SFPE Shopping Centre Case Study

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United Kingdom SFPE Chapter
May, 2016
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SUMMARY

This report was written for the Society of Fire Protection Engineers (SFPE) as part of the 11th Conference, titled ‘Performance Based Codes and Fire Safety Design Methods’, which will be held in Warsaw, Poland in May of 2016. The SFPE United Kingdom Chapter, who includes Christine Pongratz, Darren Agnew, and Sandy Kilbourne, has developed a fire safety strategy for the proposed SFPE Shopping Centre case study as a part of this SFPE Performance Based Design conference.

The objective of this case study is to prepare a performance-based fire safety strategy report for a shopping mall. The project brief, provided by SFPE, defines the goals of the “client”, and the “constraints” provided by the buildings architectural plans proposed. It is therefore the objective of this report, to outline an example a fire safety design solution from the design perspective of the United Kingdom. This report has been written to address an international fire engineering audience, mainly the SFPE case study participants, as a means to communicate an example of the U.K. design practices.

The specific requests within the SFPE design brief have been addressed by means of providing an example fire strategy. The fire strategy identifies a full set of goals and constraints (some additional from the design brief, but typical in the U.K.), and describes a fire safety design solution specifically to address (1) Means of warning and escape (2) Internal fire spread (linings) (3) Internal fire spread (structure) (4) External fire spread, and (5) Access and facilities for the fire service. The fire strategy has been written to the level of detail typical for a RIBA stage 2 (concept design stage). However, additional background (exceeding a typical stage 2 fire strategy), such as guidance document context and history, and engineering methodology descriptions and solutions, has been provided within the report for the purposes of the case study fire engineering audience. The shopping centre is assumed to be located in the United Kingdom and the basis of the fire strategy design has been considered to comply with relevant municipal statutory requirements (Part B of the Building Regulations as an example in England).

A qualitative design review has been performed to develop a fire strategy which applies both fire engineered solutions and relevant U.K. guidance for an optimal design solution at this design early stage. Specifically, the smoke control design has been developed utilising a fire engineered approach, to install a mechanical exhaust system within the shop and mall circulation areas. Design items such as structural fire precautions, firefighting etc. follow the guidance offered within BS 9999, BS 5588 (Part 7 and 10), and BS 7974.
THE TEAM

The United Kingdom Shopping Centre Case Study report has been written by the following individuals:

Christine Pongratz, BSc, MSc, AIFireE (U.K.), E.I.T (USA), Fire Engineer, Arup Fire U.K.

Christine is a Fire Engineer for Arup in London. She attended the University of Maryland, where she graduated with her B.S. (2013) and M.S. (2014) in Fire Protection Engineering. Christine has a special interest in atrium smoke management, and completed her M.S. thesis, sponsored by ASHRAE, utilising FDS to study the impact of increased velocities of make-up air on fire plume dynamics in atrium smoke control design. As a part of the Arup Fire U.K. team, her current work includes the development of the fire strategy for a 90,000 capacity stadium designed for the 2022 Football World Cup. Christine is a member of the IFE, and is currently the treasurer of the SFPE U.K. Chapter.

Darren Agnew, BSc, AIFireE, Fire Engineer, Hoare Lea

Darren graduated with Honours in 2014 from Glasgow Caledonian University with a Bachelor’s Degree in Fire Risk Engineering. After undergoing a successful placement in 2013, he joined Hoare Lea in Manchester in July 2014 as a Graduate Fire Engineer. He has worked on a number of projects across a range of sectors, including Residential, Educational and Health Care. Which have incorporated a number of aspects such as CFD modelling assessments, fire strategy reports and fire compartment surveys.

Donald “Sandy” Kilbourne, MBA, BSc, GIFE, Owner & Managing Director, Gartcarron Fire Engineering

Sandy Killbourn is an ex local authority fire officer with over 31 years’ experience in the fire service, during which he has acquired twenty three years front line fire safety management predominantly based in the greater Glasgow area.

Educated to degree level, he has a BSc (Hons) degree in Fire Risk Engineering and a Master of Business Administration. As a result he has been the lead officer for the local fire service, in conjunction with building standard’s verifiers, in the approval of numerous proposals containing fire engineered solutions.

Sandy is the owner and Managing Director of Gartcarron Fire Engineering, a small Fire Engineering practice based in Stirling. He is a Member of the Society of Fire Protection Engineers and a Graduate of the Institute of Fire Engineers.
INTRODUCTION

The SFPE United Kingdom Chapter, has developed a fire safety strategy for a proposed Shopping Centre case study. The objective of this case study is to prepare a performance-based fire safety strategy report for a shopping mall, which includes retail shops, supermarkets, food-court and restaurants, car parks, entertainment area etc. The fire strategy approach has been developed on the basis of the drawing information received in the SFPE design brief.

As a minimum, the proposed fire safety strategy meets the following fire and life safety goals as described in the SFPE design brief:

- Safeguard occupants from injury due to fire and smoke until they reach a safe place.
- Safeguard fire fighters while performing rescue operations or attacking the fire.
- Minimize smoke and fire spread inside building.
- Limit the impact on business continuity

The full set of project goals, constraints, and assumptions, utilised to inform the design solution, are identified in Sections 2 and 3 within the fire strategy report. Given the goals and constraints identified, the design solution and its methodologies are subsequently described in section 5 – 9, and outlined in a fire safety provision table in Section 4.

The fire safety solution is comprised of three components:

- **The Fire Strategy:** This is a description of what occupant, building management, and fire service behaviour and provisions are expected, for given fire scenarios. It includes a description of the evacuation zoning and any interactions between evacuation zones.
- **Fire Protection Features and Systems:** This is a description of the fire protection features (passive and active fire protection systems) that are required to enable the fire strategy.
- **Management Plan:** This is a description of the staffing duties, training, and maintenance requirements required to maintain the fire protection features and systems to ensure the correct operational response in the event of a fire or alarm. Note: A detailed and co-ordinated plan is not included within this report, but is required to be developed by the building operator.

1.1 The Design Approach

The fire safety design challenge is to engineer solutions that meet the goals within the constraints as identified by the SFPE design brief. The specific client and legislative goals set out for this U.K. case study are defined in Section 2. The constraints have been developed by identifying the buildings architecture proposed at this stage, provided by SFPE, and by identifying the potential hazards within the proposed mall, this is detailed in Section 3. The fire safety design solution is therefore achieved and supported by addressing the goals while overcoming the constraints, as the concept shows in Figure 1.
1.2 Qualitative Design Review

In order to ensure the fire strategy solution developed for The SFPE shopping mall is appropriate, a Qualitative Design Review has been undertaken. This QDR assesses whether the fire safety solution meets the goals and how this can be demonstrated (i.e. following prescription, qualitative assessment or quantified analysis). The process shown in Figure 2, identifies how the QDR fits within the fire engineering design.

![Figure 2: Fire engineering process (flow chart created from concepts in PD 7974)](image)

The United Kingdom government produces prescriptive design solution guidance, (such as BS 9999) for compliance with the municipal statutory building regulations (i.e. Building Regulations 2010, Schedule 1, Part B in England).

Fire Safety Strategy has largely been developed based on contemporary U.K. based design guidance to satisfy regulatory requirements (such as BS 9999). However, the scope of these guidance document are often is limited to the ‘more common’ types of buildings. Therefore,
the fire safety strategy also includes for the adoption of more performance-based analytical methods, specifically in support of the smoke control strategy developed for the mall area.

Fundamentally, the fire safety strategy design solution has been developed by adopting BS 9999, BS 5588 (Part 7 and 10), and BS 7974, where appropriate. The full list of guidance utilised within this report is described in the references, in Section 13.

1.3 RIBA Stage 2 design

Having considered the input required for this case study design, this strategy has been written during the initial concept development stages, as is typical for projects of this nature. Therefore, the strategy developed and information provided is relative to that produced with working to RIBA Work Stage 2 (Concept Design).

1.3.1 RIBA Stage 2 description

The RIBA Plan of work is published by the Royal Institute of British architects. The RIBA Plan of Work organises the process of briefing, designing, constructing, maintaining, operating and using building projects into a number of key stages. It details the tasks and outputs required at each stage, which may vary, or overlap, to suit specific project requirements.

The latest 2013 edition is endorsed by the Chartered Institute of Architectural Technologists, the Construction Industry Council, the Royal Incorporation of Architects in Scotland, the Royal Society of Architects in Wales and the Royal Society of Ulster Architects.

The RIBA Plan of Work provides a shared framework for design and construction that offers both a process map and a management tool. The work stages are used as a means of designating stage payments and identifying team member’s responsibilities when assessing insurance liabilities, and they commonly appear in contracts and appointment documents.

The RIBA Plan of Work outline is shown in Figure 3.
A typical RIBA Stage 2 (Concept Design), with regards the Fire Engineers deliverables for a project of this nature, may include:

- Provide advice to the design team on items relating to the fire safety design of the building via over-marked drawings (typically various iterations of drawings are allowed for in this stage, establishing communication and development of ideas between the project team) and attendance at design development workshops.

- Produce a concept stage fire strategy report, which would be largely visual in format and would build on the feasibility report developed during the previous stage of the project. At this stage a single report is expected to be needed.

- The fire strategy report should incorporate all fire safety goals and requirements as set out by the client and insurers.

- The concept report should identify risks and opportunities to ensure these are clearly understood by the client and project team.

- Communication typical for this design stage: design team meetings assumed during this stage. Numerous meetings with the approving authorities.
1.3.2 Design decisions (SFPE Design brief section 3)

The full fire safety design solution for a Stage 2 (concept design) is described in Sections 4 – 9.

In regards to section 3 of the SFPE design brief, the decision decisions requested have been addressed in the following sections of the report.

Table 1: Design decisions (per section 3 of SFPE brief)

<table>
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<th>Section within report</th>
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</tr>
<tr>
<td>Staircases number, location and sizing.</td>
<td>Section 5.4</td>
</tr>
<tr>
<td>Egress routes – location and sizing.</td>
<td>Sections 5.3.2-5.3.5</td>
</tr>
<tr>
<td>Smoke control strategy for the mall.</td>
<td>Sections 6.6.3.2 - 6.6.3.6</td>
</tr>
<tr>
<td>Smoke control strategy in shops.</td>
<td>Section 6.6.3.1</td>
</tr>
<tr>
<td>Fire compartmentation.</td>
<td>Section 6.4</td>
</tr>
<tr>
<td>Type of suspended ceilings</td>
<td>Section 6.6.2</td>
</tr>
<tr>
<td>Requirements for shop facades</td>
<td>Section 6.4.3</td>
</tr>
</tbody>
</table>
GOALS

The objective of this case study is to prepare a performance-based fire safety strategy report for a shopping mall. The fire safety solution must satisfy the client’s needs, either as the building landlord, or as an individual tenant.

As such, the importance of integrated design throughout the building life is clear; this integration therefore relates not only to design, but also construction, flexibility of use, ongoing maintenance and operation. In order to meet all the needs of the client (SFPE), the following fire strategy goals have been identified.

2.1 Regulatory Requirements

It is an essential legislative goal to comply with local building regulations. As a minimum in the U.K., the design and construction of the completed building must:

- satisfy the functional requirements of Part B of the Building Regulations 2010 (Part B) – (as an example to England specifically);
- satisfy the requirements under the Construction (Design and Management) Regulations 2007; and
- be sufficiently manageable in accordance with the Regulatory Reform (Fire Safety Order) 2005 (RRO).

This report describes how the functional requirements of the Building Regulations will be met. In addition to this, it is essential that the building is designed and constructed to meet the CDM regulations and to allow the owner/occupier to manage the building under the requirements of the RRO. For the purposes of this case study exercise, this report does not address the CDM and RRO compliance requirements. However, the CDM and RRO requirements and consideration practices in the U.K. are identified in Section 10.

Part B of the Building Regulations consider five aspects of fire safety in the design and construction of buildings:

- B1: Means of warning and escape;
- B2: Internal fire spread (linings);
- B3: Internal fire spread (structure);
- B4: External fire spread; and
- B5: Access and facilities for the fire service.

The above are addressed in Section 5-9 of this report.

2.2 Client Goals

The client, SFPE shopping centre, is focused on the base build design solution. As the shopping mall will have multiple tenants, and is a multi-use building, the client’s primary objective is to sell the potential tenants the opportunity for design fit-out flexibility. As tenant fit-out design changes are anticipated (i.e. tenant change within shop unit or tenant would like to combine to units into one), the client would like the base build design solution to allow for
maximum future flexibility. This flexibility includes minimizing construction disturbance during fit-out changes, to avoid affecting business continuity in others the area of the mall.

The goals that have been accounted as described in Table 2.

### Table 2: Client goals

<table>
<thead>
<tr>
<th>Goal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexibility for tenant fit-out design</td>
<td>The client would like the base build design to reduce limitations on the tenant fit out design, within the unit and in regards to the store front entrance</td>
</tr>
<tr>
<td>Flexibility for future shop unit size change</td>
<td>The mall is mainly fit with various size shop units. The client would allow for tenants to combine adjacent units if desired.</td>
</tr>
<tr>
<td>Limit impact of tenant fit-out construction phase on other areas of the mall</td>
<td>It is anticipated that tenant will change within the life of the building. The client would like the base build design solution to allow for minimum disruption to the rest of the shopping centre, during the tenant fit out / construction phase of an individual unit.</td>
</tr>
<tr>
<td>Limit the impact on business continuity</td>
<td>The client would like to limit disruption caused by false alarms, which do not warrant a full building evacuation.</td>
</tr>
<tr>
<td>Limit smoke damage to the building and its facilities</td>
<td>The client would like to limit smoke damage to the building.</td>
</tr>
<tr>
<td>Realistic Managing regime</td>
<td>The client will hire and train building management to follow procedures regards to the life safety and fire strategy provisions. However, all management obligations must be manageable with the number of staff available.</td>
</tr>
</tbody>
</table>

No specific insurance requirements have been identified by SFPE. Therefore, no specific property protection enhancements have been considered at this stage.

### 3 CONSTRAINTS - BUILDING DESCRIPTION

The SFPE shopping mall contains a total of 4 stories, which house retail shops (ranging from 100m$^2$ to 5000m$^2$), a food-court with seating area, restaurants, a fitness club, and a cinema with 5 theatres.

For the purposes of this Stage 2 concept design, the shop units as designated on the DWG drawings produced by SFPE, will be treated as retail units.

The building height (to highest occupied floor in east atrium is 25m, and the building extension footprint is approximately 26,920m$^2$)

The SFPE shopping mall will consist of:

<table>
<thead>
<tr>
<th>Level</th>
<th>Building description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>Shop units (largest approximately 3,724m$^2$)</td>
</tr>
<tr>
<td></td>
<td>Mall circulation space with kiosks</td>
</tr>
<tr>
<td></td>
<td>One “Kids Play” unit</td>
</tr>
<tr>
<td>Level 1</td>
<td>Shop units (largest approximately 2,417m$^2$) and mall circulation space with kiosks</td>
</tr>
<tr>
<td>Level 2</td>
<td>Shop units (largest approximately 5,222m$^2$)</td>
</tr>
</tbody>
</table>
3.1 Hazard Identification

The following key fire hazards and constraints must be considered:

- High occupancy density, many of who will be unfamiliar within the building or the evacuation procedures.
- All retail units are accessed off a central mall having a number of atria, which run the full height of the building. This presents a potential route for fire and smoke to spread between floors. As the smoke rises up the void, the volume of smoke will also increase.
- The fire growth rate within retail environments is typically fast due to the volume and type of materials stored within, however automatic suppression is likely to slow this growth and reduce the potential for fire spread.
- There is a cinema on level 3, which presents a higher occupancy density than expected within the mall.
- A kid’s play is proposed at Level 0, during evacuation families will want to congregate together before exiting the building. This presents additional egress considerations.

Note: Where a crèche (kids play) is provided for children separately from their parents or guardians, it should be sited adjacent to escape routes used by parents or guardians on their way out to avoid the clashing of streams of people as parents or guardians collect their children. A crèche should be at or as near ground level (or the level at which the final exits discharge) as practicable. In no circumstances should the accommodation for children be:

1) on a floor above the level at which their parents or guardians are accommodated, unless the escape route is through the upper level; or

2) at basement level, unless the final exit is at basement level.

The crèche should preferably be adjacent to an external wall and should not have fewer than two exits, one of which should be a final exit.

Based upon this guidance the “Kids Play Area” was relocated from level +3 to the ground floor level (Level 0). (BS9999)

- The completed building will be very large and there will be elements of complex geometry (atria voids).
- Most prescriptive design guidance for shopping centres is based on single or two-storey malls.
- There may be a desire to include fire loading within the mall in the form of displays or kiosks.
3.2 Risk Profiles

Risk profiles are an important consideration in applying BS 9999 as they provided the building blocks for the fire safety design of a particular building. They determine the travel distances that should be applied, where minimum fire safety measures applicable are in place and allow predetermined variations to those travel distances within certain limits. They also provide guidance on the most suitable level of management that should be in place for each risk profile.

