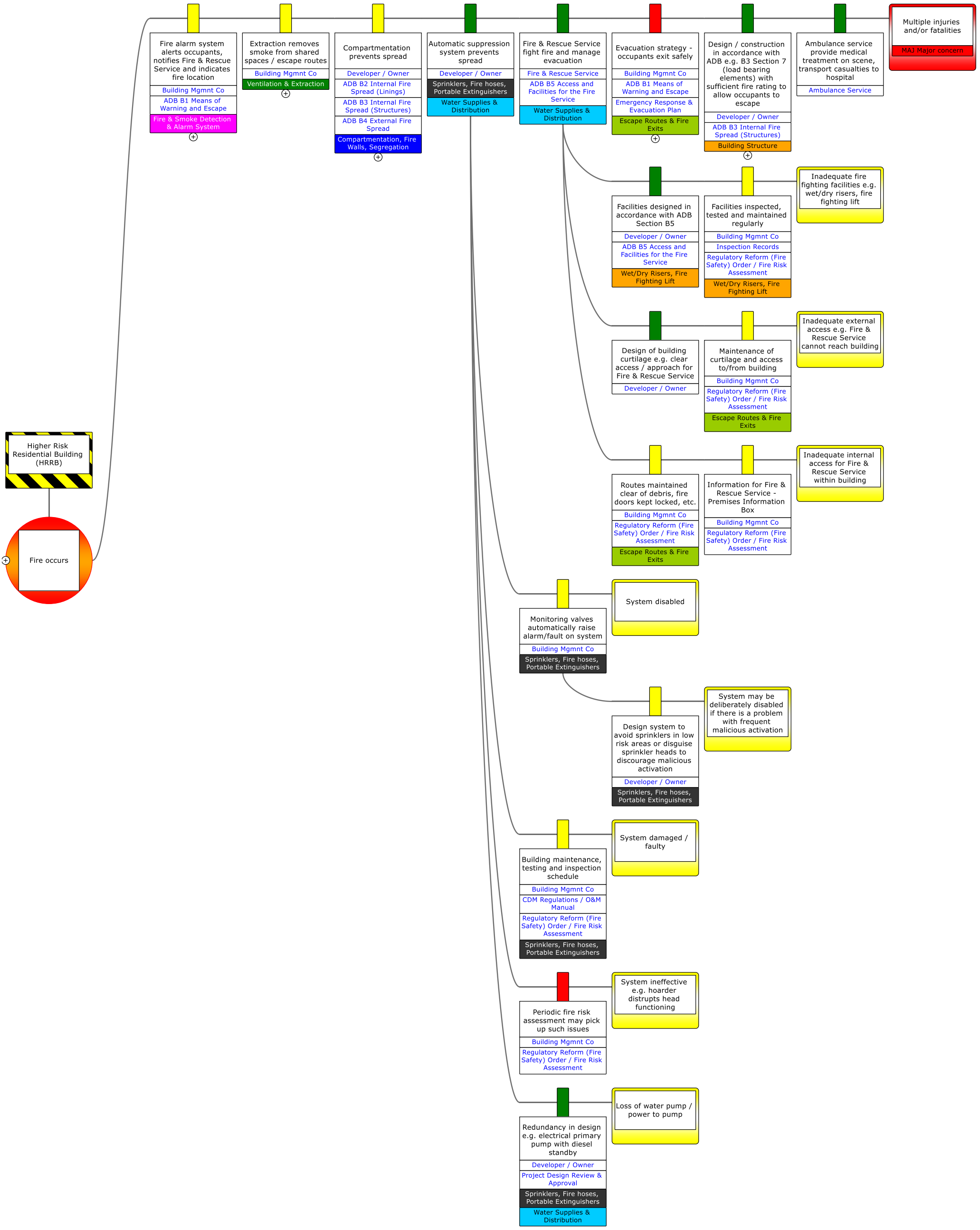
Threat Branches 4 to 7, all barriers fully expanded



