High Rise Residential Buildings: Preliminary Serious Incident Scenarios and Potential Control Measures

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The Grenfell Tower disaster, 14 June 2017, killed 72 people and injured more than 70 others. The subsequent Independent Review of Building Regulations and Fire Safety concluded that the UK building safety system is inadequate. The Government accepted the review's recommendation for a new regulatory framework. A Joint Regulators' Group, including the Health and Safety Executive, is assisting in the transition to this proposed framework.

This report describes research, done in 2019, for the Joint Regulators' Group. The research aims to identify a preliminary set of representative serious incident scenarios for high rise residential buildings, and potential control measures. The researchers: reviewed the literature on high rise building incidents, and the regulation of major rail and industrial incidents; and conducted workshops to extract critical knowledge from sector representatives. The research team has experience in safety case regimes, risk management, building construction, and fire. They used formal risk analysis techniques ('HAZID' and 'bow tie') to structure the process, and a Hierarchy of Controls approach to rank the effectiveness of potential control measures. They considered rapidly escalating events requiring immediate large scale emergency response. The report identifies ten preliminary representative serious incident scenarios. The potential control measures identified for consideration include: establishing a safety regime based on assessment of serious incident scenarios; development of an initial safety narrative for each building; near-miss incident recording; guidance for duty holders; and strong and committed leadership from dutyholders, the wider sector, and the future regulator. These findings are being used to inform the development of a risk framework for the proposed new safety case regime.

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High Rise Residential Buildings: Preliminary Serious Incident Scenarios and Potential Control Measures

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Key messages

Following the Grenfell disaster, the Independent Review of Building Regulations Fire Safety recommended a new regulatory framework for building safety in the UK. This research report describes work done for the Joint Regulators' Group, which was set up to assist in the transition to this proposed framework.

The research aims to identify a preliminary set of serious incident scenarios for high rise residential buildings, and potential control measures. For high rise residential buildings, a serious incident scenario might be considered an escalation of a rapid onset event that could adversely affect the health and safety of people and nearby infrastructure from: fire, explosion, and structural damage. Significant incident scenarios have been developed taking into account information obtained during workshops with sector representatives. The scenarios consider rapid escalation events that could lead to major consequences, usually requiring immediate and significant emergency response. Key areas for consideration from the identification of these scenarios include:

- Fires in a flat/unit in a high rise residential building
- Fires on a balcony
- Maintaining escape routes
- Dealing with unmanaged changes
- Addressing issues at the design phase is more effective in many cases
- The importance of monitoring and maintenance
- Use of multiple independent risk controls (layers of protection) for adequate resilience

The work has outlined that a safety case regime would be possible for high rise residential buildings but would bring a number of challenges that would need to be overcome.

Outcomes identified for consideration include:

- A safety regime for high rise residential buildings could be established based on an assessment of significant incident scenarios within the building, clearly identifying how they are prevented from turning into significant incidents.
- An initial safety narrative could be developed for each building as a starting point to aid dutyholders in identifying reasonably practicable risk controls and to allow the sector to become familiar with managing significant incident risks.
- Near-miss incident recording could be included as part of the safety narrative process to develop understanding of what works and when it works.
- Guidance could be developed to help dutyholders understand how to assess and manage significant incident risks associated with buildings in scope, and how they can disseminate the necessary safety information in an appropriate format.
- The need for strong and committed leadership from dutyholders, the wider sector, and from the regulator.

Executive summary

Following the Grenfell disaster, the Independent Review of Building Regulations Fire Safety recommended a new regulatory framework for building safety in the UK. This research report describes work done for the Joint Regulators' Group, which was set up to assist in the transition to this proposed framework.

The project scope was solely on high rise residential buildings. The term Higher-Risk Building (HRB), as used in the draft Building Safety Bill, however, has been primarily adopted throughout this report.

Aims

The work primarily aimed to:

- identify an initial representative set of significant incident scenarios for HRBs, and
- establish what kind of initial control measures could potentially prevent and mitigate the effects of significant incidents involving HRBs.

The main focus was on identifying significant incident scenarios for escalation from:

- Fire
- Explosion
- Structural Damage

The research project examined a wider scope to obtain additional supporting information for these types of event, but also to ensure that there were no obvious other hazards that should be included when assessing significant incident scenarios.

Method

This project was carried out over a 6-month period with completion of the work at the end of December 2019. The research team had experience in safety case regimes, risk management, building construction, and fire. There was a two-phased approach to the research.

The first phase consisted of an initial 'landscape mapping' exercise to obtain background information on the current state of the industry and to assess how existing health and safety mechanisms could be applied to building safety. This included:

- A literature review of high rise building incidents and existing building safety techniques
- A review of existing regulatory approaches for managing safety for significant hazards
- Consideration of what would constitute a significant incident in a HRB and how existing health and safety risk considerations could apply in these cases

- Identifying a list of sector stakeholders to engage in workshops to obtain pertinent industry opinion

The second phase consisted of a series of workshops with sector stakeholder representatives to obtain the views, opinions, and perspectives of those interested in HRB safety. Five workshops were held between the dates of 22 November 2019 and 28 November 2019. The participants included:

- Local Authority staff with responsibility for HRBs
- Fire and Rescue Service representatives
- Industry / Professional Bodies (e.g. engineering, construction, gas networks etc.)
- Early adopters' of HRB risk management practices (e.g. safety cases)

The workshops consisted of exercises to obtain sector stakeholder opinions to obtain a holistic overview of HRB risks and how these risks could be managed in the future.

Findings and conclusions

A simple definition of a significant incident in this context is an occurrence that has the potential to adversely impact the health or safety of many people.

A significant incident risk is then the likelihood that a number of people are harmed from that incident occurring.

The management of significant incidents places a serious emphasis on plausible high consequence incidents. This differs from the management of an individual's health and safety risks, which more holistically consider the likelihood and consequence in combination for a given risk.

This definition for a significant incident for a HRB includes the concept of a rapidly escalating event, where an initial incident quickly leads to significant (i.e. major) consequences requiring immediate large scale emergency response. The consequences could include multiple fatalities, multiple injuries or cases of serious ill-health, and/or significant property damage.

Examples of a significant incident for a HRB might include a single event that:

- has the potential to impact occupant safety on more than one floor of the building.
- has the potential to cause harm to occupants across multiple compartments. This may most specifically apply for a major fire event.
- may produce a 'domino effect': one type of event initiates another type of hazard.
- impacts nearby populations or infrastructure outside of the building.
- may lead to a significant incident being declared.

Significant incident scenarios were identified following a scientific study work programme and a series of five workshops to gather information from key sector stakeholder representatives. These covered fire and structural damage. Explosion events might be an initial cause of both fire and structural damage.

The following types of significant incident fire scenarios were identified:

Single floor scenarios

These types of scenarios are those where a fire spreads by breaching multiple compartmentation across a single floor. This includes spread of fires initiating from residential units, common areas, and local businesses.

Between floor scenarios

Between floor scenarios encompass the escalation of a fire from a single floor to another floor, whether this is from a large single floor fire event or an escalation direct from a single unit fire.

Multiple floor/whole building scenarios

These were scenarios where more than two floors were affected by the fire. This could be a direct escalation from single and between floor scenarios or from fires external to the building affecting multiple floors.

Evacuation scenarios

This was identified as an issue where a failure of evacuation routes escalates a fire event into a potential significant incident.

Emergency response scenarios

These scenario types were to consider how issues with emergency response could escalate a fire event into a potential significant incident. This included factors such as failure in early detection of a fire leading to delays in emergency response, or local access issues making it difficult for emergency services to get close enough to tackle the fire effectively.

Safety system scenarios

Safety system scenarios describe situations where a failure of one or more components of the overarching life safety systems could allow a fire event to escalate into a potential significant incident. In this context, the term life safety systems reflect a holistic overview of the whole system of safety controls within a building such as fire/smoke detection, sprinkler/suppression systems, evacuation routes, etc. and how these all interact with each other to ensure people's safety.

The following types of structural significant incident scenarios were identified:

Structural collapse: Residential Unit/Common Areas/Within Floor scenarios

These types of scenarios included collapse of walls, floors, ceilings, etc. but where only one floor would be significantly affected but could still constitute a significant incident.

Structural collapse: Multiple floor/whole building scenarios

These scenarios were where the structural collapse impacted several floors or the whole building.

A number of high-level measures to manage, control and reduce these risks were identified, largely based on input from the workshops with sector stakeholder representatives.

A Hierarchy of Controls was considered to rank the effectiveness of the measures identified:

- **Elimination:** Redesign such that the hazard is removed or eliminated.
- **Substitution:** Replace the material or process with a less hazardous one.
- **Engineering Controls:** Design measures that help control or mitigate risks such as barriers, guards, sprinkler systems, automatic ventilation systems, etc.
- **Administrative Controls:** Identifying and implementing procedures to improve safety.
- **Personal Protective Equipment (PPE):** PPE is specialised clothing or equipment that provides protection from health and safety hazards.

Controls higher up the hierarchy are considered more effective. The most effective controls eliminate or reduce the risks at a level that can improve safety for the greatest number of people but can also establish multiple layers of protection, where additional local controls can be identified to help mitigate risks.

A key control measure identified to help effectively manage HRB significant incident risks included clear identification of roles, responsibilities and accountability for the managing of those risks. Competency in the design and management of HRBs were also identified as key. Making effective use of risk assessments by undertaking and implementing the actions arising was also identified as important.

It was also identified that strong and committed leadership will be required to ensure that building risks are being managed properly. This is likely to be one of the roles of dutyholders as may be defined in relevant legislation, but also includes commitment and leadership from the wider sector and the regulator.

The observations and feedback from the sector stakeholder participants at the workshops include:

- A safety case regime for HRBs should be established based on an assessment of significant incidents within the HRB and what prevents them from turning into significant incidents.
- Identifying significant incidents in this context should consider, but not be limited to, fire, explosion, and structural events with the potential to rapidly escalate leading to serious consequences and requiring immediate emergency response.
- Including near-miss incident recording as part of the safety narrative process to build up understanding of what works to prevent and mitigate incidents that could potentially escalate to significant incidents. In essence, continuous learning is essential.
- Developing guidance to help dutyholders understand how to be compliant, and how they can provide the necessary safety information in an appropriate format. Guidance produced internally for the regulator could be made publicly available, which would help those writing safety narratives without it becoming a 'tick-box exercise'.
- That the representative scenarios identified during this work programme could be used to ensure that no significant hazards, controls, or mitigations have been overlooked; each building would need to be assessed on a case-by-case basis, however, and should not be ticked off against a checklist.

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1. Introduction

1.1 Project background

Following the Grenfell disaster, the Independent Review of Building Regulations Fire Safety recommended a new regulatory framework for building safety in the UK. This research report describes work done for the Joint Regulators' Group, which was set up to assist in the transition to this proposed framework.

The project scope was solely on high rise residential buildings. The term Higher-Risk Building (HRB), as used in the draft Building Safety Bill, however, has been primarily adopted throughout this report.

The overarching objectives of this research project were to:

- Identify an initial representative set of significant incident scenarios for HRBs.
- Establish initial control measures to prevent and mitigate the effects of significant incidents involving HRBs.

As this work was considering the recommendations in Dame Judith Hackitt's Final Report: *Building a Safer Future* (1), then to correlate to the existing high hazard industries, the term 'major accident scenario', and other similar terminology, has been used throughout the rest of this document to refer to potential incidents for which the risk should be managed.

The identification of major accident scenarios focused on the escalation of events involving:

- Fire
- Explosion
- Structural Damage

The research considered a broader scope than these three areas. This was to derive supporting information for human factors elements, and a wider consideration of root causes leading to such events, which can influence important prevention and mitigation controls for managing such risks.

An additional reason for a broader scope in the research was to ensure that the initial assumptions that these events were the main hazards to be considered when assessing HRB safety were valid. Consideration of a wider range of hazards ensured that there were no obvious other hazards that should be included when assessing major accident scenarios for HRBs.

During the project delivery, there were two building fires in the UK that received significant public and media interest; a fire on a balcony at Markland House, Notting Hill, London (23 August 2019) only 300 metres from Grenfell Tower; and a fire at The Cube student accommodation in Bolton (15 November 2019). These incidents were not considered in this research due to their occurrence during the project delivery phase. Additionally, The Cube is below the 18 m height currently used to define a HRB, albeit only by a few centimetres. It is also important to note that the Phase 1 Report of the Grenfell Tower Inquiry was published during the project delivery and was therefore also not included in the review.

1.2 Context of this report

This report draws together knowledge from HSE's experience as a regulator and in-house expertise on various aspects of risk management, building construction and fire. HSE also contracted input from Ove Arup and Partners, a major consultancy firm with experience in the design and management of HRB construction.

Input was also sought from other key sector stakeholders and literature sources. It should be borne in mind that the findings and recommendations of this report are based on these foundations. This report is not intended to provide a policy steer but to aid the assessment of next steps. The information provided can be used, whilst taking into consideration the wider context of changing building safety regulation. This is likely to be an ongoing, iterative process.

2. Major accident hazard scenarios for higher risk buildings

2.1 Hazard and risk

Throughout this document, reference is made to hazards and risks. These two words are often used interchangeably in everyday language, but each has a specific meaning when applied to health and safety (2).

- **Hazard:** *"The potential for harm arising from an intrinsic property or disposition of something to cause detriment"* (2, p. 16). In other words, a hazard is something, or an event, that could lead to harm or damage.
- **Risk:** *"The chance that someone or something that is valued will be adversely affected in a stipulated way by a hazard."* (2, p. 16). In other words, a risk is the possibility that a person is harmed, or something is damaged, from a hazard occurring.

A risk can be expressed as the likelihood of a consequence of the hazard occurring. In the health and safety context, the consequence is the level of harm, or damage, experienced from the realisation of the hazard.