The risk profiles are constructed from the occupant characteristics and fire growth rates.

3.2.1 Occupancy Characteristics

The occupancy characteristics take account of the occupant’s familiarity of the building layout and therefore their knowledge of the locations of final exits and stairs and whether the occupants are likely to be awake or asleep. The occupant characteristics are broken down into five main groups, with the classification – Occupants who are likely to be asleep: having three sub-groups to reflect the differing needs of different residential occupancy types.

Table 3: Occupancy Characteristics

<table>
<thead>
<tr>
<th>Occupancy characteristic</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Occupants who are awake and familiar with the building</td>
<td>Office and industrial premises</td>
</tr>
<tr>
<td>B</td>
<td><strong>Occupants who are awake and unfamiliar with the building</strong></td>
<td>Shops, exhibitions, museums, leisure centres, other assembly buildings, etc.</td>
</tr>
<tr>
<td>C</td>
<td>Occupants who are likely to be asleep:</td>
<td></td>
</tr>
<tr>
<td>Ci</td>
<td>Long-term individual occupancy</td>
<td>Individual flats without 24 h maintenance and management control on site</td>
</tr>
<tr>
<td>Cii</td>
<td>Long-term managed occupancy</td>
<td>Serviced flats, halls of residence, sleeping areas or boarding schools</td>
</tr>
<tr>
<td>Ciii</td>
<td>Short-term occupancy</td>
<td>Hotels</td>
</tr>
<tr>
<td>D</td>
<td><strong>Occupants receiving medical care</strong> A)</td>
<td>Hospitals, residential care facilities B)</td>
</tr>
<tr>
<td>E</td>
<td>Occupants in transit</td>
<td>Railway stations, airports</td>
</tr>
</tbody>
</table>

A) Currently occupancy characteristic D, medical care, is dealt with in other documentation and is outside the scope of this British Standard.
B) Under some circumstances, residential care facilities may be classified as occupancy characteristic Cii.
C) This occupancy characteristic is included for completeness within this table but is not referred to elsewhere in this British Standard.

For the shopping centre under consideration the occupancy characteristics “A” and “B” are relevant and have been applied in this case study.
3.2.2 Fire Growth Rate

The fire growth rate is the rate at which it is estimated that a fire will grow. The fire growth classifications have been developed through scientific research. Fire growth rates should be categorized as follows:

Table 4: Fire growth rate examples

<table>
<thead>
<tr>
<th>Category</th>
<th>Fire growth rate</th>
<th>Examples</th>
<th>Fire growth Parameter $^A) \text{kJ/s}^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Slow</td>
<td>Banking hall, limited combustible materials</td>
<td>0.0029</td>
</tr>
<tr>
<td>2</td>
<td>Medium</td>
<td>Stacked cardboard boxes, wooden pallets</td>
<td>0.012</td>
</tr>
<tr>
<td>3</td>
<td>Fast</td>
<td>Baled thermoplastic chips, stacked plastic products, baled clothing</td>
<td>0.047</td>
</tr>
<tr>
<td>4</td>
<td>Ultra-fast</td>
<td>Flammable liquids, expanded cellular plastics and foam</td>
<td>0.188</td>
</tr>
</tbody>
</table>

$^A)\text{This is discussed in PD 7974-1.}$

3.2.3 Creating the Risk Profile

Risk profiles are given as a combination of occupancy characteristic and fire growth rate. Where a number of risk profiles apply within one building, the higher risk profile should be used.

Table 5: Risk Profile from BS 9999

<table>
<thead>
<tr>
<th>Occupancy characteristic</th>
<th>Fire growth rate</th>
<th>Risk profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Occupants who are awake and familiar with the building)</td>
<td>1 Slow, 2 Medium, 3 Fast, 4 Ultra-fast</td>
<td>A1, A2, A3, A4 $^A)$</td>
</tr>
<tr>
<td>B (Occupants who are awake and unfamiliar with the building)</td>
<td>1 Slow, 2 Medium, 3 Fast, 4 Ultra-fast</td>
<td>B1, B2, B3, B4 $^A)$</td>
</tr>
</tbody>
</table>
| C (Occupants who are likely to be asleep)       | 1 Slow, 2 Medium, 3 Fast, 4 Ultra-fast | C1 $^B)$, C2 $^B)$, C3 $^B), C$ | C4 $^{A), B)}$

$^A)\text{These categories are unacceptable within the scope of BS 9999. Addition of an effective localized suppression system or sprinklers will reduce the fire growth rate and consequently change the category}$
$^B)\text{Risk profile C may be divided into sub-categories, viz. Ci1, Cii1, Ciii1, etc.}$
$^C)\text{Risk profile C3 will be unacceptable under many circumstances unless special precautions are taken.}$

Therefore, the following risk profiles are considered applicable to the shopping centre that forms the basis for this case study:
Table 6: Occupancy and Risk profile for mall population

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>Risk profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concourse or shopping mall</td>
<td>B2</td>
</tr>
<tr>
<td>Crèche 1)</td>
<td>B2</td>
</tr>
<tr>
<td>Office (open-plan exceeding 60m²)</td>
<td>A2</td>
</tr>
<tr>
<td>Shop sales area B)</td>
<td>B3</td>
</tr>
<tr>
<td>Shop sales area C)</td>
<td>B3</td>
</tr>
<tr>
<td>Office (closed-plan or office less than 60m²)</td>
<td>B2</td>
</tr>
<tr>
<td>Restaurant</td>
<td>B2</td>
</tr>
<tr>
<td>Theatre/cinema/concert hall auditoria</td>
<td>B2</td>
</tr>
</tbody>
</table>

This category is not defined within BS9999, based upon the groupings available; we have assumed that it falls within a Risk Profile B2.

B) Excluding those in covered shopping complexes and excluding department stores but including those that trade predominantly in furniture, floor coverings, cycles, prams, large domestic appliances, or other bulky goods, or cash and carry shops.

C) Including supermarkets, department stores, shops for personal services like hairdressing, shops for the delivery and collection of goods for cleaning/repair/treatment or for members of the public themselves carrying out such leaning/repair/treatment.

3.2.4 Variation of Risk Profile

Automatic sprinkler systems can provide an efficient means of fire control within a building compartment. Such provision restricts fire growth, prevents fire spread, limits heat and smoke generation, and can extinguish the fire. The guidance in BS 9999 therefore adopts an approach whereby the risk profile level can be reduced by one level when sprinklers are installed.

**EXAMPLE** The provision of an automatic sprinklered installation permits a reduction in fire growth rate, allowing larger travel distances, smaller doors, larger compartments, reduced fire resistance periods and other provisions recommended in this standard. An unsprinklered shop with a risk profile of B3 would become B2 when sprinklered and an unsprinklered office with a risk profile of A2 would become A1 when sprinklered. Also the addition of sprinklers would have the effect of reducing a not allowable B4 risk profile to an acceptable B3.

4 FIRE STRATEGY

4.1 Outline Fire Strategy Assessment and Proposed Approach

The fire protection features and systems proposed as part of the fire strategy solution for the SFPE shopping centre are described in Table 7. The table identifies the key fire safety features and challenges in reference to the design brief, and the proposed design solution strategy. As this is a stage 2 design, with various options to consider, also includes the potential risks (from an approving authority’s perspective) and the opportunities to amend the design solution by re-evaluation of goals and constraints (i.e. cost vs. benefit). Specific risks and opportunities are further described in Section 11.

Section 5 - 9 describe the life safety and fire protection systems considerations in detail, in the event of a fire within specific areas of the shopping centre.
## Table 7: Fire Safety Provisions

<table>
<thead>
<tr>
<th>Fire Safety Provision</th>
<th>Comments</th>
<th>Risks &amp; Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protected stairs and corridors</td>
<td>All protected stairs and corridors should be constructed to achieve a minimum level of fire resistance of 60 minutes (for integrity, insulation, and load-bearing capacity, where required), when tested in accordance with BS476 parts 21 &amp; 22 1987.</td>
<td>A person located within a refuge space should be assured that their presence there is known by the building management team. It is the responsibility of the building management team to inform the persons with the refuge of the emergency, and attend to their safe evacuation.</td>
</tr>
</tbody>
</table>
| Disabled refuge spaces              | Refuges are commonly located within fire protected stairwells. Each refuge should provide an area accessible to a wheelchair and in which the user can call for and await assistance. Refuges spaces should be provided on all storeys above ground of a building for:  
  a) each protected stairway affording egress from each storey; and 
  b) each final exit leading onto a flight of stairs external to the building.  
  A refuge space should be of sufficient size both to allow the user to manoeuvre into the wheelchair space without undue difficulty. The space provided for a wheelchair in a refuge should be not less than 900 mm × 1,400 mm.  
  In addition, a system of two-way communication between each refuge space and a manned control room (responsible for organising and managing building evacuation) should be provided. | A discussion is required with the client to review available space for this |
| Architecture                        |                                                                                                                                                                                                             |                                                                                        |
| Occupancy                           | The occupants of the shopping centre comprise of:  
  • Staff, both shopping centre and individual retail units, who are generally familiar with the building layout and fire safety systems within it;  
  • Members of the public who are assumed to be unfamiliar with the building layout, and their approrproate response/exit location in the event of a fire alarm or fire event  
<p>| As those unfamiliar with the building will form the largest group of occupants their risk profile takes precedence over all others. It is the clients responsibility to ensure the building management for both the shopping centre and the individual units are sufficiently trained to assist the occupants to make their escape. |                                                                                        |
| Fire control centre                 | The fire command centre should be located adjacent to the main Fire                                                                                                                                       |                                                                                        |</p>
<table>
<thead>
<tr>
<th>Fire Safety Provision</th>
<th>Comments</th>
<th>Risks &amp; Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service access point (indicative location shown in Figure 34), and is defined as a room which is either solely dedicated as a control centre or is combined with the building management/security office.</td>
<td>provision, and the Fire Service to agree and co-ordinate for this provision</td>
<td>____________________________________________________________________________________________________</td>
</tr>
<tr>
<td>Downstands</td>
<td>Fixed smoke reservoir barrier downstands, or smoke chanelling screens, are required within the mall areas to limit smoke spread beyond a defined area (i.e. smoke zone). The design and location of such downstands is described further in Section 6.6.2.</td>
<td>The depth of the downstands directly informs the smoke exhaust rate required per smoke zone. Should the proposed arrangement of such downstands require modification (either location or depth) beyond this stage, then this can affect the calculated performance of the smoke exhaust system (i.e. exhaust rate and inlet air provision).</td>
</tr>
<tr>
<td>Emergency voice communication system for refuge spaces</td>
<td>Each refuge space contains a two way communication device linking back to the fire control centre (in accordance with BS 5839-9).</td>
<td></td>
</tr>
<tr>
<td>Emergency lighting</td>
<td>All emergency escape routes should have adequate artificial lighting provided in both public and back of house areas. Lighting to escape stairs should be on a separate circuit from that supplying any other part of the escape route. In addition, all escape routes and communal areas should be provided with emergency lighting in compliance with BS 5266-1:2011.” The system should be supplied with backup power supply as it is considered a life safety system.</td>
<td></td>
</tr>
<tr>
<td>Escape signage</td>
<td>In accordance with BS 9999, every escape route (other than those in ordinary use) should be distinctively and conspicuously marked by emergency exit signs of adequate size complying with the Health and Safety (Safety signs and signals) Regulations 1996. In general, signs containing symbols or pictograms which conform to BS ISO 3864-1:2011 satisfy these regulations.”</td>
<td></td>
</tr>
<tr>
<td>Door control mechanisms</td>
<td>Power door mechanisms will be provided to all final exit doors on Level 0 upon activation of a confirmed fire due to replacement air required for the smoke control system. The final exits will provide the inlet air for the system, as described in Section 6.6.5.1. The power door</td>
<td>The automatic opening of the three final exit doors may present a security risk for the client, if the system were to operate outside mall opening hours. If so, the solution for the make-up air of the smoke control system may be reviewed at the next design stage.</td>
</tr>
<tr>
<td>Fire Safety Provision</td>
<td>Comments</td>
<td>Risks &amp; Opportunities</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Sprinkler suppression system</td>
<td>An automatic sprinkler suppression system will be installed throughout the building, including the additional enhancements for life safety, designed in accordance with BS EN 12845-1:2004.&lt;br&gt;&lt;br&gt;The sprinklers are installed for the purposes of life safety, business continuity, and property protection. Therefore a redundant water tank and sprinkler pump should be installed.&lt;br&gt;&lt;br&gt;It is proposed that fast response type sprinkler heads will be installed in all shops, mall circulation, cinema and food court areas (back of house areas do not require fast response sprinkler heads).&lt;br&gt;&lt;br&gt;Sprinklers will be installed at false ceiling level and within the base build below the floor slab (topmost height of the ceiling void).&lt;br&gt;&lt;br&gt;See section 6.3 for details.</td>
<td>There is opportunity for fast response sprinklers at false ceiling level to be omitted in shop units only. This is under the condition that the false ceiling provides a 70% opening to the ceiling void above.&lt;br&gt;See section 11.1 for details.</td>
</tr>
<tr>
<td>Emergency power</td>
<td>Emergency power should be provided to all life safety systems including fire/smoke alarms, sprinkler pumps, mechanical smoke exhaust, powered doors, etc.&lt;br&gt;&lt;br&gt;The emergency power should be achieved by either duplicate and independent incoming electrical utilities or an emergency stand-by generator.</td>
<td></td>
</tr>
<tr>
<td>Dry risers</td>
<td>Provided in the fire-fighting shafts in accordance with BS 9990. The dry riser inlet will be provided on ground level within 18m of the fire fighting access point. The dry riser outlets are located at each floor within the fire-fighting shafts.&lt;br&gt;&lt;br&gt;See section 8 for details.</td>
<td></td>
</tr>
<tr>
<td>False ceiling design in shop units and mall circulation space</td>
<td>A false ceiling with a 1.5m depth (below the 5.5m floor slab height) is required in all shop units, and mall circulation space. The suspended ceiling is required to be at least 25% ‘open’ (geometric free area) to allow smoke to rise through the ceiling. The 25% free area is based on the design of sprinklers installed at the false ceiling level.</td>
<td></td>
</tr>
<tr>
<td>Fire Safety Provision</td>
<td>Comments</td>
<td>Risks &amp; Opportunities</td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Smoke control within the shop units</td>
<td>The shop units will contain a mechanical smoke extraction system. Within the shop units, smoke reservoirs within the false ceiling will create smoke zones (see Section 6.6.3.1). Each smoke zone is limited in area to 1,300m², or 60m in length. The mechanical extraction smoke system is designed to extract smoke at a rate to allow for a smoke layer to form within the ceiling void. Smoke is then exhausted via ceiling fans/duct system. Provisions are as follows: The shop units greater than 1,300m² will require their own mechanical extraction system. The shop units less than 1,300m² will share a ceiling void / smoke reservoir with adjacent shop units Each smoke zone is to be formed by smoke retardant construction downstands of 1.5m in depth around its perimeter. See section 6.6.3.1 for details. The performance criterion for the exhaust system is detailed in Section 6.6.5.</td>
<td>The smoke extraction system is designed for a 2.5MW fire in the shop units given fast response sprinkler installation within the units. This may be considered conservative. (See 6.6.6.1 for details).</td>
</tr>
<tr>
<td>Smoke control within the mall circulation space</td>
<td>The mall circulation space (which has a floor slab immediately above) will also contain a mechanical smoke extraction system. Within the mall circulation area, smoke reservoirs within the false ceiling will create smoke zones. No smoke zone can exceed 1300m², or 60m in length. The mechanical extraction system will be designed to extract smoke at a rate to allow for a smoke layer to form within the ceiling void. Smoke is then exhausted via ceiling fans/duct system. See section 6.6.3.2 for details. The performance criterion for the exhaust system is detailed in Section 6.6.5.</td>
<td></td>
</tr>
<tr>
<td>Smoke control within atria voids (Atrium 1, 2, and 3 as identified in Figure 13)</td>
<td>The mall contains three large atria. Each atria will require a mechanical extract system to achieve the life safety and property protection goals as identified in Section 2. See section 6.6.3.3 for details.</td>
<td>The large atriums have been designed to include for a mechanical smoke extraction system utilising a zone model calculation approach. Upon review of the design fire and architectural considerations, there is an opportunity to adopt a more</td>
</tr>
<tr>
<td>Fire Safety Provision</td>
<td>Comments</td>
<td>Risks &amp; Opportunities</td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------</td>
<td>-----------------------</td>
</tr>
<tr>
<td></td>
<td>The performance criterion for the exhaust system is detailed in Section 6.6.5.</td>
<td>progressive means of analysis, such as Computational fire dynamic (CFD) modelling, to provide a more accurate assessment on the behaviour of fire and smoke within the building than is permitted by the current techniques employed.</td>
</tr>
<tr>
<td>Compartmentation – Retail Units</td>
<td>Compartments walls should be provided with 60 minutes of fire resisting construction (for integrity, insulation, and load-bearing capacity, where appropriate).</td>
<td>It should be noted that shop units less than 1300m² which share a smoke reservoir zone will not include full height separation within the ceiling void. The units are therefore fire separated (wall between units) but do not have full smoke separation. This is a potential design with relevant stakeholders, and further analysis maybe required in subsequent design stages to evaluate smoke temperatures within the ceiling void.</td>
</tr>
<tr>
<td>Compartmentation – Vertical service risers</td>
<td>As described in Section 6.4.1, compartment floors are to be provided between the retail units and any food and beverage units.</td>
<td>U</td>
</tr>
<tr>
<td></td>
<td>between the retail units and the Cinema.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Where compartment floors are to be provided, any vertical riser penetrating a compartment floor should be either: (i) enclosed in 60 minutes of fire resisting construction; or (ii) appropriately fire stopped at each floor level it penetrates.</td>
<td></td>
</tr>
<tr>
<td>Compartmentation – Horizontal service penetrations</td>
<td>All service penetrations through fire compartment walls should be adequately fire stopped/sealed to maintain the fire integrity of that wall.</td>
<td></td>
</tr>
<tr>
<td>Protected lobbies to lifts</td>
<td>Where a lift well is not contained in a protected stair, there should be smoke-retarding construction between</td>
<td></td>
</tr>
<tr>
<td>Fire Safety Provision</td>
<td>Comments</td>
<td>Risks &amp; Opportunities</td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>the lifts and the accommodation. This should be a protected lobby space, provided with self-closing smoke-sealed doors.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire Detection and alarm</td>
<td>An automatic fire detection and alarm system should be provided throughout the building, designed and installed in accordance with BS 5839-1. Furthermore, voice alarm should be provided in lieu of traditional sounders with the effect of providing a higher level of information to occupants and consequently reducing the risk associated with uncertainty during response to alarm and thus aiming to reduce occupant pre-movement time. Upon activation of a fire alarm second stage this will be recognised as a confirmed fire and the appropriate effects of the fire safety systems will operate. A double knock (confirmed fire) will be due to: - Two smoke detectors activating; - A single heat detector or sprinkler activating; - A manual call point being activated; - The investigation period timing out without the alarm being cancelled; and - The alarm being manually confirmed during the investigation period. See Section 5.2 for additional details.</td>
<td></td>
</tr>
<tr>
<td>Simultaneous evacuation</td>
<td>Due to the large volume, potential for a large population, and the public nature of the building, a simultaneous evacuation strategy is considered appropriate. As safety is the over-riding concern a simultaneous evacuation strategy is considered the best solution.</td>
<td></td>
</tr>
<tr>
<td>Evacuation of Mobility Impaired Persons</td>
<td>The building management and its tenants are responsible for managing the evacuation of Mobility Impaired Persons from within their demise to a safe refuge point within the landlord areas. The building management team will be responsible for ensuring suitable arrangements for assisting the</td>
<td></td>
</tr>
</tbody>
</table>
Fire Safety Provision | Comments | Risks & Opportunities
--- | --- | ---
Fire safety coordination between landlord and tenants | The fire safety managers of each individual organization should liaise to ensure that:
  1. the emergency procedures are clearly understood by all relevant parties;
  2. every aspect of the fire safety precautions and facilities is clearly allocated to be the responsibility of at least one party;
  3. no element of the procedures is unreasonably duplicated;
  4. evacuation strategies for disabled people are coordinated between the different occupancies. | The centre management, acting on behalf of the owners, have overall responsibility to ensure that the occupiers of the retail units comply with any reasonable instructions regarding fire safety. These instructions normally form part of the tenants' handbook.