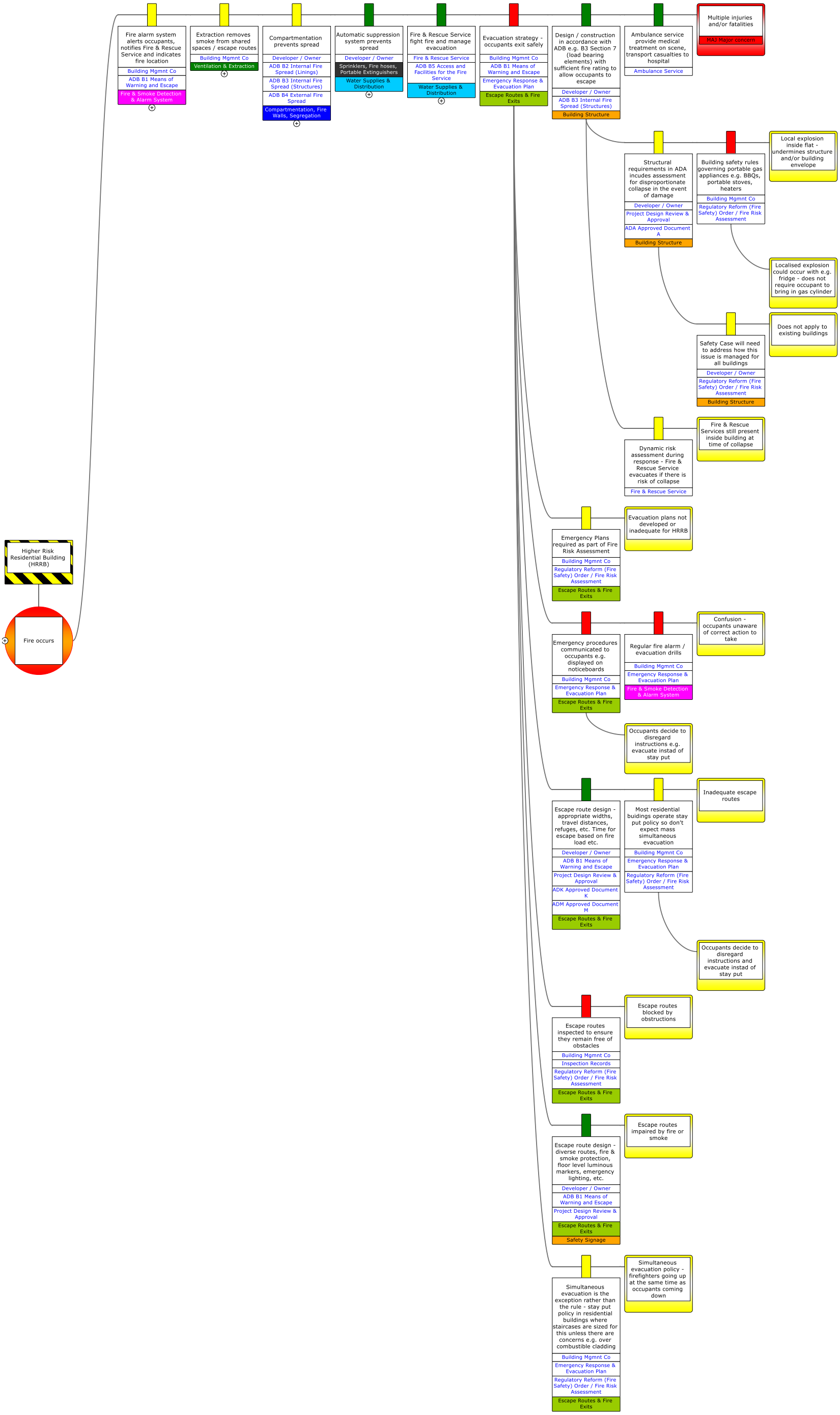
Threat Branches 8 to 12, all barriers fully expanded