It is often useful to be explicit in defining the type of hazard or risk being described, otherwise different types of hazard or risk could be compared leading to incorrect conclusions. E.g. the risk of an event occurring that could lead to harm and the risk of someone being harmed once an event has occurred are quite different interpretations of an event that could cause confusion if not properly defined.

2.1.1 Major accident hazards and risks

A simple definition of a major accident hazard is an occurrence that has the potential to adversely impact the health or safety of many people. A major accident risk is then the likelihood that a number of people are harmed from that hazard occurring.

A major accident hazard is therefore a potentially high consequence event (e.g. multiple injuries or deaths, serious damage to property, etc.) if it were to occur. However, as there usually requires a series of failures to lead to these consequences, then major accidents tend to be low likelihood events.

The focus in assessing and managing the risks from these high consequence, low likelihood type of events therefore needs to differ from when considering the 'day-to-day' risks to which people are exposed. There is a greater emphasis on the consequences of such events: what can be done to prevent these consequences? This includes consideration of preventing the event from occurring and minimising the potential consequences.

This is not to say that the likelihood of an event is ignored, and that the worst-consequence case is always assessed; there is the potential to focus on trying to control the wrong hazards if such an approach is adopted. There may be other hazards that have less significant consequences but are much more likely to occur than the 'worst case'. There needs to be a balanced consideration between the likelihood and consequences identified for major accident risks.

2.2 Representative major accident hazard scenarios

A major accident hazard for a higher risk building (HRB) might be considered to be any event that could escalate to affect the health and safety of multiple people outside the immediate area that was originally affected. For HRBs, the relevant events would be:

- Fire
- Explosion
- Structural Damage

Definitions to identify a major accident hazard might include a single event:

- That has the potential to impact occupant safety on more than one floor of the building.
- Where there is the potential to cause harm to occupants across multiple compartmentations. This may most specifically apply for a major fire event.
- Where there may be a 'domino effect': one type of event initiates another type of hazard.
- That impacts nearby populations or infrastructure outside of the building.
- That requires a significant level of emergency response.

Representative major accident hazard scenarios were derived drawing together all the information gathered throughout the research work programme and through a series of workshops with sector stakeholder representatives.

These scenarios focused on rapid onset escalating events that could adversely impact many people and would require immediate emergency response.

Some example initiators for the start and/or escalation of an incident were identified to provide some context for the scenarios identified. High-level control measures to prevent an incident/escalation were considered as were mitigation barriers that could limit escalation and, consequently, the potential impacts from an incident.

The controls identified to prevent and mitigate incidents/escalation were considered against the Hierarchy of Controls (discussed in more detail in Section 3.5.3) to identify which controls would have the most significant effects in reducing HRB major accident risks.

2.3 Fire scenarios

Fire scenarios can generally lead to direct injury and fatality, impaired evacuation, failure to prevent fire spreading, structural failure and subsequent long-term uninhabitable areas, and the building being engulfed by fire. For mixed-use buildings (e.g. where residential and commercial premises share the same building), fires initiated in either a residential or commercial premise could potentially spread to involve some or all of the entire building. The following types of fire scenarios were identified:

2.3.1 Single floor scenarios

These types of scenarios are those where a fire spreads by breaching multiple compartmentation across a single floor. This includes spread of fires initiating from residential units, common areas, and local businesses. Some of the escalation causes identified included work activities in the building, breaching of compartmentation from services and utilities installation, and from human behaviours like the propping open of fire doors.

2.3.2 Between floor scenarios

Between floor scenarios encompass the escalation of a fire from a single floor to another floor, whether this is from a large single floor fire event or an escalation direct from a single unit fire. Causes for the escalation included unsegregated stairwells, access hatches, etc. or through floor services and utilities breaching compartmentation.

2.3.3 Multiple floor/whole building scenarios

Scenarios where more than two floors were affected by the fire. This could be a direct escalation from single and between floor scenarios or from fires external to the building affecting multiple floors. Other escalation causes identified were fires spreading externally via balconies, windows, and through flammable materials on the exterior of the building.

2.3.4 Evacuation scenarios

This was identified as an issue where a failure of evacuation routes escalates a fire event into a potential major hazard accident. There were multiple causes identified for this type of escalation, mainly from building maintenance or human behaviours (e.g. clutter obstructing poorly-maintained escape routes). Smoke and other combustion products from a fire could also contribute to an escalation event.

2.3.5 Emergency response scenarios

These scenario types were to consider how issues with emergency response could escalate a fire event into a potential major hazard accident. This included factors such as failure in early detection of a fire leading to delays in emergency response, or local access issues making it difficult for emergency services to get close enough to tackle the fire effectively. Smoke and combustion products from a fire could also contribute to emergency response issues.

2.3.6 Safety system scenarios

Safety system scenarios describe situations where a failure of one or more components of the overarching life safety systems could allow a fire event to escalate into a potential major accident hazard. In this context, the term life safety systems reflect a holistic overview of the whole system of safety controls within a building such as fire/smoke detection, sprinkler/suppression systems, evacuation routes, etc. and how these all interact with each other to ensure people’s safety. If effective management of fire risks is dependent on the full range of life safety system controls, then a failure of any component could have a knock-on effect to the effectiveness of the whole range of controls.

2.4 Structural collapse scenarios

Structural major accident scenarios involved some degree of structural collapse that can generally lead to injury, fatality, loss of function, loss of asset and failure/damage to services. There is also potential external impact on nearby people, buildings and infrastructures.

2.4.1 Structural collapse: Residential Unit/Common Areas/Within Floor scenarios

These types of scenarios include collapse of walls, floors, ceilings, etc. but where only one floor would be significantly affected but could still constitute a major accident. A range of potential escalation causes were identified, including during works activities, degradation due to ageing, overloading from external impact events, or as a domino effect from the realisation of another hazardous event, such as fire, explosion, or flooding.

2.4.2 Structural collapse: Multiple floor/whole building scenarios

These scenarios were where the structural collapse impacted several floors or the whole building. These events could escalate from the single floor events or could be initiated through a similar set of causes mentioned for the single floor events, such as works, degradation, external impacts and other hazards. An understanding of the range of risks and effective design were identified as the best approaches for dealing with these types of escalation risks.

2.5 Control measures

The high-level control measures were derived from the initial reviews undertaken and from the information gathered at the workshops with sector stakeholder representatives.

This list of controls should not be used blindly as a checklist of controls to manage the risks for a HRB. Rather, these controls should be used as a guide to allow consideration, discussion and identification of building-specific controls that are reasonably practicable to reduce and manage risks and that are appropriate and effective. In many cases, the efficacy of controls is more dependent on their implementation rather than their inherent properties.

The control measures that should be applied for a particular HRB, and the effectiveness of those measures, therefore, needs to be ascertained from assessment of the HRB-specific major accident risks.

Not all of the controls identified will be appropriate for all cases; if it can be demonstrated that a particular type of control measure is not appropriate for a building then there is some assurance that proper consideration has been given to that control and that it has not been accidentally overlooked.

2.5.1 Hierarchy of Controls

A Hierarchy of Controls approach can be used to establish which control measures are most effective at eliminating or reducing risks. This is discussed in more detail in Section 3.5.3.

Consideration has been given to such a hierarchy for the control measures. This analysis helps highlight possible areas to focus on for the most significant returns in risk management improvements. It also allows an assessment of whether current commonly used control measures can be used to give multiple ‘layers of protection’ to manage and reduce major accident risks for HRBs.

The hierarchy of controls used is:

- **Elimination:** Redesign such that the hazard is removed or eliminated.
- **Substitution:** Replace the material or process with a less hazardous one. Care is required to avoid introducing new hazards from the substitution.
- **Engineering Controls:** Design measures that help control or mitigate risks such as barriers, sprinklers, ventilation, etc. Priority should be given to measures that provide collective protection rather than those that just protect individuals or a small group of people.
- **Administrative Controls:** Identifying and implementing procedures to improve safety. For example, increasing safety signage, performing risk assessments, preparing and communicating emergency procedures.

- **Personal Protective Equipment (PPE):** If, despite the preceding levels of control, a hazardous situation arises then it may still be possible to protect people from harm. In many industrial situations this is achieved using PPE, specialised clothing or equipment that provides protection when the hazard to their health or safety is present. People must be familiar with the function and limitations of each item of PPE.

In the context of HRBs, PPE in the standard sense is unlikely to be used by residents. The scope of this is open to interpretation but might include resident-use fire protection equipment, such as fire blankets, or relate to emergency services activity.

Risk reduction measures should be assessed in the order of priority given in the hierarchy. This is because it is recognised that the types of control at the higher level, such as Elimination, are more effective at reducing the risks than those lower down the hierarchy, such as PPE. The costs of more effective controls may be perceived to be a barrier to these controls being implemented (see Section 3.5 for an outline of costs versus benefits). In such a case, there may need to be a greater emphasis on identifying other controls to manage the risks or there may be a need to identify interim controls to be used until the more effective measures can be implemented.

2.5.2 Building controls hierarchy

Many of the controls identified for HRBs from the workshops could be interpreted as being in more than one of the levels of the hierarchy of controls dependent on how effectively the control is implemented. Some examples of the controls identified include:

Elimination:

- Clear roles, responsibilities, and accountability
- Commissioning and testing
- Competency
- Design standards
- Fire safe design
- Future proofing/resilience
- Legal framework including enforcement (may need right to inspect, monitor & repair)

Substitution:

- Alternate escape routes
- Competency
- Design standards
- Fire safe design
- Future proofing/resilience
- Legal framework including enforcement (may need right to inspect, monitor & repair)

Engineering controls:

- Active fire protection: suppression systems (e.g. sprinklers, inerting)
- Alarms
- Alternate escape routes
- Commissioning and testing
- Crash deck
- Design standards
- Fire fighter access and facilities
- Fire safe design
- Passive Fire protection: containment/compartmentation/segregation (e.g. fire doors)
- Strong floors
- Structural monitoring systems
- Underpinning/propping and shoring
- Ventilation

Administrative controls:

- Signage
- Building information/record keeping, including change control
- Building risk assessments, including implementation of control measures
- Communication/resident engagement
- Effective emergency response
- Effective procurement
- Fire risk assessments, including implementation of control measures
- General evacuation plans
- Housekeeping e.g. maintaining clear routes
- Inspection-based and audit preventative maintenance
- Investigation and lessons learnt
- Mandatory incident/near miss reporting
- Personal Emergency Evacuation Plans (PEEPs)
- Risk based inspection and maintenance
- Third party/independent checks
- Up to date information for FRS (building information pack / ‘battle box’)

PPE equivalent controls:

- Fire extinguishers; fire blankets
- Effective use of inbuilt firefighter facilities
- Effective use of passive Fire protection: e.g. fire doors
- Effective use of Personal Emergency Evacuation Plans (PEEPs)
- Effective use of ventilation

2.5.3 Analysis of identified building control types

The analysis undertaken demonstrates that the most common type of control measure identified for HRBs are Administrative Controls. As this is the second lowest layer of the hierarchy then this means that a lot of the controls are dependent on communications, planning, and building management; areas that were not considered to be particularly strong in the sector by the stakeholders during the workshops (Section 3.7).

Committed leadership in addressing HRB risks is essential to make these types of control as effective as possible. This involves leadership from individual dutyholders, but also from across the sector and the regulator. Identification of good practice in building management, communications, and emergency planning could help ensure that these measures are being applied effectively.

A large number of the controls identified were also Engineering Controls. This was especially true for Structural scenarios, where there were more Engineering Controls identified than Administrative Controls.

Engineering Controls are considered to be more effective than Administrative Controls; however, they need to be properly maintained to be effective. This, again, requires committed leadership, especially at a dutyholder level, to ensure that effective maintenance of control measures is planned and sustained.

Many Engineering Controls also have associated failure rates; this is where an item will not work as anticipated for a small percentage of the time. Inspection and maintenance plans can help identify potential failures early before they become a significant issue. Any risk assessment should consider cases when such systems may fail and identify additional controls that help prevent escalation should this occur.

There were a number of controls that could be considered as PPE equivalent controls, and where possible these should be used in addition to as many other controls as reasonably practicable from higher in the hierarchy.

There were a number of Elimination and Substitution control measures identified, but once again these were heavily focussed on committed leadership and competence in building design, construction, and management.

It was identified that the Elimination and Substitution controls could be applied most effectively at the design and construction phases. Sector stakeholder representatives at the workshops identified that these controls might be too costly or too difficult to implement once a building was occupied.

The Elimination and Substitution controls could significantly inconvenience residents during implementation or could introduce new hazards for implementation in occupied buildings. Again, each HRB would have to be assessed on a case-by-case basis to determine whether such measures were reasonably practicable to implement.

This analysis demonstrates the usefulness of considering multiple layers of controls from across the hierarchy to provide a defence in depth for HRBs to try to avoid the escalation of incidents before they become major accidents.

The hierarchy of controls is a tool to help assess at a high level the effectiveness of risk control measures. However, it is preferable to implement control measures when benefits are identified rather than delaying through overanalysing solutions, referred to as "*paralysis by analysis*" (2, pp 36-37).

2.6 Other hazard scenarios

A range of other hazard scenarios were identified at the workshops. Whilst many of these are technically major accident hazards in that they could adversely impact large numbers of people from a single event, they were often events that are covered by other existing legislation.

Consequences of 'other' hazard scenarios can vary significantly. Generic consequences could include injury, fatality, structural damage, damage to property, damage to services, damage/failure of safety systems and re-housing of occupants.

There were also a number of other health and safety hazards identified that were less severe, or did not have the capacity for rapid escalation, or would not require immediate emergency response. Many of these are events that could be managed by dutyholders, but they are potentially more day-to-day building management rather than part of a safety regime.