5 MEANS OF WARNING AND ESCAPE

5.1 Evacuation Philosophy

5.1.1 Evacuation Strategy

The evacuation procedures are an essential part of the overall fire strategy. There are two basic categories of evacuation procedure:

- *total evacuation* of the occupants to a place of ultimate safety, by either simultaneous or phased procedures;
- *progressive evacuation* of the occupants, initially to a place of relative safety within the building where they can remain or, if necessary, complete the evacuation to ultimate safety as part of a managed system.

A simultaneous evacuation (total evacuation) is considered appropriate for the SFPE shopping centre.

5.1.2 Simultaneous evacuation

Simultaneous evacuation is a common approach adopted in premises where it would be unreasonable to expect the occupants to remain in an affected area for a prolonged time when there is a fire. This takes into account not only the physical effects of the fire, but the psychological response of occupants confronted by an outbreak of fire. There are two categories of simultaneous evacuation.

I. Single-staged evacuation: In a single-staged evacuation, the activation of a call point or detector gives an instantaneous warning from all fire alarm sounders for an immediate evacuation.
II. Two-staged evacuation: In a two-staged evacuation, there is an investigation period (or grace period) before the fire alarm sounders are activated. A typical sequence of events for two-staged evacuation is as follows.

1) Initially a coded staff alert is given.
2) There is then an investigation period (or grace period).
3) The evacuation signal is broadcast:
   - if a fire is confirmed; or
   - if an agreed investigation period lapses without the alarm being cancelled; or
   - if a second detector is activated, “break glass” operated or sprinkler flow switch operated during the investigation period.

In this instance, where there are large atria through which occupants would be aware of what was happening elsewhere in the centre, and the potential for smoke to travel quickly into the upper levels a strategy of simultaneous evacuation is appropriate. A delay of 5 minutes between detector actuating and full evacuation commencing is considered appropriate. Such a delay would allow the centre management to investigate any automatic fire signal and limit the exposure of the traders having to evacuate for false alarms.

5.2 Automatic fire detection and alarm

The guidance in BS 9999 outlines the suggested fire alarm and detection system (performance and coverage) based on the risk profile of the occupancy space.

Throughout the mall, it is considered that the level of coverage is consistent with a category “L2” system defined by BS 5839-Part 1. The L2 system calls for detection coverage to escape routes, rooms accessed off escape routes, and some additional supporting areas.

In summary the detection and alarm system should be installed as follows:

- Point smoke detection is provided in the mall circulation areas beneath the soffit above (applicable at ground, first, second, and third level);
- Point smoke detection is provided within the corridors and lobbies forming part of the escape routes, including back of house corridors, protected corridors to stairs, stairs, escape corridors;
  Point smoke detection in all retail units;
- Aspirating detection system is provided at high level, along the roof structure;
- The installed system is addressable (with fire control panel in fire control centre)

Automatic fire alarm and detection systems do not provide any degree of fire containment. However, such systems, in addition to giving an alarm, can be used to initiate such functions as:

- closing down ventilation and air conditioning plant to prevent smoke spread;
- operating fire suppression and/or smoke control systems;
- releasing passive fire protection equipment (e.g. automatic closing doors and shutters);

Multiple occupancy premises should be provided with a common detection and alarm system appropriate to the individual risks. In areas with noisy environments or where people might
otherwise have difficulty in hearing the fire alarm, flashing warning beacons must be considered (i.e. mall circulation, retail, and cinema).

5.3 **Horizontal means of escape**

Escape routes from each storey (or level) should be so sited that a person confronted by fire can turn away and make a safe escape via an alternative exit/route. Routes of travel should be free from any construction that could cause undue delay, especially to mobility impaired persons, e.g. raised thresholds or steps, or doors that are difficult to open.

5.3.1 **Number of occupants**

A realistic estimate should be made of the maximum occupancy associated with the intended use of the building, taking into account that a proportion of people have some form of disability. The occupant capacity of a room, storey, building or part of a building is either:

- the maximum number of persons it is designed to hold; or
- the number calculated by dividing the area of room or storey(s) (m$^2$) by the appropriate floor space factor (m$^2$ per person).

**NOTE 1** “Area” excludes stair enclosures, lifts, sanitary accommodation and any other fixed part of the building structure, but includes such features as counters, bars, seating and display units.

The capacity of the stairs should not be used as a basis for determining the occupancy capacity of a room, as this might result in an estimated occupancy that could not be controlled in the event of an emergency.

Table 8: Occupancy load factors

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>Occupancy Load Factor (m$^2$ per person)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concourse or shopping mall &lt; 8m wide</td>
<td>0.75</td>
</tr>
<tr>
<td>Concourse or shopping mall &gt; 8m wide</td>
<td>2 $^{1}$</td>
</tr>
<tr>
<td>Crèche</td>
<td>2 $^{2}$</td>
</tr>
<tr>
<td>Office (open-plan exceeding 60 m$^2$)</td>
<td>5</td>
</tr>
<tr>
<td>Shop sales area</td>
<td>2</td>
</tr>
<tr>
<td>Restaurant</td>
<td>1</td>
</tr>
<tr>
<td>Theatre/cinema/concert hall auditoria</td>
<td>As per the number of seats provided, including wheelchair spaces.</td>
</tr>
</tbody>
</table>

Applies only to the portion of the mall greater than 8m wide.

Occupancy load factor for classroom has been used.

**NOTE 2** Occupancy Load Factors are only typical and higher or lower factors might be more appropriate depending on the circumstances of the intended use and nature of the occupants.

5.3.2 **Minimum number of escape routes**

The escape route design must allow for a minimum number of escape routes based on the maximum number of persons expected in each space. The minimum number of escape routes is identified in BS 9999, and shown in Table 9.
### Table 9: Minimum number of escape routes

<table>
<thead>
<tr>
<th>Maximum number of persons</th>
<th>Minimum number of escape routes and exits from a room, tier or storey</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>1</td>
</tr>
<tr>
<td>600</td>
<td>2</td>
</tr>
<tr>
<td>More than 600</td>
<td>3</td>
</tr>
</tbody>
</table>

#### 5.3.3 Alternative escape routes

Where in multi-storey buildings more than one stair might be needed for escape, every part of each storey should have alternative access to more than one stair. For those areas involving initial dead-end conditions, this access should be provided when the alternative routes become available.

![Diagram showing escape routes](image)

**Figure 5 Escape routes 45° or more apart**

Alternative routes are available from C because angle ACB is 45° or more, and therefore CA or CB (whichever is the less) should be no more than the maximum distance for travel given for alternative routes. Alternative routes are not available from D because angle ADB is less than 45°. There is also no alternative route from E.

**a) Option 1**

**b) Option 2 (travel distance in dead-end condition)**

**Note** The use of dotted lines is to aid use of the diagrams and does not have any other significance.

### Single escape routes and exits

A single escape route is acceptable in the following situations:

- parts of a floor from which a storey exit can be reached within the travel distance limit for travel in one direction, provided that, in the case of places of assembly and bars, no one room in this situation has an occupant capacity of more than 60 people, or 30 people if the occupants require assistance to escape;
- levels with an occupant capacity of not more than 60 people, provided that the travel distance limit for travel in one direction only is not exceeded.
In many cases there is no alternative at the beginning of the route. For example, there might be only one exit from a room to a corridor, from which point escape is possible in two directions. This is acceptable provided that the overall distance to the nearest storey exit is within the limits for routes where there is an alternative, and the “one direction only” section of the route does not exceed the limit for travel where there is no alternative.

5.3.4 Access to storey exits

Any storey that has more than one escape stair should be planned so that it is not necessary to pass through one stairway to reach another. However, it would be acceptable to pass through one stairway’s protected lobby to reach another stair.

5.3.5 Width of Doors, Corridors and Escape Routes

Every escape stair should be wide enough to accommodate the number of persons needing to use it in a simultaneous evacuation emergency; this width depends on the number of people using the stair on each storey, as further explained in Section 5.4. In a building designed for simultaneous evacuation, the escape stairs should have the capacity to allow all floors to be evacuated simultaneously and to enable people on the fire floor to leave the floor quickly.

5.3.5.1 Doors

The door width per person expected to use the door should generally not be less than the value given for the appropriate risk profile and the total door width should be:

* not less than the aggregate of the exit widths; and
* not less than 800 mm regardless of risk profile.

However, if additional fire protection measures are provided the width may be reduced subject to certain limitations.

**NOTE** An increased door width might be necessary on some access routes.

Where the minimum level of fire protection measures are provided the minimum width of doors based upon the risk profile is:

<table>
<thead>
<tr>
<th>Risk profile</th>
<th>Minimum door width per person (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2</td>
<td>3.6</td>
</tr>
<tr>
<td>B2</td>
<td>4.1</td>
</tr>
<tr>
<td>B3</td>
<td>6</td>
</tr>
</tbody>
</table>

If a storey has two or more storey exits it has to be assumed that a fire might prevent the occupants from using one of them. The remaining exit(s) need to be wide enough to allow all the occupants to leave quickly. Therefore, when calculating the aggregate of the exit widths the largest exit width should be discounted.

Generally, the total width of doors is calculated by multiplying the maximum number of occupants by the minimum door width per person for the appropriate risk profile. This is calculated as follows:

\[ W = \frac{C \times d}{N - 1} \]

Where:
W = Door width
C = Occupancy Capacity
d = Minimum door width per person in mm
N = Minimum number of exits, when more than one is provided, or number of exits actually provided if the minimum number is exceeded.

NOTE 1  This can result in very wide exits and additional exits may be provided to reduce the actual width of the exits.

5.3.5.2  Exit Widths (Malls)

The total occupancy capacity of the mall has been used to calculate the required exit width from the various levels. On the ground level (level 0) the proposed entrances/ exits can be used as there are three of them with a total width of 24m. However, on the upper levels the exit widths relate to stair or ramps to ensure adequate exits. The table below details the appropriate exits widths for the malls on each level.

Table 10: Total minimum exit widths – Example

<table>
<thead>
<tr>
<th>Location</th>
<th>Total Occ Cap</th>
<th>Minimum No of Exits</th>
<th>Total Width of Exits (m)</th>
<th>Average width of exits (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minimum Fire Safety</td>
<td>Additional Fire Safety Measures</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>W_T=C*4.1/1000</td>
<td>W_{TP}=C*3.3/1000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minimum Fire Safety</td>
<td>W_A=W_T/3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>W_{AP}=W_{TP}/3</td>
</tr>
<tr>
<td>Level 0</td>
<td>5717</td>
<td>3</td>
<td>23.44</td>
<td>18.87</td>
</tr>
<tr>
<td>Level +1</td>
<td>6176</td>
<td>3</td>
<td>25.32</td>
<td>20.38</td>
</tr>
<tr>
<td>Level +2</td>
<td>4855</td>
<td>3</td>
<td>19.90</td>
<td>16.02</td>
</tr>
<tr>
<td>Level +3</td>
<td>5709</td>
<td>3</td>
<td>23.41</td>
<td>18.84</td>
</tr>
</tbody>
</table>

Where:
W_T = Total Exit Width with minimum Fire Safety Measures in place;
C = Occupancy Capacity;
W_{TP} = Total Exit Width when additional fire safety measures are in place;
W_A = Average Exit Width with minimum Fire Safety Measures in place;
W_{AP} = Average Exit Width when additional fire safety measures are in place.

It is demonstrated that very wide exits are required when limited to the minimum number of exits.

For the purposes of this case study the minimum fire safety requirements have been exceeded and as a result the exit widths applicable to the malls have been taken to be the figure for “Additional Fire Safety Measures”.
As identified in Table 10, the level 3 requires a minimum total of 18.84m of exit width. The proposed stair locations, and protected corridors identifies a total of 5 stairs required based on the number of people expected, and minimum exit numbers required. Therefore, each stair will be sized to 3.8m width (18.84m divided by 5 total stairs). This example applies to the shopping centre mall area only, the cinema exit example is identified in Section 5.4.1.

NOTE: The Food court consists of a standing area immediately in front of the kiosk where people wait to be served and a seating area with tables and chairs for people to eat their food. These two areas have been included in the mall capacity as they are open to the mall with no clear delineation between the areas.

5.3.5.3 Shop Exit Widths

A similar exercise was carried out on the retail units, and subject to a minimum exit width for a B3 risk profile of 1m regardless of the calculated exit width. Table 12 below details the total exit width required for each retail unit on Level 0.

Due to the lack of detail available at this time – storage areas within the retail units, service corridors, toilet facilities, staff areas etc. a full design of escape routes has not been possible. These areas for which we currently have no details for would reduce the retail area and as a consequence the occupancy capacity of the unit. The calculations presented are indicative of the entire defined space being used for retail purposes. This has resulted in larger levels of occupants that will actually be the case.