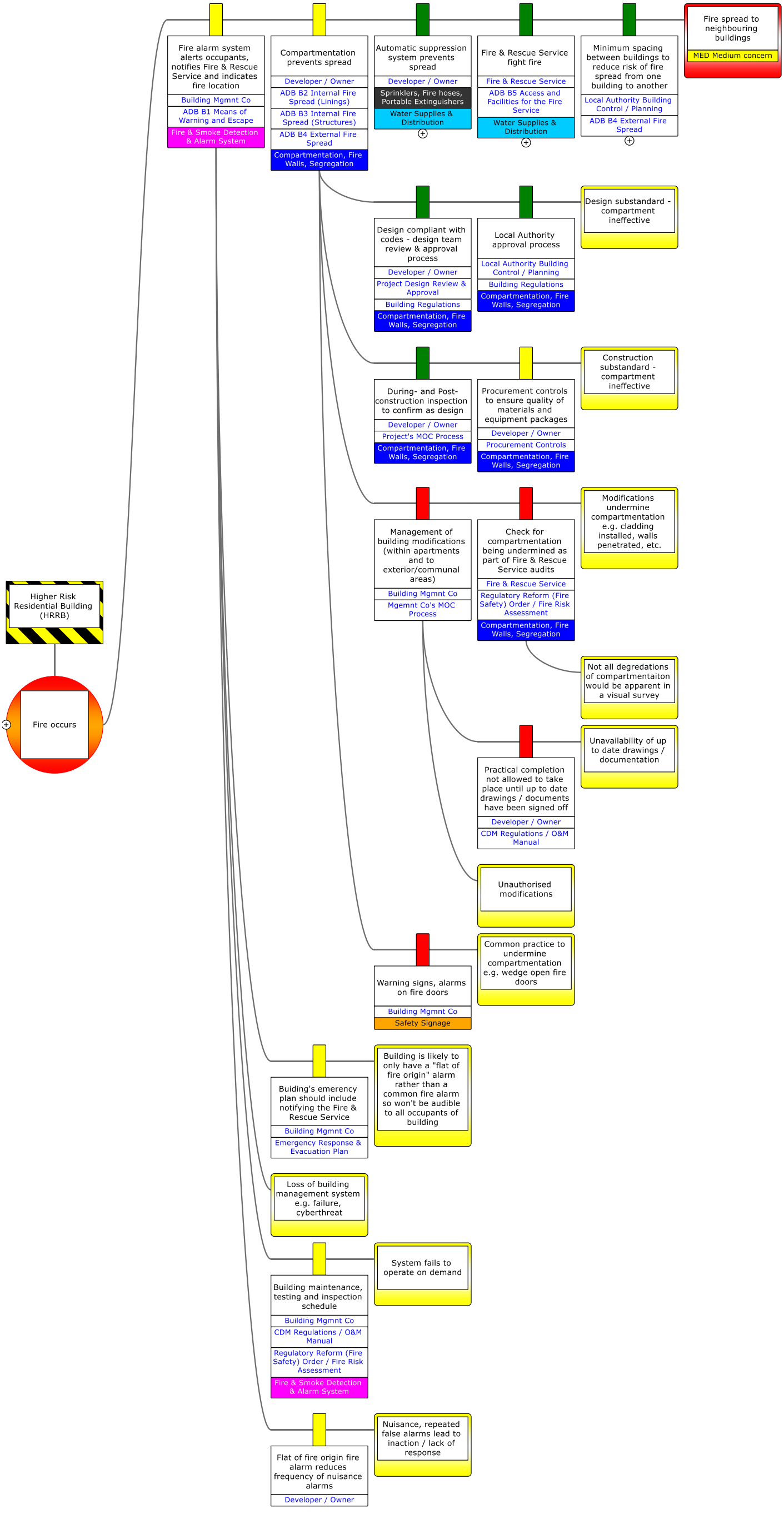
Consequence Branch 1, Barriers 1, 2 and 3 fully expanded