Scenarios identified include:

- Exposure to asbestos
- Carbon monoxide poisoning
- Asphyxiation from gas release
- Legionella
- Lightning strike
- Utilities failure
- Waste systems overflow
- Falls from height and items dropped from height

If some of these events were to occur during a fire or structural collapse event, then they could be escalating factors, i.e. they could potentially increase the chances of, or impacts from, a fire or structural event. This would need to be considered on a case-by-case basis and demonstrates why good building control is necessary to manage risks.

3. Research work programme overview

The programme of work was split into two key work packages, with the purpose of identifying information to help derive representative major accident hazard scenarios for HRBs:

- Work Package 1: Landscape Mapping, consisting of
  - a literature review
  - a review of regulatory approaches to risk management
  - defining a major accident hazard and tolerability of risk
  - stakeholder mapping
- Work Package 2: Defining Major Accident Scenarios
  For the purpose of the project, representative scenarios may be considered as the key major accident risks that should be managed by dutyholders in HRBs. The representative major accident scenarios were developed largely through a series of workshops with sector stakeholder representatives and subsequent analysis of the information obtained from these workshops.

3.1 Literature review

The findings of the literature review had a significant focus on fire as a major accident hazard scenario, and it was possible to extract key initiating events and outcomes/consequences. To some extent, there was reference to key escalation pathways.

The review highlighted that there are some significant gaps in the literature. Much information on incidents can be found in what is commonly referred to as grey literature, most typically in the form of news articles. Articles from peer reviewed sources, or formal incident investigations were less common. Whilst the literature search endeavoured to focus on HRBs within scope, there was often not enough detail on building type and context etc. in the literature to allow this to be ascertained.

As a result, it was not possible to answer a number of the research questions as initially planned for the literature review. For example, a number of standards relevant to HRBs were identified, but the literature did not shed any light on the efficacy of these standards in preventing or mitigating incidents, particularly the types of major accident scenarios relevant to this work. Nor did the literature indicate whether buildings were compliant with the specific standards in the first instance; and if they were, it was also not possible to determine if or how standards may have impacted (positively or negatively) on event escalation and overall outcomes.

Publication bias (particularly from the perspective of the media) may also have resulted in incidents that were well contained being poorly represented in the literature. Such incidents would be valuable, as they may shed more light on the effectiveness of barriers. As an example, the Local Government Association (LGA) guidance document (3) notes some data from the Fire and Rescue Services (FRS) reporting system. In the financial year 2009-2010 there were 8,000 fires attended by FRS in blocks of flats. Of these, only 22 (less than 0.3%) required the evacuation of more than 5 people. Key lessons are likely embedded in those cases that did not escalate.

Another noteworthy point from the literature review was that information sources from the media included examples of counterfactual arguments. Such arguments are commonly made in hindsight and can be considered a failure in logic. For example:

> ‘If action x had been taken, then outcome y would not have occurred.’

However, it is not possible to conclude with a degree of certainty that an action/inaction that was different to reality would have resulted in a different (safer) outcome as the range of variables is likely too complex to enable such an accurate prediction.

With the above points taken into account, a key recommendation here for the safety of HRBs (and ensuring lessons are learnt) is the future consideration of how information is captured from major accidents in a more robust, scientific, and systematic manner.

For example, the following list of investigation considerations would likely help ensure consistency of learning points captured from a major accident in a HRB. It should be noted that the list is not exhaustive, and that other major hazard sectors typically apply systematic and rigorous investigation processes:

- The general context of the building and surrounding infrastructure (building height, design/construction methods, commercial operations etc.)
- Demographics of occupants (e.g. vulnerable persons etc.)
- Key initiating events
- Other contributing factors
- Barriers that were present
- Barriers that functioned/worked effectively, and those that failed
- Standards that should have been complied with
- Any standards that were not applied/met
- Pathways that may have contributed to escalation
- Mitigation controls in place
- Mitigation that functioned/worked effectively, and those that failed
- Consequences and potential consequences
- Learning points from escape and emergency response

In particular, the inclusion of incidents which may have been relatively minor ('near misses') because they were prevented from escalating (by action or design features) could shed significant light in relation to further sector learning.

3.2 Review of structural and fire engineering literature and data

A further targeted review for structural and fire engineering issues was undertaken by subject matter experts (SMEs) to identify particular incidents or literature sources. This input was provided by Arup on structural and fire engineering issues in the context of HRBs. The findings outline some common factors recognised by Arup expertise that, either in isolation or combination, can result in buildings with an increased likelihood of structural failure. The following sections summarise the observations made by Arup following a review of these structural factors.

3.2.1 Cost / budget

Enhancing safety at any stage of a building's lifecycle is likely to entail costs, which will often, therefore, act as a barrier to safety considerations being implemented. Structural integrity can typically be seen as a non-value adding cost, except generally in hindsight of an incident occurring. The industry is known to be highly cost-conscious and operating on low profit margins, and the motivation to save cost is therefore very high.

Structural engineering depends on exercising engineering judgement: codes of practice exist but are not exhaustive and always leave it open for the engineer to exercise discretion in their design. With regard to quality and safety, structural engineers have a duty to develop a safe design. However, opinions may be split in relation to what constitutes 'safe'. In the face of budgetary restraints, there may be pressure on the engineer/designer to reduce measures adopted in the design with regard to safety, or sometimes a second opinion may be sourced to give a more cost-focussed view. In the most extreme examples, the engineer's appointment may be terminated because the client or project manager favours another engineer who is willing to give a more cost-compliant opinion.

Such costs can often be perceived as being increasingly disproportionate after initial construction (e.g. due to retrofit, modification, or retrospective changes to standards, regulation, or codes of practice etc.). Processes such as quality assurance/checking can commonly be restricted, due to further cost saving.

3.2.2 Value engineering

Value engineering in the purest sense refers to a process in which creative, team-based ideas are generated to formulate alternatives to the existing solution. However, in some cases this process may be focussed on consideration of the availability, lead time, cost, and profits of different materials and construction methods without the involvement of the original engineer/designer.

Those undertaking value engineering may often fail to recognise that different materials or construction methods may not be directly comparable, even if meeting the same product standards. These cost-saving behaviours may have a deleterious impact on structural or fire integrity e.g. through substitution, which remains unrecognised because the original engineer/designer is not given opportunity to input into the process.

3.2.3 Procurement

Modern procurement methods include many in which both design responsibilities and design liabilities are passed down to the lowest level of the supply chain. Design-build procurement, in which the main contractor is made responsible for the design and construction of the building in accordance with a set of Employer's Requirements, is the dominant method of procurement in modern building contracts. Design-build procurement came to the fore in the wake of the Latham report published in 1994 (4) and the Egan report in 1998 (5). It was conceived as a means of limiting the risk to the client, by placing the responsibility for the coordination of the design in the hands of the main contractor. However, this may result in:

- The main contractor, in turn, limiting their commercial risks by requiring their suppliers and subcontractors to accept design responsibility, resulting in fragmentation of the design responsibility.
- The engineer being appointed by the contractor, removing the 'healthy tension' and independence needed to challenge design and construction decisions and to ensure sufficient oversight and scrutiny of the contractor's design and construction.
- The main contractor, because they are appointed on a lump sum basis, being motivated to minimise the involvement of the engineer in post-tender design and construction duties.

This approach is not conducive to there being a 'directing mind' on matters of structural safety, with the potential consequence being uncontrolled change. In particular, it is often not recognised that accountability rests with the main contractor and cannot be passed down the supply chain, or that the engineer must be able to scrutinise and hold the contractor accountable for contractor-led design and construction.

3.2.4 Competence

It is recognised that a lack of, or insufficient, engineer, designer, and client competence can impact on structural integrity issues. It has also been identified that competence among all engineers and designers is not necessarily at levels considered desirable from a safety perspective.

Application of newer construction methods and materials in relatively untested contexts may further increase structural failure risks (e.g. use of timber materials in taller buildings). This risk could be exaggerated if construction or structural principles are 'borrowed' from construction methods applied to traditional tall building materials, such as steel and concrete and applied inappropriately because the engineer lacks sufficient competence in the construction method or material being used to fully appreciate the implications of their adoption.

Whilst a lack of client competence on structural integrity (i.e. not being an ‘intelligent customer’) can result in a lack of focus on structural integrity from a client requirements perspective, contractors, suppliers, and labourers may also contribute to structural integrity issues (e.g. due to poor workmanship). This may be linked to competence or other pressures (e.g. time, financial etc.).

Materials and construction methods etc. may vary from the original design intent or plans. This may be due to construction workers not having the same competence or understanding as the designers, and/or the original designer not having sufficient oversight of the post-tender design and construction written into their appointment.

Changes or modifications in building use by owners or occupants may also impact on structural integrity, largely due to changes being made without competence/awareness of their impact on the building.

3.2.5 Lack of client accountability

The legal entity of the client and dutyholder on many construction projects is incorporated for the sole purposes of that individual project. Corporate entities such as ‘The [building name] partnership limited’ are common and have nominal assets. In turn they may be owned by a pension fund or other investment vehicle. Frequent reference has been made to such entities being registered offshore for tax purposes, and the difficulty of identifying the dutyholder or there being no effective dutyholder in such circumstances.

Commonly, a project manager is appointed to deliver the project on behalf of the client, who may not be present in any design discussions or have any employees. The project manager, who is not the dutyholder, may make the design decisions based on the terms of their appointment, including who to appoint as the engineer, other designers, and matters affecting cost and safety.

3.2.6 Fragmented nature of the industry

In contrast with other hazardous industries where there is generally a relatively small cohort of well-informed clients (an ‘intelligent customer’), in the construction industry there are thousands of clients and thousands of contractors. Other issues relevant here which may make it challenging to create the conditions for an ‘intelligent customer’ include:

- Many building owners may never have undertaken a development on the same scope and scale previously, which may be exacerbated by the ‘absentee’ nature of many clients described in Section 3.2.5 above.

- Building owners in many cases do not intend to be the long-term operator of the building but instead are seeking to maximise the financial return on the investment before 'disposing' of the asset.

3.2.7 Disjointed nature of design teams over building lifecycles

The number of engineers and other stakeholders involved over a building's lifecycle can mean that a joined-up perspective of structural integrity may be inadvertently lost. This can lead to omissions and incorrect assumptions etc. that could contribute to structural integrity issues. It is recognised that increased building complexity can exacerbate such issues further, as can supply chains and contractor chains (e.g. due to an increasing number of interfacing individuals and organisations).

Despite there being a requirement for health and safety information to be handed over to the building owner and occupiers, practical considerations often inhibit this from happening or it may not be of sufficient quality to be of real benefit. The lack of an 'engineer of record' means there may be no controlling mind who understands the risks inherent in the structural design.

Additionally, health and safety information is often lost when the building is transferred from one building owner to another. Consequently, the level of knowledge about the as-built structure and the risks inherent in the design is often low. Clear collection and appropriate communication of building information over its lifecycle is frequently missing. This could contribute to omission of appropriate maintenance through a building's lifecycle, which may then increase the likelihood of structural or façade-related failures.

3.2.8 Lack of incentives for compliance, adherence to standards, and ambiguity

Whilst many detailed standards, codes of practice, and regulations exist (some of which have been put in place following incidents e.g. Ronan Point in 1968), it is recognised that these may not always be complied with. There appear to be a variety of reasons, including some already listed above (e.g. cost, competence, etc.), as well as different assumptions and interpretations (or misinterpretations) on the intent of such requirements. Indeed, it is not required that the engineer comply with any particular code of practice. This is, in part, recognising that many structural arrangements do not fall within the scope of the codes of practice and, in part, recognising the professionalism of the engineer to be able to originate the design as they see fit. This, however, gives rise to the possibility of gaps, deviations and misinterpretation of the codes of practice. The number of standards, codes of practice, and regulations and how these all relate to each other is not necessarily well understood by many in the sector.

3.2.9 Checking

Systems exist for independent checking in design; however, for the reasons highlighted above these are now adopted only rarely. Such checks can be seen by some as an unnecessary expense which does not add value. Cases where checks are passed down the supply chain may mean that any independent check may become a matter for the subcontractor, and commission of an independent check by the main contractor may be considered unnecessary.

Checking, however, is acknowledged in many industries, particularly those dealing with low-likelihood high-consequence risks, as serving an important part of the overall design process. Without transferring or diluting design responsibility, it provides independent scrutiny and challenge of design decisions, and also increases the weight of the designer’s argument in the face of cost, programme, or other pressures.

3.2.10 The role of building control

Amendments to the Building Safety Act 1984 (6) has opened the building control system to the private sector. This allows the client to choose the building control body they wish to appoint for the project, including the terms on which they should be appointed. For the reasons discussed above, decisions may be made on the basis of cost. In such cases, building control may be seen as an issue of necessary compliance rather than a process which adds value by reducing risk in the design.

The appointment of the building control body on such terms may weaken the checks and balances in place around the design and construction, especially if combined with the removal of the independence of the engineer in having oversight of the design and construction.

3.3 Existing regulatory safety regimes for housing

Any safety case regime would either replace or sit alongside existing regulatory regimes.

Two of the existing regimes include systems for assessing relevant safety aspects of some buildings, with HRBs being in scope of both. These are the Regulatory Reform (Fire Safety) Order 2005 (7), often abbreviated to FSO, and the Housing Health and Safety Rating System (HHSRS) which is mandated by the Housing Act 2004 (8) as the system to be used by regulators in assessing the type and significance of potential health and safety risks affecting the occupants of any residential building and defined in the Housing Health and Safety Rating System (England) Regulations 2005 (9).

It is reasonable to consider whether either of these existing regimes (separately or in conjunction with one another) could achieve the same outcome for safety as a new and completely separate mandatory safety case regime.