Once further details are available then the exit widths from each retail unit will be reviewed and where necessary amended.
Table 11: Calculated exit widths for Level Retail Units

<table>
<thead>
<tr>
<th>Level 0</th>
<th>Shop No.</th>
<th>Area (m²)</th>
<th>Occ Cap</th>
<th>No. of Exits</th>
<th>Total Exit Width (m)</th>
<th>Min Width (m)</th>
<th>Min Width of Each Exit (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A=L*W</td>
<td>C=A/O</td>
<td>N</td>
<td></td>
<td>W₁=C*6/1000</td>
<td>W₂=C*5.3/1000</td>
<td>WA=(C*d)/N</td>
</tr>
<tr>
<td>1</td>
<td>3717</td>
<td>1859</td>
<td>3</td>
<td></td>
<td>11.15</td>
<td>9.85</td>
<td>3.72</td>
</tr>
<tr>
<td>2</td>
<td>2557</td>
<td>1279</td>
<td>3</td>
<td></td>
<td>7.67</td>
<td>6.78</td>
<td>2.56</td>
</tr>
<tr>
<td>3</td>
<td>2183</td>
<td>1092</td>
<td>3</td>
<td></td>
<td>6.55</td>
<td>5.78</td>
<td>2.18</td>
</tr>
<tr>
<td>4</td>
<td>525</td>
<td>263</td>
<td>2</td>
<td></td>
<td>1.58</td>
<td>1.39</td>
<td>1.00</td>
</tr>
<tr>
<td>5</td>
<td>273</td>
<td>137</td>
<td>2</td>
<td></td>
<td>0.82</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>6</td>
<td>253</td>
<td>127</td>
<td>2</td>
<td></td>
<td>0.76</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>7</td>
<td>370</td>
<td>185</td>
<td>2</td>
<td></td>
<td>1.11</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>8</td>
<td>976</td>
<td>488</td>
<td>2</td>
<td></td>
<td>2.93</td>
<td>2.59</td>
<td>1.46</td>
</tr>
<tr>
<td>9</td>
<td>562</td>
<td>281</td>
<td>2</td>
<td></td>
<td>1.69</td>
<td>1.49</td>
<td>1.00</td>
</tr>
<tr>
<td>10</td>
<td>700</td>
<td>350</td>
<td>2</td>
<td></td>
<td>2.10</td>
<td>1.86</td>
<td>1.05</td>
</tr>
<tr>
<td>11</td>
<td>89</td>
<td>45</td>
<td>1</td>
<td></td>
<td>0.27</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>12</td>
<td>3030</td>
<td>1515</td>
<td>3</td>
<td></td>
<td>9.09</td>
<td>8.03</td>
<td>3.03</td>
</tr>
<tr>
<td>13</td>
<td>999</td>
<td>500</td>
<td>2</td>
<td></td>
<td>3.00</td>
<td>2.65</td>
<td>1.50</td>
</tr>
<tr>
<td>14</td>
<td>1745</td>
<td>873</td>
<td>3</td>
<td></td>
<td>5.24</td>
<td>4.62</td>
<td>1.75</td>
</tr>
<tr>
<td>15</td>
<td>242</td>
<td>121</td>
<td>2</td>
<td></td>
<td>0.73</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>16</td>
<td>1033</td>
<td>517</td>
<td>2</td>
<td></td>
<td>3.10</td>
<td>2.74</td>
<td>1.55</td>
</tr>
<tr>
<td>17</td>
<td>66</td>
<td>33</td>
<td>1</td>
<td></td>
<td>0.20</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>18</td>
<td>867</td>
<td>434</td>
<td>2</td>
<td></td>
<td>2.60</td>
<td>2.30</td>
<td>1.30</td>
</tr>
<tr>
<td>19</td>
<td>370</td>
<td>185</td>
<td>2</td>
<td></td>
<td>1.11</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>20</td>
<td>425</td>
<td>213</td>
<td>2</td>
<td></td>
<td>1.28</td>
<td>1.13</td>
<td>1.00</td>
</tr>
<tr>
<td>21</td>
<td>313</td>
<td>157</td>
<td>2</td>
<td></td>
<td>0.94</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>22</td>
<td>225</td>
<td>113</td>
<td>2</td>
<td></td>
<td>0.68</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Note: The total width calculation uses a value of 6mm per person to calculate the exit width and where additional fire safety measures are in place this value reduces to 5.3mm per person.

5.3.5.4 Corridors and escape routes

The width of a door in a corridor should be not less than either the calculated corridor width minus 150 mm, or 1,050 mm, whichever is the greater. In those limited circumstances where the corridor is not required to be accessible to wheelchair users, e.g. in maintenance areas, the width of the door may be reduced to 800 mm.

Where double doors are provided the width of one of the leaves should be not less than 800 mm. The width of a corridor or escape route should be not less than the calculated width of any door leading on to it or 1 200 mm, whichever is the greater. Where the corridor is not required to be accessible to wheelchair users, e.g. in maintenance areas, the width may be reduced to 1000 mm.

5.4 Vertical means of escape

The number of escape stairs needed in a building (or part of a building) is determined by:

- the constraints imposed on the design of horizontal escape routes;
• whether a single stair is acceptable;
• whether independent stairs are required in mixed occupancy buildings; and
• the provision of adequate width for escape while allowing for the possibility that a stair might have to be discounted because of fire or smoke.

In larger buildings, it is necessary to provide access for the fire and rescue service, in which case some escape stairs might also need to serve as fire-fighting stairs.

5.4.1 **Width of escape stairs**

The guidance in BS 9999 provides the following to detail the width of escape stairs:

- should be not less than the width(s) of any exit(s) affording access to them;
- should not be reduced at any point on the way to a final exit; and
- should be not less than the dimensions given for the appropriate occupancy characteristic.

The width of the escape stairs is dependent on the occupancy use of the area which it serves. The minimum width of the upward and downward travel defined by BS 9999 is shown in Figure 10. The required width of escape stairs which serve a simultaneous evacuation, as described below, should be compared to values in Table 12, to confirm compliance.

<table>
<thead>
<tr>
<th>Occupancy Characteristic</th>
<th>Width of stair for downward travel (mm)</th>
<th>Width of stair for upward travel (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1000</td>
<td>1200</td>
</tr>
<tr>
<td>B (except assembly)</td>
<td>1000</td>
<td>1200</td>
</tr>
<tr>
<td>B (assembly only)</td>
<td>1100</td>
<td>1200</td>
</tr>
<tr>
<td>C</td>
<td>1000</td>
<td>1200</td>
</tr>
</tbody>
</table>

The width of an escape stair should be measured as the clear width between the walls or balustrades, at the narrowest point up to 1500 mm above pitch line.

**NOTE** Handrails and strings which do not intrude more than 100 mm into this width may be ignored.

The escape stairs are sized using the guidance from BS 9999, which defines the minimum width of stair per person over a total number of floors served for simultaneous evacuation, based on the risk profile of the building.
Table 13: Width of escape stairs - Simultaneous evacuation (BS 9999)

<table>
<thead>
<tr>
<th>Risk profile</th>
<th>Minimum width of stair per person served over total number of floors served</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 floor</td>
</tr>
<tr>
<td>A1</td>
<td>3.90</td>
</tr>
<tr>
<td>A2</td>
<td>4.50</td>
</tr>
<tr>
<td>A3</td>
<td>5.40</td>
</tr>
<tr>
<td>A4 A1</td>
<td>—</td>
</tr>
<tr>
<td>B1</td>
<td>4.20</td>
</tr>
<tr>
<td>B2</td>
<td>4.80</td>
</tr>
<tr>
<td>B3</td>
<td>7.00</td>
</tr>
<tr>
<td>B4 A1</td>
<td>—</td>
</tr>
<tr>
<td>C1</td>
<td>4.20</td>
</tr>
<tr>
<td>C2</td>
<td>4.80</td>
</tr>
<tr>
<td>C3 A1</td>
<td>7.00</td>
</tr>
<tr>
<td>C4 A1</td>
<td>—</td>
</tr>
</tbody>
</table>

NOTE: The widths of stairs have been calculated on the assumption that all floors are evacuating simultaneously. This is conservative, as the occupants on the fire floor are likely to move more quickly than on the other floors. The flow times on the stairs are based on research data.

Example Level 3 Mall

As an example from the mall area of level 3, the total occupant load within the mall is expected to be 5709 using the methodology described in Section 5.3.1. Therefore, using the B2 risk profile minimum width as identified in Table 13, a total of 19.41m of stair width is required to serve the level 3 mall (3.4mm/persons x 5709 persons = 19.41m). It is currently proposed for level 3 to have a total of 5 escape stairs serving the mall area, as shown in Figure 4, therefore, each stair will require an average of 3.88m in width.

As the minimum width per stair serving the level 3 mall is 3.88m, the 1100mm minimum width for downward travel required by Table 12 has been considered, and is exceeded appropriately.

Example Level 3 Cinema

The simultaneous evacuation strategy will apply to the entire building including the cinema.

Where shopping centre complexes contain office blocks, hotels, residential accommodation or places of entertainment such as theatres and cinemas, dance halls, etc. each of these other occupancies needs to have its own internal means of escape arrangements set out in accordance with accepted principles.

Alternative exits from these other occupancies should not discharge onto a mall even where they have an entry from a mall.

Means of escape from these other occupancies should be separate from protected stairways serving the malls or units. Thus the cinema complex requires its own means of escape as follows:

<table>
<thead>
<tr>
<th>Cinema Complex</th>
<th>Occupancy Capacity (C) Including Staff</th>
<th>1000 (960 + 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Profile</td>
<td></td>
<td>B2</td>
</tr>
<tr>
<td>No of exits/ Stairs</td>
<td>*based on exit number provisions from occupant load</td>
<td>3</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----------------------------------------------------</td>
<td>---</td>
</tr>
<tr>
<td>Door Exit Width</td>
<td>= 1000 persons *3.3 (mm/person) /1000mm *based on door exit width provisions per person</td>
<td>3.3 m</td>
</tr>
<tr>
<td>Average Exit Width</td>
<td>= 3.3/3</td>
<td>1.1 m</td>
</tr>
<tr>
<td>Stair Width</td>
<td>= 1000 persons *3.4(mm/person) /1000mm *based on stair width provisions per person</td>
<td>3.4 m</td>
</tr>
<tr>
<td>Average Stair Width</td>
<td>= 3.4m/3 stair</td>
<td>1.13 m per stair</td>
</tr>
</tbody>
</table>

As the minimum width per stair serving the level 3 cinema is 1130mm, the 1100mm minimum width for downward travel required by Table 12 has been considered, and is exceeded appropriately.

5.4.2 Discounting of stairs

Where two or more stairways are provided, it should be assumed that one of them might not be available due to fire or smoke. When determining the aggregate capacity of all the stairways, it is therefore necessary to discount each stair in turn in order to ensure that the capacity of the remaining stairway(s) is adequate for the number of persons needing to escape.

The stair discounting process is not required if:

- the escape stairs are approached on each storey through a protected lobby. In such a case the likelihood of a stair not being available is significantly reduced and it is not necessary to discount a stair. A protected lobby need not be provided on the topmost storey for the exception still to apply;
- the stairways are protected by a smoke control system designed in accordance with BS EN 12101-6 (i.e. fitted with a pressure differential system to inhibit smoke ingress)
- the building is provided with automatic sprinkler suppression system

As this building has been constructed with protected lobbies and sprinklers installed there is no need to discount any of the escape stairs serving the mall.

5.5 Persons with Restricted Mobility

The preferred method of evacuation for disabled people is by horizontal evacuation to the outside of the building or another fire compartment or by evacuation lift. If these are not available or not in operation, then it might be necessary to carry a person with limited mobility up or down the escape stair. Means of escape for disabled people may comprise a combination of structural provisions (e.g. lifts, refuge areas, ramps) and management procedures (e.g. assisted escape). A strategy should be designed to enable a flexible response to different situations.

Even with extended distances (where additional means of support are included), most disabled people are expected to be able to reach a place of relative safety without assistance. However, certain people, such as some wheelchair users, cannot negotiate stairs unaided. The
following give advice on additional measures that can be taken to aid the evacuation of disabled people:

- **Evacuation Lift** - A lift to be used for the evacuation of disabled people should be an evacuation lift and should be operated under the direction and control of the fire safety manager or a delegated trained staff representative.

- **Other Lifts** - A lift not designed for evacuation may be usable for evacuation in certain situations. If this is to be considered then a suitable fire risk assessment should be undertaken to evaluate whether the lift meets the functional recommendations of an evacuation lift.

- In the risk assessment all the features of fire protection in a building should be taken into account. For example, in a building with automatic sprinklers and significant compartmentation or smoke control, a risk assessment might conclude that a non-evacuation lift would be usable in the initial stages of a fire. Likewise, in a very large building, a non-evacuation lift which is remote from a fire in the initial stage might also be usable.

- **Refuges** - The use of refuges within a building can be of great advantage in the evacuation of disabled people as it enables their escape to be managed in a way that does not hinder that of other users of the building.

5.6 **Final Exits**

Final exits need to be dimensioned and sited to facilitate the evacuation of persons out of and away from the building. Accordingly, they should be not less in width than the escape route(s) they serve and should also meet all of the following conditions:

- **Final exits** should be sited to ensure rapid dispersal of persons from the vicinity of the building so that they are no longer in danger from fire and smoke. Direct access to a street, passageway, walkway or open space should be available. The route clear of the building should be well defined, and if necessary (e.g. potential traffic hazard) suitably guarded.

- **Final exits** should be apparent to persons who might need to use them. This is particularly important where the exit opens off a stair that continues down, or up, beyond the level of the final exit.

- **Final exits** should be sited so that they are clear of any risk from fire or smoke in a basement (such as the outlets to basement smoke vents, or from openings to transformer chambers, refuse chambers, boiler rooms and similar risks).

- **Where a final exit leads to steps outside the building, care should be taken to ensure that there is space for a wheelchair user to move so they do not obstruct the flow of other people leaving the building. Wherever possible final exits should provide a level or ramped route away from the building.**
6 INTERNAL FIRE SPREAD

6.1 Linings

In order to limit the risk of fire and smoke spread, all wall and ceiling linings should meet the recommendations of BS 9999 Table 35, as follows:

<table>
<thead>
<tr>
<th>Location</th>
<th>Class of Lining</th>
<th>U.K. National Class</th>
<th>European Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small rooms of area not more than 30m²</td>
<td>3</td>
<td>D-s3, d2</td>
<td></td>
</tr>
<tr>
<td>Other rooms</td>
<td>1</td>
<td>C-s3, d2</td>
<td></td>
</tr>
<tr>
<td>Other circulation spaces</td>
<td>0</td>
<td>B-s3, d2</td>
<td></td>
</tr>
</tbody>
</table>

Table 14: Lining classifications

The architect must ensure that the above lining classifications are met through their choice and specification of materials.

A Class 0 finish must be used in the mall and escape routes and gives the slowest spread of fire when tested in accordance with BS 476: Part 6 and 7. Typical examples include concrete, ceramic tiles and plasterboard.

A Class 1 finish can be used in retail units and achieves a slightly lower performance compared to a Class 0 finish.

A Class 3 finish may be used in small rooms. Typical examples include timber with a density greater than 400kg/m², timber particle board or glass reinforced polyesters.

6.2 Structural fire protection

Under the guidance of BS 9999, a fully sprinklered retail or assembly and recreation building with a floor level not more than 18m in height from external Ground Level to the top finished floor level, all structural frames, beams, columns, load bearing elements, and floor structures are required to have 60 minutes fire resistance (integrity and insulation).

If the loadbearing elements of structure that only support a roof (and not any fire resisting wall) then they need not be provided with fire resistance.

6.3 Sprinkler system

A sprinkler system will be installed throughout the shopping centre. The sprinklers are installed for the purposes to limit fire and smoke spread from the compartment of origin by controlling the size of a fire in order to allow adequate means of escape. Additionally the sprinkler system is installed to meet the client objective of property protection and business continuity.

It is proposed to provide sprinkler protection throughout the building at false ceiling level and below structural slab level (within the ceiling void). An example of the false ceiling design for smoke control, which includes the sprinkler location is shown in Table 11 in the following section. The ceiling void should be maintained as fire sterile (no commodities to be stored or built within the space).
There is opportunity to review the design solution to omit sprinklers a false ceiling level within the retail units only. This is further described in Section 11.1, for stakeholder review for the next planning stage.

6.3.1 Sprinkler Performance requirements

The sprinkler system should be designed and installed in accordance with BS EN 12845 serve the building throughout.