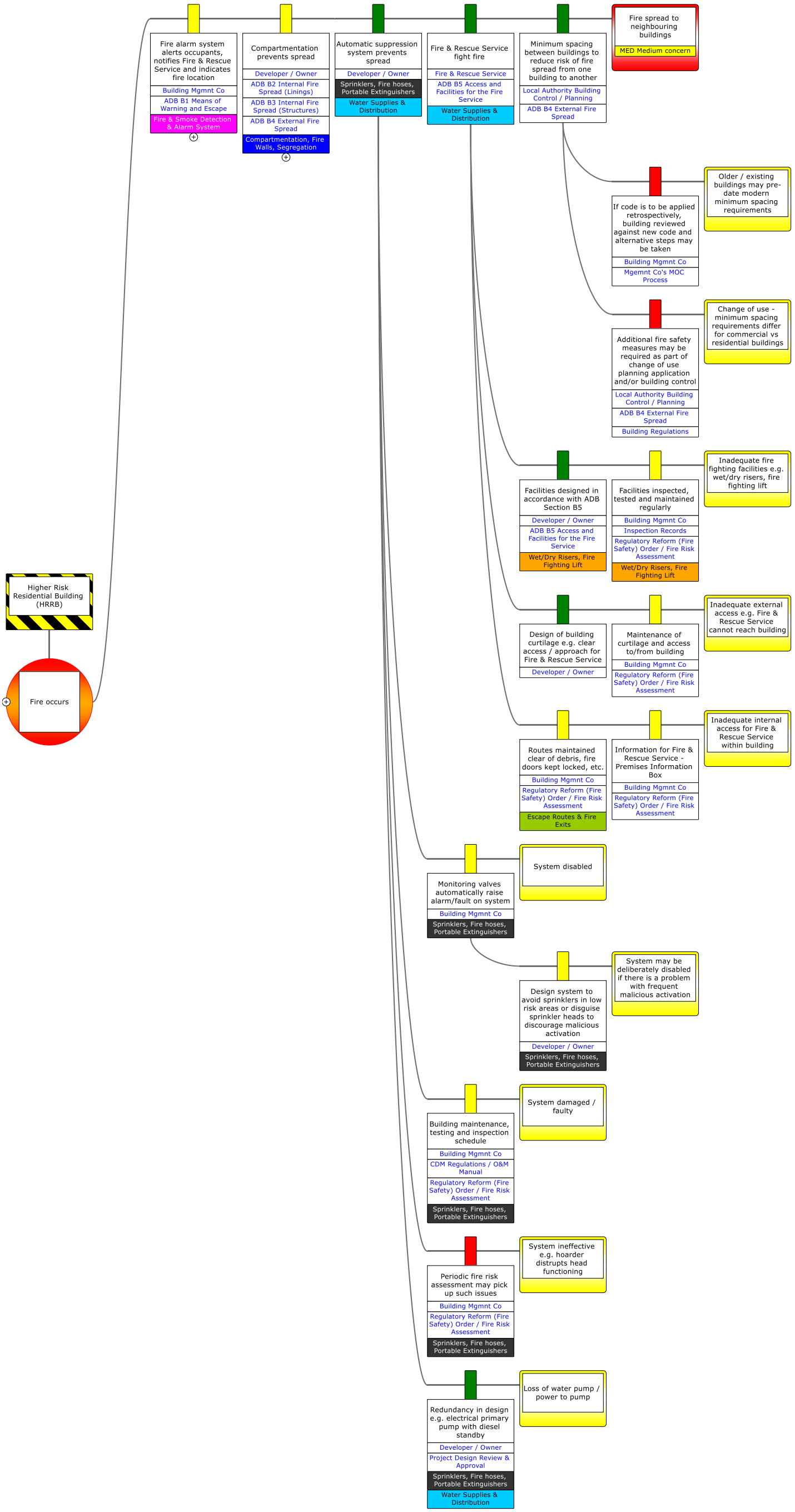
Consequence Branch 1, Barriers 4 and 5 fully expanded