The FSO includes a requirement that each premise within its scope has a suitable Fire Risk Assessment that is maintained over time and that general fire precautions are implemented to provide adequate control of the fire risks that have been identified. The assessment is the responsibility of the ‘responsible person’ (typically the building owner or manager for residential areas and the occupier of any commercial premise sharing a HRB). For most buildings, including HRBs and commercial premises within mixed-use HRBs, the enforcing authority for the FSO is the local Fire and Rescue Authority.

The HHSRS is used by Local Housing Authorities to assess the suitability of any residential property when they have reason to consider that there may be particular safety or health concerns for its residents.

Both regimes address some of the aspects of a HRB that impact on major hazards.

In considering the role of these regulatory regimes for HRB major hazards, it is worth reiterating that major hazards in HRBs arise from events which can affect many separate dwellings and many people at the same time, and the likelihood of such events is typically much lower than events that only affect a single dwelling. The philosophy already applied to the management of major accident hazards in other sectors is to apply much greater focus to the management of severe negative consequences, with less consideration of the likelihood of such an event. With such infrequent events it is inherently challenging to accurately assess the likelihood of them occurring, which is a major reason for using a safety case rather than a more typical risk assessment approach.

3.3.1 Regulatory Reform (Fire Safety) Order (FSO)

The scope of the FSO is limited to non-domestic premises. This means that in a typical HRB the FSO does not cover fire safety within individual flats / apartments. It does, however, cover the common areas (such as corridors, stairs, lifts, lobbies, plant rooms etc) in HRBs and any commercial premises that share the building.

The exclusion of the flats/apartments within a HRB means that the risk assessment required by the FSO does not directly apply to many of the individual fire risks that may arise within HRBs.

In order to support the people carrying out fire risk assessment in compliance with the FSO a range of guidance documents were issued alongside the legislation. For the most part, HRBs are covered in the fire risk assessment guide for ‘sleeping accommodation’. Alongside HRBs, this guide also covers all commercially operated overnight accommodation from large hotels to rented caravans, boarding school dormitories to bail hostels. This wide scope meant that specific detail for HRBs is limited.

In 2011, the Local Government Association produced a document specifically addressing fire safety in purpose built blocks of flats (10), including most HRBs. Although this is now outdated in respect to some of the more recent legislation, it provides much greater detail on the topics for an FSO Risk Assessment and the controls that may be appropriate for fire risks. In particular, it emphasises the importance of including both external cladding and internal fire-resistant partitioning, particularly flat entrance fire doors, within a fire risk assessment.

However, there is anecdotal evidence that FSO has not been consistently applied in these latter cases, in part this may be because the responsible person may have limited or no control, particularly with flat entrance doors.

The Interim report by Dame Judith Hackitt (11 p. 71) noted in an information box on ‘Definition of “common parts” under the Fire Safety Order’ that “Under the Fire Safety Order, common parts do not include any aspects of fire safety within flats or on the outside of a building, such as cladding.” Even if this is not completely correct, it indicates a lack of clarity in the scope of the FSO.

Note: Planned legislation is expected to clarify that both flat entrance doors and external cladding materials are covered by the FSO.

Where the HRB has mixed use, commercial occupants will have their own fire risk assessment which may be based on other guidance documents.

The FSO requires the fire risk assessments to be up to date and the guidance recommends that the assessment is kept under review and revised when necessary.

In almost all cases of occupied HRBs, the enforcing authority for the FSO will be the local Fire and Rescue Authority.

Published fire statistics for 2018 (12) show that during that year just over 54,000 buildings in England were audited for compliance with the FSO. These included just over 3,000 buildings categorised as ‘purpose built flats >=4 storeys’. Blocks of four or more storeys will include most HRBs along with a number of buildings which will be below the >18 m definition. 21% of these ‘purpose built flats’ were found to be unsatisfactory, requiring additional action to bring them into compliance with the FSO. 10 of the buildings in this category, approximately 1 in 300 of those audited, was found to have fire safety issues serious enough for a notice to be issued, prohibiting or restricting the use of the building until the issues were corrected. As these values are not limited to HRBs, it is not clear from the data how representative they are of the national stock of HRBs. However, they do indicate that there is an appreciable degree of non-compliance with the FSO.

3.3.2 Housing Health and Safety Rating System (HHSRS)

The HHSRS is a system used to provide a structured assessment of all the major aspects of health and safety that might affect anyone resident in a particular dwelling. It covers a wide range of hazards, from unhealthy temperatures, damp and mould through to structural collapse.

The Housing Act makes it mandatory for the Local Housing Authority to assess a particular dwelling using the HHSRS if they have reason to believe that it poses an unusually high risk to the health or safety of its residents. HHSRS assessments are typically reactive, being carried out in response to concerns raised about particular dwellings. They are not carried out as a normal part of the lifecycle of a dwelling.

In the context of HRBs, each individual flat/apartment is considered separately. This includes an assessment of the common areas of a HRB, both in terms of the immediate safety of residents in a given flat and their impact on the long-term physical and mental health.

HHSRS assessments are made following Operating Guidance issued shortly before the system came into force (13). In November 2018 an addendum to this guidance was issued specifically addressing the assessment of high rise buildings with unsafe cladding. This addendum emphasised that the common areas of a HRB could be assessed and rated separately to the individual dwellings. The addendum also highlighted the links between risk in common areas and individual dwellings, suggesting that concerns raised in the common areas might be a driver for inspections in some or all of the dwellings. This is now usually implemented with a Joint Inspection Team.

The guidance tabulates the ‘average likelihood’ of someone being harmed by each of the 29 hazards that are considered, along with the proportion of those people suffering each of four classes of harm, ranging from a fatal or very serious outcome in Class I to a relatively minor but still significant outcome in Class IV. From these probabilities, an average HHSRS score is derived.

An HHSRS assessment takes these tabulated baseline values and the assessor then adjusts the figures up or down based on an individual assessment of the specific circumstances for the occupants of the dwelling being assessed. Scores are calculated for each hazard, and these are summed to give a combined overall HHSRS rating based on the whole range of issues.

Depending on the overall score, the Local Authority may require improvements to be made or may be required to take action themselves to prevent residents at greatest risk being harmed.

Only a few of the issues covered in a HHSRS assessment have the potential to affect multiple dwellings and large numbers of residents in a single event. However, HHSRS assessments do address fire, explosion and building collapse, which are relevant to potential major hazards in HRBs.

Fire

Flats are considered as a separate category to other housing, and the average likelihood of being affected by fire is higher for a flat, even before any adjustment for the particular circumstances of each dwelling and its location. The spread of harm figures show that the baseline for very serious/fatal outcomes is slightly lower in flats than in houses. No general distinction is drawn between HRBs and any other flats.

An HHSRS assessment will cover fire spread from one dwelling into adjacent dwellings and into escape routes.

The baseline risks relate to normal standards of building for fire separation and, in the HHSRS guidance, reference is made to Approved Document B (the Approved Documents are guidance for compliance with different aspects of the Safety Regulations and Approved Document B covers matters relating to fire safety) and to relevant British Standards. The guidance does not add to, interpret or summarise these references.

Other than fire separation matters, the assessment considers the presence of warning and mitigation measures (alarms and firefighting equipment) and the risk of a fire starting within the dwelling being assessed. For the latter, it also considers some factors affecting resident behaviour (for example, people are categorised as at greater risk from fire if they need to use portable heaters because there is no effective central heating or no access to facilities for them to dry washing more safely).

Explosion
Explosion risks are given a single ‘average likelihood’ and spread of harm for any building. No general distinction is drawn between HRBs and any other type of dwelling.

The HHSRS assessment concentrates on those factors that might prevent an explosion. It covers issues such as: work on gas equipment by people without Gas Safe registration; failure to maintain LPG (Liquefied Petroleum Gas) heaters; and the testing of pressure relief devices on hot water systems.

The baseline risks relate to normal standards of installation and maintenance, and in the HHSRS guidance reference is made back to Approved Documents G and J and to relevant British Standards. The guidance does not add to, interpret or summarise these references.

Structural collapse
Flats are considered as a separate category to other housing. The average likelihood of being affected by collapse is somewhat lower for flats than for other houses. However, the spread of harm shows the risk of a very serious/fatal outcome, while still very low at 0.7%, is higher for flats than for houses even before any adjustment for the particular circumstances of each dwelling and its location. No general distinction is drawn between HRBs and any other flats.

Some consideration of collapse is included as a possible consequence of an explosion.

Other than that, the assessment of building collapse is limited to consideration of failures “*because of inadequate fixing, disrepair, or as a result of adverse weather conditions.*”

These are aspects that can be assessed by direct observation and without an in-depth technical knowledge of structural engineering.

Overall assessment
As discussed above, if applied within a HRB, the HHSRS produces a combined rating (for each separate dwelling) based on all the hazards. In practice, it is usually only those hazards that are of particular concern that are assessed as these will dominate the overall score.

The Housing Act requires a local authority to take or require remedial actions for dwellings assessed with ‘category 1’ hazards. These are dwellings scoring more than 1000 in the HHSRS assessment.

Major hazards in HRBs are typically low probability events, but ones with the potential to affect large numbers of individual dwellings at one time.

The HHSRS acknowledges that the baseline likelihood of residents being affected by fire and structural collapse is higher for flats than other houses. This reflects the potential for such events to affect more than one dwelling. However, because they occur very infrequently, the HHSRS average scores for the sort of event that may become a major accident hazard are very low; between 17 and 39 for fire in flats of different ages, 1 for any explosion and 1 for any collapse. With these low baseline scores, an assessor would need to regard the risk of fire, explosion or collapse as several hundred times more likely than in an average dwelling before the HHSRS would flag them as 1000+ point, category 1 hazards.

The HHSRS assessor is required to exercise their judgement over the actual likelihood associated with any of the hazards as they apply to the residents of a particular dwelling. This means that an individual assessor with the appropriate evidence, knowledge and competence could include a broad range of factors in their assessment.

Even where a specific dwelling has deficiencies that significantly increase the residents’ risk of involvement in a major hazard event, those risks will still be low in absolute terms as major accidents are rare events. The assessment process carried out in the HHSRS is not intended to flag up such events.

3.3.3 Proposed changes to FSO and HHSRS

Both the FSO and the HHSRS were the subject of separate public consultations in 2019.

A call for evidence on the FSO was launched in tandem with a wider consultation on proposals to reform the building safety regulatory system. This specifically addressed HRB matters. At the time of writing (February 2020), there had been no formal response to the consultation on the FSO, which was carried out in June and July 2019.

However, the government has announced that a future Fire Safety Bill will clarify the responsibilities for HRBs under the FSO (14).

Following the February 2019 consultation on the HHSRS, in July 2019 the government issued a response (15) stating that its policy was to review and update the underlying legislation (Part 1 of the Housing Act) and to revise the HHSRS in order to:

- simplify the hazard profiles and outcome measures (reduce the level of granularity).
- extend and expand the standards incorporated into the assessment.
- review and update the guidance documents.

3.3.4 Use of FSO/HHSRS for a HRB major hazards safety case regime

A safety case regime for HRBs would need to be sufficiently robust to operate effectively in an environment where there are the challenges of a wide range of design, history, management and ownership models for HRBs. This raises the questions of whether the FSO or HHSRS systems could form the foundation for a safety case regime or, if not, how they might contribute to a new HRB safety regime.

FSO

FSO risk assessments consider fire events. Although fire is the most prominent major hazard topic for HRBs, it is not the only one.

The FSO risk assessment process described in the guidance documents is a sensible and effective one, employing an appropriate methodology for assessing those risks covered by the FSO.

Some of the major accident scenarios will be directly addressed in an FSO risk assessment. For example, it can be expected that assessment of the evacuation routes for escape from fire will be done in the context of the building evacuation plan, and recommendations and controls arising from a fire based FSO assessment are also likely to be appropriate for other escape scenarios.

Guidance, particularly the LGA guidance for purpose-built flats, describes the fire concerns and assessment process appropriate for typical HRBs. In particular, this guidance acknowledges that an assessment of fire spread from a fire within a flat (which is not covered by the FSO) to other flats via the common areas (which are covered) requires assessment of the flats themselves; stating, "*However, it will normally be necessary to gain limited entry to at least a sample of flats. This is to examine the necessary measures to ensure when a fire occurs in a flat, that there is not undue risk to other residents.*"

While this is likely to be practical in most cases, because the FSO does not provide legal powers to enter residences nor to require changes to be made within them, there may be some situations in which such assessment is limited, or not possible at all.

In the case of mixed-use HRBs there may be multiple FSO fire risk assessments covering individual commercial premises as well as one for the common areas of the residential sections.

Because of the limitations in scope and legal powers, it seems unlikely that the FSO could form the basis of a new HRB safety regime.

The approach taken to properly conducted FSO risk assessments is appropriate for assessing fire risks within its limitations and would be appropriate as part of the wider assessment needed for HRB major hazards.

HHSRS

An HHSRS assessment has the potential to overcome some of the limitations of an FSO fire risk assessment. For example, the Housing Act provides powers to enter a residence and, if an HHSRS assessment shows a high enough score, to require changes needed to improve safety.

The broader scope of the HHSRS covers the range of major accident scenarios, addressing each to greater or lesser extent. An HHSRS fire assessment is a much broader stroke assessment than the more detailed FSO approach.

However, the HHSRS is very much a quantitative system, providing a score to be compared against an action level along with a clear picture of the issues that need to be addressed to reduce that score to an acceptable value.

Because the HHSRS considers individual dwellings, and the actual risk from escalating events is built into the overall risk level for flats, there is no formal mechanism for separately acknowledging the expectation of much lower levels of risks for those major accident events affecting large numbers of people.