The sprinkler system should be provided with fast response heads. On this basis, a design fire size of 2.5MW has been used in the assessment, as recommended by BRE 368 ‘Design methodologies for smoke and heat exhaust ventilation’.

The fast response sprinkler head will have a Response Time Index (RTI) of 50 ms$^{1/2}$, and an activation temperature of 68ºC.

The sprinklers are installed for the purposes of life safety, business continuity, and property protection. Therefore a redundant water tank and sprinkler pump should be installed.

It is the responsibility of the sprinkler specialist contractor (not the fire engineer) to design and fit the system to purpose.

6.4 Compartmentation

6.4.1 Compartment Floors

In accordance with BS 9999, it is considered necessary to provide compartment floors in the following locations:

- between the retail units and any food and beverage units.
- between the retail units and the Cinema.

It is not considered necessary to provide compartment floors between different storey levels within a single retail unit.

6.4.2 Compartment Walls

In accordance with BS 9999, the walls between retail units should be provided as compartment walls which are provided with 60 minutes fire resistance (for integrity and insulation, and lead-bearing capacity, where appropriate). It is also necessary to provide 60 minutes fire resistance to the walls separating the retail units from any escape corridors. A period of fire resistance is defined by BS 476–21, in which elements of structure are required to demonstrate a time period of resistance to a standard fire test.

The large retail unit on the second floor is in excess of 4000m$^2$ and as such is required to be provided with a compartment wall. However, this is subject to discussion with the tenant. This should be developed at the next stage of the project in consultation with the tenant.

6.4.3 Shop Façade Compartmentation

In a covered shopping mall, the circulation space is effectively a substitute for the open street during initial escape from a fire-affected unit. Due to the local proximity to other shop units,
the impact that a fire in one unit might have on another unit (adjacent or facing) is an important consideration, and could effect a person’s safe exit through the mall circulation route (between facing retail units).

The guidance in BS 5588 Part 10 identifies the increased hazard to occupants means of escape within a covered shopping mall, however, specific quantitative methods of engineering practice is not included in the guidance. Also consulted for guidance, the Scottish, “Non Domestic Technical Handbook (NDTH), Annex C for additional guidance for enclosed shopping centres, identifies a minimum mall width to be 6m (measured from shop to shop front), which consequently exempts fire resisting construction on the shop façade facing the mall.

It is considered acceptable to design for no additional fire resistance along the shop façade facing the mall, as the minimum width of the mall circulation area is no less than 6m between all facing shop units. Furthermore, this is considered acceptable due to the installation of fast response sprinklers within each shop unit and within the mall circulation area (limiting fire growth and spread).

### 6.4.4 Cinema

The cinema is to be treated as a single 60 minute compartment to assist means of escape, and separation of the mall void. It is also recommended that the Foyer is separated from the adjoining accommodation by a 60 minute fire rated compartment wall.

### 6.4.5 Places of Special Fire Hazard

Places of special fire hazard are defined in Table 31 of BS 9999, and require fire resistance as below:

Table 15: Places of special fire hazard

<table>
<thead>
<tr>
<th>Type of construction needed to separate ancillary accommodation from other parts of the building</th>
<th>Areas of ancillary accommodation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robust construction having a minimum standard of fire resistance of 30 minutes</td>
<td>Storage areas not more than 450m² (except refuse storage areas)</td>
</tr>
<tr>
<td></td>
<td>Repair and maintenance workshops where flammable or highly flammable liquids are not used or stored</td>
</tr>
<tr>
<td></td>
<td>Kitchens (separately or in conjunction with an associated staff restaurant or canteen)</td>
</tr>
<tr>
<td></td>
<td>Transformer, switchgear, and battery rooms for low-voltage or extra-low-voltage equipment</td>
</tr>
<tr>
<td></td>
<td>Engineering services installation rooms (except those listed below)</td>
</tr>
<tr>
<td></td>
<td>Dressing rooms or changing rooms</td>
</tr>
<tr>
<td></td>
<td>Cinema projection rooms</td>
</tr>
<tr>
<td>Robust, solid, non-combustible construction having a minimum standard of fire resistance of 60 minutes</td>
<td>Storage areas more than 450m² (except refuse storage areas)</td>
</tr>
<tr>
<td></td>
<td>Places classified as High Fire Risk areas</td>
</tr>
<tr>
<td></td>
<td>Repair and maintenance workshops where flammable or highly flammable liquids are used or stored</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Robust, solid, non-combustible</td>
<td>Covered loading bays and storage areas not covered above</td>
</tr>
<tr>
<td>construction having a minimum</td>
<td>Refuse storage areas</td>
</tr>
<tr>
<td>standard of fire resistance</td>
<td>Boiler rooms</td>
</tr>
<tr>
<td>equivalent to that required for</td>
<td>Fuel storage spaces</td>
</tr>
<tr>
<td>the elements of structure (i.e.</td>
<td>Transformer and switchgear rooms for equipment above LV</td>
</tr>
<tr>
<td>90 minutes)</td>
<td>Rooms housing fixed internal combustion engine(s)</td>
</tr>
<tr>
<td></td>
<td>Scene docks</td>
</tr>
</tbody>
</table>

### 6.4.6 Including protection of opening and fire stopping and cavity barriers

Where appropriate, suitable provisions should be made to prevent the unseen spread of fire and smoke through cavities or concealed spaces by the use of cavity barriers. The provision of any such barriers should meet the general recommendations of Section 34 of BS 9999.

Openings in any fire-separating element (e.g. compartment walls, cavity barriers, protected corridor etc.) should be protected with appropriate fire stopping or sealing to ensure that the fire resistance of the element is not compromised. The provision of any such protection should meet the general recommendations of Section 35 in BS 9999.

### 6.5 Proposed compartmentation arrangements

The figures below, have been prepared to indicate the proposed location of compartment walls. However, it should be noted that at this early of the design that no stairs, protected shafts, service corridors etc. have been included. For further details identifying the compartmentation of the fire-fighting shafts see Section 8.1.

The compartmentation walls which require 60 minutes fire resisting construction (insulation and integrity), are shown in red in Figure 5 - Figure 8.
Figure 5: Level 0 indicative compartment walls (red lines demark 60 minutes fire compartment walls)

Figure 6: Level 1 indicative compartment walls (red lines demark 60 minutes fire compartment walls)
Figure 7: Level 2 indicative compartment walls (red lines demark 60 minutes fire compartment walls)

Figure 8: Level 3 indicative compartment walls (red lines demark 60 minutes fire compartment walls)
6.6 Smoke control strategy

In order to evaluate the appropriate smoke extract system within each space of the shopping centre, an analysis was completed to evaluate the potential hazards within the area. Individual scenarios are considered to review each type of space (i.e. shop, circulation area, cinema) to determine the appropriate means of smoke control for life safety purposes, and smoke clearance after a fire event. The detailed consideration of each design fire for smoke control purposes is explained in section 6.6.6.

6.6.1 Description of the smoke control system

In order to design for safe evacuation within the mall a smoke control system is proposed for the shop units to limit smoke spread into the central mall. Extracting smoke within the fire origin zone has life safety benefits compared to letting smoke spill out of the units and being extracted from the mall. This is because it reduces the amount of smoke produced (due to less air entrainment from a spill plume) and contains the smoke within the retail unit so less people are affected (also limiting smoke damage of affected areas). The objective of the system is to prevent smoke from spilling into the mall.

Both shop units and mall circulation space (which have a slab to slab distance of 5.5m) will be provided with a false ceiling, which will act as a smoke reservoir for the extraction system. A mechanical smoke extraction system, with each smoke reservoir powered by exhaust fans, and are to be ducted to outlets within the ceiling void to remove smoke from the reservoir. The false ceiling design is further described in Section 6.6.2. The extraction rate required within each zone has been designed in regards to the potential fire size that could be generated within the zone. The design fire scenarios are further detailed in Section 6.6.6.

![Smoke Reservoir within Ceiling Void - Section View](image)

Figure 9: Smoke reservoir within ceiling void – Section view

The shop units and mall circulation space will be divided into smoke control zones according to area and length. The mechanical smoke extraction system in a specific zone will activate upon a confirmed fire within that smoke zone. The perforated ceiling will allow for smoke to travel within the ceiling void. The mechanical extract is designed to keep the smoke layer formation just above the false ceiling height, as illustrated in Figure 9.
Each defined smoke control zone will require powered extraction according to the extraction rates detailed in Section 6.6.3. A smoke barrier, or downstand, will be provided around the perimeter of each smoke control zone. The design intent is to restrict smoke flow to adjacent smoke control zones by extracting the smoke at a rate which will keep the smoke layer within the ceiling void of the original smoke zone of fire origin.

**Activation of extraction system zone**

Each smoke extraction system in a specific zone will activate upon a confirmed fire within that zone. Scenarios which lead to a confirmed fire are described in Table 7.

Addressable smoke detectors will be located at false ceiling level within each zone, designed to BS 5839-Part 1, as described in Section 5.2. Additionally, the fire brigade and building management may activate a specific smoke extraction zone via the fire control panel (located in the Fire Control Centre, as described in Section 8.2).

**Smoke strategy principles within the building:**

- **Shop units greater than 1300m$^2$** will be provided with their own mechanical smoke extraction system within the false ceiling design.
- **Shop units which are less than 1300m$^2$** will be provided with mechanical smoke extraction within the false ceiling design, which will be shared with adjacent units (up to a combined maximum area of 1300m$^2$).
- **Mall circulation space** with a floor slab directly above will be provided with mechanical smoke extraction within the false ceiling design.
- **Atrium 1, 2, and 3** (as identified in Figure 13) will be provided with mechanical smoke extraction within the false ceiling at roof level.
- **Dome 1** (as identified in Figure 13) will have a smoke clearance system, utilising the day-to-day HVAC system to clear smoke if it accumulates at high levels (not for life safety purposes).
- **The smaller dome voids** on level 0 will have a smoke clearance system, utilising natural ventilation if smoke accumulates at high levels (not for life safety purposes).
- **The kitchen area** within the food court on level 3 will have local hood extraction at each kitchen unit (in addition to a bespoke suppression system for each hob). No additional smoke extraction will be provided.
- **The cinema** will utilise the day-to-day HVAC system to clear smoke in the event of a fire (the cinema does not require additional smoke extraction for life safety purposes).

The details regarding the smoke strategy / zoning principles are detailed within Section 6.6.3.

### 6.6.2 False ceiling and mechanical extract design

The ceiling height is 5.5 between floor slabs (for the purposes of this design, the floor slab thickness is not considered). The reservoir depth is 1.5 m, which is 27% percent of the overall height. This depth will allow for a smoke layer to form within the smoke reservoir, the smoke will then be exhausted through local extract fans within the ceiling void.

Smoke resistant downstands (i.e. laminated or toughened glazing – considered acceptable in lieu of fire rated construction because of the cooling of the smoke layer by the sprinkler system) are provided at the front of the retail units to create a smoke reservoir. Downstands
are to be located around the perimeter of each smoke zone specified. It should be noted that the downstands will extend through the ceiling voids to the floor slab above.

Smoke will be removed from within the ceiling void of the retail units. Therefore the suspended ceiling in each retail unit will be at least 25% ‘open’ to allow smoke to rise through the ceiling, into the void from where it can be extracted. The details of the openings in the ceiling will be provided by the fit out teams but could take the form of slots, coffers or other types of perforations, which ensure an even distribution of the openings is achieved.

An illustration in section view of the false ceiling design in shown in Figure 10.

![Section View](image)

(1) Smoke barrier (down-stand) located around the perimeter of each smoke zone
(2) Perforated ceiling must be at least 25% open (geometric free area)
(3) Sprinkler pendants located below the perforated ceiling and below the floor slab
(4) Location and number of exhaust fans to be specified based on plugholing calculations
(5) Exhaust duct located within false ceiling, to exhaust smoke directly outside the building

Figure 10: False ceiling design - Section View

The smoke control zone principle strategy and extract rate per smoke zone is specified in Section 6.6.3.

### 6.6.3 Smoke control zoning strategy

The smoke control zoning strategy per area (i.e. shop, atria, cinema, etc.) is described in Sections 6.6.3.1 - 6.6.3.7. A summary of the extraction details are identified in Table 16. The performance criteria for the exhaust system is identified in Section 6.6.5

#### 6.6.3.1 Shop units

The individual smoke zones have been determined for the mall based on the guidance of BRE 368, Design methodologies for smoke and heat exhaust ventilation. This guidance recommends that a reservoir within a shopping mall should not exceed 1300m$^2$ where powered smoke exhaust is used. Additionally, the smoke reservoir should have a maximum length of 60m.

The shop units, which exceed 1300m$^2$, will have their own separate smoke zone. If the specific retail shop exceeds 1300m$^2$, the unit will require two zones, etc. No smoke zone should exceed 1300m$^2$. 
Each shop unit, which is less than 1300 m², will also have a smoke extraction system. However, the ceiling void above the shop unit will be shared with the adjacent shop units. Therefore, the smoke reservoir to exhaust smoke will be shared between shop units. The shared smoke zone system will be designed so no smoke zone exceeds 1300m². An example of the smoke zoning for shop units is shown in Figure 11. As described in Section 6.4.2, the walls between retail units are to be provided with 60 minutes fire resistance.

![Figure 11: Shop units smoke zones - Section View](image)

Smoke extraction zoning diagrams are presented in Figure 18 - Figure 21. The drawings identify which shops require individual smoke extraction, and which shops will include a shared false ceiling (i.e. shared smoke extraction system).

The smoke extraction rate per zone for the retail units is 12.1m³/s. This is based for a potential fire size of 2.5MW fire. The design fire size was established by means of sprinkler consideration and guidance from BRE 368. The design fire discussion is presented in Section 6.6.6.1. The extraction rate is based on an axisymmetric plume (i.e. the fire is located below the smoke zone and bellows directly into the false ceiling / smoke reservoir).

It is a primary client goal to allow for a flexible design, in which shop units can change tenant in the future. The shop locations as drawn currently may change, as tenants wish to combine units and alter shop fronts. Given the extraction rate is based on an analysis from an axisymmetric plume, the rate is less than would be required for a balcony spill plume. A spill plume analysis would require additional consideration to elements of the store architecture. The benefit of the smoke extraction within each shop unit is this presents no limitations on the width of the store entrance door. There is also potential for shop units to combine, or change storefront design. As this is a key goal of the clients, this solution offers the best solution for flexibility for future changes.

It is of the building owner’s responsibility that the base build design of the false ceiling reservoir (downstand) arrangement, which is shared between units, remains intact. Any changes to this design will comprise the design intent of the smoke control strategy and will need to be redesigned by a competent fire engineer.
6.6.3.2 Mall circulation space

The mall circulation space, which includes only areas that have a direct floor slab 5.5 m above (not to include any void areas), will have the same extraction system as specified for the shop units. The design fire is also specified as 2.5MW, see Section 6.6.6.2 for details. The mall zoning strategy is identified per level in Figure 18 - Figure 21. The extraction rate per smoke zone within the mall circulation space is also 12.1m$^3$/s.

A section view example of the mall circulation space is identified as design fire 2 in Section 6.6.6.2.

![Diagram of mall circulation space](image)

*Figure 12: Fire in mall circulation - section view*

6.6.3.3 Mall Atrium space

The mall atrium space (i.e. large voids above) has been identified as three different atrium spaces. The three atriums, are identified in Section view in Figure 13. These three atriums will be designed with mechanical smoke extraction. The roof of each atrium is assumed to be a skylight. There will be however, solid ceiling area around the perimeter of the skylight on roof level, to allow for smoke extraction fans.
6.6.3.3.1 Atrium 1 and 2

The fuel load within the atrium space is assumed to be items such as kiosks, or seasonal decoration, such as a Christmas tree. Therefore, the fire size for the atrium voids 1 and 2 are designed for the largest practical fire size, which is 5MW (Christmas tree). The design fire solution analysis is detailed in 6.6.6.3. The extraction rate required for Atrium 1, which is a total of 19.5m, is 91\,m^3/s. The extraction rate required for Atrium 2, which is a total of 25m, is 130.1\,m^3/s.

The minimum clear height to design a smoke layer within a shopping mall, per guidance from the 5th ed. of the SFPE Handbook Chapter 63, is 2.5m above the height walking surface. On the top level of atrium 1 and 2, the mechanical smoke extraction will be located around the skylight. As it is anticipated the time for this zone to fill with smoke will exceed the evacuation time (no occupants from the cinema will escape by the atrium 2), a 2.5m clear height on the top level is used to size the exhaust fans in these zones.

A section view to illustrate the basic smoke control principle within Atrium 2, is shown in Figure 14.

Figure 13: Section view A-B-C of Mall
6.6.3.3.2 Atrium 3

The 4m x 4m voids on levels 1 and 2 which span across the south circulation area of the mall will be treated as one atrium. Similar to Atrium’s 1 and 2, the space will have mechanical smoke extraction around the perimeter of the roof (also assuming the roof is mainly skylight).