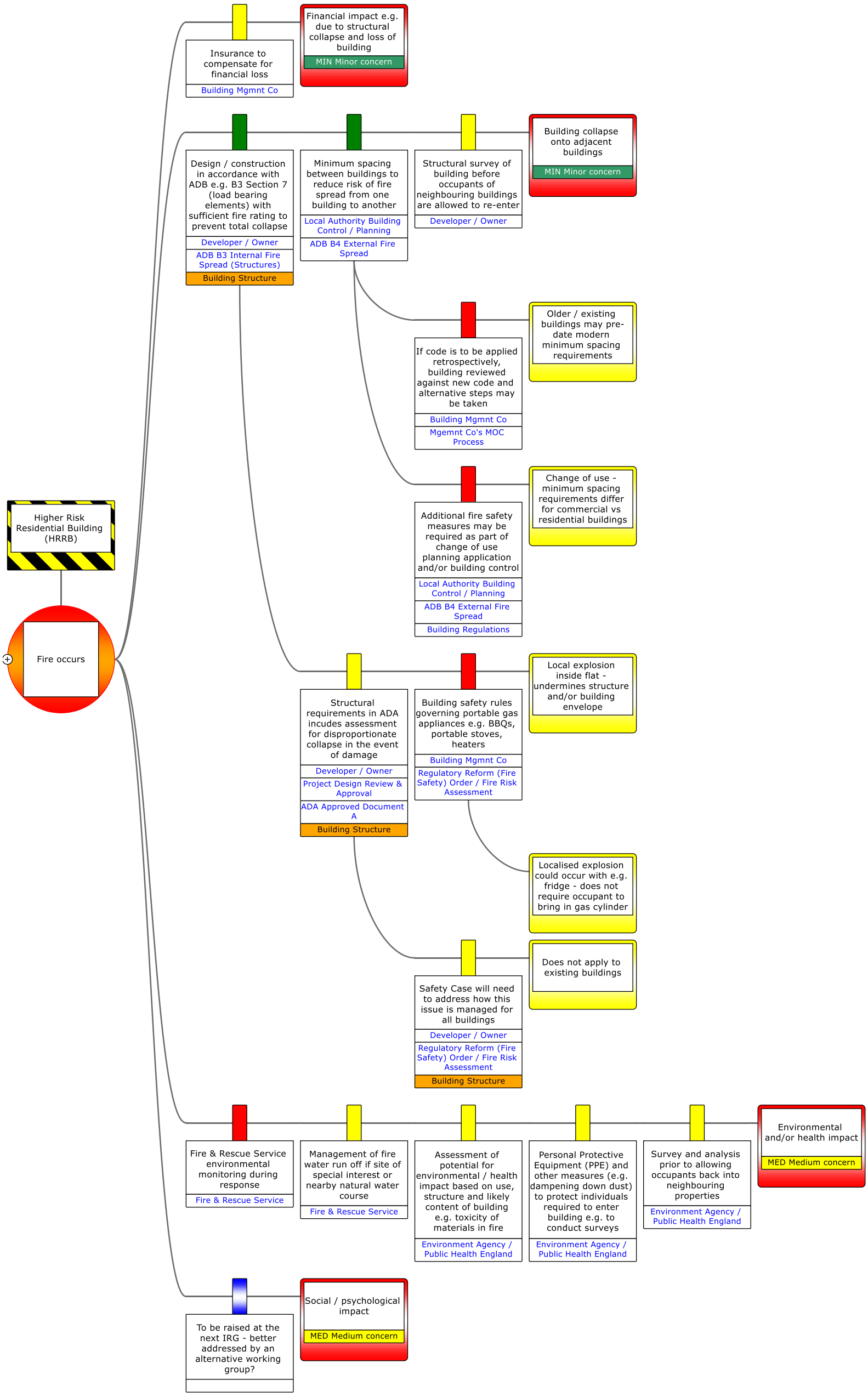
Consequence Branch 1, Barriers 6 and 7 fully expanded