It is possible that the addition of some further mechanisms for separating out just those HHSRS factors that have major hazard potential and then appropriately collating the individual dwelling risks might give a picture of the HRB as a whole.

This would be a significant departure from the existing HHSRS approach.

A safety case exists to demonstrate that all the hazards with the potential to affect a large number of people have been identified, considered, and that the controls in place are sufficient to support the case for continued operations (which would be occupation of the building in the case of HRBs).

The quantitative approach of the HHSRS makes it unlikely that it would be a good basis for a future safety case regime addressing inherently low risk events where good quality quantitative data is unlikely to be available.

The HHSRS may well continue to be the appropriate tool for addressing more common housing issues within HRBs, with the evidence in a HRB safety case being part of the input into an HHSRS assessment.

3.4 Review of other regulatory approaches to risk management

The initial review based on HSE experience provides an indication that, in principle, a safety case regulatory framework would be a workable solution in the context of HRBs. Comments during the workshops validated this, with a feeling that a structured and systematic process, such as safety cases, is required to ensure future HRB safety. The major hazards regulatory model and the principles of a safety case are set out below.

3.4.1 HSE Major Hazards Regulatory Model

This model describes the safety management expectations for all major hazard sectors regulated by HSE, including the existing HSE onshore and offshore safety case regimes. The following principles apply to the regulation of specific dutyholders:

- Responsibility for managing risk rests with the dutyholder and not with the regulator.
- Dutyholders are responsible for identifying, profiling and managing the major hazard risks they create in a systematic way, and for complying with legal duties in respect of those risks.
- Major hazard dutyholders will be subject to a level of regulatory scrutiny that is proportionate to their risks and performance.
- In permissioning regimes, the regulator will keep the arguments and commitments set out in safety cases/reports under regular review and carry out a critical assessment in light of actual dutyholder performance; for example, annual review for intervention (inspection) planning and possible additional review in response to any incidents or inspection findings.
- The interplay between technical, organisational, and management factors is critical to effective risk control.
- The effectiveness of senior management leadership (for control of major hazards within a business) is an important determinant of dutyholder success in managing major hazard risks.
- HSE inspectors will make regulatory decisions taking all these issues into account and, where a gap exists, use HSE’s Enforcement Management Model (EMM) to guide their actions.
- Regardless of their performance, dutyholders will be subject to a degree of periodic inspection to provide public reassurance that major accident risks continue to be managed appropriately.

The aim of HSE's regulatory intervention programmes in the major hazard sectors is to:

- Confirm, through sampling, that dutyholders have properly focused their risk management efforts on major accident hazards.
- Confirm that, where dutyholders are subject to a permissioning regime, the basis of the demonstration remains valid, and that the dutyholder can show they are effectively controlling risks.
- Take proportionate action, including enforcement, to ensure that dutyholders make improvements where there is evidence of significant shortfalls or failures in the way that they have implemented control measures.

Safety management system
Major hazard risk control has to be systematic, and as well as preventive measures, it should also confirm that there are robust mitigation and emergency arrangements in place to limit the impact of a serious event. All safety management systems contain the steps: Plan, Do, Check, Act (PDCA) and the actions involved in delivering effective arrangements:

- Plan - Determine your policy/Plan for implementation
- Do - Profile risks/Organise for health and safety/Implement your plan
- Check - Measure performance (monitor before events, investigate after events)
- Act - Review performance/Act on lessons learned

Control measures for major accident risks
Major hazard risks have to be managed in a multi-layered way and the layers of protection or control measures will address technical, managerial and procedural arrangements. This is typically represented as bow ties by dutyholders. This format was also used for the workshops with sector stakeholder representatives to capture potential scenario elements and barrier options for escalation and safety factors relevant to HRBs.

The dutyholder should be able to show a logical and rational flow of analysis leading from hazard identification through to effective risk control, expressed as a set of appropriate 'barriers' (or risk control systems). This should involve a process of hazard identification, risk assessment and identification of the measures (barriers) necessary to control the risks as low as reasonably practicable (ALARP). There is not a 'one-size-fits-all' solution to determine appropriate control measures.

Systems and arrangements and the supporting organisational safety culture cannot be sustained without effective leadership. The potentially complex systems and arrangements needed to manage major hazard risks need to be delivered and maintained by managers with vision and determination, and they cannot be left as the sole preserve of safety specialists within an organisation.

Dutyholders have to routinely monitor and review their arrangements and act on the findings. As well as reactive monitoring through incident investigation, dutyholders should have programmes in place to audit their safety management system and use leading and lagging key performance indicators to provide routine information on performance.

3.4.2 Principles of a Safety Case

A safety case is a structured argument that demonstrates adequate safety and links to the evidence that supports the argument. Depending on the regulatory regime, there are usually detailed requirements for what needs to be included and how the arguments need to be made. These detailed requirements can help to:

- Achieve consistency in the approach and level of detail between different safety cases.
- Ensure that all the required hazards and issues are addressed.
- Provide sufficient background and detail to allow the arguments to be assessed.

A safety case system has to be properly implemented to achieve these benefits. Various elements have been identified, such as the ones listed by Professor Andrew Hopkins (16):

- The safety case should provide a risk or hazard management framework.
- Its development should include workforce involvement (as workers are best placed to understand the issues).
- It should make a case to the regulator and be assessed by the regulator.
- The regulator should be competent, well-resourced and independent.
- The safety case should use ALARP as a criterion which allows standards to be nudged upwards as technology improves.

With any safety case regime, there is a need for the requirements to develop and take account of changes over time. For example, both the COMAH and Offshore regimes have developed so that less assessment effort is given to the required 5-yearly review/revisions of the safety case, unless significant changes have been made. Modification safety cases remain important because any modification to the underlying processes, or construction, has the potential to significantly change the risk profile; this also applies for safety cases for new installations/sites.

One way in which regulator effort is matched to the changing risk profile is that national inspection projects on specific topics (for all relevant sites/installations) may be developed, based on increased incidents or worsening inspection history, to address such issues.

A regime could be implemented for HRBs, which would involve having progressive requirements for the safety case over time rather than static expectations from the start. This would particularly be useful for already occupied buildings, helping to identify the key elements to be addressed to give assurance of assessment and control of risks.

Safety case framework
A number of features point to the importance of a safety case framework to apply across the whole lifecycle of what is being managed by the safety case. In particular:

- The safety case should be developed alongside the design phase
- It should be a living document/process throughout the lifecycle, in particular, the different stages such as maintenance, changes in use, modifications/refurbishment
- The safety case needs to pass from one 'owner/manager' to the next, through each stage of the lifecycle and through changes of ownership

Independent assessment by the regulator is important. Teams comprised of various technical disciplines are required to assess onshore and offshore high hazard sectors because of the complexity of the design and major accident scenarios in the energy and chemicals sector. For a HRB, appropriate disciplines would be needed for assessment, but it should be less onerous than for an industrial complex.

Management of change is an important part of a safety case. Existing regimes require modification safety cases for any significant modifications that could change the risk profile. Five-yearly review of the safety case is expected to pick up any smaller modifications. The impact on the risk profile, and the safety narrative should be considered for each change. The safety management system (SMS) is expected to include procedures (including approval levels) for safety studies, such as management of change (MOC) for minor or major modifications. This would include organisational changes (such as staffing levels), permit to work (PTW) systems to ensure safe maintenance and installation of new equipment, and assessment and approval of additional temporary safety barriers to permit continued operation if there is a failure of any existing safety barriers.

Change of ownership is likely to occur during the lifetime of a HRB. Change of ownership could be seen as a modification (to the safety management system). The regulator would take an interest even if not covered by the safety case. It is necessary for all documentation relevant to safety to be passed on to the new owner (the safety case itself and all underpinning records). The new owner needs to familiarise themselves and take over accountability for safety and for continued prevention/control/mitigation of the hazards and risks.

A safety case regime places overall responsibility for safety on the company directors (or equivalent). The SMS includes specification of all the delegated roles and responsibilities for its implementation.

The Risk Management Maturity Model (RM3) originating from the rail sector provides more detail on the elements that might be included in the SMS and shows at a high level how this aligns with PDCA.

Incident data

Awareness of relevant incidents and failures is an essential part of any major hazards regulatory regime. It is needed as part of the hazard identification stage of any risk management framework. In major hazards regimes, such as COMAH, Offshore Oil and Gas, and Nuclear, the sharing of information about incidents and the lessons learned is strongly encouraged because such incidents need to be prevented to the point that many companies will not have directly experienced them. This is mitigated by investigation of near-miss events as well as accidents, and by sharing throughout and beyond industry sectors, so that all can learn.

Incident data should be reviewed alongside a structured hazard identification process. Common and unexpected failures can be identified from incident data: failure frequencies can be calculated, and specific controls developed for areas that show the need for special consideration.

The relatively large number of HRBs becomes an advantage in learning from safety events and near misses, as the larger population is likely to generate more of these within a given time period. However, this is only useful if the relevant data is collected as it arises and is then curated in a manner that allows it to be readily interrogated to extract common issues.

For the safety case regimes considered, there are many similarities in the safety management system. Any safety case regime will however need to reflect unique challenges and issues related to the risks and hazards specific to the situation and circumstances. An example of a unique aspect that could be of interest to HRBs is from the Gas Safety (Management) Regulations. These include a requirement to consider supply emergencies, which essentially requires a consideration of the reliability of providing the gas supply. Safety cases are also expected to include and justify the emergency response plans, including resources required and interaction/communication with emergency responders (e.g. Fire and Rescue).

3.5 Defining a major accident and establishing tolerability of risk

Initial consideration was made of points concerning:

- The definition of a major accident hazard for HRBs.
- How HSE interpretation of health and safety law can help ascertain how to determine whether risks identified for HRBs are being managed to minimise risks appropriately.

3.5.1 Major accident hazard definition

If consideration is being given on how to manage the risks of major accident hazards in HRBs, then what is considered a major accident hazard needs to be defined.

A major accident hazard might be considered to be any event that could escalate to affect the health and safety of multiple people outside the immediate area that was originally affected. For HRBs, the relevant events would be:

- Fire
- Explosion
- Structural Damage

Definitions to identify a major accident hazard might include a single event:

- That has the potential to impact occupant safety on more than one floor of the building.
- Where there is the potential to cause harm to occupants across multiple compartmentations. This may most specifically apply for a major fire event.
- Where there may be a ‘domino effect’: one type of event initiates another type of hazard.
- That impacts nearby populations or infrastructure outside of the building.
- That requires a significant level of emergency response.

3.5.2 Assessing and minimising risks

The risk of injury or ill-health is present throughout our daily lives, it is just that the likelihoods of many of the risks are sufficiently low that they are never realised. The Health and Safety at Work etc. Act 1974 requires dutyholders to ensure that the risks from work activities to workers and to the general public are reduced so far as is reasonably practical (SFAIRP). HSE considers a dutyholder to have discharged its duty to reduce risks SFAIRP if it can be demonstrated that risks are as low as reasonably practicable (ALARP).

If a goal-setting approach to safety is to be adopted similar to that used by HSE then a dutyholder would need to be identified for a HRB, who/which is responsible for ensuring that major accident risks are reduced. The dutyholder is likely to be those people who have control of implementing and maintaining the building’s layers of protection.

Risks should be controlled and reduced to prevent major accidents. All people that might be adversely affected should be considered when assessing accident consequences and the effectiveness of risk controls, especially if a control measure transfers significant risk from one group to another.

Figure 1 illustrates a diagram that demonstrates the Tolerability of Risk (TOR) concept adopted by HSE when assessing whether risks are reduced ALARP. The diagram is often referred to as the TOR triangle or TOR ‘carrot’ in literature.

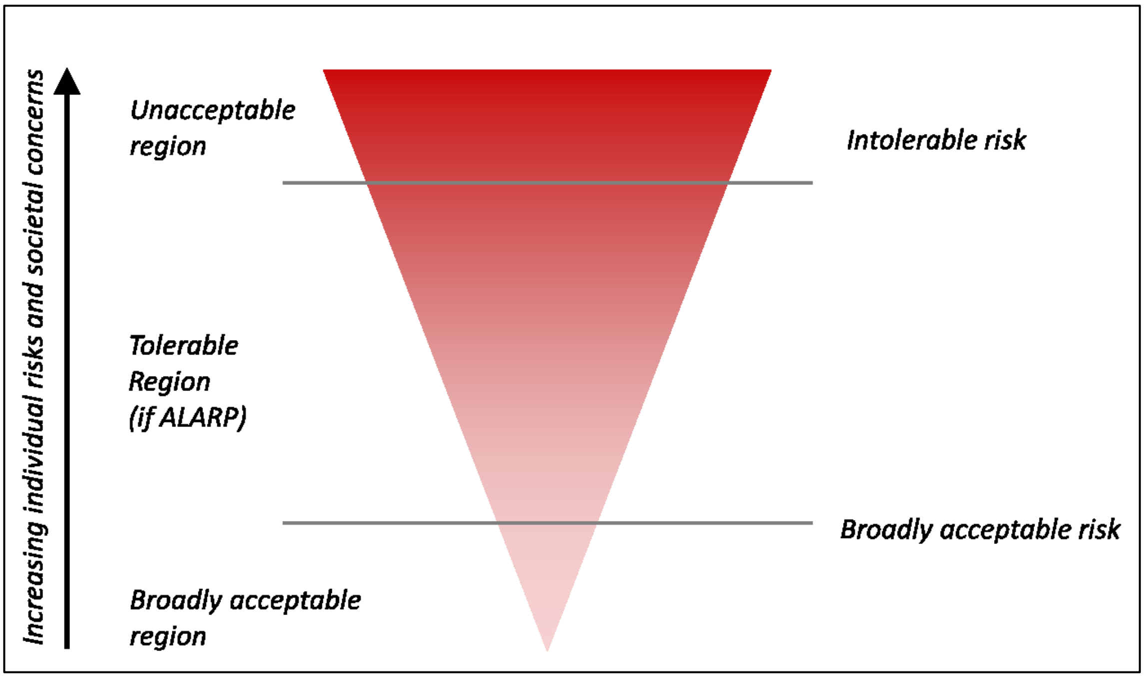

Figure 1 HSE Tolerability of Risk

When assessing other high hazards, quantitative risk assessment (QRA) techniques are often used to determine the level of risk to individuals from a hazard using the likelihood of an event combined with an assessment of the consequences.