Given the smaller size of the voids, the fuel load is assumed to be items such as kiosks. For the purposes of this stage C design, the fire size for this atrium is assumed to be 2.5MW. The details regarding the design fire chosen for this space is explained Section 6.6.6.4.

The atrium smoke extraction is designed for an axisymmetric plume, which is for a fire located directly below the 4m x 4m void. The extraction rate is designed to keep the smoke layer 4.0m above level 3 (the highest walking surface). The exhaust rate required for an axisymmetric plume to generate a smoke layer to remain above 15.0m from the base of the fire is 69.5 m$^3$/s.

If a fire within this atrium on ground level is below the level 1 floor slab, the smoke will be extracted through the local mall circulation space extraction system. Although the space is treated as a large atrium, the floor slabs on level 1 and 2 may be considered obstructions for possible smoke extraction at roof level. A fire within that void may generate a plume width exceeding 4m, and smoke could spread to level 1 or 2.

A basic engineered analysis is applied to approximate the potential smoke plume width at level 1 and 2, for an axisymmetric plume at level 0. Chapter 51, Control by Mechanical Exhaust or Natural venting in the 5th Edition of the SFPE Handbook, approximates a plume diameter to be 25-50% of the distance above the top of the fuel package.

Using the most onerous approximation for plume with diameter of 50% above the base of the fire, a fire at ground level may have a plume width of 5.5m when it reaches level 2 (11m above ground). Therefore, it is expected for smoke to spill to level 2. As there is a local smoke extraction system at level 2, the excess smoke may be detected and the smoke control extract system at level 2 may clear this smoke. With two smoke control systems running at the same time, it must be ensured that there is sufficient inlet air being achieved as part of the design calculation.
A section view to illustrate the basic smoke control principle within Atrium 3, is shown in Figure 15.

![Diagram of smoke control principle](image)

**Figure 15: Fire in Atrium 3 - section view**

### 6.6.3.4 Dome Void 1

The dome void as detailed in Figure 13, is assumed to be of completely skylight roofing (glazing) and will have no bespoke extraction system. The large dome which extends from level 0 through level 1 (floor to ceiling height of 21.5m at the peak), will have limited fuel load located directly below the void space. It is assumed this circulation space houses stairs and escalators for occupants to transverse floors close to the entrance. The limitation to fuel load within this area is specified in Section 6.6.7 of this report.

This void does require a smoke clearance system, per BS 9999. A smoke clearance system is designed to remove smoke following a fire and used at the direction of the fire and rescue service to assist fire-fighting operations. This system is not intended for life safety during a fire event, but simply for smoke removal if smoke were to accumulate in this space after an event.

The guidance for atrium space in BS 9999, Annex B, describes for a void space of less than 30m but greater than 18m in height, given a simultaneous evacuation strategy, a mechanical smoke clearance system is needed.

As recommended in BS 9999 the mechanical extraction system is designed as a part of the day-to-day HVAC system within this space. Given this is a sprinklered building (sprinklers located at floor height – not within dome), the system would need to be capable of four air changes per hour.
The illustration, detailed in Figure 16, is taken from Annex C of BS 9999 (Figure C.9). The dome would require the same characteristics as illustrated where the smoke clearance system (dedicated as number 1 in the image) is simply the day-to-day HVAC system operating at four air changes per hour.

![Diagram of smoke clearance system](image)

**Key**
1. Smoke clearance system  
2. Smoke-retarding enclosure but not fire-resisting  
3. Open or enclosed  
4. Atrium base: use and contents comparable with that adjoining the atrium  
5. Make-up air  
6. Smoke reservoir  
AFD: Automatic fire detection connected to the building fire alarm system  
AFD/A: Automatic fire detection and alarm throughout the building  
SE: Simultaneous evacuation

Figure 16: BS 9999 requirements for atrium design

### 6.6.3.5 Small Dome voids on level 1

The smaller dome voids located on ground level, which are approximately 10m tall at their peak, are assumed to be of completely skylight roofing (glazing) and will have no bespoke extraction system. Similar to the larger void, this area will require a smoke clearance system.

Given the height of this space does not exceed 18m, BS 9999 allows for natural ventilation to remove smoke from this void. Therefore, natural exhaust vents should be provided within the glazing of the roof area. The vents should not be less than 10% of the maximum plan area of the dome.

### 6.6.3.6 Kitchen / food court

The kitchen area within the food court will be provided with local hood extraction systems above all hobs (stoves). As noted previously, bespoke suppression systems will be installed above any hobs subject to fit out requirements. The food court seating area is within the
atrium 2 void space. In the event of a confirmed fire within this zone, the atrium 2 smoke extraction system will activate. As described in Section 6.6.3.3.1, a clear height of 2.5m is designed within this zone.

6.6.3.7 Cinema

The cinema does not require a dedicated smoke extraction for life safety purposes. As described in Section 5.1.2 the evacuation of the cinema is separate from the mall/food court area, provided with its own egress stairs sized for simultaneous evacuation.

If smoke were to accumulate in a cinema, the mechanical ventilation system installed could be designed to be used to remove smoke.

6.6.4 Smoke Zone Diagrams per level

As stated previously, the smoke zone reservoirs may not exceed 1300m$^2$ or 60m width. The key in Figure 17 identifies the colour scheme for the plan view diagram of the smoke zoning strategies on all levels as identified in Figure 18 - Figure 21.

![Smoke Zone Key](image)

Figure 17: Smoke zone key

![Figure 18: Level 0 Smoke Zones](image)
Figure 19: Level 1 Smoke Zones

Figure 20: Level 2 Smoke Zones
6.6.5 Smoke extract system - performance requirements

The smoke control strategy is summarized in Table 16, which identifies the method of smoke control used in each location, and the extraction details as explained in Section 6.6.3. The description of the make-up air (inlet air) strategy is explained in section 6.6.5.1. The extraction details are based on the design fire scenarios as further explained in Section 6.6.6.
Table 16: Smoke Control Design by Location

<table>
<thead>
<tr>
<th>Location</th>
<th>Smoke Control method</th>
<th>Extraction Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shop units - greater than 1300m²</td>
<td>Mechanical Extract</td>
<td>12.1 m³/s extraction rate, minimum of two outlets per zone (see design fire 1 described Section 6.6.6.1 for details)</td>
</tr>
<tr>
<td>Shop units - less than 1300m²</td>
<td>Mechanical Extract</td>
<td>12.1 m³/s extraction rate, minimum of two outlets per zone (see design fire 1 described Section 6.6.6.1 for details)</td>
</tr>
<tr>
<td>Mall circulation space underneath floor slab on level above</td>
<td>Mechanical Extract</td>
<td>12.1 m³/s extraction rate, minimum of two outlets per zone (see design fire 2 described Section 6.6.6.2 for details)</td>
</tr>
<tr>
<td>Atrium 1</td>
<td>Mechanical Extract</td>
<td>91 m³/s extraction rate (see design fire 3 described Section 6.6.6.3 for details)</td>
</tr>
<tr>
<td>Atrium 2</td>
<td>Mechanical Extract</td>
<td>130.1 m³/s extraction rate (see design fire 3 described Section 6.6.6.3 for details)</td>
</tr>
<tr>
<td>Atrium 3</td>
<td>Mechanical Extract</td>
<td>69.5 m³/s extraction rate (see design fire 4 described Section 6.6.6.4 for details)</td>
</tr>
<tr>
<td>Dome Void 1</td>
<td>Day-to-day HVAC system (smoke clearance for non-life safety purposes)</td>
<td>Accumulated smoke will be extracted through day-to-day HVAC system. Mechanical ventilation system required to achieve four air changes per hour.</td>
</tr>
<tr>
<td>Small Dome Voids on Level 1</td>
<td>Natural venting (smoke clearance for non-life safety purposes)</td>
<td>Natural exhaust vents, of at least 10% of plan roof (dome) area</td>
</tr>
<tr>
<td>Cinema</td>
<td>Day-to-day HVAC system (smoke clearance for non-life safety purposes)</td>
<td>Accumulated smoke could be designed to be extracted through day-to-day HVAC system.</td>
</tr>
<tr>
<td>Food Court Kitchen area</td>
<td>Local kitchen hood extract system</td>
<td></td>
</tr>
</tbody>
</table>
Extraction System – Fans and Ducting

The guidance in BS 5588-Part 7 states that each system will have two fans, sized at 100% capacity (duty / standby arrangement). The back-up fan provided will have the same performance as the largest and most powerful fan. Each fan will be provided with a primary and back-up power supply. This is to provide sufficient redundancy so that if a fan malfunctions or the primary power supply is not available, the smoke control system will still operate as intended. The fans will be capable of operating at 300°C for at least 60 minutes and enclosed in a 60 minute fire rated plant room.

The ductwork will be fire rated to 60 minutes (integrity / insulation / stability) between the fans and the retail units. Any distribution ductwork within the retail units will be fire rated to 30 minutes integrity and stability only.

If the tenant fit-out design teams wish to deviate from this approach, they will be responsible for the design of the smoke control system. All ductwork will be designed in accordance with BS 476-24 and BS EN 13501-3/4.

As the mechanical exhaust rates which serve the retail and mall space (no atrium areas) require the same ventilation rate, therefore there are options for the fans installed to serve multiple zones. The damper system for the ductwork will have to be coordinated appropriately to serve the activated smoke zone.

There may be scenarios such that multiple smoke zones will require mechanical extraction activation. Therefore, smoke zones should not be interlocked.

For example, this may be true:

• In a shop unit if smoke spreads significantly within a unit requiring multiple smoke zones within that unit to activate, or
• in atrium 3 where the axisymmetric fire below the void may hit the floor slab at level 2 requiring activation both within the atrium roof, and on level 2.

In both examples, upon a confirmed fire within the smoke zone, the dedicated smoke extraction system within that zone will activate (may be more than one zone which receives confirmed fire status). Consideration is required by the mechanical engineers when designating shared fan and ductwork systems between zones.

6.6.5.1 Make-up air

While the mechanical extraction system is exhausting smoke from the mall, fresh air is required to replenish the space to equate pressure in the compartment and allow for fresh air to form the clear layer at low levels. This make-up air, must enter the mall a low levels (below the designed smoke layer height).

The make-up air for all mechanical and natural extraction systems will be provided from the main entrances at level 0. In the event of a confirmed fire (whereby an extraction system may be activated), occupants on the lower levels will use the final exits on level 0 as identified in Figure 23. The three final exits identified in, Figure 23, will be power supplied, to open automatically upon a confirmed fire. The doors require a back-up power supply, as this design item is a part of a life safety system. This may present a security risk for the system operating outside mall hours and this risk must be managed by the client and the building management security team.
It is typical practice in the U.K., to limit make-up air velocities to 5m/s at exit doors, which oppose occupant egress. This is based on experimental data published in the ODPM research report, titled, ‘The Effects of Wind Speed on Escape Behaviour through Emergency Exits’, which investigated the influence of the intake air speed on people's ability to escape through an emergency exit of a shopping precinct. The report concluded that a maximum air speed of 5m/s (at the mall exit) is acceptable for all users of a shopping mall (but are equally valid in any situation where an approach corridor leads to a double door).

The drawings indicate that the final three exit doors on ground floor can achieve 24 meters in door width. Given cladding and door frame structure expected, it is assumed a total of 18m is available as clear width (25% cladding/door structure assumed at this early stage).

For make-up air through an open door, a coefficient of flow must be considered. As suggested by TM19, the geometric area of the door, is multiplied by a discharge coefficient of 0.7, to determine the aerodynamic free area provided by the door for make-up air.

Given the total geometric free area provided by the three final exists on level 0 is 72m² (assumed door height of 3m), the aerodynamic free area is then 70% of this value, which is 50.4m². Within the mall, the largest required extraction rate from the atria is 130.1m³/s., therefore, make-up air should not exceed 2.5 m/s across the final exit doors during an emergency event. This make-up air value meets the 5m/s acceptability criteria.

Within retail shops, make-up air will enter the mall via the final exit doors, and entire the shop through the unit front entrance doors. Additionally, the door opening size of the shop units must be sufficient to ensure a balanced system for the extraction rate specified, this must be reviewed at the next design stage.
6.6.6 Solution Analysis – Design Fires

In order to determine the appropriate means of smoke control for a space, the potential fire hazards are considered within each space. The following design fires identified in Figure 24, are used to determine the mechanical extraction rates within each smoke zone, as listed in Table 16.

![Figure 24: Design Fires considered](image)

6.6.6.1 Design Fire 1 – Fire in a shop (level 0)

Fuel load – Design fire size

In order to evaluate a design fire size in a shop unit a method to determine the potential fire size at the time of sprinkler head activation is first considered. The floor to slab level height is 5.5m. It is anticipated the temperatures generated within the ceiling void (smoke layer) will be greater than temperatures closer to the design layer height at 4m. Therefore, the analysis method uses a sprinkler activating at 5.5m.

This method utilizes basic correlations for jet temperatures and velocities, using Alpert’s correlations. These correlations are also used by the NIST developed software, FPE Tool. The equations for this method, along with the assumptions and input values for a standard sprinkler head, are shown in Table 17 and Figure 25.

Table 17: Inputs used for fire size calculation at sprinkler activation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Input</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTI</td>
<td>50</td>
<td>Relevant for life safety systems</td>
</tr>
<tr>
<td>Fire growth rate</td>
<td>Fast</td>
<td>BS 9999 for retail accommodation</td>
</tr>
<tr>
<td>Activation temperature</td>
<td>68°C</td>
<td>BS EN 12845</td>
</tr>
</tbody>
</table>
The results conclude that a fire may grow to a size of 1295 kW before activation of a sprinkler head at 166 seconds at which point the fire would become steady state (i.e. the sprinklers suppress further fire growth). This calculation method assumes a fire is in direct line with the closest sprinkler head.

However, in retail shops there are often obstructions and layout configurations that could impede direct suppression of a fire when the first sprinkler head activates. This is referred to a “shielded fire”.

Historically, guidance from BRE 368 suggested a 5MW design fire should be used for retail shops that could have shielded fires, given experimental data. However, there are several conservatives within this experimental data, which must be considered to ensure onerous values are not applied for the smoke control design. The 5MW fire conservatives included using non-quick response sprinkler heads used, and locating the sprinkler heads 400mm below the ceiling (activation will take longer).
Statistical data indicates that a 5MW fire is only likely to occur in less than 5% of fires in sprinklered shops. Additionally, where sprinklers operate it is unlikely that heat release rate would be sustained at 5MW. Whilst any smoke control systems in a retail premises must be designed to operate at peak fire size, it is worth noting that for the majority of the time the volume of smoke is expected to lower. Further studies carried out by BRE, used fast-response sprinkler heads. Upon the conclusion of these studies, BRE suggested design fire in premises, which include fast-response sprinkler heads, can be reduced from 5MW to 2.5MW.

At this early stage, it is not clear if there could be potential shielded fires within the retail shop units. As a client goal is to keep the retail tenant fit-out options flexible, a 2.5MW design fire is assumed for design of the mechanical smoke extraction system.

**Mechanical extraction calculations**

The required mechanical exhaust rate to maintain a 4.0m clear layer height and a 1.5m reservoir depth, given a 2.5 MW can then be calculated using the parameters in Table 18. When completing the calculations, 100mm is added to the total clear layer height, to allow for the smoke layer to form within the reservoir.

The mechanical exhaust rate is calculated using equations presented in TM19 for an axisymmetric plume. The results present the required volumetric exhaust rate required per smoke reservoir (zone), and also include the minimum number of exhaust outlets per zone (in order to avoid plugholing). The TM19 equations, identified in Figure 26, can be applied using the following assumptions:

- Smoke properties are assumed to be uniform throughout the smoke layer (this is a 2 zone model)
- No heat loss is assumed from the smoke layer to its surroundings, via radiation or convection/ conduction
Figure 26: TM19 equations for mechanical exhaust rate calculations

The assumptions and input values for this methodology is shown in Table 18 and Figure 27.