Consequence Branch 2, Barriers 1 and 2 fully expanded



Consequence Branch 2, Barriers 3, 4 and 5 fully expanded



Consequence Branches 3 to 6, all Barriers fully expanded

Appendix B FIRE IN A HRRB – PREVENTION AND MITIGATION MEASURES

Accountable	Barrier	No	Effectiveness
Ambulance Service	Ambulance service provide medical treatment on scene, transport casualties to hospital		Effective
Building Mgmnt Co	Audit / inspection by Building Management Company or Project Manager		Partially Effective
Building Mgmnt Co	Building's emergency plan should include notifying the Fire & Rescue Service		Partially Effective
Building Mgmnt Co	Building maintenance, testing and inspection schedule	**5**	Partially Effective
Building Mgmnt Co	Building management company competence specifications for contractors / individuals, approved subcontractor list, etc.		Partially Effective
Building Mgmnt Co	Building occupancy rules to limit number of people in a dwelling		Ineffective
Building Mgmnt Co	Building safety rules governing portable gas appliances e.g. BBQs, portable stoves, heaters	**3**	Ineffective
Building Mgmnt Co	CCTV & security patrols		Partially Effective
Building Mgmnt Co	Communication of building safety rules to occupants - fire safety awareness		Ineffective
Building Mgmnt Co	Controlled access (e.g. fob)		Effective
Building Mgmnt Co	Emergency Plans required as part of Fire Risk Assessment		Partially Effective
Building Mgmnt Co	Emergency procedures communicated to occupants e.g. displayed on noticeboards		Ineffective
Building Mgmnt Co	Escape routes inspected to ensure they remain free of obstacles		Ineffective
Building Mgmnt Co	Evacuation strategy - occupants exit safely		Ineffective
Building Mgmnt Co	Extraction removes smoke from shared spaces / escape routes		Partially Effective
Building Mgmnt Co	Facilities inspected, tested and maintained regularly	**2**	Partially Effective
Building Mgmnt Co	Fire alarm system alerts occupants, notifies Fire & Rescue Service and indicates fire location	**2**	Partially Effective
Building Mgmnt Co	If code is to be applied retrospectively, building reviewed against new code and alternative steps may be taken	**3**	Ineffective
Building Mgmnt Co	If code is to be applied retrospectively, building reviewed against new code and retrofitted or alternative steps taken		Partially Effective
Building Mgmnt Co	Information for Fire & Rescue Service - Premises Information Box	**2**	Partially Effective
Building Mgmnt Co	Insurance to compensate for financial loss		Partially Effective
Building Mgmnt Co	Maintenance of curtilage and access to/from building	**2**	Partially Effective
Building Mgmnt Co	Management of building modifications	**3**	Partially Effective
Building Mgmnt Co	Management of building modifications (within apartments and to exterior/communal areas)	**2**	Ineffective
Building Mgmnt Co	Management of curtilage e.g. bins, lighting, etc.		Partially Effective
Building Mgmnt Co	Monitoring valves automatically raise alarm/fault on system	**2**	Partially Effective
Building Mgmnt Co	Most residential buidings operate stay put policy so don't expect mass simultaneous evacuation		Partially Effective
Building Mgmnt Co	Periodic fire risk assessment may pick up such issues	**2**	Ineffective
Building Mgmnt Co	Periodic testing of the system is a legal requirement		Effective
Building Mgmnt Co	Permit to work system / risk assessment for hot works		Ineffective
Building Mgmnt Co	Precautionary evacuation of occupants in event of a threat		Partially Effective
Building Mgmnt Co	Regular fire alarm / evacuation drills		Ineffective
Building Mgmnt Co	Regular removal of waste etc. to avoid build up of flammable loads		Partially Effective
Building Mgmnt Co	Restricted access to machinery spaces, etc.		Partially Effective
Building Mgmnt Co	Routes maintained clear of debris, fire doors kept locked, etc.	**2**	Partially Effective
Building Mgmnt Co	Scheduled maintenance, inspection and testing of building systems	**2**	Partially Effective
Building Mgmnt Co	Simultaneous evacuation is the exception rather than the rule - stay put policy in residential buildings where staircases are sized for this unless there are concerns e.g. over combustible cladding		Partially Effective
Building Mgmnt Co	Training and supervision of individuals by subcontractor		Partially Effective
Building Mgmnt Co	Warning signs, alarms on fire doors	**2**	Ineffective
Building Occupant	Appliances operated in accordance with manufacturers' instructions, product recalls, safety alerts, etc.		Ineffective
Building Occupant	Gas appliances correctly installed & maintained		Ineffective
Building Occupant	Product safety rules - combustability of furnishings, fused plugs, safety cut outs, etc.		Ineffective
Building Occupant	Works carried out on electrical installations must be carried out by an insured contractor	**4**	Ineffective
Building Occupant	Works carried out on gas installations must be carried out by an insured, qualified, competent contractor		Ineffective
Developer / Owner	Aircraft warning lights on top of building		Ineffective
Developer / Owner	Automatic suppression system prevents spread	**2**	Effective
Developer / Owner	Circuit breakers & protective devices (e.g. fused plugs, safety cut-outs, etc.) to isolate supply on fault		Effective
Developer / Owner	Circuit breakers & protective devices to isolate supply on fault		Effective
Developer / Owner	Compartmentation prevents spread	**2**	Partially Effective
Developer / Owner	Design & installation of electrical systems to code	**2**	Effective
Developer / Owner	Design & installation of gas systems to code, including safety cut out and other safety devices	**2**	Effective