There are difficulties in applying such a QRA approach for HRBs, especially where there is a large amount of uncertainty in the likelihood of initiating events as well as the consequences of escalation. There is also limited data on the efficacy of a number of prevention and mitigation barriers.

This does not mean that the assessment of the tolerability of risk concepts used by HSE cannot be applied to the assessment of HRB risks. Assessing where a risk is on the TOR triangle (Figure 1) can still be made using qualitative assessments.

This allows an assessment of where risks are:

- **Broadly acceptable:** the risk is low enough to not adversely impact beyond the everyday risks to which we are exposed.
- **Tolerable if ALARP:** we can only live with this level of risk if it can be demonstrated that the risk is reduced SFAIRP / ALARP, where risk controls are being implemented and managed effectively.
- **Intolerable:** we cannot live with this level of risk; something needs to be done immediately to reduce the risk to a tolerable managed level.

This qualitative approach supports the proposal of a safety case regime for the sector, where a safety narrative can be presented: outlining the particular safety interventions identified to address and minimise a HRB's major accident risks. This narrative can be supported by data and evidence that illustrates that the risk levels are being assessed and managed appropriately, but without cluttering or clouding the main thrust of dealing with the major risks identified.

3.5.3 Identifying the suitability of controls and mitigation

Consideration of the Hierarchy of Controls could be used, when required, to help establish the risk reduction measures for a building. The most effective controls eliminate or reduce the risks at a level that can improve safety for the greatest number of people but can also establish multiple layers of protection, as additional local controls can be identified to help mitigate risks.

The control types traditionally considered in a Hierarchy of Controls are:

- Elimination
- Substitution
- Engineering Controls
- Administrative Controls
- Personal Protective Equipment (PPE)

Controls higher up the hierarchy are considered more effective. In application to workplace assessments, only after all the previous measures have been tried, and found to be not fully effective in controlling risks to a reasonably practicable level, should PPE be used.

For HRB safety, however, it is suggested that it is worthwhile assessing how useful other interventions lower down the hierarchy are to establish an in-depth defence through multiple layers of protection. This is partially to address the fact that in HRBs there may be less control of engineering controls, administrative controls, and PPE than in a work environment. This also recognises that the term PPE might have a broader meaning when applied to managing major accident risks for HRBs.

This type of analysis might be useful to establish where there may be gaps in the layers of protection for dealing with a particular type of accident.

An alternative approach that might be applicable to assist with the identification of reasonably practicable control measures is a health and safety Cost Benefit Analysis (CBA). There are established techniques and guidelines available to undertake a health and safety CBA that allows an assessment of the impact of introducing a measure to reduce risks to be expressed in monetary terms.

This can then be compared to the costs of implementing the measure. If following such an approach, the costs to implement the measure must be in gross disproportion to the benefits, for a decision to be taken not to implement a measure (i.e. the measure is not considered 'reasonably practicable').

The concept of disproportion would be dependent, however, on the risk ‘appetite’ identified for such high consequence incidents. This will require considerable work on the part of the regulator, the dutyholder community and other key actors across wider society to create relevant benchmarks which help those with legal duties identify and implement proportionate risk control and mitigation approaches.

3.5.4 Guidance

HSE publishes a number of different types of guidance, amongst which are:

- General guidance for dutyholders: this type of guidance is not law, but signposts measures available to manage risks and to highlight what is considered good practice.
- Internal guidance: HSE openly publishes the guidance that it produces for its own assessors reviewing COMAH safety reports. This allows industry dutyholders to understand at a high level how HSE is assessing the safety reports submitted by industry, without allowing the guidance to be used as a ‘tick box exercise’ by the dutyholder.
- Approved Codes of Practice (ACOPs): these guidance documents have special legal status. Following the guidance given in an ACOP should mean you are compliant with the law. A dutyholder can choose to adopt a different approach but then the onus is on the dutyholder to demonstrate that what has been done is at least as good as, if not better, than the guidance given in the ACOP.

Consideration will need to be given to what type of guidance documents would be most useful to aid building sector dutyholders understand how best to manage a HRB’s major accident risks. Whilst the sector does not necessarily have the experience or understanding of major accident risk management, it would be useful to get some key information disseminated early. This could include some basic information to encourage dutyholders to take ownership of major accident risk management and start dealing with risks rather than waiting for specific government intervention.

3.5.5 Summary

The concept of TOR can be applied to HRB safety, but consideration is needed of what the risk ‘appetite’ of society / government is to HRB major accidents. As TOR is a key aspect of assessing whether dutyholders are reducing risks SFAIRP/ALARP, then this is something that may need to be thought about, even if only at a high level.

A qualitative analysis of the risks as part of a safety narrative for a HRB would allow an assessment of where risks have been reduced SFAIRP / ALARP and where additional intervention might be necessary. The fundamental purpose should be to allow the dutyholder to identify reasonably practicable measures to manage the major accident risks identified for the HRB.

Methods are available (hierarchy of controls, cost-benefit analysis) to help focus on reasonably practicable controls to improve HRB safety.

3.6 Sector workshops: identification of hazards, barriers, and escalation pathways

At the workshops, stakeholder representatives from the sector assisted in the identification of hazard scenarios for HRBs; the main focus being on fire and structural major accident hazards, but this was not limited to these types of major accident hazards to ensure that nothing significant was overlooked. This exercise was done using a HAZID approach.

The potential pathways that could lead to a major accident hazard occurring were identified using a Bow Tie diagram approach. The barriers that could prevent an incident occurring and the barriers that would mitigate the impact of an event escalating were also considered as part of this stakeholder exercise.

3.6.1 Outcomes from the HAZID exercise

A HAZID is a general term for a hazard identification assessment. It is typically a systematic qualitative team based exercise to consider potential hazard scenarios.

Potential hazards are considered, and potential causes and consequences identified. It is also useful to consider prevention and mitigation barriers specific to these hazard-cause-consequence sequences.

For the workshops, a more flexible approach was used to be more engaging and to enable the mixed expertise of the participants to input into the areas they wished.

Three topics were explored during the HAZID exercises at the workshops: fire, structural, and an open ‘other hazard’ category.

The HAZID exercises generated a large amount of information across the five workshops. Unsurprisingly, there were a large number of initiating factors identified for the different types of escalation event considered at the workshops. There were, however, also a large number of potential prevention and mitigation barriers identified that were explored in more detail during the Bow Tie exercises (see Section 3.6.2).

Compartmentation was identified as a key issue for preventing escalation of fire events, and this included maintaining the integrity and effectiveness of compartmentation and fire stopping controls.

A wide range of initiating factors was identified for fire escalation events, many of which related to human factors issues. Key controls identified were high level leadership and accountability, with fire-safety design and fire-safety systems management identified as useful control measures. Taking responsibility included effective communications with residents and emergency services to allow everyone to play their part in managing risks. It was also highlighted that multiple layers of protection were seen as essential in maintaining control of fire escalation risks.

The structural HAZID identified that many of the events that could lead to significant structural consequences were secondary impacts, or 'domino effects' from some other type of hazard. This included consideration of fire, flooding, and explosion events. Poor design and construction, however, were also identified as contributors to this type of event. This meant that many of the controls identified involved addressing the impact of other hazards when considering structural integrity. Building management was identified as a significant way of managing structural risks.

Competence in design and management were identified across the board as essential high-level controls, just as lack of competence in building design, construction, and management were identified as key underlying root causes for incidents.

The 'other' HAZID identified a wide range of hazards, although some key concerns were identified across all of the workshops. Whilst many of these could adversely impact many people from a single incident (e.g. legionella outbreak in a building), it was identified that these types of event were managed differently from fire and structural hazards.

Compared with the other major hazards that were identified, it was observed that the fire and structural events could escalate rapidly, usually requiring immediate and significant emergency response. The other hazard events did not tend to have this rapid onset.

This suggests that the major accident hazards in scope for management under a safety regime would largely be rapid onset escalating fire, structural, or explosion events.

3.6.2 Outcomes from the Bow Tie exercise

The Bow Tie diagrams constructed for each topic from all of the workshops were compared and common themes identified that allowed the construction of tables outlining the key causes, consequences and barriers identified during the five workshops.

A table format for presenting the Bow Ties has been used to allow an easy reading of the causes, consequences and barriers identified.

The Bow Tie tables can be used to ascertain high level causes and consequences for the different events and failure modes assessed during the workshops. These could be used as an aid for working out high level scenarios for HRBs and help to identify possible prevention controls and/or mitigation barriers, taking the specifics of the building being assessed into consideration.

The Bow Tie tables produced have been used to inform the major hazard accident scenarios outlined in Section 2.

The Fire Bow Tie and the Structural Bow Tie were the two main topics focussed on in the workshops and a number of key themes emerged from across all of the workshops. The main themes identified for the fire and structural accident hazards were also reflected when looking at the more detailed areas, such as failure of escape routes, emergency response, and life safety systems, and especially when considering wider human factors issues.

The Bow Tie tables produced for a Fire event and a Structural event are illustrated in Figure 2 and Figure 3 respectively.

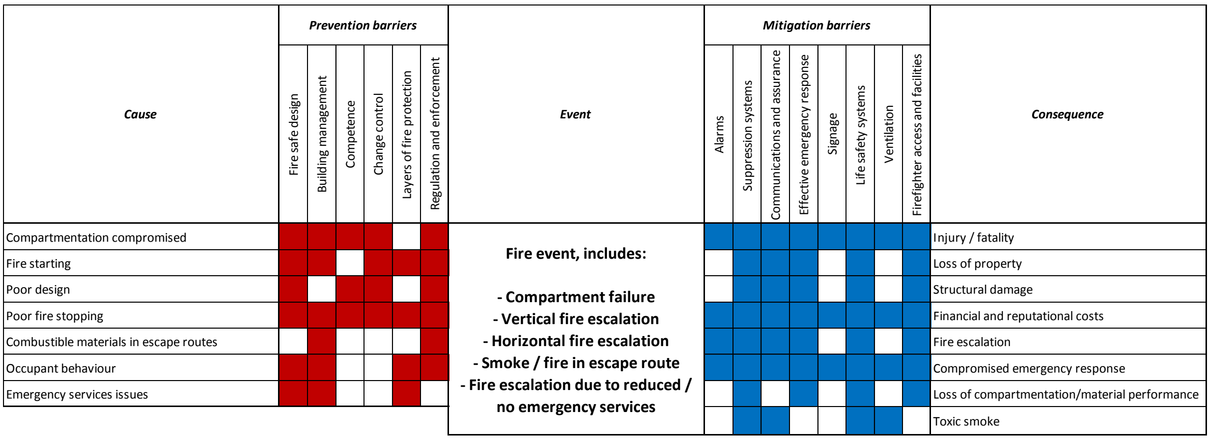

Figure 2 Fire event Bow Tie Table

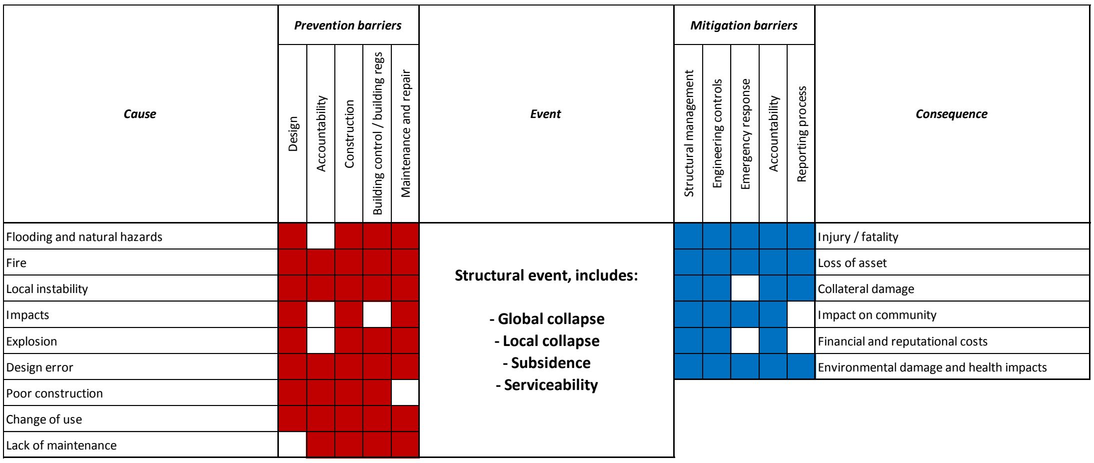

Figure 3 Structural event Bow Tie Table

For the assessment of fire escalation hazards, keeping some form of compartmentation integrity was identified as a major area on which to focus, but there was also an identification of wider life safety systems (e.g. effective detection and suppression as well as multiple escape routes where possible).

As well as engineering and administrative controls (e.g. suppression, fire doors, emergency plans), there were some key control areas identified for dealing with the root cause of issues. These included the design and management of a building with fire safety in mind; and it was also linked heavily to competence in design, construction, management and maintenance of the building.