Table 18: Input values to calculate the mechanical exhaust rate required – Design fire 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Input</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor to slab height</td>
<td>5.5m</td>
<td>Measured from section</td>
</tr>
<tr>
<td>Reservoir depth</td>
<td>1.5m</td>
<td>Measured from section</td>
</tr>
<tr>
<td>Total clear height to be achieved</td>
<td>4.1m (100mm added to design clear layer height to allow for layer to form within the reservoir- above downstand)</td>
<td>Measured from section</td>
</tr>
<tr>
<td>Air specific heat capacity</td>
<td>1 kJ/kg.K</td>
<td>TM19¹</td>
</tr>
<tr>
<td>Ambient density</td>
<td>1.2 kg/m³</td>
<td>TM19</td>
</tr>
<tr>
<td>HRR density</td>
<td>500 kW/m² (total) 350 kW/m² (convective)</td>
<td>TM19</td>
</tr>
<tr>
<td>Total heat release rate</td>
<td>2500 kW</td>
<td></td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>20°C</td>
<td>Typical for U.K. office</td>
</tr>
<tr>
<td>Convective fraction</td>
<td>66.7%</td>
<td>TM19</td>
</tr>
</tbody>
</table>

The results indicate that required mechanical exhaust rate per zone is 12.1 m$^3$/s. The minimum number of exhaust outlets to achieve the total 12.1 m$^3$/s per smoke zone is two outlets. The total exhaust rate should be evenly distributed between the two outlets.

6.6.6.2 Design Fire 2 – Fire within mall circulation space (level 0)

Covered shopping centres are typically aligned with smaller open retail stall units, known as kiosks, located down the centre of the circulation space. The second design fire considers a kiosk fire located along the walking circulation route on the ground level.

Fuel load – Design fire size

As kiosk units carry a fuel load similar to a retail shop, guidance from BRE 368 is applied by utilising experimental data, which approximates a heat release rate density of 625 kW/m$^2$ for retail areas. The area of the kiosks may range, for the purposes of a Stage C design, a typical kiosk size of 2m x 2m is used. It is approximated a 4m$^2$ fuel load area could therefore generate 2.5 MW fire. This closely aligns with the retail design fire as explained in Section 6.6.6.1.

In addition, fast response sprinklers are installed within the mall circulation space at slab level (5.5m) and false ceiling level (4.0m). It is anticipated a 2.5 MW would be controlled by the sprinkler to inhibit further fire spread.
The provision of kiosk’s or retail islands in the concourse of the mall will need to be reviewed and assessed on an on-going basis by the shopping centre management to ensure that the smoke control system is able to maintain tenable conditions in the mall in the event of a fire given the exhaust provision assumptions are understood and upheld. This will need to be included as part of the Regulatory Reform Order risk assessment.

Section 6.6.7 details the minimum separation distance requirements for kiosks and retail units at this design stage. There is an opportunity to assess and amend the separation distance requirements in the next design stage, as more detail regarding the potential kiosk and retail shop unit is provided by the client.

**Mechanical extraction calculations**

The floor to ceiling height and reservoir depth is the same for the mall circulation space as it is for the retail units. Therefore, the mechanical extraction rate per zone is the equivalent to that required in the shop units. As described in Section 6.6.6.1, a 12.1m³/s extraction rate with a minimum of two outlets is required.

**Separation of fuel packages (Kiosks)**

In order to limit potential fire spread between fuel load packages, the separation distance between kiosks must also be considered within the mall circulation space. This study is further explained in Section 6.6.7, and is prescribed as a building management item in Section 9.

6.6.6.3 Design Fire 3 – Fire within Atrium 2 (level 0)

Atrium 2, as identified in Figure 13, is located in the east side of the building, and is the largest and tallest atria in the mall.

**Fuel load – Design fire size**

Given the size of the atrium, it is assumed the fire load at the base may be the largest (i.e. extravagant decorations such as a Christmas tree). As a Christmas tree is considered to presents the most onerous fire size, and is likely within this space, a Christmas tree design fire load is used for the purposes of assessing the smoke extraction system. The Christmas tree design fire load is applied in Atrium 1 as well as Atrium 2.

In 2011, BRE published a document, “Design Fires for use in fire safety engineering” by Mayfield and Hopkin. This document presents experimental data of test set-ups for various fuel load commodities, and examples occupancy scenarios (i.e. compartment fires set with retail and office commodities). Many experiments give results with for sprinklered and non-sprinklered compartments. The results are presented to inform fire engineered assumptions for design fire sizes.

Various Christmas tree fires were experimentally tested. The details regarding the tree characteristics, and the results from the total heat release rate versus time is shown in Figure 28 and Figure 29.
The worst case scenario, identified as Tree 3, shows a total output just above 5MW in just 50 seconds from ignition. Given this data, a 5MW fire is used for Christmas tree design fires. Although the tree burns very quickly, and may not produce steady-state like conditions (as it is only at its peak for above 20 seconds), additional decorations or adjacent fuel load such as chairs may contribute to the total ignition source. The 5MW design fire is therefore considered an appropriate fire size to determine the smoke extraction rates at this stage. There is a potential in subsequent design stages to re-evaluate potential fuel load within Atrium 2 in order to reduce the extraction rate required in the large space.
Mechanical extraction calculations

The mechanical extraction is sized to accommodate a 5MW fire on the ground floor, which is located directly under the large void which extends to roof level. Therefore, an axisymmetric plume is considered within the atrium.

Similar input parameters as described in design fire 1 have been applied, as detailed in Table 19.

The atrium is a total of 25m tall, and the available reservoir depth is 6m. The calculations are therefore considered to keep a 19.0m clear layer height.

Table 19: Input values to calculate the mechanical exhaust rate required – Design fire 3

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Input</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor to roof height</td>
<td>25m</td>
<td>Measured from section</td>
</tr>
<tr>
<td>Reservoir depth</td>
<td>6m</td>
<td>Measured from section</td>
</tr>
<tr>
<td>Total clear height to be achieved</td>
<td>19.1m (100mm added to design clear layer height to allow for layer to form within the reservoir-above downstand)</td>
<td>Measured from section</td>
</tr>
<tr>
<td>Air specific heat capacity</td>
<td>1 kJ/kg.K</td>
<td>TM19</td>
</tr>
<tr>
<td>Ambient density</td>
<td>1.2 kg/m³</td>
<td>TM19</td>
</tr>
<tr>
<td>HRR density</td>
<td>500 kW/m² (total)</td>
<td>TM19</td>
</tr>
<tr>
<td></td>
<td>350 kW/m² (convective)</td>
<td></td>
</tr>
<tr>
<td>Total heat release rate</td>
<td>5000 kW</td>
<td></td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>20°C</td>
<td>Typical for U.K. office</td>
</tr>
<tr>
<td>Convective fraction</td>
<td>66.7%</td>
<td>TM19</td>
</tr>
</tbody>
</table>

The results indicate that required mechanical exhaust rate per zone is 130.1m$^3$/s. The minimum number of exhaust outlets to achieve the total 130.1m$^3$/s per smoke zone is two outlets. The total exhaust rate should be evenly distributed between the two outlets.

**Separation of fuel packages**

In order to limit potential fire spread between fuel load packages, the separation distance between kiosks or Christmas tree like decorations must also be considered within the mall circulation space. This study is further explained in Section 6.6.7, and is prescribed as a building management item in Section 9.

### 6.6.6.4 Design Fire 4 – Fire within Atrium 3 (level 0)

**Fuel load – Design fire size**

Similar to design fire 2, it is assumed that kiosks will line the centre of the Section A-A (south) mall area. Given there are 4m x 4m voids above the mall circulation area, it is assumed large Christmas trees will not be located within these smaller voids, and will be placed in Atrium 1 or 2. Therefore, the kiosk fire size as described in 6.6.6.2 is assumed within this space.
**Mechanical extraction calculations**

Atrium 3 is considered an open space due to the 4m x 4m voids located along Section A-A. The mechanical extraction is sized to accommodate a 2.5MW fire on the ground floor, which is located directly under a 4m x 4m void. Therefore, an axisymmetric plume is considered within the atrium.

It is assumed if a kiosk is located underneath the level 1 floor slab, the local mechanical extract will exhaust the smoke as designed.

Similar input parameters as described in design fires 1-3 have been applied, as detailed in Table 20.

The atrium is a total of 19.5m tall, and the available reservoir depth is 4.5m. The calculations are therefore considered to keep a 15.0m clear layer height.

**Table 20: Input values to calculate the mechanical exhaust rate required – Design fire 4**

<table>
<thead>
<tr>
<th><strong>Parameter</strong></th>
<th><strong>Input</strong></th>
<th><strong>Reference</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor to roof height</td>
<td>19.5m</td>
<td>Measured from section</td>
</tr>
<tr>
<td>Reservoir depth</td>
<td>4.5m</td>
<td>Measured from section</td>
</tr>
<tr>
<td>Total clear height to be achieved</td>
<td>15.1m (100mm added to design clear layer height to allow for layer to form within the reservoir-above downstand)</td>
<td>Measured from section</td>
</tr>
<tr>
<td>Air specific heat capacity</td>
<td>1 kJ/kg.K</td>
<td>TM19¹</td>
</tr>
<tr>
<td>Ambient density</td>
<td>1.2 kg/m³</td>
<td>TM19</td>
</tr>
<tr>
<td>HRR density</td>
<td>500 kW/m² (total)</td>
<td>TM19</td>
</tr>
<tr>
<td></td>
<td>350 kW/m² (convective)</td>
<td></td>
</tr>
<tr>
<td>Total heat release rate</td>
<td>2500 kW</td>
<td></td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>20°C</td>
<td>Typical for U.K. office</td>
</tr>
<tr>
<td>Convective fraction</td>
<td>66.7%</td>
<td>TM19</td>
</tr>
</tbody>
</table>

The required mechanical exhaust rate per zone is 69.5 m³/s. The minimum number of exhaust outlets to achieve the total 69.5 m³/s per smoke zone is two outlets. The total exhaust rate should be evenly distributed between the two outlets.

### 6.6.7 Separation distance requirements through mall circulation space

The following calculations have been undertaken to provide the client with indicative separation distances, should they wish to provide retail islands in the concourse of the shopping centre, and this will need to be considered on an ongoing basis.

The risk of fire spread from a retail island/kiosk to an adjacent shop front or vice versa is from radiant heat transfer. As it is likely that the client will want to allow for retail island/kiosk in the concourse, the following calculation methodology should be applied when assessing the separation distances:

\[
r = \sqrt{\frac{3\dot{Q}}{4\pi\dot{q}_r}}
\]

\(\dot{Q}\) = Total heat release rate (kW)

0.3 = the fraction of the HRR that is radiation

\(\dot{q}_r\) = Limit of heat flux (kW/m²)
r = required separation distance (m)

It is advised that q is equal to 10 kW/m² which represents the radiation required to ignite clothing, paper, etc. Following this methodology a provisional separation distance can be calculated as below:

Assuming a worst case fire scenario of 5MW (BRE 368 unsprinklered fire), over an area of 10m², a separation distance from the centre of a fire to an adjacent retail unit or kiosk is calculated as approximately 4m.

\[ r = \sqrt{(0.3 \times 5000)/4\pi(10)} = 3.45 \text{m} \]

It should be noted that BS 9999 requires the escape provisions to be considered should the retail islands reduce the exit widths through the concourse. As such the methodology for calculating the separation distance, and the impact on means of escape should these kiosks be installed, will be assessed during the next stage of the design (when the dimensions, and fuel loads of the kiosks can be fully understood).

The separation distance of the fuel load package (kiosks) configuration and fit out will require understanding from the building management team, this responsibility is identified in Section 9.

7 EXTERNAL FIRE SPREAD

Under the guidance of BS 9999, it is necessary to construct the external walls such that the amount of unprotected area on the side of the building overlooking the elevation is restricted, such that the potential for fire spread by radiant heat transfer is limited.

In order to evaluate the external fire spread requirements, the relevant boundaries to existing or potential buildings (or property) is considered. It has been assumed that the shopping centre is located at a distance sufficiently removed from these relevant boundaries and the risk of fire spreading to or from the shopping mall is negligible.

7.1 External Wall Construction

As a minimum the external surfaces of the walls should be provided with a minimum rating of not more than 20 (National Class) or Class C-s3,d2 or better (European Class) to a height less than 18m above ground level.

8 FIRE FIGHTING ACCESS AND FACILITIES

8.1 Internal fire fighting provisions

BS 9999 recommends that if a shopping centre development is not provided with wet fire mains, Fire Service vehicle access should be provided within 18m of each of a sufficient number of entry points so that no point in the building is more than 60m from an entry point, when measured along a route suitable for laying hose.

A shopping centre with a floor level more than 7.5m above fire fighter access level and more than 900m² in area should be provided with a minimum of two firefighting shafts. The shafts
should be located such that the maximum hose distance to the most remote point of each floor level is no more than 60m from the dry rising main in either stair, when measured on a route suitable for laying hose.

*Design of firefighting shafts*

**Firefighting Shaft**

Where stairs are designated as ‘Fire Fighting Stairs’ then their minimum width should not be less than 1800mm.”

**Firefighting lift**

The top floor level of the mall is less than 18m above external ground floor level, but has a floor area of greater than $900\text{m}^2$, therefore a firefighting shaft is required, but which need not include a firefighting lift.

**Firefighting lobby**

To ensure sufficient space for the fire service to prepare for firefighting operations, the minimum area of each firefighting lobby should not be less than $5\text{m}^2$ (and not more than $20\text{m}^2$).

**Dry Rising Fire main**

Each firefighting shaft should be provided with a dry rising fire main, with an outlet located within the firefighting lobby at every storey level.

The inlet point for the dry risers should be located at fire service access level, adjacent to the entry point to the buildings. There should be fire service vehicular access within 18m of the inlet valve and in line of sight.

**Fire Resistance**

The firefighting shaft (stair and lobby) should be enclosed in 120 minutes fire resisting construction. Doors separating the lobby from the accommodation should be to a self-closing FD 60S standard. FD60S, is a fire door which achieves 60 minutes when tested to BS 476-22, and the ‘S’ denotes the requirement of smoke seals.

Internally within the shaft, the stair and lift shafts should be enclosed in 60 minutes fire resisting construction. The door between the stair and the lobby should be to a self-closing FD30S standard. A schematic from BS 9999 highlighting the general requirements is shown below:
Ventilation

Each firefighting shaft should be provided with ventilation to both the stair and the firefighting lobby.

Ventilation to the stair can be achieved by the provision of a 1.5m² openable ventilator located over the head of the stair. Alternatively, a 1.0m² ventilator can be provided at every storey level.

Ventilation of the firefighting lobby may be provided by one of the following methods:

- A 1.5m² openable ventilator direct to outside at every storey above/below entry level.
- A mechanical ventilation system consisting of a smoke shaft approximately 0.5m² in area.
- A 1.5m² automatically opening vent which discharges into a natural smoke shaft measuring 3m² in plan area.

Protection of External Façade

Under the guidance of BS 9999, it is necessary to prevent fire breaking into a fire-fighting staircase, where the external wall is on the same plane as the fire-fighting shaft. In this case it is proposed to provide a 0.5m separation between any non-fire resisting elements of the façade as shown in Figure 33.

Figure 32: Indicative fire resistance requirements of firefighting shaft

Figure 33 — Examples of protection of the fire-fighting shaft from external fire
Where the staircase is at right angles to the façade of the building, any portion of the façade within 5m of the fire-fighting shaft should be provided with 120 minutes fire resistance.

**8.2 Vehicle Access**

**Vehicle Access Routes**

All access routes for fire service vehicles should satisfy the following specification (it should be noted that this can vary from Service to Service, and is subject to consultation with the Statutory Authority):

- Minimum width of road between kerbs – 3.7m.
- Minimum width of gateways – 3.1m.
- Minimum turning circle between kerbs – 16.8m.
- Minimum turning circle between walls – 19.2m.
- Minimum clearance height – 3.7m.
- Minimum carrying capacity – 12.5 tonnes.

Access should be provided for a Fire Service pump appliance to within 18m of the dry rising main inlet within the firefighting shaft and those in each of the stairs serving the cinema. The guidance in BS 9999 recommends that if any portion of the route is a ‘dead-end’, turning facilities will be required (e.g. turning circle, hammerhead, or other point at which vehicle can turn) so that Fire Service vehicles do not have to reverse more than 20m.

**Fire Hydrants**

If any building is constructed more than 100m from an existing hydrant in BS 9999 recommends that additional hydrants should be provided within 90m of an entry point to the building or a dry rising main inlet and not more than 90m apart.
The provision of fire hydrants is subject to confirmation regarding the location of existing statutory street hydrants around the site, and following conducting a water main water flow and pressure test to confirm the water flow characteristics in vicinity to the building.

**Fire Control Centre**

A fire control centre should be provided in large/complex buildings, to enable the Fire Service to assist the premises management control an incident immediately on arrival.

The fire control centre should be either:
- a room dedicated solely as a fire control centre; or
- combined with the management central control room.

The fire control centre should be adjacent to a Fire Service access point, or other location agreed with the Fire Service, and it should be readily accessible, preferably directly from the open air. If this is not practicable, the route to the fire control centre should be protected. An indicative location for the fire control centre is shown in Figure 34.