Accountable	Barrier	No	Effectiveness
Developer / Owner	Design / construction in accordance with ADB e.g. B3 Section 7 (load bearing elements) with sufficient fire rating to allow occupants to escape		Effective
Developer / Owner	Design / construction in accordance with ADB e.g. B3 Section 7 (load bearing elements) with sufficient fire rating to prevent total collapse		Effective
Developer / Owner	Design compliant with codes - design team review & approval process	**2**	Effective
Developer / Owner	Design includes lightning protection systems		Effective
Developer / Owner	Design of building curtilage e.g. clear access / approach for Fire & Rescue Service	**2**	Effective
Developer / Owner	Design of building key structural members to withstand impact and design of curtilage e.g. vehicle crash barriers		Partially Effective
Developer / Owner	Design of the building and curtilage to deter intruders		Partially Effective
Developer / Owner	Design system to avoid sprinklers in low risk areas or disguise sprinkler heads to discourage malicious activation	**2**	Partially Effective
Developer / Owner	During- and Post-construction inspection to confirm as design	**2**	Effective
Developer / Owner	Escape route design - appropriate widths, travel distances, refuges, etc. Time for escape based on fire load etc.		Effective
Developer / Owner	Escape route design - diverse routes, fire & smoke protection, floor level luminous markers, emergency lighting, etc.		Effective
Developer / Owner	Facilities designed in accordance with ADB Section B5	**2**	Effective
Developer / Owner	Flat of fire origin fire alarm reduces frequency of nuisance alarms	**2**	Partially Effective
Developer / Owner	Gas supply to building avoided or removed where practical		Effective
Developer / Owner	Practical completion not allowed to take place until up to date drawings / documents have been signed off	**5**	Ineffective
Developer / Owner	Procurement controls to ensure quality of materials and equipment packages	**2**	Partially Effective
Developer / Owner	Project / developer competence specifications for contractors / individuals	**2**	Partially Effective
Developer / Owner	Redundancy in design e.g. electrical primary pump with diesel standby	**2**	Effective
Developer / Owner	Safety Case will need to address how this issue is managed for all buildings	**2**	Partially Effective
Developer / Owner	Structural requirements in ADA incudes assessment for disproportionate collapse in the event of damage	**2**	Partially Effective
Developer / Owner	Structural survey of building before occupants of neighbouring buildings are allowed to re-enter		Partially Effective
Developer / Owner	Thorough understanding and management of the supply and sub-contractual chain	**2**	Partially Effective
Environment Agency / Public Health England	Assessment of potential for environmental / health impact based on use, structure and likely content of building e.g. toxicity of materials in fire		Partially Effective
Environment Agency / Public Health England	Personal Protective Equipment (PPE) and other measures (e.g. dampening down dust) to protect individuals required to enter building e.g. to conduct surveys		Partially Effective
Environment Agency / Public Health England	Survey and analysis prior to allowing occupants back into neighbouring properties		Partially Effective
Fire & Rescue Service	Action of Fire & Rescue Service to fight external fire and prevent spread to this building	**2**	Partially Effective
Fire & Rescue Service	Check for compartmentation being undermined as part of Fire & Rescue Service audits	**2**	Ineffective
Fire & Rescue Service	Communication - building occupants notified (e.g. by building management company or Fire & Rescue Service) and advice given, precautionary evacuation	**2**	Partially Effective
Fire & Rescue Service	Dynamic risk assessment during response - Fire & Rescue Service evacuates if there is risk of collapse		Partially Effective
Fire & Rescue Service	Fire & Rescue Service environmental monitoring during response		Ineffective
Fire & Rescue Service	Fire & Rescue Service fight fire		Effective
Fire & Rescue Service	Fire & Rescue Service fight fire and manage evacuation		Effective
Fire & Rescue Service	Management of fire water run off if site of special interest or nearby natural water course		Partially Effective
Local Authority Building Control / Planning	Additional fire safety measures may be required as part of change of use planning application and/or building control	**3**	Ineffective
Local Authority Building Control / Planning	Local Authority approval process	**2**	Effective

Accountable	Barrier	No	Effectiveness
Local Authority Building Control / Planning	Minimum spacing between buildings to reduce risk of fire spread from one building to another	**3**	Effective

RISKTEC OFFICES

PRINCIPAL OFFICE
Risktec Solutions Ltd
Wilderspool Park
Greenall's Avenue
Warrington
WA4 6HL
United Kingdom
Tel +44 (0) 1925 611 200
enquiries@risktec.tuv.com

TÜV RHEINLAND HEADQUARTERS
TÜV Rheinland Group
Industrial Services
Am Grauen Stein
51105 Cologne, Germany
tuv.com

EUROPE
Aberdeen
Crawley
Derby
Edinburgh
Glasgow
London
Rijswijk

MIDDLE EAST
Dubai
Muscat

NORTH AMERICA
Calgary
Houston

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