Insights from Bow Tie analysis

It was also clear during the workshop Bow Tie sessions that the use of multiple layers of protection to give in-depth defence was seen to reflect the realities that many of the control/mitigation barriers identified were not 100% effective. This was reflected in the identification of combinations of active and passive fire protection systems alongside good building management. Effective three-way communications between the dutyholders, residents and emergency responders was also considered across the workshops as a way to ensure maximum effectiveness of the interventions, barriers and mitigation identified for fire hazards.

Some similar root cause themes were identified for structural accident hazards. Key areas highlighted were the competence of those designing, constructing and then managing the building during occupancy. Many of the structural hazards identified reflected secondary or 'domino' effects where some other major incident triggered the structural accident, such as fire, flooding, explosion, etc.; this meant that a greater emphasis was on the design and construction factors to ensure that these types of trigger would not lead to a catastrophic structural accident.

This extended to competence on general maintenance to avoid structural issues, which was a key area considered when assessing ageing buildings and where there may be creeping changes: anomalies that do not seem significant on their own but over time may lead to major accident hazards.

A further area identified to help control risks as buildings change and age was better data collection, including for incidents, and learning from lessons across the sector.

The impacts on communities from any type of major accident were also considered as a consequence that could lead to wider health issues alongside the initial accident. This included mental health issues for those involved and the wider impacts on the community from any blight in the area following such an accident.

These analyses are useful as an overview for gaining a high-level picture of what could lead to escalation hazards and how these might be controlled and mitigated. Assessing the major hazard risks for each HRB needs to be done on a case-by-case basis, however, taking the building specifics into context. The Bow Ties and the scenarios identified can only be used as guidelines / a starting point to ensure that no significant hazards, controls, or mitigations are missed. Dutyholders should not treat these as final products that can be copied and pasted into a safety narrative, safety case, or similar.

3.7 Sector workshops: ‘other considerations’

The workshops with sector stakeholder representatives provided essential information for the development of the HAZID tables and Bow Tie diagrams. They also provided an opportunity for further feedback relating to the management of major hazards in HRBs, and potential future considerations for a regulatory regime. This section aims to summarise some of the common themes identified by sector stakeholder representatives across the five workshops.

3.7.1 Safety Case regime (or similar) seen as a useful framework

Comments from participants largely reflected agreement that a safety case regime would provide a sensible, structured and practical way for the sector to demonstrate major accident hazard risk management of HRBs. The success of safety cases in other sectors was noted.

Along with a number of comments, there was an implicit recognition by workshop participants that current approaches and standards are not resulting in desirable levels of safety.

Workshop participants identified that dutyholders should be made aware that any representative ‘hazard scenarios’ and controls published in risk management guidance will not be exhaustive and that there should be a duty for them to own/and identify, as well as to manage, the risks for their particular HRB. HSE’s document Reducing Risks, Protecting People, was mentioned here as a helpful document by some workshop participants.

There was generally a consensus amongst workshop participants that the sector is currently in a state of relatively poor risk management, which is exacerbated by a range of factors (see sections below). The workshop participants also noted that self-regulation was not seen as viable, with one workshop comment being, “*if you rely on self-regulation for change to happen – it won’t happen*”.

Some participants did recognise that safety cases will also carry a burden/cost, and will take time, resource, competence, and culture change to complete effectively. A concern was raised as to whether safety cases would be too complicated for the sector.

3.7.2 A regulator is perceived as a necessity

Following on from a general set of workshop participant concerns regarding the current state of identifying and managing major accident hazards, it was largely seen as necessary to have a regulator “*with teeth*”, able to support / guide the sector, but also provide appropriate action where risk management falls short. Getting the regulatory framework right within the current process was seen by participants as a “*once in a lifetime opportunity*”.

Legal rights of building owners were also highlighted as a concern by participants, e.g. lack of power to ensure that occupant modifications are corrected where they impact on building safety. Some building owners at the workshops raised serious difficulties that had arisen when they had challenged residents who had modified their apartments. In some cases, resident modifications had impacted negatively on critical barriers (e.g. breaching compartmentation by replacing fire doors), and the courts had favoured the rights of the tenant over building safety. Mismatches between criminal law and civil law were recognised here by participants.

Other seemingly innocuous modifications, such as installation of cable/satellite television were also seen to impact on safety barriers, for example, by creating unprotected breaches of fire compartmentation where cables passed through walls/ceilings.

In addition, participants identified that other stakeholders will drive behaviours, e.g. insurers were recognised as having either a positive or detrimental influence. It is therefore likely worth considering how broader stakeholder involvement may impact both positively and negatively on HRB safety.

3.7.3 Clarity on dutyholders

It was widely recognised by the workshop participants that the current system leads to a lack of transparency on areas, such as building ownership and the contracting of others to manage different aspects of the building, and therefore in who may act as a dutyholder in a regulatory regime.

Workshop participants recognised that owners, either intentionally or unintentionally, are able to 'hide' from responsibilities. The use of shell companies and non-UK domiciled owners were recognised as some of the factors contributing to these challenges. There was some suggestion that there should be a recognised, named dutyholder, and that they should be domiciled in the UK. Fire authorities noted that significant time and resource is taken up simply trying to identify the responsible person under current arrangements.

As those that create risks are responsible for managing those risks is a fundamental principle of managing safety, then a process is needed to allow the identification of a responsible dutyholder for each HRB. An area for future consideration is to address how to ensure that suitable dutyholders can be identified.

Workshop participants also recognised that currently, building owners have no right of access to many leased or tenanted properties, which can restrict their ability to monitor and influence overall building safety. This is unlikely to change as it could infringe on the rights of residents. This is something that may need to be considered more fully when assessing building safety prevention and mitigation barriers.

3.7.4 Ensuring there is a risk-based element to safety

Workshop participants raised concerns with regards to large step changes in required risk management practices based purely on building height (e.g. over 18 metres). Focusing on height was seen as a justifiable part of a phased regulatory roll-out (i.e. to avoid a significant burden in the short-term); although some considered that an initial focus on the tallest buildings by number of storeys might be more appropriate than what was perceived as a fairly arbitrary height of 18 metres.

However, many participants at the workshops considered that the approach to safety regulation for buildings should take into account other factors, which may make them 'high(er) risk'. Examples of these were:

- building materials.
- construction type/methods (e.g. large panel structure buildings have known weaknesses).
- occupant demographics (e.g. number/percentage of vulnerable occupants).
- location/environmental context (an area with known or potential flooding issues).
- the presence of multiple building purpose groups (e.g. mixed residential/commercial).

Workshop participants widely noted that building height is not necessarily related directly to risk in a comparable way to thresholds applied in other regulated sectors. For example, sites falling under Control of Major Accident Hazards (COMAH) regulations may choose to reduce their inventory so that they no longer fall under COMAH regulations. Reducing inventory, however, does increase inherent safety for such sites. A height threshold does not necessarily have the same safety improvement implications for buildings. For example, when constructing a 6-storey building on sloping ground, the decision to build up or sink one side of the foundations may determine whether the height of the same structure, with exactly the same hazards and risks, is considered to be above or below 18 metres.

Workshop participants also raised some concerns that new builds close to a borderline would likely aim to fall marginally below the threshold simply in order to avoid the need to demonstrate safety measures, such as those required with a safety case.

Associated with these issues was a concern amongst the participants of the workshops that additional costs to meet any additional requirements for buildings above 18 metres might lead to "*safety funding*" being channelled away from buildings lower than 18 metres. There was implicit concern that this could negatively impact the safety of buildings less than 18 metres in height.

This is an area that will need further consideration as the processes are developed to manage building safety and could benefit from further engagement with the sector.

3.7.5 Competence and culture

Workshop participants recognised that any move forwards to improve the safety for HRBs will require a significant shift in relation to current culture and competence levels. While this was generally seen as a positive thing in the long-term, it was noted that this needs to be considered in relation to how such a regulatory framework is implemented and progressed.

It was identified that there will be a need for greater clarity on how competence is determined and documented.

Related to this point were comments by participants that HRBs are often perceived by their owners simply as investment opportunities, rather than peoples' homes. As a result, the long-term future of the building may be overlooked.

Workshop participants also noted that residents often do not appreciate the impact their actions can have on maintaining or degrading / defeating major accident hazard barriers. Modifications to apartments were frequently identified as areas where residents may compromise the design intent of the building in terms of fire safety, and even structural safety. Examples were given of a lack of awareness (or concern) about the role of fire compartmentation (particularly fire doors at flat entrances), internal structural walls or areas designed to be 'fire sterile'.

There was recognition by workshop participants s that language is different amongst various stakeholders, e.g. the term 'perils' is used by insurance companies instead of 'hazards'. This has the potential to lead to misunderstanding and mistakes.

A lack of critical information in relation to buildings was also highlighted by many participants as a sector/cultural challenge. At one end, the owners of a building may not have been given, or may not have retained, details of the safety design intent and important construction details of the building. At the other end, the owners may not be aware of changes in occupancy and use of the building. For example, changes in family size, and complexities such as subletting etc. can mean that owners are unaware of how many occupants are in any given apartment or building. Involvement of residents was seen as a 'must' for any changes / improvements to the sector.

Case studies were noted as a useful part of culture change / education. Use of "*build right first time*" case studies was given as an example.

There were also comments from some participants regarding wider influences to shaping culture, for example whether owners / dutyholders should be still be able to obtain insurance if safety measures were not considered suitable / appropriate to manage risk.

3.7.6 Maintaining an understanding of societal/technological changes

Wider changes in society were noted by participants to be of important consideration. For example, the potential for gas networks to move towards use of hydrogen could impact on safety considerations for HRBs. Use of solar panels on HRBs and potential fire risk was also highlighted. Also, the growing use of high energy storage battery technologies were mentioned, both in individual items and for local electrical supply management, e.g. are 'powerwalls' the future equivalent of storage heaters?

3.7.7 Overlap between standards and existing regulation

A number of sessions mentioned the fact that numerous standards, guidelines and regulations currently exist. It was noted that these did not always map together in a coherent way for the safety of HRBs over their entire lifecycle. Workshop participants recognised that this could be made clearer with any new regulation. For example, there was discussion of how existing areas covered by regulation, such as Construction Design and Management (CDM) regulations, would fit in.

3.7.8 Lifecycle challenges

Workshop participants recognised that the lifecycle of a building will result in changes / transfer of the dutyholder over time. It was considered essential that any regulatory regime should ensure that it is clear about who the dutyholder is at any particular time.

Some workshop participants recognised that the wider lifecycle of a building should be considered when assessing building safety. This would align with hierarchy of controls (HoC) principles (sometimes referred to as Eliminate, Reduce, Inform and Control; ERIC in the construction sector), where designing with inherent safety in mind can be more effective in terms of both safety and cost. It should be mentioned that this has been identified by MHCLG through a new system of gateway points to ensure building safety during design and construction. It also links to some extent with the existing regulation principles of CDM.

3.7.9 Reducing safety to reduce cost

There was some recognition by participants that major accident hazard safety is often secondary to profit / reducing costs. Indeed, it was considered by some to be common practice for firms to "*bid low*" for construction and renovation work in the expectation that "*value engineering*" on the original design would be possible to produce a profit margin. This often meant compromises to the design that reduced safety margins. Workshop participants identified that any changes to improve safety "*will not be cheap*". There may need to be some level of consideration with regards to the potential time and cost implications.

3.7.10 Verification and supervision

Workshop participants noted that, as well as planned "*value engineering*", there are many opportunities for unapproved work practices during build or modification to deviate from design specifications. There was mention by some workshop participants of consideration of appropriate supervision/verification to ensure that such deviation has a higher chance of detection and appropriate management / rectification. At all of the workshops it was noted that the disappearance of the permanent presence of a 'Clerk of Works' was perceived as having led to a reduction in the quality of work and compliance with design details.

3.7.11 Progress on improving building safety

A fairly common theme to emerge from the workshops was concern over lack of progress on driving change / improvement for the sector. Many of the attendees were passionate about the need for such change / improvement, but also held a feeling of helplessness without it being driven by effective regulation.

Agreements to make improvements following the Lakanal House fire, which were perceived as not having been followed through, were cited as a particular frustration.

At the time of the workshops, workshop participants mentioned that there had been no formal response to the 'Building a safer future' consultation held over June and July 2019, which was seen by many as an unreasonable delay in the process of making changes that were urgently needed.

Workshop participants acknowledged that whilst the sector could be making positive changes itself without waiting for legislation, there is a concern over spending time and money moving down a specific route to managing safety that then does not correspond with the legal requirements once legislation is passed. The preferred method for the sector seems to be to understand the legal requirements first before starting to implement the necessary processes and controls.

Engaging with the sector as legislation is developed will be an opportunity to encourage the sector to start taking ownership of the risks and making the necessary changes to start managing these risks more effectively.

3.7.12 Information sharing and safety critical communication

There was recognition by the workshop participants that safety critical information regarding building information and occupants could/should be shared with emergency services to enable an appropriate response from them.

Sharing of information and best practice amongst the sector would also benefit improving safety for HRBs, but this would have to be led from those within the sector itself.

3.7.13 Continuous learning

Workshop participants noted that lessons may be identified in various parts of the country, and that such lessons should be shared. For example, different Fire and Rescue Services may have different ways of operating due to lessons learnt. It was felt that there are not currently any systematic approaches for such sharing of good practice.

This is another area where those in the sector itself could lead and help improve lessons learnt across the sector.

3.7.14 Engagement method for workshops

A number of those attending the workshops highlighted that the workshop process to explore hazards and controls worked well, and the consideration of multiple (related) centre events during the Bow Tie development exercise was a pragmatic approach. Ensuring future approaches are engaging and pragmatic for stakeholders is likely to be a key component of success.

3.8 Summary

The Landscape Mapping exercise and the sector stakeholder workshops supported that a safety case (or similar) regime appears to be an appropriate way to demonstrate that major accident scenario risks are being managed effectively for HRBs.