![Indicative Fire Control Centre location](image)

**Indicative Fire Control Centre location**

Because of the possible need for the fire control centre to be operational over an extended period of time, it should be separated from the remainder of the building by 2 hours of fire resisting construction and should incorporate facilities to enable it to function as normal during an emergency.

The fire control centre should be provided with a 3 hours non-maintained system of emergency lighting supplied from a source independent of the normal lighting, to enable the control centre to operate satisfactorily in the absence of the normal lighting supply.
It should be noted that some form of communication should be provided to the fire control centre, and all fire safety systems should be available to the Fire Service.

9 MANAGEMENT

BS 9999 makes recommendations with regards to the required minimum level of management for different risk profiles. The standard or quality of management is referred to here as the management level. There are three management levels, with level 1 giving the highest level of management, level 2 giving a normally acceptable level of management, and level 3 giving a very basic level of management.

Table 21: Management level based on occupancy characteristics

<table>
<thead>
<tr>
<th>Occupancy characteristic (from Table 2)</th>
<th>Fire growth rate</th>
<th>Risk profile</th>
<th>Management level</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Occupants who are awake and familiar with the building)</td>
<td>1 Slow, 2 Medium, 3 Fast, 4 Ultra-fast</td>
<td>A1, A2, A3, A4</td>
<td>3&lt;sup&gt; A) &lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Not applicable&lt;sup&gt; B) &lt;/sup&gt;</td>
</tr>
<tr>
<td>B (Occupants who are awake and unfamiliar with the building)</td>
<td>1 Slow, 2 Medium, 3 Fast, 4 Ultra-fast</td>
<td>B1, B2, B3, B4&lt;sup&gt; A) &lt;/sup&gt;</td>
<td>2</td>
</tr>
<tr>
<td>C (Occupants who are likely to be asleep)</td>
<td>1 Slow, 2 Medium, 3 Fast, 4 Ultra-fast</td>
<td>C1&lt;sup&gt; B) &lt;/sup&gt;, C2&lt;sup&gt; B) &lt;/sup&gt;, C3&lt;sup&gt; B), C) &lt;/sup&gt;, C4&lt;sup&gt; A), B) &lt;/sup&gt;</td>
<td>2</td>
</tr>
</tbody>
</table>

<sup> A) </sup> A level 3 system might not be acceptable in some circumstances.<br><sup> B) </sup> Due to Ultra-Fast fire growth

In the U.K. buildings should not be designed with overly onerous expectations on the buildings management.

9.1 Specific Management Requirements

Based on the aforementioned, the shopping centre has been designed with a level 2 management system, based on overreliance on the buildings management post-design outlined in level 1 management.

It should be noted that in the event of a building failing to have this level of management, it is considered very likely that the building would not have the correct level of management to satisfy the Regulatory Reform Order (RRO) and steps should be taken to rectify the situation as appropriate. The RRO is further explained in Section 10.1.

Planning on changes of management systems

Management systems should include procedures for anticipating and taking into account, either on a permanent or a temporary basis, changes to the occupancy and/or fire growth characteristics of the building and its contents over the life cycle of the building. These procedures should form part of the overall audit and review process for the fire safety strategy and should be able to determine whether any such changes will necessitate
alterations to the fire precautions provided, including the management systems, and to put any such alterations into effect.

A level 2 system identifies and reacts to any changes as they occur, including changes to the occupancy, periods of abnormal occupancy, and fire growth characteristics. The system identifies any alternative protection and management measures that will be required as a result, and ensures that they are implemented.

**Resources and authority**

For the management of fire safety to be effective, the fire safety manager needs to be empowered and able to command sufficient resources to maintain the systems (money needs to be available). In a level 2 system, the responsibility for fire safety, and the necessary supporting staff and resources, are likely to be divided over a number of different individuals, departments or even companies. It is likely that the implementation of any necessary changes will require approval of those not directly responsible for the routine management of fire safety within the premises.

**Staff level**

The role of staff is an important element of the fire safety strategy. The appropriate staffing level (for fire safety purposes) for a particular building is influenced by the use of the building and fire growth characteristics; the types of occupant; the fire safety systems in place; and the roles and levels of the staff concerned in ensuring the fire safety of the occupants.

In a level 2 system, there will not be any arrangements for contingencies such as training, sickness, and other unexpected absences, etc., nor there provision for security such as regular patrols, perimeter controls, entry control systems, or staff able to respond to an intrusion.

**Fire Training**

Training of staff and others for action in the event of a fire is an essential element of fire safety management.

In a level 2 system, the training ensures that there are sufficient numbers of staff trained in all aspects of fire prevention, fire protection and evacuation procedures, and able to use the appropriate extinguishing equipment, so as to provide full coverage of the building, but has no contingency provision.

**Work Control**

Management systems should control work on site, e.g. repairs to structure, and in particular hot work.

A level 2 work control system is developed reactively to work required on site to include clear lines of responsibility; a permit system; and logging and audit processes.

**Communication Procedures**

Communication procedures include means of being alerted to a fire; communications between management, and between management and staff; messages to occupants; and communications with the fire and rescue service in the event of a fire.

A level 2 communications system will provide information to all those involved, with alternative formats as necessary, but will not have contingency arrangements.
Maintenance and testing of fire safety systems

Maintenance and testing is essential to ensure that fire safety systems will operate correctly in the event of a fire. A level 2 maintenance system is one where there is monitoring of the fire safety systems, and the equipment is kept fully functional at any time the building is in use. When systems, equipment and other arrangements are not available or not functioning correctly, alternative procedures are determined reactively.

Liaison with Fire and Rescue service

A good relationship with the fire and rescue service will have benefits for both the occupier and the fire and rescue service. In particular it will ensure that the fire and rescue service are able to have an appropriate pre-determined response strategy for the premises concerned and will enable the occupier to seek advice where appropriate on:

- how to prevent fires and restrict their spread in their buildings and other property;
- the means of escape from buildings and other property in case of fire.

In a level 2 system, the liaison includes arrangements for notifying the fire and rescue service of changes to the occupancy, periods of abnormal occupancy, fire growth characteristics, and other relevant factors. However, the arrangements are unlikely to provide for routine meetings with the fire and rescue service or where a change in the building or its occupancy is proposed.

Fire loading in the mall

In terms of the managing the fire load, consideration will need to be made with regards to the furnishings, and control of combustibles on the concourse. At level 3, the food court area should be provided with hard furnishings (preferably class 0 products).

10 REGULATORY COMPLIANCE

As an example to England specifically, it has been assumed the development will be subject to the requirements of the Building Regulations 2010 and, therefore, it will be necessary for it to meet the requirements of Schedule 1 of the Regulations relating Part B1-B5, as listed in Section 2.1. Guidance on how these functional requirements can be achieved in buildings is provided in a number of guidance documents, such as Approved Document B - Fire Safety (the ‘AD-B’). However, AD-B is not the only method of achieving compliance and this document permits the use of Fire Engineering as an alternative tool for achieving compliance. On this basis, it has been proposed to design the building using the guidance given in BS 9999: Code of Practice for fire safety in the design, management and use of buildings.

10.1 Regulatory Reform (Fire Safety) Order

The Regulatory Reform (Fire Safety) Order (RRO) is based on risk-appropriate compliance and requires a fire risk assessment to be carried out. The Fire Service will conduct inspections of premises to enforce the regulations. It will be necessary for a risk assessment to be conducted on the premises, to parts of the premises where employees may work (i.e. not within residential apartments). However, the management and risk assessment requirements of the RRO are outside the scope of this report.
Where the architect or other consultants use this report or any design guide, standard or recommendation to specify works they are understood to be competent in alerting the Client, CDM Coordinator, Contractors and Building Occupier of CDM issues as required under the CDM Regulations.

10.2 Construction, Design and Management Regulations (CDM)

Projects undertaken within the U.K. are subject to the requirements of the Construction (Design and Management) Regulations 2007 (CDM). This report provides a holistic strategy for meeting the functional requirements under Part B of the Building Regulations 2010. It is intended to form part of the submission for approval by the Enforcing Authority under these regulations.

Where particular products, materials, or construction methodologies have been specified, these have been assessed, in accordance with CDM Regulations 11 and 18 (duties for designers). In the event that these involve unusual or complex hazards which are likely to be missed, rather than well-known or well understood construction hazards, this information will be passed on to those that will need it in a format that is readily accessible to them.

11 ENGINEERED SOLUTIONS – RISKS AND OPPORTUNITIES

The fire design solution as explained in Section 4 - 9 outline the key fire safety design solutions for the SFPE shopping centre at RIBA design stage 2. It is understood, that at this early concept design stage, the current architectural drawings are still to be resolved, and changes to the design are anticipated. As such the proposed design solution must be reviewed in the next design by a competent fire engineer to determine the solution validity given alternations to the proposed SFPE shopping centre design.

As a part of the concept stage design, the proposed design must be reviewed determine if the design solution does meet the goals and constraints driven by all stakeholders involved. The principle fire safety features, as described in Table 7 identify potential risks and opportunities at this design stage given the proposed design solution. The following items may be further discussed with stakeholders during the next design stage.

11.1 Sprinklers design in shop units

It is proposed at this early design stage to install fast response sprinklers within the SFPE shopping centre. Sprinklers are beneficial in reducing fire and smoke spread, by reducing temperatures within the fire origin area. The objective of sprinkler suppression is to control a fire (limiting its size), which may ultimately lead to safer egress conditions for occupants, and may reduce property damage.

It is currently within the design solution to install sprinklers at the floor slab level (within the ceiling void) and at the false ceiling level (below the 25% perforated ceiling), as shown in Figure 35 and described in Section 6.6.2. The base build design will be fit with sprinklers directly below slab level, and an outlet will be provided for the tenant to install sprinklers below their false ceiling fit-out design.
However, the sprinkler system within the retail unit at false ceiling height is not required for life safety purposes. As explained in section 6.6.6.2, the design fire used to size the mechanical smoke extraction system is taken from the BRE 368 recommendation of 2.5MW. This is based on potential “shielded fires”, using fast response sprinklers. The floor height at which the sprinklers are installed is not directly dependent on this design fire for the design solution at this stage.

There is a possibility to allow tenants to choose if they would prefer to install sprinklers at false ceiling level. If there are no sprinklers installed at false ceiling level, the base build sprinklers installed below the floor slab will be the only sprinkler system within this space. However, the base build must provide all shop units with the option to install sprinklers (provide zone check value for sprinkler installation).

In order to design for the sprinklers to effectively control a fire at floor level, BS EN 12845 requires the false ceiling to meet the following conditions:

- the total open plan area of the ceiling, including light fittings, is not less than 70 % of the ceiling plan area;
- the minimum dimension of the ceiling openings is not less than 0.025 m
- the structural integrity of the ceiling and any other equipment, such as light fittings within the volume above the suspended ceiling, will not be affected by operation of the sprinkler system;
- there are no storage areas below the ceiling

This false ceiling arrangement option is illustrated in Figure 36.
Section View

Figure 36: False ceiling - sprinkler located on floor slab (within ceiling void)

Careful consideration to the potential design fire (if reduced in the next stage) must be considered if sprinklers at false ceiling level are removed.

11.2 Smoke control design within the shop units

The objective of the smoke control strategy, by means of smoke reservoir zones and mechanical extract, is to isolate smoke within the fire origin zone. Extracting smoke within the fire origin zone has life safety benefits compared to letting smoke spill out of the units and being extracted from the mall, as described in detail Section 6.6.

Additionally, the smoke control design solution to allow for a false ceiling with mechanical extraction regardless of the unit size meets the following client goals:

1. Flexibility for tenant fit out design – Design allows for no restriction to shop unit entrance door widths (as there is no spill plume to consider).

2. Flexibility for future shop unit size changes – Although the code does not require smoke extraction for units less than 1300m², this design is will allow for smaller shop unit sizes to combine into larger shops in the future.

3. Minimum business disruption (tenant fit out construction) – As a false ceiling / smoke extraction design will be installed within each unit, future shop unit size changes will not require additional construction to introduce fans / ducting system into a shop unit which did not previously have this design (minimizing future cost and construction disturbance).

The level of flexibility allowed for by the base build design at this stage is considered appropriate given the client objectives. The client and stakeholders must review the design in order to determine the cost vs. benefit of the smoke control strategy at this stage.

In the subsequent design stage, items such as downstand/false ceiling height may be reconsidered. For example if the client would like to design for a larger false ceiling height, the downstand (reservoir depth) is reduced and smoke extraction rates will increase.
Conversely, if the client would like to reduce extraction rates expected due to cost, downstand depths could be increased to allow for a deeper smoke reservoir and reduced smoke extraction rates required.

11.3 Design fire size to inform smoke control

The intent and reasoning behind the design fires chosen in the fire strategy are identified in Section 6.6.6. The design fire size informs the mechanical extraction rates required in each smoke zone. The design fire sizes identified at this early concept stage may be considered conservative, if the fuel load estimated is greater than that planned by the building owner.

There is an opportunity for the stakeholders to detail the fire load intended within each space during the next stage. A detailed fire size assessment, completed by a competent engineer, may allow for a revaluation of the mechanical extract rates required per smoke zone.

12 CONCLUSION

This document outlines the key fire safety considerations for the SFPE shopping centre. The U.K. SFPE chapter team, has applied qualitative design review, by considering the design goals and constraints (both typical to the UK and in line with the SFPE design brief) to determine an optimal design solution for a concept stage design. The fire safety solution is comprised of the fire strategy, the fire safety features and system, and a fire safety management plan. The fire safety provision are outlined in Section 4, and the detailed consideration of the fire features, system, and management are described in Section 5 – 9 within the report.

The key aims of the fire strategy which include, (1) safeguarding occupants from injury due to fire and smoke during egress, (2) safeguarding fire fighting during fire and rescue operations, (3) minimizing the smoke and fire spread inside the building, and (4) limiting the impact on business continuity, have all been considered methodically to deliver the optimal design for the client, tenants, and the buildings future inhabitants.

Key design features which address these goals include:

- Means of escape provisions which consider a total evacuation (simultaneous evacuation) strategy from both the mall and cinema. Each area within the building has been considered for adequate travel distances, and horizontal, and vertical escape access widths.
- The simultaneous evacuation strategy is activated on a double-knock detection system which allows for full evacuation only upon a confirmed fire. This will minimise the event of a false alarm, to limit the impact on business continuity.
- A sprinkler system will be installed throughout the building to limit fire and smoke spread to the room of origin, for the purpose of life safety, property protection, and business continuity.
- The mall circulation space and atria are designed with mechanical exhaust, to limit smoke spread and safeguard occupants during egress by designing the system to allow for a clear height above the highest walking surface (smoke reservoir within false ceiling void).
- All shop units are designed with mechanical smoke extraction. As it is a key goal for the client to allow for flexibility within the shop tenant fit out units, the smoke control
strategy has been developed to provide flexibility for each unit within the base build
design. This smoke control design will allow for future tenant shop change of size (i.e.
small units combine to large units), and change of shop front design (i.e. no restrictions
on door width). This design will also reduce impact on business continuity by limiting the
need for additional construction of exhaust systems in future. By designing smoke
extraction within each shop unit, smoke spread throughout the mall is reduced.

A number of risks and opportunities have been identified in Section 12, which will be
developed in subsequent design stages both with the design team and with the approving
authorities. The client must review and provide any feedback on the proposed strategy prior
to the commencement of the subsequent design stage. Further any other fire requirements
from external stakeholders, such as insurers or tenants, must be provided as soon as possible
to enable these to be incorporated into the fire strategy.

Further it is recommended that discussions with the approving authorities are initiated early
in the subsequent design phase, so the proposal can gain agreement ‘in principle’ at an early
stage of the design.

All tenants are responsible for developing a fire safety management plan for their respective
tenancies and for ensuring that these are co-ordinated. To this end, specific management
requirements which must be accounted for in order to enable the efficiency of the fire safety
solution have been highlighted in Section 9 and must be incorporated into the landlord and
tenant fire safety management plans, as produced by others.

Overall it is considered that the life safety standards required for compliance with the
municipal Building Regulations can be achieved within the building in subsequent design
stages through the fire strategy solution outlined in this report.
REFERENCES

British Standards Publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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BS 5516-2, Patent glazing and sloping glazing for buildings – Part 2: Code of practice for sloping glazing

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BS 9999, British Standard Code of practice for fire safety in the design, management and use of buildings 2008


BS 5588-10, Fire precautions in the design, construction and use of buildings — Part 10: Code of practice for shopping complexes – Section 5 Escape from fire - 5.1 General 1991

BS EN 12845, “Fixed firefighting systems- Automatic sprinkler systems – Design, installation and maintenance”

PD 7974-1, Application of fire safety engineering principles to the design of buildings – Part 1: Initiation and development of fire within the enclosure of origin (Sub-system 1)

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Other Publications


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