Whilst the decision to follow the recommended safety case approach had already been made by government, the research supports this decision; if the research had indicated otherwise then this might have suggested that there would be significant difficulties in implementing such a regime.

This is not to suggest that implementing a safety regime for HRBs is an easy task, but there seem to be approaches that could be used and which should help with the future implementation of any regime adopted.

The type of major accident hazard to be managed under a safety regime was identified to be a hazard that could rapidly escalate from an initial fire, structural or explosion event.

The research indicated that the regime should include the consideration and demonstration of risks being effectively managed throughout a building lifecycle. This could include:

- Initial design and build: consideration during design and build phases offers the opportunity to have a more significant impact on major accident hazard safety. It should be mentioned that this has been identified as important through the proposal of a new system of gateway points to ensure building safety during design and construction that can provide information to support safety cases for new buildings.

- Decision-making which may alter/modify the risk profile, such as:
  - Changes to building usage (including residential and commercial activities),
  - Other building changes/modifications, or repurposing,
  - Routine or reactive maintenance activities,
  - Potential life extension,
  - Potential owner or occupant behaviour that could impact on the efficacy of control measures.

Consideration would be needed on what format exactly a safety case should take for HRBs, taking into consideration that this will necessarily have to differ from the type of case presented in the process industries.

Regulatory terms will need defining in the context of HRBs from a legal context, for example: who would be a dutyholder? This is one area already under discussion within government and with external stakeholders, but this and other regulatory terms need to be properly clarified and, once established, the legal definitions communicated to stakeholders.

However, there needs to be leadership demonstrated within the sector showing that there is an appetite to do what is necessary to safely manage HRBs. This will require dutyholders to take ‘ownership’ of the risks generated and make necessary decisions to manage and reduce these risks.

At present there seems to be a reluctance within parts of the sector to move forward in dealing with these issues without a detailed government steer. This is understandable to some degree that people do not want to waste limited resource doing the ‘wrong thing’; however, time spent identifying major risks and potential controls is not going to be wasted time. This is potentially a message that needs to be given to the sector more clearly.

4. Observations

From the results of the landscape mapping analysis and the outcomes of the sector stakeholder workshops, it appears that a safety case regulatory approach is technically a feasible approach to managing building safety to reduce the risk of major accident hazards. Whilst the decision to follow this approach has already been made by government, the research findings support that decision; this means that an approach should be able to be developed, even though this is not an insignificant task.

A safety case regime should allow a focussed approach to managing those risks that could lead to significant consequences.

However, there are genuine concerns across the sector over the practical aspects of introducing any system that is a significant deviation from current practices when considering building safety. One major concern from the stakeholders at the workshops was that any system that was based largely on self-regulation would not deliver the safety improvements required and could ultimately lead to further catastrophic events.

These concerns include:

- the relative inexperience of the sector in considering, let alone documenting, high consequence low-likelihood safety issues.
- what appears to be a clear division between those building new HRBs for the future and those managing existing HRBs. The new builders may be better placed to produce more comprehensive assessments. Those with older buildings typically have less information on which to base an assessment and there is concern that there is less that can actually be done to address any weaknesses.
- the sheer number of HRBs. Depending on the definitions used for HRBs, this could vary from the order of 10,000 buildings (over 18 metres in height) to 100,000 buildings (over 11 metres in height) that could be in scope. It is not clear that sufficient competence and capacity exists nationally to implement a safety case regime across these numbers of HRBs, at least in the short term. However, experience from other safety case regimes shows how these rely on the availability of competent people to develop and manage the safety cases, to provide the necessary independent review of those safety cases and to regulate the system.

Such concerns reflect that the effective implementation of any safety regime remains a challenging task.

Any regime that is implemented is likely to need a lead-in period to allow the sector time to learn about managing these high consequence risks. However, there is also a need to prioritise the highest risk areas to identify where controls and mitigation are needed to reduce those risks proportionately.

Existing industrial permissioning regimes (e.g. COMAH, Offshore) that require safety cases have been developed over many years to get to their current approaches. These approaches continue to evolve over time. This has allowed the development of expertise in writing safety cases and identification of how these should be used in regulation.

Any new safety regime identified for HRBs will need to evolve over time, so initial adoption of a pragmatic and practical approach would be preferable to a large amount of detailed prescription over a short timeframe.

Existing building safety regimes such as the FSO and HHSRS may be useful for creating some of the parts needed in an individual safety case.

However, neither the FSO nor the HHSRS are suitable starting points for the development of an overall safety case that can aid dutyholders in understanding and managing their own risks and provide a regulator with assurance that this is being done.

It is, perhaps, useful to set out what is needed from a safety case regime as they have been applied elsewhere.

4.1 Safety case for buildings

A safety case is, quite simply, the case outlining why something is safe. The use of the expression ‘safety case’ can conjure up images of large technical documents and complex risk assessments. This is not necessarily a true reflection of what is required. The purpose of a risk assessment is to identify the risks and the appropriate control measures to manage the risks identified to those that might be affected.

Rather than moving directly to a comprehensive and detailed safety case regime, an initial approach could be to first implement a simpler framework involving a ‘safety narrative’ for each HRB.

This safety narrative approach can perhaps be seen as one of the first stages of ongoing engagement between dutyholders and the regulator to develop the necessary understanding and the overarching framework. Whilst this suggested approach echoes ongoing discussions within government, there is nothing published yet that reflects this initial approach to the iterative process in developing a safety regime.

The principal aims of the safety narrative, however, should be to allow the dutyholders to understand their most significant major accident risks and to successfully identify measures to prevent and mitigate these risks in a relatively quick timeframe.

The safety narrative would require the dutyholder to explain the hazards that they had identified for their building, what controls were in place to prevent such events occurring, what mitigation controls and evacuation procedures were in place, and to include an action plan to detail planned maintenance or improvements.

The types of event to prioritise implementation of control measures would be those that could lead to a rapid onset of an escalating hazard. This would be mainly from an initiating fire, structural or explosion event, but not necessarily limited to just those types of hazards. Prioritisation would need to be on a case-by-case risk-basis rather than being limited to a prescribed list of hazards.

For existing HRBs, an initial safety narrative may simply focus on the three or four biggest major hazard risks for the building and identify what concerns there are should an event occur (e.g. not having fire doors where they are needed, escape routes that are not fully usable, people not knowing what to do in the event of a major fire, either in advance or at the time).

This approach would create a basic understanding of the most important overarching risks for each building and where to target improvements. Feedback at the workshops indicates that this is currently not well understood within the sector. This is still a significant undertaking due to the number of buildings that need to be addressed, even assuming a staged implementation prioritised, for example, by building height.

However, this approach means that a highly detailed and technical safety case would not be required. Rather than requiring high level specialists, those that are involved in the management, design, survey, or even residents of such buildings could assist in delivering this initial narrative.

The safety narrative should be specific and holistic for that building, that is, it should consider the overall building as a system when assessing the safety considerations. Over time, the safety narrative can signpost to supporting documentation and evidence that forms a portfolio to aid safety decision-making.

Local knowledge of the building (building safety manager, residents' group) to reflect the reality of how things work (or not) in the building may be as useful as technical understanding of control systems.

In some cases, additional information may need to be gathered in an iterative process of engagement between the dutyholder and the regulator. This is similar to some of the approaches adopted in established safety case regimes. This helps establish elements of the underlying safety approach, or safety management system, that is used to keep the building safe on a 'day-to-day' basis.

4.2 Safety case process

The safety case/safety narrative is an ongoing process (a 'living document') that develops as the building evolves over time. To think of it as a paper report is to miss the advantages of such an approach.

To ensure that it remains relevant and allows change to reflect best practices, adding any incidents or near-misses to the safety narrative for each building could help establish those situations when barriers work or when they do not work as anticipated. Useful insights to improve systems can be obtained even if there has been a successful intervention to prevent an incident escalating e.g. was it a good intervention or just good fortune that stopped the incident? If such information, collected as part of the management of each HRB, is also shared with the regulator then this allows a wider assessment of new and/or important matters common to a range of HRBs. Introducing a process of systematic event reporting with appropriate collection and curation mechanisms would be most effectively done during the initial implementation of a safety case regime.

The legal rights of residents to make changes to their homes may negatively impact overall building safety. It does seem likely that case law will continue to favour the rights of residents in this area. Therefore, when considering the holistic safety considerations of a HRB, it may be necessary to explicitly assess the risks from this type of scenario. There are different ways to deal with this, which include enhanced detection: where the potential consequences of the alteration are actively monitored to detect an incident early, or enhanced protection: where extra layers of protection are used to account for a local modification in an apartment.

The information gathered at the workshops indicated that the regulator would need to be a 'guiding hand' initially to help the sector learn how to adapt to the new regulatory approaches. It is, therefore, suggested that guidance is developed on what should be considered in a safety narrative.

The major hazard accident scenarios identified during this research project, outlined in Section 2, have been produced to help the regulator. This information could be included in guidance to be used as pointers/aids. Care would be needed to ensure that this type of guidance does not just lead to a 'tick-box exercise'. Each safety narrative has to be specific to the building being assessed.

HSE publishes its internal guidance for assessors reviewing safety cases on its website (17). This allows those writing safety cases to understand what is going to be assessed but avoids the guidance being used to create 'cut-and-paste' safety cases. A similar approach could be considered here.

As a regulator will need to establish and document internal processes before passing on requirements to dutyholders, then publishing the regulator's own internal guidance allows information to be made available in a shorter timeframe than working out what needs to be done internally and then reinterpreting as dutyholder guidance.

Once a ‘simple safety narrative’ approach was beginning to mature, the benefits of including more detail and a more complete range of hazards could be considered.

The regulator will also benefit from growing knowledge and understanding of both progressive and sudden changes of materials and techniques. There is likely to be a requirement for collection, or even generation, of the science of innovative and alternative materials and techniques, and review of such evidence in the context of the improved management of existing risks and the introduction of new ones. This could be paired with the collection of event data, such that new risks which may not have been predicted in advance are identified at an early stage.

4.3 Summary

- A safety regime for HRBs is established based on an assessment of major hazards within a HRB and identification of what stops them escalating and turning into major incidents. The key focus of any regime needs to be to aid the dutyholder in the identification of risks and suitable control measures.
- Major accident hazards considered should include those that lead to rapidly escalating fire, structural, or explosion accidents needing immediate emergency response. This is not an exhaustive list, however and risks should be assessed on a case-by-case basis.
- An initial safety narrative could be developed for each HRB as a starting point for assessing the risk profile. This should allow dutyholders to identify measures to manage their major accident risks in a relatively quick timescale and the sector to become familiar with major hazard management concepts.
- Near-miss incident recording could be considered part of the safety narrative regulatory framework process to build up understanding of what works and when it works to prevent and mitigate incidents that could potentially escalate to major accidents.
- Guidance could be developed to help dutyholders understand how they can provide the necessary safety information in an appropriate format. Guidance produced internally for the regulator could be made publicly available, which would help those writing safety narratives, without it becoming a ‘tick-box exercise’.
- Future research on HRB safety could also help strengthen the evidence base to underpin decision making for the regulator and dutyholders.
- The set of representative scenarios developed during this work programme could be used by the regulator to inform discussions with dutyholders to ensure that the risk management of common issues is not overlooked.

4.4 Closing comments

While the primary aims of this work programme were to develop a set of major accident hazard (MAH) scenarios in the context of HRBs, the project also resulted in many other key findings. Many of these align with those outlined in Dame Judith Hackitt's Final Report (1). As a result, some of the recommendations outlined here may have already begun further consideration, or application.

Examples of alignment include:

- Recognition of a lack of clarity on roles and responsibilities for key sector stakeholders, and,
- Relative ignorance in the context of risk management, particularly with regard to major accident hazards.

There is further alignment in the recommendations/suggested improvement areas noted in Dame Judith Hackitt's Final Report and some of the outcomes identified in this work programme. For example:

- The need to increase clarity on accountabilities, particularly the 'responsible person', or 'dutyholder'
- The need for a significant shift in the culture and competence related to major accident hazard safety
- The need to move towards being a more simplified and collaborative sector approach, rather than the current, seemingly disjointed/siloed approach
- The need for a regulatory framework that more robustly considers major accident hazards (such as that adopted by safety case regimes), and one which will help to drive the changes that are much needed (a regulator 'with teeth')
- The need for greater sector learning.

This research project also echoes Dame Judith Hackitt's Final Report commentary that there are many in the sector who are highly engaged, and desire to contribute to progressive and much needed change.

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The Grenfell Tower disaster, 14 June 2017, killed 72 people and injured more than 70 others. The subsequent Independent Review of Building Regulations and Fire Safety concluded that the UK building safety system is inadequate. The Government accepted the review's recommendation for a new regulatory framework. A Joint Regulators' Group, including the Health and Safety Executive, is assisting in the transition to this proposed framework.

This report describes research, done in 2019, for the Joint Regulators' Group. The research aims to identify a preliminary set of representative serious incident scenarios for high rise residential buildings, and potential control measures. The researchers: reviewed the literature on high rise building incidents, and the regulation of major rail and industrial incidents; and conducted workshops to extract critical knowledge from sector representatives. The research team has experience in safety case regimes, risk management, building construction, and fire. They used formal risk analysis techniques ('HAZID' and 'bow tie') to structure the process, and a Hierarchy of Controls approach to rank the effectiveness of potential control measures. They considered rapidly escalating events requiring immediate large scale emergency response. The report identifies ten preliminary representative serious incident scenarios. The potential control measures identified for consideration include: establishing a safety regime based on assessment of serious incident scenarios; development of an initial safety narrative for each building; near-miss incident recording; guidance for duty holders; and strong and committed leadership from dutyholders, the wider sector, and the future regulator. These findings are being used to inform the development of a risk framework for the proposed new safety case regime.

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